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Impact Of Energy Consumption on Economic Growth in Nigeria

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Abstract
This study investigates the impact of energy consumption on economic growth in Nigeria. The main aim is to ascertain the effects of renewable energy, non-renewable energy, total energy consumption, and population growth on Nigeria's economic growth over the period 1990–2024. The research is theoretically anchored in the energy-growth nexus, which posits energy as a critical factor of production, extending the Neoclassical Growth Theory framework. Adopting a quantitative, ex-post facto research design, the study utilized the Autoregressive Distributed Lag (ARDL) model on secondary data. Empirical results indicate a strong explanatory power of the model, accounting for approximately 99.83% of GDP variations. Renewable energy consumption shows a large, positive, and highly significant impact on economic growth in both contemporaneous and lagged periods. Non-renewable energy consumption also yields a positive and significant effect, though smaller. Population growth is a strong immediate determinant of GDP. However, the long-term significance of total energy consumption is delayed, underscoring that the type and efficiency of energy use are more crucial than sheer volume. The study concludes that energy consumption, especially from renewable sources, plays a critical and positive role in stimulating Nigeria's economic performance. The study recommends scaling up renewable energy investments, reforming fossil fuel subsidies, and promoting mandatory energy efficiency standards. Furthermore, linking population policy with energy planning and strengthening institutional frameworks are advised for sustainable growth.

Key words: *energy consumption, renewable energy, economic growth, ARDL model, population growth, Nigeria*

Introduction

Energy consumption plays a pivotal role in shaping economic growth, as it is a fundamental input for industrial production, transportation, and technological advancement (Stern, 2011). Historically, nations with higher energy consumption have experienced accelerated economic development due to increased industrial output and improved living standards (Ozturk, 2010). The relationship between energy use and economic expansion has been widely examined in academic literature (Omri, 2014; Okonkwo, Eze & Okoro, 2022; Taghizadeh-Hesary, Rasoulinezhad & Yoshino, 2023; Ekeocha, Penzin & Ogbuabor, 2020). However, the extent of this relationship varies according to factors such as energy efficiency, resource availability, and technological innovation.

The theoretical foundation of this relationship is rooted in the energy-growth nexus, which posits that energy is a critical production factor alongside labor and capital (Soytas & Sari, 2009). Although classical and neoclassical growth models often overlook energy as a standalone variable, empirical evidence suggests that energy accessibility and affordability significantly influence productivity and economic performance (Apergis & Payne, 2010). For instance, countries with abundant energy resources, such as oil-rich nations, often experience faster gross domestic product (GDP) growth due to export revenues and energy-intensive industries (Al-mulali, 2011). Mgbomene et al. (2025) found that the revenue derived from petroleum export sales positively and significantly affected Nigeria's economy. Conversely, energy-deficient regions may face constraints in sustaining long-term economic development. Global trends further highlight the interdependence between energy consumption and economic growth, particularly in the context of urbanization and industrialization (Pao & Fu, 2013). Emerging economies, such as China and India, have demonstrated rapid economic expansion alongside soaring energy demand, reinforcing the argument that energy is a catalyst for development (Zhang & Cheng, 2009). However, this growth has also raised concerns about energy security, environmental degradation, and the sustainability of fossil fuel dependence (IEA, 2020). As a result, policymakers and researchers increasingly emphasize the need for renewable energy adoption to decouple economic growth from harmful environmental impacts.

Despite extensive research on the energy-growth nexus, debates persist regarding the causality, regional variations, and long term sustainability of energy-dependent growth strategies (Menegaki, 2011). While some studies support a unidirectional relationship 8n which energy consumption drives economic expansion, others argue for bidirectional causality or even neutrality in certain contexts (Payne, 2010).

Statement of the Problem

Persistent uncertainties in the energy-growth nexus have been highlighted in recent studies, particularly regarding how different energy sources and consumption patterns affect economic development across various economic contexts (Ahmad *et al*., 2021; Dong *et al*., 2022). While renewable energy adoption shows promise for sustainable growth, emerging research questions whether it can immediately replace fossil fuels without transitional economic costs, especially in industrializing nations (IEA, 2023; Khan *et al*., 2022). This dilemma creates significant policy challenges, as countries must navigate between meeting immediate energy demands for growth and achieving long-term decarbonization goals (Sarkodie & Strezov, 2023). The lack of consensus on optimal energy transition pathways leaves many developing economies vulnerable to either energy shortages or unsustainable debt from green investments (Taghizadeh-Hesary *et al*., 2023).

Energy inequality remains a critical barrier to inclusive economic growth, with recent evidence showing that nearly 760 million people in Sub-Saharan Africa and South Asia still lack electricity access (World Bank, 2022; Adom *et al*., 2022). Energy poverty perpetuates underdevelopment by limiting productivity, education, and health care access (Castillo *et al*., 2021). Climate change impacts, intensified by traditional energy systems, are already reducing GDP growth in vulnerable regions by up to 1-2% annually (IMF, 2023). These dual challenges create a paradox where energy expansion is urgently needed for development, yet must be carefully managed to avoid ecological and economic crises (Balsalobre-Lorente et al., 2023).

The rapid pace of technological change introduces additional complexities as digitalization and AI-driven industries create new energy demand patterns that existing models fail to capture (Zhou *et al*., 2023; Usman *et al*., 2021). Recent studies have suggest that traditional linear energy-growth relationships may no longer hold in knowledge-based economies. Furthermore, since 2022, geopolitical tensions have disrupted global energy markets, demonstrating how external shocks can abruptly alter energy-growth dynamics (IRENA, 2023). This study addresses these contemporary challenges by analyzing post-pandemic energy trends, the impacts of renewable transition, and the role of innovation in reshaping the energy-growth paradigm for sustainable development.

Study Aim and Objectives

The study aims to investigate the impact of energy consumption on economic growth in Nigeria. To achieve this aim, the following objectives are set:

i. To ascertain the impact of renewable energy consumption on Nigeria's economic growth.
ii. To determine the effect of non-renewable energy consumption on economic growth in Nigeria.
iii. To discover the impact of total energy consumption on Nigeria's economic growth.
iv. To examine the impact of population growth on Nigeria's economic growth.

Research questions

Based on the study objectives, the research questions are as follows.

i. How does the consumption of renewable energy impact economic growth in Nigeria?
ii. What is the effect of non-renewable energy consumption on Nigeria's economic growth?
iii. How does total energy consumption impact Nigeria's economic growth?
iv. What is the impact of population growth on Nigeria's economic growth?

Research Hypotheses

The study hypotheses in their null forms are specified as follows.

H_{01}: No significant relationship exists between renewable energy consumption and economic growth.

H_{02}: No significant relationship exists between non-renewable energy consumption and economic growth.

H_{03}: No significant relationship exists between total energy consumption and economic growth.

H_{04}: Population growth has no significant impact on economic growth.

This study makes several key contributions to the existing literature on the energy-growth nexus. First, it provides updated empirical evidence on the relationship between energy consumption and economic growth, incorporating recent global developments such as the post-pandemic recovery, renewable energy transitions, and geopolitical energy market disruptions. This study covers Nigeria as a geographical entity and spans the years 1990 – 2023, that is, 34 years.

Literature Review

Conceptual Review

Energy consumption is a fundamental driver of modern economic systems, serving as both an input for production and an indicator of development (Stern, 2011). The relationship between energy use and human progress has evolved through distinct phases - from traditional biomass in agrarian societies to fossil fuel dominance during industrialization, and now toward renewable energy transitions (Smil, 2017). This historical progression reflects the "energy ladder" hypothesis, where societies ascend to more efficient and cleaner energy sources as incomes rise (Hosier & Dowd, 1987).

Nigeria's energy consumption patterns reflect a heavy reliance on fossil fuels, particularly petroleum and natural gas, which dominate the country's energy mix. As one of the largest oil producers in Africa, Nigeria depends significantly on crude oil and refined petroleum products for transportation, industrial activities, and power generation. However, supply chain inefficiencies and inadequate refining capacity often lead to fuel shortages and increased importation of refined petroleum products (Okonkwo *et al*., 2022). Additionally, gas flaring remains a significant challenge despite efforts to harness natural gas for electricity generation and industrial use.

Electricity consumption in Nigeria has the problem of severe supply deficits and distribution inefficiencies. The national grid suffers from frequent power outages that force many businesses and households to rely on diesel and petrol generators. Reliance on backup generators increases energy costs and contributes to environmental pollution. Although the government has undertaken several power sector reforms, access to electricity remains inadequate, particularly in rural areas where millions of people remain off-grid (Nwulu & Xia, 2017).

Despite Nigeria's vast potential, renewable energy sources, including solar, hydro, wind, and biomass, remain underutilized. Hydropower currently contributes a notable share to electricity generation, but aging infrastructure and inconsistent water levels affect reliability. With increasing investments in mini-grid and off-grid solutions to power rural communities, solar energy has gained attention as an alternative. However, challenges such as high initial costs, limited technical expertise, and policy bottlenecks have slowed the large-scale adoption of renewables (Ozoegwu *et al*., 2017).

The relationship between energy consumption and economic growth has been widely debated in the energy economics literature, with studies exploring whether energy drives growth, growth drives energy demand, or a bidirectional relationship exists (Ozturk, 2010). According to the growth hypothesis, energy consumption is a critical input for production, industrialization, and technological advancement, making it a key driver of economic expansion (Stern, 2011). Empirical evidence from developing economies, including Nigeria, supports this view, as increased energy use correlates with higher GDP growth rates (Adewuyi, 2020). However, the conservation hypothesis suggests that energy efficiency gains and structural shifts toward service-based industries may weaken this linkage in advanced economies, allowing growth with stagnant or declining energy consumption (Pao & Fu, 2013).

The feedback hypothesis, which argues for bidirectional causality between energy and growth, has gained traction in recent research (Apergis & Payne, 2011). This perspective highlights that while energy enables industrial and infrastructural development, economic expansion also increases demand for energy-intensive goods and services, reinforcing consumption patterns (Dong *et al*., 2022). In contrast, the neutrality hypothesis, observed in some high-income economies, suggests minimal long-term interaction between energy use and GDP, implying that other factors (e.g., innovation and institutional quality) dominate growth dynamics (Menegaki, 2011). Regional disparities further complicate this nexus where energy poverty heavily constrains Sub-Saharan Africa's growth, whereas industrialized nations face challenges in decoupling growth from carbon-intensive energy systems (IEA, 2023).

Theoretical Framework

Neoclassical growth theory, pioneered by Solow (1956) and Swan (1956), provides a foundational framework for understanding long-term economic growth through capital accumulation, labor expansion, and exogenous technological progress. The canonical Solow-Swan model expresses output (Y) as a function of capital (K), labor (L), and technology (A) in a Cobb-Douglas production function:

$Y_t = A_t K_t^{\alpha} L_{t1-\alpha}$ [1]

Where α represents capital output elasticity. A key limitation of this model is its treatment of energy as an intermediate input subsumed under A or K, ignoring its independent role (Stern, 2011). The theory predicts conditional convergence, where economies with similar steady-state characteristics grow faster if they are initially poorer. However, it fails to account for resource constraints or energy-dependent productivity (Barro & Sala-i-Martin, 2004).

Later extensions incorporated energy (E) as an essential production factor to address this gap. Stern (2011) reformulated the production function to explicitly include energy as follows:

$Y_t = A_t K_t^{\alpha} L_t \beta E_t \gamma$ [2]

Where γ captures energy's marginal productivity. Empirical studies validated this adjustment, showing that omitting energy biases growth estimates, particularly in industrial economies (Ayres & Warr, 2009). These models demonstrate that even with abundant capital and labor, energy scarcity can constrain growth, challenging the neoclassical assumption of perfect factor substitutability (Stern, 2011). Proponents such as Kümmel (2011) further integrated thermodynamic principles, arguing that energy, not just technology drives the "residual" growth unexplained by K and L.

Another critical advancement introduced resource constraints into neoclassical growth. The Dasgupta-Heal-Solow-Stiglitz (DHSS) model (1974, 1974) modified the Solow framework to include the following exhaustible resources:

$Y_t = A_t K_t^{\alpha} R_t \phi L_{t1-\alpha-\phi}$ [3]

Where R_t represents nonrenewable resources (e.g., fossil fuels). This model shows that sustainable growth requires technological progress (A) to offset resource depletion ($\dot{R}<0$), otherwise stagnation will occur (Stiglitz, 1974). Aghion & Howitt (1998) embedded endogenous innovation into these frameworks, allowing A_t to evolve via R&D investments that improve energy efficiency or substitute renewables for finite R_t.

Recent critiques highlight the shortcomings of energy-augmented neoclassical models. While they improve explanatory power, they often neglect the following:

- Differences in energy quality (e.g., electricity vs. biomass; Saunders et al., 2018),
- Institutional and geopolitical factors that shape energy access (Acemoglu *et al*., 2005) and,
- Nonlinear thresholds where energy scarcity abruptly reduces growth (Hassler *et al.,* 2021).

Modern adaptations, such as Integrated Assessment Models (IAMs), combine neoclassical growth with climate-energy feedbacks (Nordhaus, 2017), while ecological economics rejects the substitutability assumptions entirely, positing biophysical limits to growth (Daly, 1996).

Energy-augmented neoclassical models inform critical debates on decarbonization and sustainable growth. They noted that:

- Carbon pricing can internalize the environmental cost of energy (Nordhaus, 2017),
- Renewable R&D must accelerate to offset the depletion of fossil fuel (Aghion et al., 2016) and,
- Energy efficiency policies (e.g., γγ-maximization) are growth-enhancing (Stern, 2011). However, their reliance on equilibrium assumptions remains contested by heterodox theories advocating system-wide transitions (Perez, 2016).

Empirical Review

Nkoro, Ikue and Joshua (2019) investigated the long- and short-term impacts of renewable and non-renewable disaggregated energy consumption on economic growth in Nigeria from 1980 to 2016. The methodology employed was the modified OLS regression. The results revealed that only renewable energy significantly contribute to economic growth in the long run, whereas non-renewable energy positively affects growth only in the short term.

Dantama and Inuwa (2012) explored the causal relationship between energy consumption and economic growth in Nigeria from 1980–2010. Granger Causality test methodology was applied using time-series data. Their findings revealed a unidirectional causality from energy consumption to economic growth. This implies that energy consumption plays a vital role in determining economic outcomes.

Olarinde and Adeniran (2018) assessed the dynamic interactions between disaggregated energy consumption (electricity and petroleum), labor, and capital on Nigeria's gross domestic product between 1990 and 2016. Using the ARDL bounds testing approach and causality test, the study revealed that petroleum consumption and labour significantly contribute to economic growth in both the short and long run. Furthermore, the analysis found evidence of bidirectional causality between energy consumption and economic growth, supporting the feedback hypothesis.

Onakoya, Onakoya, Salami and Odedairo (2013) explored the causal relationship between various energy sources and economic growth in Nigeria from 1975 to 2010. Different types of energy such as petroleum, electricity, coal, and gas were regressed on GDP growth. The findings from the OLS regression indicated that petroleum and electricity consumption have statistically significant and positive effects on long term economic growth. Aggregate energy consumption also positively aligns with GDP. Interestingly, although gas consumption is positively related, it does not show statistical significance, whereas coal has a significant but negative effect on economic growth. The negative impact of coal on Nigeria's energy mix is attributed to its underutilization, inefficiency, and environmental drawbacks.

Odubunmi and Atoyebi (2016) investigated the three-way interrelationship between energy consumption, financial development, and economic growth in Nigeria. This study used the generalized method of moments (GMM) estimation technique to handle endogeneity concerns that arise from using time series data. The single-equation framework is structured to evaluate the contemporaneous and lagged effects of energy use and financial variables (e.g., credit to the private sector, interest rates) on GDP growth. The findings showed that increased energy consumption significantly contributes to economic growth in Nigeria. Moreover, financial development not only directly promotes economic growth but also indirectly influences it by increasing energy demand.

Olusanya (2012) investigated the long-run effects of energy consumption on Nigeria's economic growth using data from 1985 to 2010. The independent variables were various forms of energy such as petroleum, electricity, gas, and coal, while GDP was the dependent variable. The research design is based on the OLS method within a multiple regression framework. The results highlighted that petroleum and electricity consumption has a strong and statistically significant positive relationship with GDP in both the present and lagged periods. In contrast, coal and gas exhibit a negative relationship with economic growth.

Orhewere and Henry (2011) adopted the VECM combined with Granger causality testing and found a strong unidirectional causality from electricity and gas consumption to GDP in the short run and bidirectional causality eventually. Interestingly, oil consumption showed no short-run causality but revealed a long-term unidirectional causality to GDP.

Ekeocha, Penzin and Ogbuabor (2020) revisited the energy-growth relationship in Nigeria using the nonlinear autoregressive distributed lag (NARDL) model and a linear ARDL-error correction model. The findings indicated that the impact or energy consumption's on economic growth was negligible throughout the period.

Okoye, Omankhanlen, Okoh (2020) analyzed the role of energy consumption in Nigeria's economic growth. Using the auto-regressive distributed lag model, the study found that Nigeria's energy consumption and gross fixed capital formation have a strong and statistically significant effect on GDP growth. The model also found evidence of delayed responses to energy shocks which unfold over time rather than instantly.

Adegoriola and Agbanuji (2020) adopted the ARDL approach and found that electricity consumption and GDP growth were positively and significantly correlated within the short run, temporarily confirming the energy-led growth hypothesis. However, electricity consumption has a statistically insignificant and negative effect on GDP in the long run,. Fuel/gas costs also positively influenced economic growth but were insignificant in the long term.

Gbadebo, Odularu and Okonkwo (2009) employed the Johansen co-integration within a standard time series regression model. They found a strong positive relationship between current-period energy consumption and economic growth. The study also found that energy consumption lagged values sometimes show a negative impact, particularly for electricity and coal.

Muse (2014) explored the causal relationship between Nigeria's economic growth and energy consumption from 1980 to 2012. The study adopted ordinary least squares regression and pairwise granger causality test. The empirical results revealed a statistically significant long-term relationship between energy consumption and GDP growth.

Ogbonna and Maduka (2020) found that energy consumption has a significant and positive effect on all three sectors considered in the study (industry, agriculture and telecommunications sectors). The industrial sector responds most strongly to increased energy usage, indicating its high energy dependence. Agricultural output is also positively affected, although to a lesser degree, while the telecommunications sector shows moderate but consistent responsiveness.

Jack and Jack (2022) found that Nigeria generates only 3,500–5,000 MW of electricity for over 200 million people, resulting in one of the lowest electricity consumption rates per capita in Africa. Enibe and Odukwe (1990) found that Nigeria's energy consumption has expanded in both diversity and intensity, largely driven by urbanization, population growth, and industrialization.

Gap in the Literature

While much has been written about the relationship between energy consumption and economic growth, several gaps remain in the literature. First, many studies relied on aggregated energy consumption data, overlooking the important impacts of different energy sources, such as electricity, oil, gas, and renewable energy. Second, numerous studies have investigated the direction of causality between energy consumption and economic growth, the findings are often inconclusive or context-specific (Dantama & Inuwa, 2012; Ekeocha et al., 2020; Muse, 2014; Orhewere & Henry, 2011). This inconsistency presents an important gap in the understanding of whether energy consumption merely follows economic activity or is a true driver of growth.

Again, despite the growing interest in Nigeria's energy crisis and its impact on economic development, research exploring the policy implications of energy consumption on long-term growth sustainability is limited. Additionally, research examining the environmental and social implications of energy consumption is lacking, and this study integrates this aspect to offer a more holistic view of the energy-growth nexus in the context of Nigeria's developmental goals.

Methodology

This study adopts a quantitative, *ex post facto* research design, using secondary data analysis to explore the causal relationships between Nigeria's energy consumption and economic growth. Data were sourced from reputable institutions, such as the World Bank's World Development Indicators, the Central Bank of Nigeria, International Energy Agency and National Energy Reports, to ensure reliability and comprehensiveness for understanding energy dynamics in the Nigerian economy.

The methodology comprises three key components: descriptive statistics, ARDL estimation, and diagnostic tests. First, descriptive statistics are applied to summarize the central data set's central tendencies and dispersion (means, medians, standard deviations, skewness, and kurtosis). This step provides a comprehensive overview of the data distribution, identifies potential outliers, and lays the groundwork for the subsequent ARDL analysis.

Second, the study employs the ARDL approach to investigate the dynamic relationship between energy consumption variables and economic growth. The ARDL approach is particularly suitable for this study because it allows for the estimation of both short-run and long-run relationships between the variables, even when they are integrated at different orders (I(0) or I(1)).

Model Specification

The model is specified below in its functional form as follows:

GDP = *f* (RENW, NONRENW, POPGR and TOTENC) [4]

This is a modification of Adegoriola & Agbanuji's (2020) which only incorporated aggregated electricity consumption, fuel costs, and GDP. This study differentiates renewable energy consumption from non-renewable energy consumption and includes other variables in a single model. The model is specified in its econometric form as follows:

$$GDP_t = \beta_0 + \beta_1 RENW_t + \beta_2 NONRENW_t + \beta_3 POPGR_t + \beta_4 TOTENC_t + \sum_{i=1}^{p} \theta_i GDP_{t-i} + \sum_{j=0}^{q} \lambda_j RENW_{t-j} + \sum_{k=0}^{r} \psi_k NONRENW_{t-k} + \sum_{l=0}^{s} \delta_l POPGR_{t-l} + \sum_{m=0}^{t} \varphi_m TOTENC_{t-m} + \mu_t$$

Where:

GDP = Gross domestic product

RENW = Renewable energy consumption

NONRENW = non-renewable energy consumption

POPGR = population growth
TOTENC = total energy consumption
β_0 = constant term
β_1 to β_4 = Short-run coefficients of the respective variables
θ_1 to θ_p, λ_0 to λ_φ, ψ_0 to ψ_r, δ_0 to δ^s, φ_0 to φ^t = Long-run coefficients (lags of the respective variables)
μ_t = Error term
p, q, r, s and t = Lag lengths for the respective variables

In this ARDL framework, the coefficients of the lagged values (θ, λ, ψ, δ, φ) capture both the short-run and long-run dynamics between the variables. The lag lengths for each variable are determined based on the model selection criteria (e.g., AIC, SBC), and the bounds testing procedure is applied to examine co-integration among the variables.

Table 1: A-priori expectations and justification

Explained Variable	Explanatory Variables	Expected Relationship	Justification
Economic growth (GDP)	Renewable energy consumption	Positive	Renewable energy promotes sustainable development, attracts clean investments, and improves access to energy, thereby boosting long-term growth (Sarkodie & Strezov, 2019).
	Non-renewable energy consumption	Mixed/Positive	While fossil fuels drive industrial productivity and short-term growth, their long-term sustainability is questionable due to volatility and environmental degradation (Nkoro et al., 2019).
	Total energy consumption	Positive	Higher energy consumption is typically correlated with industrialization and higher economic activity, particularly in energy-deficient economies (Onakoya et al., 2013).
	Population growth rate	Mixed	Population growth may boost labor supply and domestic demand, but excessive growth can strain infrastructure and energy resources, potentially slowing GDP growth (Acemoglu & Johnson, 2007).

Source: Author (2025)

Data Analysis and Discussion

This section presents all the estimation results and the different tests that the data were subjected to. We would begin with descriptive statistics results as follows

Table 2: Descriptive statistics

Descriptive Stats.	GDP	RENW	NONRENW	POPGR	TOTENC
Mean	45721.83	84.10882	100.1143	4395575.	730.3692
Median	42482.04	84.50000	100.2112	4546886.	726.1921
Maximum	77936.10	88.60000	123.3055	5053744.	773.3575
Minimum	21680.20	77.30000	74.38070	3335174.	673.1835
Std. Dev.	20725.38	3.009416	14.34092	483391.7	28.87692
Skewness	0.161292	-0.416260	0.069372	-0.817504	-0.311530
Kurtosis	1.387944	2.144301	1.931075	2.459300	2.085305
Jarque-Bera	3.828943	2.019190	1.645954	3.089175	1.275906
Probability	0.147420	0.364367	0.439123	0.213400	0.528373

Observations	34	34	34	34	34

Source: Author (2025)

The descriptive statistics summarized in Table 2 show the key variables' central tendencies and dispersion. The mean GDP is approximately ₦45,721.83 billion, with a median of ₦42,482.04 billion, indicating a right-skewed the average slightly rises above the midpoint in some years of high GDP performance. This upward skew is modest, as supported by the skewness value of 0.16, and it implies that Nigeria's economic growth has generally increased over the period, although with notable fluctuations. The standard deviation of ₦20,725.38 billion further confirms a considerable degree of GDP variability, implying that the country has experienced periods of both economic expansion and contraction.

In terms of energy consumption dynamics, Renewable consumption (RENW) has a mean of 84.11 and a relatively narrow range between 77.3 and 88.6, showing limited variability across the years (standard deviation = 3.01). Non-renewable energy (NONRENW) shows a mean of 100.11 with wider variation than RENW (standard deviation = 14.34). Population growth (POPGR), measured in absolute terms, averages approximately 4.40 million people annually over the period. The relatively high standard deviation (483,391.7) and range from about 3.34 million to over 5.05 million reflect Nigeria's dynamic and rapidly expanding population

Total energy consumption (TOTENC) has a mean of 730.37 with a standard deviation of 28.88, indicating moderate variability over the years. The lack of statistical significance in the Jarque-Bera tests for all the variables further confirms a relatively normal distribution, supporting the suitability of the variables for regression analysis.

Table 3: Summary of Unit Root Tests (ADF vs. Phillips-Perron)

Variables at the Level				
Variable	**ADF test (t-stat, *p-value*)**	**Phillips-Perron test (t-stat, p-value)**	**Critical Values (1%, 5%, 10%)**	**Remarks**
GDP	-2.2517 (0.0461) *	-2.4693 (0.0472) *	-3.65, -2.96, -2.62	Stationary
RENW	-0.7189 (0.8282)	-0.6510 (0.8454)	-3.65, -2.95, -2.62	Not Stationary
NONRENW	-1.7028 (0.4206)	-1.6051 (0.4688)	-3.65, -2.95, -2.62	Not Stationary
POPGR	-2.7439 (0.0863)	-1.1182 (0.6905)	-3.86, -3.04, -2.66	Not Stationary
TOTENC	-1.6293 (0.4528)	-1.5649 (0.4844)	-3.74, -2.99, -2.64	Not Stationary
Variables at 1st Difference				
Variable	**ADF test (t-stat, *p-value*)**	**Phillips-Perron test (t-stat, p-value)**	**Critical Values (1%, 5%, 10%)**	**Remarks**
ΔGDP	-3.0271 (0.0430) *	-2.9736 (0.0483) *	-3.65, -2.96, -2.62	Stationary
ΔRENW	-5.6528 (0.0000) *	-5.6669 (0.0000) *	-3.65, -2.96, -2.62	Stationary
ΔNONRENW	-6.3506 (0.0000) *	-6.5598 (0.0000) *	-3.65, -2.96, -2.62	Stationary
ΔPOPGR	-2.8310 (0.0069) *	-2.7207 (0.0089) *	-2.67, -1.96, -1.61	Stationary
ΔTOTENC	-5.1965 (0.0004)	-5.2960 (0.0003)	-3.75, -2.99, -2.64	Stationary

	*			

* - Variable is stationary at 5% significance level

Source: Author's computation (2025)

Table 3 presents the results of the unit root test which reveal the stationarity properties of the variables under consideration. At their levels, only gross domestic product (GDP) was found to be stationary at the 5% significance level under both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, suggesting that GDP is integrated of order zero, I(0). However, RENW, NONRENW, POPGR, and TOTENC became stationary after first differencing, while GDP also retained stationarity at first difference. The implication of these findings is that all other variables are integrated of order one, I(1) except for GDP which is stationary at level. This mix of I(0) and I(1) series justifies the application of the ARDL bounds testing approach, which is well-suited for handling variables with such integration properties.

Table 4: Result of the ARDL (Bounds) Cointegration Test

F-Bounds Test	**Null hypothesis: No relationship between levels**	
Test statistic	Value	K
F-statistic	19.91124	4
Critical value bound		
Significance	**I0 Bound**	**I1Bound**
10%	2.20	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Author's computation (2025)

The result of the ARDL Bounds test (Table 4) confirms the existence of a long-run relationship among the variables from 1990 to 2023. The computed F-statistic of 19.911 is far greater than the upper critical bound (I1) values at all conventional significance levels. The test statistic exceeds the upper bound; thus the null hypothesis of no co-integration is decisively rejected. Therefore, the hypothesis concludes that the variables have long-term relationship.

Estimation of ARDL Model

This section presents the estimation of the ARDL model, and the optimal lag length will be determined before model estimation to ensure robust results.

Table 5: Selection Criteria for VAR Lag Order

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-750.8176	NA	2.40e+22	65.72327	65.97011	65.78535
1	-652.7920	144.9074	4.47e+19	59.37321	60.85429*	59.74570
2	-616.5765	37.79000*	2.42e+19*	58.39796*	61.11327	59.08085*

* indicates the lag order selected according to the criterion

Source: Author's computation (2025)

Table 5 shows that the lag order selection criteria use the five commonly used criteria: LR, FPE, AIC, SC, and HQ, with lag 2 being the most optimal choice. Specifically, the sequential modified LR test (LR), the final prediction error (FPE), the Akaike information criterion (AIC), and the Hannan-Quinn information criterion (HQ) all select lag 2, while only the Schwarz criterion (SC) favor lag 1. Given that the majority of the criteria emphasize lag 2, it is considered the most appropriate lag length for the model. Having established the optimal lag, the ARDL model is estimated as follows.

Table 6: ARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP (-1)	0.405017	0.275494	1.470149	0.1723
GDP (-2)	0.388618	0.224044	1.734559	0.1135
RENW	481.7773	53.49790	9.005540	0.0000
RENW (-1)	41.94571	268.1753	0.156412	0.8788
RENW (-2)	535.5273	224.4122	2.386356	0.0382
NONRENW	23.35155	11.40386	2.047686	0.0421
POPGR	0.028284	0.003613	7.827896	0.0000
POPGR (-1)	-0.013674	0.008949	-1.527922	0.1575
POPGR (-2)	0.009336	0.006172	1.512597	0.1613
TOTENC	5.442486	24.15425	0.225322	0.8263
TOTENC (-1)	-33.44833	23.87951	-1.400713	0.1916
TOTENC (-2)	61.62427	21.66761	2.844074	0.0174
C	-38370.75	61505.99	-0.623854	0.5467
R-squared	0.998327	Mean dependent var		56620.30
Adjusted R-squared	0.996319	S.D. dependent var		16118.71
F-statistic	497.2374	Durbin-Watson stat		2.253430
Prob(F-statistic)	0.000000			

Source: Author’s computation (2025)

The estimated ARDL model in Table 6 has two lags for GDP, and most of the regressors capture both the immediate and delayed effects of renewable energy, non-renewable energy, population growth, and total energy consumption on economic growth within the sample period.

Starting with the lagged GDP terms, both GDP (-1) and GDP (-2) are positive but not statistically significant at the conventional levels. This indicates that past GDP values contribute positively to current GDP but not strongly enough to be decisive. This implies that although growth tends to persist over time, the economy is more influenced by external drivers, such as energy and demographic changes, than by its own inertia.

Regarding renewable energy consumption (RENW), the contemporaneous coefficient (481.78) is highly positive and statistically significant (p = 0.0000). This demonstrates that increases in renewable energy consumption have a strong and immediate effect on GDP. In other words, investments in renewable energy directly stimulate economic growth. Interestingly, while RENW (-1) is insignificant, RENW (-2) is positive and significant (535.53, p = 0.0382). This suggests a lagged spillover effect in which the benefits of renewable energy investments also materialize after 2 years. In other words, renewable energy policies may not only generate immediate growth but also create enduring effects over time.

The coefficient of non-renewable energy consumption (NONRENW) is positive and significant (23.35, p = 0.0421). This means that non-renewable energy also contributes positively to GDP, although its effect is much smaller than that of renewable energy. While fossil fuels still play an important role in supporting Nigeria’s growth, their relatively weaker contribution compared to renewables reinforces the importance of transitioning toward cleaner energy.

Population growth (POPGR) has a strong and statistically significant positive effect on GDP (0.0283, p = 0.0000). This indicates that a growing population expands economic activity, most likely by enlarging the labor force and increasing domestic demand. However, its lagged effects (POPGR (-1) and POPGR (-2)) are not significant. This implies that population growth contributes to economic growth immediately, but its delayed effects are less predictable.

The total energy consumption (TOTENC) has mixed effects. While the contemporaneous and first lag terms are insignificant, TOTENC (-2) is positive and significant (61.62, p = 0.0174). This implies that total energy consumption does not immediately influence GDP, but its cumulative impact becomes significant after 2 years. This reflects the delayed effects of large-scale energy use on industrial output and broader economic activities.

Regarding the overall model fit, the R-squared (0.9983) indicates that the model explains approximately 99.83% of the variations in GDP, while the high F-statistic (497.23, p = 0.0000) confirms the regressors' joint significance. The Durbin-Watson statistic (2.25) implies the absence of serious autocorrelation, further validating the model's robustness.

Test of the Hypotheses

H_{01}: No significant relationship exists between renewable energy consumption and economic growth.

From the ARDL results, RENW demonstrates long-run significance, therefore H_{01} is rejected.

H_{02}: No significant relationship exists between non-renewable energy consumption and economic growth.

The ARDL estimates confirm that NONRENW is a dominant and significant driver of Nigeria's GDP, reflecting its oil-dependent economy. Therefore, H_{02} is rejected.

H_{03}: No significant relationship exists between total energy consumption and economic growth.

Total energy consumption (TOTENC), as the aggregate of renewable and non-renewable energy, often emerges as highly significant in ARDL models, especially in the long run. Given the statistical evidence, H_{03} is rejected as total energy consumption significantly affects Nigeria's economic growth.

H_{04}: Population growth has no significant impact on economic growth.

The ARDL results reveal that population growth is significant, hence, H_{04} is rejected. Therefore, population growth significantly impacts economic growth, although the impact differs across time horizons.

Table 7: Normality, heteroskedasticity and autocorrelation tests

Test	**Statistic**	***p-value***
Normality test (Jarque-Bera)	0.947274	0.6227
Serial correlation LM test (Breusch-Godfrey)	0.742295	0.4900
Heteroskedasticity (Breusch-Godfrey)	1.266749	0.3159

Source: *Author's computation (2025)*

The diagnostic tests summarized in Table 7 provide a rigorous evaluation of the OLS regression model's econometric soundness by testing three key assumptions: normality of residuals, absence of serial correlation, and homoskedasticity. The normality of the residuals was assessed using the Jarque-Bera test. The null hypothesis (H_o) of the test asserts that the residuals are normally distributed. The test produced a *p-value* of 0.6227, which is well above the 5% significance level, leading to acceptance of the null hypothesis. This implies that the residuals approximate a normal distribution, satisfying one of the key assumptions.

The Breusch-Godfrey Serial Correlation LM test was used to determine whether the model suffers from autocorrelation, particularly at lag lengths of up to two periods. The null hypothesis posits the absence of a serial correlation in the residuals. The *p-value* obtained from the test

is 0.4900, which exceeds the conventional threshold of 0.05. Consequently, the null hypothesis is rejected indicating that the residuals are not significantly correlated.
The Breusch-Pagan-Godfrey test was used to examine the presence of heteroskedasticity, where the variance of the error term might change across observations. The null hypothesis assumes homoskedasticity, i.e., constant variance of residuals. The test produced a *p-value* of 0.3159, which is comfortably above the 0.05 level of significance. This leads to a failure to reject the null hypothesis, indicating that the model does not exhibit heteroskedasticity. The implication is that the residuals have a constant variance, satisfying another critical OLS assumption.

Discussion of the Findings

The findings, especially the descriptive statistics, reveal that GDP has grown steadily but with significant fluctuations, consistent with Nigeria's volatile macroeconomic performance documented by PricewaterhouseCoopers (2023) and the IMF (2023). The relatively higher variability of non-renewable energy compared to renewable energy reflects Nigeria's long-standing dependence on oil and gas (Okonkwo et al., 2022; NNPC, 2023), while the limited fluctuations in renewable energy suggest underutilization, aligning with the arguments of Ozoegwu et al. (2017) and Nwulu and Xia (2017) who highlight infrastructural and policy barriers to scaling up renewables. The stability in total energy consumption despite population growth further underscores the persistence of energy access deficits in Nigeria (World Bank, 2022; IEA, 2023).
The results of the bounds test confirm the existence of a long-run equilibrium relationship between GDP, renewable, non-renewable energy, population growth, and total energy consumption. This finding is in line with the broader literature that emphasizes the co-evolution of energy consumption and economic performance (Stern, 2011; Apergis & Payne, 2010), and it supports the energy-growth-environment interdependence noted by Omri (2014) and Usman and Balsalobre-Lorente (2022) in the sub-Saharan African context. The existence of cointegration implies that energy and demographic factors jointly determine Nigeria's long-run growth trajectory, reinforcing the institutional approach to development's structural interdependence emphasized by Acemoglu et al. (2005).
The ARDL estimates provide more clarity on growth's short- and long-term drivers. The strong and immediate effect of renewable energy on GDP both contemporaneous and with lagged spillovers, aligns with the evidence of Apergis and Payne (2011) and Pao and Fu (2013), who found renewable energy to be growth-enhancing in emerging economies. This contrasts with Menegaki (2011), who observed a neutrality hypothesis in Europe, emphasizing the contextual importance of renewable energy in Nigeria, where it remains largely untapped. The positive but comparatively smaller effect of non-renewable energy on GDP is consistent with fossil fuels' transitional role in resource-dependent economies (Dong et al., 2022), but it also highlights fossil dependence in driving long-term sustainable growth (Bridge et al., 2018; Nordhaus, 2017).
Population growth is shown to contribute immediately and significantly to GDP, which resonates with the inclusive growth potential emphasized by Ejemeyovwi and Osabuohien (2021). However, population growth insignificant lagged effects raises concerns about Nigeria's ability to translate demographic expansion into sustained productivity gains, echoing the challenges raised in the Nigeria Poverty Assessment (NBS, 2022) regarding employment and human capital absorption. The delayed positive impact of total energy consumption on GDP supports Fouquet (2014) and Smil (2017) argument that energy demand adjustments and infrastructural effects often materialize over time, making investments in energy systems critical for long-run industrial growth.
These findings confirm that Nigeria's growth dynamics are tightly bound to its energy mix and demographic realities. While fossil fuels continue to contribute to growth, renewable energy emerges as a more potent and sustainable driver, echoing the call for a green growth transition

championed by Adewuyi and Olowu (2019), IRENA (2023), and OECD (2011).

Conclusion and Recommendations

The research concludes that energy consumption, particularly from renewable sources, plays a significant and positive role in stimulating Nigeria's economic performance. While non-renewable energy continues to contribute to output, the stronger influence of renewable energy underscores the importance of diversifying the country's energy portfolio in line with global sustainability trends.

The findings reflect the evolving narrative of energy and development in the 21st century from a broader perspective. Historically, Nigeria's economic growth has been closely tied to fossil fuel exploitation, a path that has yielded short-term gains but also exposed the economy to volatility, environmental degradation, and institutional inefficiencies. However, this study aligns with a growing body of literature advocating for cleaner, more resilient energy systems that not only sustain growth but also promote environmental stewardship and social equity.

As the population of Nigeria continues to grow, policymakers must ensure that energy expansion strategies are aligned with human capital development and sustainable urban planning. The following recommendations are proposed:

a) Given the significant positive impact of renewable energy on economic growth, the Nigerian government should prioritize and scale up investment in solar, wind, biomass, and small hydropower systems.
b) While non-renewable energy still contributes to GDP, the global transition to cleaner energy requires Nigeria to rethink its subsidy policy. The gradual removal of fossil fuel subsidies should be pursued with caution and transparency.
c) When disaggregated energy types were accounted for, total energy consumption was found not to be significantly linked with growth. This highlights the inefficiencies in usage. Policies should focus on mandatory energy efficiency standards for industries, buildings, and appliances, public awareness campaigns on energy conservation, and performance-based regulation for utility providers to reduce transmission and distribution losses.
d) With population growth positively influencing GDP but, posing sustainability risks, integrating demographic planning into energy policy is necessary.
e) Effective implementation of energy policy requires strong institutions. The government should enhance the autonomy and technical capacity of energy regulatory bodies, such as the Nigeria Electricity regulatory Commission (NERC) and the Rural Electrification Agency (REA).

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