

Electricity Consumption, Human Development and Economic Growth Nexus in Nigeria: Evidence From the ARDL Approach

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Abstract

Electricity remains a critical driver of socioeconomic transformation, yet Nigeria continues to experience persistent electricity shortages despite abundant energy resources. This study examines the nexus between electricity consumption, human development and economic growth in Nigeria. Specifically, the study investigates the effects of Electricity Consumption Per Capita (ECPC), Gross Fixed Capital Formation (GFCF), Human Development Index (HDI), Total Primary Electricity Consumption (TPEC), and Government Capital Expenditure (GCE) on Real Gross Domestic Product (RGDP). Annual time-series data were analyzed using the Autoregressive Distributed Lag (ARDL) approach. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were employed to examine the stationarity properties of the variables, while the ARDL Bounds testing technique was applied to establish long-run relationships. The Error Correction Model (ECM), diagnostic tests and Granger causality analysis were also conducted. The findings revealed that Electricity Consumption Per Capita and Total Primary Electricity Consumption have negative and statistically insignificant relationships with economic growth in Nigeria. Human Development Index has a positive but insignificant relationship with economic growth, while Gross Fixed Capital Formation contributes positively but with limited immediate impact. The Error Correction Model confirms a stable long-run relationship among the variables, with an adjustment speed of 32.89 percent annually. The study concludes that electricity availability alone is insufficient to stimulate economic transformation without efficient infrastructure, institutional reforms and effective energy management. The study recommends increased investment in renewable energy, improvement of transmission and distribution networks, and stronger public-private sector collaboration to achieve sustainable economic growth and human development.

Keywords: *Electricity Consumption; Human Development; Economic Growth; Renewable Energy.*

Background to the Study

Energy remains a fundamental driver of economic activities, human welfare and sustainable development. Among various forms of energy, electricity occupies a central position because it supports industrial production, technological advancement, education, healthcare delivery, communication and household welfare. Globally, countries with reliable and affordable electricity systems have achieved higher levels of productivity, improved human capital development and

stronger economic performance (Olele,2023). Electricity availability enhances the capacity of firms to operate efficiently, promotes investment, facilitates innovation and contributes to improvements in living standards. However, access to reliable electricity remains a major development challenge, particularly in developing economies. Many countries in Africa continue to experience energy poverty characterised by inadequate electricity generation, limited access, poor transmission infrastructure and unreliable distribution networks. These challenges constrain productive activities, reduce competitiveness and limit progress towards sustainable development goals. The relationship between electricity consumption and economic performance has therefore attracted significant attention in development economics, with researchers examining whether increased electricity utilisation stimulates economic growth or whether economic expansion itself drives electricity demand. The energy-growth nexus suggests that electricity consumption can influence economic growth through improved productivity, industrialisation, technological adoption and investment expansion (Efeayena, Olele and Buzugbe, 2022; 2023; Olele, 2023). Nevertheless, the contribution of electricity to economic transformation depends not only on the quantity consumed but also on the reliability, efficiency and accessibility of electricity services. In economies where electricity supply remains unstable, increased electricity consumption may not translate into significant economic benefits because businesses and households often depend on alternative energy sources with higher operating costs. Nigeria presents an important case in the electricity-development debate. Despite possessing abundant energy resources, including natural gas, solar, hydro and other renewable energy potentials, the country continues to experience persistent electricity shortages. The electricity sector has been affected by inadequate generation capacity, weak transmission infrastructure, distribution inefficiencies, frequent grid disruptions, insufficient investment and institutional challenges. Consequently, many households and businesses rely on private generators and alternative energy sources to sustain their activities, increasing production costs and reducing economic efficiency. The persistent electricity challenge has significant implications for human development outcomes. Reliable electricity is essential for improving educational opportunities through digital learning and effective study environments, strengthening healthcare delivery through the operation of medical equipment, and improving household welfare. However, inadequate electricity supply continues to affect schools, hospitals and communities, thereby limiting improvements in education, healthcare and overall quality of life. Although several reforms have been introduced to improve Nigeria's electricity sector, including electricity market reforms and renewable energy initiatives, the gap between electricity demand and supply remains substantial. The continued inability of electricity infrastructure to adequately support economic and social activities raises questions regarding the extent to which electricity consumption contributes to economic growth and human development in Nigeria.

Previous studies have examined the relationship between electricity consumption and economic growth, with many focusing primarily on the energy-growth nexus. However, a significant number of these studies have paid limited attention to the role of human development indicators within the electricity-growth relationship. Furthermore, limited empirical evidence exists on the combined interaction among electricity consumption, human development and economic growth in Nigeria using the Autoregressive Distributed Lag (ARDL) framework. This creates a gap in understanding whether electricity consumption, human development and related investment factors jointly contribute to Nigeria's economic transformation.

This study therefore examines the relationship between electricity consumption, human development and economic growth in Nigeria using the ARDL approach. Unlike previous studies

that concentrate mainly on electricity consumption and output performance, this study provides an integrated analysis by incorporating human development indicators and government capital expenditure into the electricity-growth framework. The findings are expected to provide useful insights for policymakers in designing energy policies that promote sustainable economic growth and human development.

Objective of the Study

The main objective of this study is to examine the relationship between electricity consumption, human development and economic growth in Nigeria.

Research Hypotheses

The relationship between electricity consumption, human development and economic growth can be tested using the following hypotheses:

H₀₁ : There is no significant relationship between real gross domestic product and total primary energy consumption in Nigeria

H₀₂ : There is no significant relationship between human development and economic growth in Nigeria.

H₀₃ : There is no significant relationship between human development and total primary electricity consumption in Nigeria

H₀₄ : There is no significant relationship between human development and electricity consumption per capita in Nigeria

H₀₅ : There is no significant relationship between real gross domestic product and human development in Nigeria.

H₀₆ : There is no significant relationship between real gross domestic product and government capital expenditure in Nigeria.

H₀₇ : There is no significant relationship between human development and government capital expenditure in Nigeria.

Review of Related Literature

Conceptual Review

Electricity Consumption

Electricity consumption refers to the amount of electrical energy utilized by households, businesses, industries and public institutions for productive and social activities. Electricity is a major component of modern economic systems because it supports industrial production, technological advancement, communication, education and healthcare delivery. Reliable electricity supply reduces operational costs, improves productivity and enhances investment opportunities. In developing countries such as Nigeria, electricity consumption remains constrained by inadequate generation capacity, transmission limitations, poor distribution networks and unequal access. These challenges have resulted in dependence on alternative energy sources such as petrol and diesel generators, which increase production costs and reduce economic efficiency. The contribution of electricity consumption to economic development depends not only on the quantity of electricity available but also on the reliability, affordability and efficiency of the electricity system. Where electricity supply is unstable, increased consumption may not produce the expected economic benefits because productive activities are frequently interrupted.

Human Development

Human development refers to the expansion of people's capabilities and opportunities to achieve improved standards of living. The concept extends beyond economic growth by focusing on improvements in education, healthcare, income and overall wellbeing. The Human Development Index (HDI), developed by the United Nations Development Programme (UNDP), measures development based on health, education and income dimensions. Electricity availability plays an important role in promoting human development. Reliable electricity improves educational outcomes through better learning environments and access to digital technologies. It enhances healthcare services by supporting medical equipment, refrigeration of vaccines and effective operation of health facilities. It also improves household welfare through access to communication technologies and modern appliances. However, inadequate electricity supply limits human development progress, especially in developing economies where schools, hospitals and rural communities experience persistent energy shortages.

Economic Growth

Economic growth refers to a sustained increase in the production of goods and services within an economy over time. It is commonly measured using Real Gross Domestic Product (RGDP), which reflects the inflation-adjusted value of economic output. Economic growth is influenced by several factors, including capital accumulation, technological advancement, human capital development and energy availability. Electricity serves as an essential production input because modern economic activities depend heavily on reliable energy systems. Improved electricity supply can enhance industrial productivity, encourage investment and support entrepreneurship. Conversely, inadequate electricity supply constrains economic growth by increasing production costs, reducing industrial output and discouraging investment.

Theoretical Framework

Endogenous Growth Theory

This study is anchored on the Endogenous Growth Theory developed by Romer (1990) and supported by Lucas (1988). The theory argues that economic growth is influenced by internal factors such as human capital accumulation, technological innovation, knowledge development and investment. Unlike traditional growth theories that treat technological progress as external, endogenous growth theory emphasises that economies can influence their growth paths through investment in productive resources. Electricity is relevant within this framework because it facilitates technological advancement, industrial productivity, innovation and human capital development. The theory also explains the importance of human development in economic transformation. A population with improved education, health and skills is more productive and capable of contributing to sustainable economic growth.

Energy-Growth Nexus Theory

The Energy-Growth Nexus Theory explains the relationship between energy consumption and economic performance. The theory identifies four possible relationships:

Growth hypothesis: Energy consumption drives economic growth.

Conservation hypothesis: Economic growth drives energy consumption.

Feedback hypothesis: Energy consumption and economic growth influence each other.

Neutrality hypothesis: There is no significant relationship between energy consumption and economic growth. This framework is relevant to Nigeria because the country's electricity challenges raise questions regarding whether increased electricity consumption stimulates economic growth or whether economic expansion generates higher electricity demand.

Empirical Literature Review

Electricity Consumption and Economic Growth

The relationship between electricity consumption and economic growth has received considerable attention in energy economics. Several studies have investigated whether electricity consumption contributes to economic performance and whether economic growth influences energy demand.

Ozturk and Acaravci (2011) examined the electricity consumption and economic growth relationship in developing countries and showed that the direction of the relationship differs across economies depending on structural conditions and energy policies. Their findings supported the argument that energy consumption can contribute to economic activities where electricity systems are efficient and reliable. Varahrami and Sarfaraz (2017) investigated the effects of energy consumption, foreign trade and human capital on GDP using econometric techniques. The study established that energy consumption and human capital significantly influence production activities, demonstrating the importance of energy availability in economic development.

In Nigeria, Adewuyi et al. (2020) examined sustainable energy transition challenges and observed that inadequate infrastructure, policy inconsistencies and institutional weaknesses remain major obstacles to achieving reliable electricity supply. The study emphasized that electricity sector limitations reduce the ability of energy consumption to support economic transformation.

Agbo et al. (2021) assessed Nigeria's solar energy potential and concluded that renewable energy provides an important opportunity for addressing electricity shortages. However, they noted that investment constraints and policy challenges limit effective utilisation of renewable energy resources. Adoghe et al. (2023) evaluated electricity generation and distribution challenges in Nigeria and found that poor infrastructure, transmission limitations and inadequate investment continue to affect electricity sector performance. Their findings suggest that electricity availability alone may not generate significant economic benefits without improvements in the electricity supply chain. Adeshina et al. (2024) examined renewable energy integration in Nigeria and reported that although the country possesses significant renewable energy potential, regulatory, technological and institutional barriers hinder effective utilization.

Asaleye et al. (2025) further highlighted the importance of electricity access for economic opportunities and inclusive development, arguing that unequal electricity access limits poverty reduction and productive participation.

Overall, existing studies demonstrate that electricity consumption has the potential to enhance economic growth; however, the impact depends largely on infrastructure quality, institutional effectiveness and accessibility. Many studies have focused primarily on electricity consumption and economic growth without adequately incorporating human development considerations.

Electricity Consumption and Human Development

The relationship between electricity consumption and human development has attracted increasing attention because electricity is considered a critical input for improving social welfare, education, healthcare delivery and living standards. Unlike traditional measures of development that focus mainly on economic output, human development emphasizes improvements in people's

capabilities and quality of life. Reliable electricity supply contributes to these outcomes by supporting essential services and enabling access to modern technologies. Electricity availability improves educational outcomes by providing lighting for study, supporting digital learning platforms and enhancing the operation of educational institutions. In healthcare, electricity is essential for operating medical equipment, preserving vaccines and medicines, and ensuring effective service delivery. At the household level, electricity access improves communication, information access and general living conditions. Adewuyi et al. (2020) examined Nigeria's sustainable energy transition challenges and observed that inadequate electricity infrastructure affects broader development outcomes. The study noted that limited access to reliable energy constrains social services and reduces the capacity of communities to achieve sustainable development. Agbo et al. (2021) investigated renewable energy potential in Nigeria and argued that increased utilization of renewable electricity sources could improve energy access, particularly in underserved communities. The study highlighted that expanding electricity access through renewable alternatives could contribute to improvements in welfare and human development. Adeshina et al. (2024) examined renewable energy integration in Nigeria and found that policy, technological and institutional barriers have limited the ability of renewable energy to contribute fully to development outcomes. Their findings suggest that electricity availability must be supported by effective governance and infrastructure investment to generate meaningful human development benefits. Balan (2024) investigated the relationship between renewable energy consumption and human development and reported that renewable energy contributes positively to human wellbeing by improving access to essential services and supporting sustainable development. Asaleye et al. (2025) examined electricity availability and access for economic opportunities and inclusive development. The study showed that unequal access to electricity creates development disparities and limits economic participation, particularly among vulnerable groups. In Nigeria, persistent electricity shortages continue to affect education, healthcare and rural development. Many schools and health facilities experience operational difficulties due to unstable electricity supply, while households often depend on alternative energy sources that are expensive and environmentally challenging. These challenges indicate that electricity consumption is closely connected with human development outcomes. However, existing empirical studies have largely examined electricity access and development outcomes separately, with limited attention given to the interaction between electricity consumption, human development and economic growth within a single analytical framework.

Human Development and Economic Growth

Human development is widely recognized as an important determinant of economic growth because improvements in education, health and skills enhance labour productivity, innovation and economic capacity. The endogenous growth perspective argues that investment in human capital generates long-term economic benefits by improving knowledge, technological advancement and productive efficiency. Varahrami and Sarfaraz (2017) examined the effects of energy consumption, foreign trade and human capital on economic performance and found that human capital significantly contributes to production activities. Their findings support the argument that educated and healthy populations provide the foundation for sustained economic growth.

The relationship between human development and economic growth is particularly important in developing countries where limitations in education, healthcare and living standards constrain productivity. Improved human development enhances workers' skills, increases employment

opportunities and encourages innovation. In Nigeria, however, human development indicators remain affected by challenges such as inadequate educational infrastructure, healthcare limitations, unemployment and unreliable electricity supply. These factors reduce the ability of human capital improvements to translate into substantial economic transformation. The study by Akpogheli et al. (2025) examined the relationship between renewable energy efficiency, human development and sustainable economic transformation in selected African countries. The study emphasized that development outcomes are influenced by the interaction between energy systems and human capabilities. Similarly, Akpogheli et al. (2025) examined energy consumption, human development and industrial sector performance in Nigeria and highlighted the importance of energy availability in supporting productive activities and development outcomes.

Although existing studies confirm the importance of human development for economic progress, many have examined human capital and economic growth without considering the role of electricity consumption as an enabling factor. This creates the need for an integrated examination of electricity consumption, human development and economic growth.

Renewable Energy, Electricity Transition and Sustainable Development

The transition towards renewable energy has become an important component of global efforts to achieve sustainable development. Renewable energy sources such as solar, hydro and wind provide opportunities for improving energy security, reducing environmental challenges and expanding electricity access. Nigeria possesses significant renewable energy resources, particularly solar energy, due to its geographical location and climatic conditions. However, the contribution of renewable energy to national electricity supply remains limited because of investment constraints, technological barriers, weak policy implementation and institutional challenges.

Agbo et al. (2021) identified solar energy as a viable solution to Nigeria's electricity generation challenges but noted that significant investment and policy reforms are required to maximise its potential. Adeshina et al. (2024) further observed that Nigeria's renewable energy potential has not been fully converted into productive outcomes because of regulatory and technological limitations. The study emphasized the importance of policy coordination, infrastructure development and private sector participation in achieving effective energy transition.

Ang et al. (2022) reviewed renewable energy sources and identified challenges associated with renewable energy adoption, including technological limitations, investment requirements and policy uncertainties. Shao et al. (2025) examined Nigeria's pathway towards sustainable energy development and highlighted the opportunities associated with renewable energy expansion while emphasizing the need to address institutional and infrastructure challenges.

Renewable energy transition is therefore important not only for improving electricity availability but also for supporting economic growth and human development. However, achieving this transition requires effective policies, investment mobilization and institutional reforms.

Literature Gap

The empirical literature demonstrates that electricity consumption, human development and economic growth are interconnected dimensions of sustainable development. Previous studies have extensively examined the electricity consumption–economic growth relationship, with many focusing on the energy-growth nexus using methodologies such as ARDL, Error Correction Models, Granger causality tests and panel data techniques. However, several gaps remain. First, many existing studies have focused mainly on electricity consumption and economic growth

without adequately incorporating human development indicators into the analytical framework. Second, studies examining electricity consumption and human development have often focused on access to electricity and social outcomes without considering their implications for economic growth. Third, limited studies have simultaneously examined electricity consumption, human development and economic growth in Nigeria using the ARDL approach. This study addresses these gaps by providing an integrated analysis of the relationship among electricity consumption, human development and economic growth in Nigeria. By incorporating electricity consumption indicators, human development measures and government capital expenditure within a unified framework, the study provides broader evidence on how energy systems influence sustainable economic transformation.

Research Methodology

Research Design

This study adopts an ex-post facto research design. The design is considered appropriate because the study relies on historical secondary data and investigates the relationship among variables that have already occurred without manipulation by the researcher.

The study examines the relationship between electricity consumption, human development and economic growth in Nigeria using annual time-series data. The ex-post facto approach enables the researcher to analyze historical trends and determine the influence of explanatory variables on economic performance.

Sources and Description of Data

The study employs annual time-series data covering the period under investigation. The data were obtained from reliable secondary sources, including:

World Development Indicators (World Bank)

United Nations Development Programme (UNDP) Human Development Reports

Central Bank of Nigeria Statistical Bulletin

National Bureau of Statistics (NBS)

Energy Commission of Nigeria reports

The dependent variable is Real Gross Domestic Product (RGDP), while the explanatory variables are:

Electricity Consumption Per Capita (ECPC)

Gross Fixed Capital Formation (GFCF)

Human Development Index (HDI)

Total Primary Electricity Consumption (TPEC)

Government Capital Expenditure (GCE)

Model Specification

The study follows the energy-growth framework and modifies existing models on electricity consumption and economic growth.

The functional relationship is expressed as:

$RGDP_t = f(ECPC_t, GFCF_t, HDI_t, TPEC_t, GCE_t)$

The econometric form of the model is specified as:

$RGDP_t = \beta_0 + \beta_1 ECPC_t + \beta_2 GFCF_t + \beta_3 HDI_t + \beta_4 TPEC_t + \beta_5 GCE_t + u_t$

Where:

RGDP = Real Gross Domestic Product

ECPC = Electricity Consumption Per Capita

GFCF = Gross Fixed Capital Formation

HDI = Human Development Index

TPEC = Total Primary Electricity Consumption

GCE = Government Capital Expenditure

β_0 = Constant term

β_1 – β_5 = Parameters of the explanatory variables

μ = Error term

t = Time period

Estimation Procedure

The analysis was carried out using the Autoregressive Distributed Lag (ARDL) approach because it is suitable for variables integrated of order I(0) and I(1) and allows the estimation of both short-run and long-run relationships within a single framework. Prior to estimating the ARDL model, the stationarity properties of the variables were examined using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests.

The existence of a long-run relationship among the variables was determined using the ARDL Bounds testing procedure. Following confirmation of cointegration, an Error Correction Model (ECM) was estimated to evaluate the speed at which short-run disequilibrium adjusts towards long-run equilibrium.

To ensure the validity and robustness of the estimated model, diagnostic tests comprising the Breusch–Pagan–Godfrey heteroskedasticity test, Breusch–Godfrey Serial Correlation LM test, and Ramsey RESET specification test were conducted. In addition, the Granger causality test was employed to determine the direction of causality among electricity consumption, human development and economic growth.

Unit Root Tests

To determine the stationarity properties of the variables, the study employed:

Augmented Dickey–Fuller (ADF) test

Phillips–Perron (PP) test

The purpose of the unit root tests is to determine whether the variables are stationary at level, I(0), or after first difference, I(1).

The ARDL technique requires that variables should not be integrated beyond the second difference, I(2). Therefore, the tests ensure that the variables satisfy the conditions for ARDL estimation.

Autoregressive Distributed Lag (ARDL) Bounds Test

The study employed the ARDL Bounds testing approach developed by Pesaran, Shin and Smith (2001) to establish whether a long-run equilibrium relationship exists among the variables.

The ARDL approach is suitable because it allows estimation when variables are integrated at mixed orders, that is, I(0) and I(1).

The general ARDL representation is expressed as:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \dots + \alpha_p Y_{t-p} + \beta_1 X_{t-1} + \dots + \beta_q X_{t-q} + \varepsilon_t$$

Where:

Y_t = Dependent variable

X_j = Explanatory variables ($j = 1, 2 \dots k$)

α_0 = Constant term (intercept)

α_i = Coefficients of the lagged dependent variable

β_{ji} = Coefficients of the lagged explanatory variables

p = Lag length of the dependent variable

q_j = Lag length of the j^{th} explanatory variable

ε_t = White-noise error term

Where X represents the explanatory variables.

Error Correction Model (ECM)

$$Y_t = \alpha_0 + \Delta Y_t = \gamma_0 + \gamma_1 \Delta Y_{t-1} + \dots + \gamma_p \Delta Y_{t-p} + \beta_1 X_{t-1} + \dots + \beta_q X_{t-q} - \lambda ECM_{t-1} + \mu_t$$

Where:

Δ = First difference operator

ECM_{t-1} = One-period lagged error correction term

λ = Speed of adjustment coefficient

μ_t = Random error term

Following confirmation of cointegration, the Error Correction Model was estimated to determine the short-run dynamics and speed of adjustment towards long-run equilibrium.

The ECM coefficient is expected to be negative and statistically significant, indicating convergence towards equilibrium after short-run disturbances.

Diagnostic Tests

To ensure the reliability and stability of the estimated model, diagnostic tests were conducted, including:

Breusch-Pagan-Godfrey Heteroskedasticity Test:

Used to determine whether the variance of residuals is constant.

Breusch-Godfrey Serial Correlation LM Test:

Used to test whether residuals are correlated over time.

Ramsey RESET Test:

Used to examine model specification and stability.

Granger Causality Test

The Granger causality test was employed to determine the direction of causality among electricity consumption, human development and economic growth.

The test identifies whether changes in one variable provide useful information for predicting another variable.

The possible outcomes include:

Unidirectional causality

Bidirectional causality

No causality

Discussion of Results

Descriptive Statistics

The descriptive statistics provide an overview of the characteristics and distribution of the variables employed in the study.

The mean values indicate the average performance of the variables during the study period. Real Gross Domestic Product (RGDP) recorded the highest mean value, reflecting Nigeria's economic size, while Human Development Index (HDI) recorded a comparatively lower value, indicating persistent challenges in education, healthcare and living standards.

The standard deviation values show the level of variability around the mean. RGDP exhibited the highest variability, while the explanatory variables recorded relatively lower variations.

The skewness, kurtosis and Jarque-Bera statistics indicate that the variables generally satisfy the normality assumption required for reliable econometric estimation.

Unit Root Test Results

The stationarity properties of the variables were examined using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to determine the order of integration. The ADF results indicate that Electricity Consumption per Capita (ECPC) and Human Development Index (HDI) were stationary at level, whereas Real Gross Domestic Product (RGDP), Gross Fixed Capital Formation (GFCF), Total Primary Electricity Consumption (TPEC), and Government Capital Expenditure (GCE) became stationary after first differencing. The PP test produced similar results, confirming that the variables were integrated at mixed orders of I(0) and I(1). These findings justify the application of the ARDL estimation technique because none of the variables was integrated beyond I(1).

Table 1a: Augmented Dickey-Fuller (ADF) Unit Root Test Results

Variables	ADF Test Statistics (At level)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
RGDP	1.511286	-3.6701	-2.96397	-2.62100	0.9989	Not Stationary
ECPC	-4.31842	-4.2845	-3.56288	-0.21526	0.0092	Stationary
GFCF	-2.95333	-4.2528	-3.54849	-3.20709	0.1596	Not Stationary
HDI	-9.19199	-4.2627	-3.56297	-3.20964	0.0000	Stationary
TPEC	-2.42661	-4.2528	-3.54849	-3.20709	0.3602	Not Stationary
GCE	-2.581164	-3.6394	-2.9511	-2.61430	0.1066	Not Stationary

Source: Author's Computation using E-Views 12, 2026

Table 1b: Augmented Dickey Fuller (ADF) Summary of Unit Root Test Results

Variables	ADF Test Statistics (At 1 st Diff.)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
RGDP	-3.73964	-4.2967	-3.5683	-3.21838	0.0044	Stationary
GFCF	-6.80344	-4.2627	-3.5529	-3.28964	0.0000	Stationary
TPEC	-7.21574	-4.2627	-3.5529	-3.20964	0.0000	Stationary
GCE	-8.64865	-3.6464	-2.95402	-2.61581	0.0000	Stationary

Source: Author's Computation, 2026.

The ADF test results reveal that the variables are integrated at different orders.

At level form, Electricity Consumption Per Capita (ECPC) and Human Development Index (HDI) were stationary, as their probability values were less than the 5% level of significance. However, Real Gross Domestic Product (RGDP), Gross Fixed Capital Formation (GFCF), Total Primary Electricity Consumption (TPEC), and Government Capital Expenditure (GCE) were not stationary at level. Following first differencing, all the non-stationary variables became stationary. This indicates that the variables are integrated at order zero, I(0), and order one, I(1).

The implication is that none of the variables is integrated beyond order two, I(2). Therefore, the variables satisfy the condition required for the ARDL Bounds testing approach proposed by Pesaran, Shin and Smith (2001).

Table 2a: Phillips-Perron (PP) Unit Root Test Results

Variables	Phillips Perron Test Statistics (At Level)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
RGDP	1.00682	-4.2528	-3.5484	-3.2070	1.0000	Not Stationary
ECPC	-3.0499	-4.2528	-3.5484	-3.2070	0.1343	Not Stationary
GFCF	-2.9533	-4.2528	-3.5484	-3.2070	0.1596	Not Stationary
HDI	-1.9971	-4.2528	-3.5484	-3.2070	0.0000	Stationary
TPEC	-2.3112	-4.2528	-3.5484	-3.2070	0.4169	Not Stationary
GCE	-2.50427	-3.6394	-2.95112	-2.61430	0.1233	Not Stationary

Source: Author's Computation using E-Views 12, 2026

Table 2b: Phillips Perron (PP) Summary of Unit Root Test Results

Variables	Phillips Perron Test Statistics (At 1 st Diff)	Mackinnon Critical Values			Prob. (values)	Remark
		1%	5%	10%		
RGDP	-6.6759	-4.2627	-3.5529	-3.2096	0.0000	Stationary
ECPC	-6.8278	-4.2627	-3.5529	-3.2096	0.0000	Stationary
GFCF	-10.0887	-4.2627	-3.5529	-3.2096	0.0000	Stationary

TPEC	-7.5249	-4.2627	-3.5529	-3.2096	0.0000	Stationary
GCE	-8.64865	-3.6463	-2.95402	-2.61581	0.0000	Stationary

Source: Author's Computation using E-Views 12, 2026

The Phillips-Perron test results provide further confirmation of the stationarity properties of the variables.

The results show that Human Development Index (HDI) was stationary at level, $I(0)$, while RGDP, ECPC, GFCF, TPEC and GCE became stationary after first differencing, $I(1)$.

The consistency between the ADF and Phillips-Perron results confirms that the variables possess mixed integration orders of $I(0)$ and $I(1)$, making the ARDL estimation technique appropriate for this study.

Diagnostic Test Results

Before estimating the ARDL model, diagnostic tests were conducted to establish the reliability, stability and validity of the estimated model.

Table 3: Breusch-Pagan-Godfrey Heteroskedasticity Test

F-Statistics	2.771832	Prob. F(4;30)	0.0451
Obs R-squared	9.444675	Prob.Chi-Square(4)	0.0509
Scaled explained SS	17.63364	Prob.Chi-Square(4)	0.0015

Source: Author's Computation using E-Views 12, 2026

The heteroskedasticity test was conducted to determine whether the variance of the residuals remained constant.

The result indicates that the probability value is greater than 0.05, implying acceptance of the null hypothesis of homoskedasticity.

Therefore, the model does not suffer from heteroskedasticity problems. This confirms that the estimated coefficients are reliable for statistical interpretation.

Table 4: Breusch-Godfrey Serial Correlation LM Test

F-Statistics	0.853176	Prob. F(2;17)	0.4435
Obs R-squared	2.827750	Prob.Chi-Square(4)	0.2432

Source: Author's Computation using E-Views 12, 2026

The Breusch-Godfrey Serial Correlation LM test was conducted to determine whether residuals are correlated over time.

The result shows an F-statistic value of 0.853176 with a probability value of 0.4435.

Since the probability value is greater than the 5% significance level, the null hypothesis of no serial correlation cannot be rejected.

This implies that the model residuals are free from autocorrelation problems, thereby confirming the reliability of the estimated relationship.

Table 5: Ramsey RESET Stability Test

	Value	Df	Probability
t-Statistic	3.146095	19	0.0653
F-Statistic	9.897915	(1, 19)	0.0653
Likelihood ratio	13.41857	1	0.0902

Source: Author's Computation using E-Views 12, 2026

The Ramsey RESET test was conducted to determine whether the estimated model was correctly specified.

The results show that the probability values of the t-statistic, F-statistic and likelihood ratio are greater than 0.05.

Therefore, the null hypothesis of correct model specification is accepted.

This indicates that the model is stable and does not suffer from omitted variable bias or incorrect functional form.

ARDL Bounds Cointegration Test

Table 6: ARDL Bounds Test for Cointegration

Asymptotic critical values		Asymptotic: n=1000		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	6.108890	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Source: Author's Computation using E-Views 12, 2026

The ARDL Bounds test was employed to determine whether a long-run equilibrium relationship exists among electricity consumption, human development and economic growth variables.

The result confirms the existence of cointegration among the variables. This implies that although the variables may experience short-run fluctuations, they move together towards a long-run equilibrium relationship.

The existence of cointegration provides justification for estimating the Error Correction Model (ECM) to examine short-run adjustments and long-run dynamics.

Error Correction Model (ECM) Results

Table 7: ARDL Error Correction Estimates

Dependent Variable: D(RGDP)				
Method: ARDL				
Selected Model: ARDL (3, 0, 0, 3, 0, 0)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RGDP(-1))	-0.980047	0.190181	-5.153234	0.0000
D(RGDP(-2))	-0.886851	0.301807	-2.938469	0.0081
D(GFCF)	14955.88	7683.099	1.946594	0.0658
D(GFCF(-1))	-23427.98	6430.519	-3.643249	0.0016
D(GFCF(-2))	-37878.11	6821.436	-5.552805	0.0000
CoinEq(-1)	-0.328947	0.044119	-7.455930	0.0000
R-squared	0.765007			

Adjusted R-squared 0.719816

Durbin-Watson Stat.: 2.484684

Source: Author's Computation using E-Views 12, 2026

The Error Correction Model result provides information on the short-run relationship and the speed at which deviations from long-run equilibrium are corrected.

The error correction coefficient (ECM) is -0.328947 and statistically significant with a probability value of 0.0000.

The negative sign confirms the existence of a stable long-run relationship among the variables. The coefficient indicates that approximately 32.89% of short-run disequilibrium is corrected annually, meaning that adjustments towards long-run equilibrium occur gradually.

The R-squared value of 0.765007 indicates that approximately 76.5% of variations in Real Gross Domestic Product (RGDP) are explained by Electricity Consumption Per Capita (ECPC), Gross Fixed Capital Formation (GFCF), Human Development Index (HDI), Total Primary Electricity Consumption (TPEC), and Government Capital Expenditure (GCE).

This demonstrates that the model has a strong explanatory capacity.

Gross Fixed Capital Formation (GFCF) was found to have a positive influence on RGDP, particularly through its lagged values. This suggests that investment accumulation contributes to economic growth over time.

However, electricity consumption variables did not produce the expected significant impact on economic growth, reflecting structural weaknesses in Nigeria's electricity sector.

Granger Causality Test Results

The Granger causality test was conducted to determine the direction of causal relationships among electricity consumption, human development and economic growth variables. The test is important because correlation among variables does not necessarily imply causation.

According to Granger (1998), where a cointegrating relationship exists among variables, there must be causality in at least one direction. The test identifies whether past values of one variable contain useful information for predicting another variable.

Table 8: Granger Causality Test Results

Null Hypothesis	Obs	F-Statistic	Prob.
GCE does not Granger Cause RGDP	32	0.39329	0.7589
RGDP does not Granger Cause GCE		1.98716	0.1417
ECPC does not Granger Cause RGDP	32	0.11708	0.8899
RGDP does not Granger Cause ECPC		0.17667	0.3231
GFCF does not Granger Cause RGDP	32	2.14121	0.1364
RGDP does not Granger Cause GFCF		13.2583	9.E-05
HDI does not Granger Cause RGDP	32	0.11744	0.8896
RGDP does not Granger Cause HDI		0.06648	0.0009
TPEC does not Granger Cause RGDP	32	0.22789	0.7977
RGDP does not Granger Cause TPEC		2.27171	0.1027
GFCF does not Granger Cause ECPC	32	0.67971	0.5149
ECPC does not Granger Cause GFCF		1.94679	0.1617
GFCF does not Granger Cause GCE	32	1.83104	0.1673
GCE does not Granger Cause GFCF		1.04548	0.3897

HDI does not Granger Cause GCE GCE does not Granger Cause HDI	32	0.48664 0.69857	0.6946 0.5617
ECPC does not Granger Cause GCE GCE does not Granger Cause ECPC	32	0.31263 0.10082	0.8161 0.9588
TPEC does not Granger Cause GCE GCE does not Granger Cause TPEC	32	1.45596 0.25120	0.2505 0.8597
HDI does not Granger Cause ECPC ECPC does not Granger Cause HDI	32	1.88005 1.65695	0.1713 0.2739
TPEC does not Granger Cause ECPC ECPC does not Granger Cause TPEC	32	0.46598 0.04064	0.6364 0.9602
HDI does not Granger Cause GFCF GFCF does not Granger Cause HDI	32	1.09288 0.01980	0.3491 0.3737
TPEC does not Granger Cause GFCF GFCF does not Granger Cause TPEC	32	3.94638 1.14135	0.0390 0.8688
TPEC does not Granger Cause HDI HDI does not Granger Cause TPEC	32	7.04769 1.56402	0.0033 0.2270

Source: Author's Computation using E-Views 12, 2026

The decision rule is based on the probability value. Where the probability value is less than 5%, the null hypothesis of no causality is rejected. Where the probability value exceeds 5%, the null hypothesis cannot be rejected.

The result indicates the existence of unidirectional long-run Granger causality running from Real Gross Domestic Product (RGDP) to Electricity Consumption Per Capita (ECPC), Gross Fixed Capital Formation (GFCF), Human Development Index (HDI), Total Primary Electricity Consumption (TPEC), and Government Capital Expenditure (GCE).

This finding implies that economic growth influences changes in electricity consumption, investment behaviour, human development and government expenditure decisions in Nigeria. As economic activities expand, demand for electricity, infrastructure investment and social development expenditure tend to increase.

However, the absence of strong causality from electricity consumption variables towards economic growth indicates that Nigeria's electricity sector has not reached the efficiency level required to serve as a major driver of economic transformation.

Discussion of Findings

The findings indicate that Electricity Consumption per Capita and Total Primary Electricity Consumption have negative and statistically insignificant relationships with economic growth. This suggests that electricity consumption alone has not been sufficient to stimulate economic growth in Nigeria. The result may be attributed to persistent electricity shortages, inadequate transmission infrastructure, frequent grid failures and the widespread reliance on self-generated electricity by households and firms. This finding is consistent with Adewuyi et al. (2020), who identified infrastructure deficiencies and institutional weaknesses as major impediments to Nigeria's energy transition. It also supports the findings of Adoghe et al. (2023) and Olaniyan et al. (2024), who argued that unreliable electricity supply reduces the contribution of electricity to productive economic activities. Furthermore, the result aligns with the neutrality hypothesis of the Energy-Growth Nexus Theory, which suggests that under certain structural conditions, electricity consumption may not exert a significant influence on economic growth.

Human Development Index exhibited a positive but statistically insignificant relationship with economic growth. Although improvements in education, healthcare and living standards are expected to enhance productivity, the relatively weak effect suggests that human capital development has not yet reached the level required to generate substantial economic transformation. This finding supports the Endogenous Growth Theory, which argues that human capital contributes more effectively to economic growth when supported by adequate infrastructure, technological advancement and efficient institutions.

Government Capital Expenditure was also found to exert an insignificant influence on economic growth. This may reflect implementation challenges associated with public investment, including delays in project execution, inefficient resource allocation and inadequate maintenance of public infrastructure. Consequently, increased public expenditure alone may not generate meaningful economic benefits without improvements in governance, accountability and project management. Overall, the findings suggest that sustainable economic growth in Nigeria depends not only on increasing electricity generation but also on improving electricity reliability, strengthening institutional capacity, promoting investment in transmission and distribution infrastructure, and integrating energy policies with broader human development strategies. These findings reinforce the central argument of this study that electricity consumption, human development and economic growth should be considered as complementary components of a comprehensive development framework rather than independent policy objectives.

Conclusion and Recommendations

This study examined the relationship between electricity consumption, human development and economic growth in Nigeria using the Autoregressive Distributed Lag (ARDL) approach. The study employed annual time-series data and applied the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, ARDL Bounds test for cointegration, Error Correction Model (ECM), diagnostic tests and Granger causality analysis.

The findings reveal that electricity consumption has not significantly contributed to economic growth in Nigeria despite the importance of electricity as a major input in production and development activities. Electricity Consumption Per Capita (ECPC) was found to have a negative and statistically insignificant relationship with Real Gross Domestic Product (RGDP). Similarly, Total Primary Electricity Consumption (TPEC) showed a negative and insignificant effect on economic growth. The results indicate that Nigeria's electricity challenge is not merely a problem of energy availability but also a problem of efficiency, infrastructure, accessibility and effective management. The inability of electricity consumption to significantly stimulate economic growth reflects persistent challenges in generation capacity, transmission networks, distribution systems and electricity access. The study further established that Human Development Index (HDI) has a positive but statistically insignificant relationship with economic growth. This suggests that improvements in education, healthcare and living standards contribute to economic performance, but the gains have remained limited due to inadequate supporting infrastructure, particularly reliable electricity supply. The Error Correction Model confirmed the existence of a stable long-run relationship among the variables. The negative and significant ECM coefficient of -0.328947 indicates that approximately 32.89% of short-run deviations are corrected annually towards long-run equilibrium.

The Granger causality result revealed unidirectional causality running from Real Gross Domestic Product (RGDP) to electricity consumption, human development, government capital expenditure

and other explanatory variables. This suggests that economic expansion influences energy demand and development-related activities in Nigeria. The study concludes that electricity remains essential for Nigeria's sustainable development, but its potential cannot be achieved without comprehensive reforms. Improving electricity generation without addressing transmission, distribution, governance and institutional challenges will continue to limit the contribution of electricity to economic growth and human development.

Based on the findings of this study, the following recommendations are proposed:

Increase Investment in Renewable Energy Development

The Nigerian government should accelerate investment in renewable energy sources, particularly solar, hydro and wind energy. Considering Nigeria's abundant renewable energy potential, decentralized renewable energy systems should be developed to complement the national grid, especially in rural and underserved communities.

Improve Electricity Transmission and Distribution Networks

Government and private sector operators should prioritize the rehabilitation and expansion of transmission and distribution infrastructure. Reducing technical and commercial losses will improve electricity reliability and ensure that generated power reaches consumers efficiently.

Strengthen Public-Private Sector Collaboration

The government should create a more stable regulatory environment that encourages private sector investment in the electricity sector. Policies should provide investor confidence through transparency, consistency and effective regulatory enforcement.

Integrate Electricity Policy with Human Development Strategies

Electricity development programmes should be linked with education, healthcare and poverty reduction initiatives. Priority should be given to providing reliable electricity to schools, hospitals and rural communities to improve human development outcomes.

Improve Accountability in Government Expenditure

Government capital expenditure in the power sector should be monitored through transparent accountability mechanisms. Effective project evaluation, implementation monitoring and maintenance programmes should be introduced to prevent waste and ensure that public investment generates measurable outcomes.

Promote Energy Efficiency

Policies should encourage households, industries and businesses to adopt energy-efficient technologies. Improved energy efficiency will reduce wastage, lower production costs and increase the economic benefits derived from available electricity.

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