Optimizing Energy Consumption for Sustainable Development in Nigeria: A Data-Driven Analysis

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Abstract
This study examined the dynamic relationship between energy consumption and sustainable development in Nigeria. Utilizing annual data from 1990 to 2024, the analysis applied structural equation modelling of the form of Seemingly Unrelated Regression model and other econometric framework involving ARDL bounds testing, ADF unit root test, and Toda Yamamoto Granger causality to explore short- and long - run interdependencies. The findings revealed that a 1% increase in total energy consumption and renewable energy usage enhances electricity access by 26% and 0.26%, respectively. However, infrastructure inefficiencies – such as transmission losses and supply instability reduce access by 3.73%, exposing critical systemic weaknesses. Cointegration tests confirmed the existence of a long run equilibrium between energy variables and sustainable development, while causality results identified economic growth as a key driver of energy demand. The study underscores the need for urgent policy interventions to modernize grid infrastructure, expand renewable energy capacity, and strengthen regulatory enforcement.

Keywords: *Sustainable development; Energy consumption; SDG's, Econometric modelling.*

1. Introduction

Energy use is a major topic in conversations about development, sustainability, and climate change. It drives infrastructure, transportation, healthcare, education, and industrialisation worldwide (Khan et al., 2021). Specifically, Goal 7 (Affordable and Clean Energy) and Goal 13 (Climate Action) of the United Nations Sustainable Development Goals underscore the importance of energy. Energy is a double-edged sword for emerging nations like Nigeria, though, as it is also a major source of environmental stress.

Nigeria, the most populous and largest economy in Africa, has a lot of fossil and renewable energy resources, but it also has persistent energy shortages. Nigeria suffers from energy poverty, which leaves more than 85 million people (43% of the population) without access to dependable electricity despite the country's abundance of coal, oil, gas, hydropower, and solar potential (IEA, 2021; World Bank, 2022). Private investment, industrial expansion, and human development—

including access to healthcare, education, and employment opportunities—are all hampered by this energy shortage.

With more than 80% of its energy consumption derived from natural gas and petroleum products, Nigeria's energy landscape is mostly dependent on fossil fuels, which power industry and electricity generation (John, Onwuagbu, and Chigozie, 2025). Although this energy mix has aided in economic expansion and urbanisation, it also increases carbon emissions, air pollution, and environmental damage (Aliyu et al., 2015). Due to unstable grid electricity, diesel and petrol generators are widely used, which worsens environmental problems and raises energy prices for small enterprises and low-income households.

Rather than being solely a technical issue, energy poverty is a complex development issue. It continues social exclusion and regional disparities, especially for women and rural communities, and exacerbates indoor air pollution health risks, especially for households that use biomass fuels (more than 60%) (WHO, 2021). It becomes difficult to strike a balance between the need for energy to propel economic expansion and the unsustainable social and environmental effects of the way energy is currently consumed.

Studies on Nigeria's energy sector frequently concentrate on the connection between economic growth—usually as indicated by GDP or industrial output—and energy consumption (Akinlo, 2008; Akpan & Akpan, 2012). The wider facets of sustainable development, such as institutional, social, and environmental considerations, are rarely taken into account in research, though. Research on the relationship between energy access and important development outcomes, such as poverty alleviation, food security, healthcare, and education, is notably lacking (Adeniran et al., 2020).

This study offers a thorough examination of the connection between energy use and sustainable development in Nigeria, taking into account social, environmental, and economic aspects such as access to power. It investigates the intricate relationships influencing Nigeria's energy and development dynamics using a systems-equation modelling technique in an effort to guide policy changes for a more sustainable future.

2. Literature Review

2.1. Theoretical Review

2.1.1. Energy Ladder Hypothesis

According to the energy ladder hypothesis, households switch from traditional biomass to cleaner energy sources like electricity and LPG as income increases (Rahut *et al*., 2017). However, the model's applicability varies; some studies support the linear model (Zhao *et al*., 2017; Waweru *et al*., 2022), while others find households use multiple fuels simultaneously ("energy stacking") (Choumert-Nkolo *et al*., 2019; Masera *et al*., 2000). The model's shortcomings include oversimplification and the neglect of regional and cultural variations (Masera *et al*., 2000).

2.1.2. Energy Consumption theory

Economic benefits from production and service operations may exceed energy expenses, according to the energy consumption theory, sometimes referred to as the energy cost hypothesis (Khusaifan, 2018). Small-scale upgrades can boost the economy and promote general expansion (Vosooghzadeh, 2020). Increases in demand-driven financial transactions may inspire innovative solutions that lower the cost of energy generation (Taghizadeh & Pourrabbi, 2013). In essence, businesses might profit from lower power usage costs, while consumers may be able to pay for energy expenses as a result of better financial circumstances.

2.1.3. EKC HYPOTHESIS

An inverted U-shaped association between economic expansion and environmental degradation is suggested by the Environmental Kuznets Curve (EKC) theory (Hoang *et al*., 2024; Almeida *et al*., 2024). Economic expansion initially causes environmental degradation to worsen, but at a certain point, technology developments, more stringent laws, and a move towards service-based economies cause environmental quality to improve (Wang *et al*., 2013; Tuna *et al*., 2023; Hoang *et al*., 2024). This implies that as wealthier countries make investments in environmental protection and cleaner technologies, economic growth can eventually result in environmental sustainability (Hoang *et al*., 2024).

2.2. Empirical Review

A substantial body of literature has explored the intricate relationships between energy consumption, economic growth, and sustainable development, though findings often diverge across regions and contexts. In particular, studies on the Nigerian and broader Sub-Saharan African context reveal both the potential and the limitations of energy as a driver of inclusive and sustained growth.

2.2.1. Energy Consumption and Economic Growth

Numerous studies affirm that energy consumption is positively associated with economic growth, albeit with variation in the strength and direction of causality. For instance, Ogundipe and Apata (2013), Antai et al. (2015), and Sama and Tah (2016) observed a reciprocal causality between energy use and GDP growth, suggesting a reinforcing feedback loop wherein increased energy availability stimulates output, which in turn raises energy demand. In Nigeria, Olarinde and Adeniran (2018) found a significant long-run relationship between petroleum consumption and GDP growth, with evidence of a causal feedback loop between energy and labour inputs.

However, not all findings are uniformly supportive. Ekeocha et al. (2020) reported a negligible impact of energy use on growth in Nigeria between 1999 and 2016, attributing this to inefficiencies in energy infrastructure. Mustapha and Fagge (2015) similarly found no causal relationship between energy use and GDP, arguing instead that capital accumulation and labour productivity played more central roles. These divergent results may reflect the unique structural and institutional dynamics of the Nigerian energy sector.

Further, several studies highlight the existence of long-term cointegration between energy use and GDP. Adegbemi et al. (2013), Kahia and Ben-Aissa (2014), and Twerefou et al. (2018) demonstrated that while short-term effects are often weak or statistically insignificant, long-term energy investments have meaningful implications for sustained output growth. These findings reinforce the importance of understanding the temporal dynamics in energy-growth relationships.

2.2.2. Renewable vs Non-Renewable Energy Sources

A growing strand of research has differentiated between the economic impacts of renewable and non-renewable energy sources. Nkoro et al. (2019) and Khide and Adjasi (2015) concluded that while non-renewables tend to drive short-term GDP growth, renewable energy exerts a more significant and favourable long-term impact in Nigeria. In the G7 countries, Behera and Mishra (2019) found that both types of energy contributed to growth, but with different magnitudes and time horizons.

Adams et al. (2018), examining 30 Sub-Saharan African countries, reported that a 10% increase in fossil fuel energy consumption resulted in a 2.11% rise in GDP, compared to a 0.27% rise from renewables. Similarly, Ntanos et al. (2018) showed that in higher-GDP European countries, renewable energy was more closely linked to economic growth, reflecting institutional and infrastructural readiness for sustainable transition.

Moreover, studies from Brazil (Pao & Fu, 2013), Pakistan (Zeshan et al., 2012), and other emerging economies have underscored that the growth implications of energy type are context-dependent. Brazil's experience highlighted the importance of non-hydroelectric renewables for growth, while Pakistan's data revealed feedback relationships among GDP, energy sources, and capital inputs.

2.2.3. Energy, Environment, and Sustainable Development

While energy's role in economic expansion is well-documented, its environmental and sustainability dimensions have attracted increasing academic attention. Sibanda et al. (2024), focusing on SADC countries, found a strong positive correlation between energy use and carbon emissions, suggesting environmental degradation. However, the study also emphasized that technological interventions—such as expanded ICT access—can mitigate these negative externalities.

In a global study involving 74 countries, Nate et al. (2021) analyzed how energy consumption affects all three pillars of sustainable development: economic, social, and ecological. Their findings revealed that while energy restriction policies might reduce ecological footprints, they could simultaneously undermine social welfare outcomes. This reinforces the need for a balanced approach to energy policy that integrates ecological and human development goals.

Bojnec and Papler (2011) emphasized the importance of energy efficiency and technological innovation, noting that countries with higher R\&D expenditure and technologically intensive exports achieved both reduced energy intensity and improved economic efficiency. These insights are critical for countries like Nigeria, where energy infrastructure remains underdeveloped.

2.2.4. Governance, Infrastructure, and Institutional Factors

Institutional quality and governance structures significantly mediate the effectiveness of energy use in driving development. Ana-Maria et al. (2019), studying Central and Eastern Europe, found that electricity consumption and GDP growth were closely linked, but this relationship was conditioned by governance quality. Countries with stronger institutions experienced more positive energy-growth interactions, while those with weak governance witnessed stagnation or even contraction.

In West Africa, Twerefou et al. (2018) concluded that although electricity and petroleum consumption positively affected long-run GDP, their short-term impact was limited due to infrastructural bottlenecks. Likewise, Ekeocha et al. (2020) argued that the inability of Nigeria's energy system to translate usage into economic output stems from structural inefficiencies in distribution and planning.

2.2.5. Energy Access, Inequality, and Human Development

An emerging literature addresses the socio-economic outcomes of energy access. Pachauri and Spreng (2011) introduced the Energy Access-Consumption Matrix based on household-level data in India. Their findings showed declining biomass use but widening energy access disparities, underscoring the multi-dimensional nature of energy poverty.

In Cameroon, Sama and Tah (2016) found that energy consumption was strongly influenced by population growth, GDP, and inflation—highlighting the demand-side drivers of energy use. In

Nigeria, Olarinde and Adeniran (2018) established a feedback loop between labour force growth and energy consumption, emphasizing that demographic and labour market factors play key roles in shaping energy needs and development trajectories.

2.2.6. Synthesis and Gap Identification

Overall, the empirical literature supports the notion that energy consumption is essential for economic growth and sustainable development. However, the extent and nature of this impact vary across energy types, governance contexts, and development stages. In Nigeria, the findings are mixed: some studies show robust causal relationships, while others report weak or no linkages largely due to infrastructural inefficiencies, governance weaknesses, and limited renewable energy integration.

Despite the growing research base, critical gaps remain. Few studies examine the multi-dimensional nature of sustainable development using disaggregated energy variables. Even fewer account for institutional quality, transmission losses, or access equity. This study addresses these gaps by applying a systems-equation modeling approach to explore the long-run and causal relationships between energy consumption and sustainable development in Nigeria from 1990 to 2024.

3. Methodology

3.1. Variable Construction

There are several aspects that influence sustainable development. The connection between energy use, efficiency, and sustainable development especially in the economic context has been the subject of much research. We'll list the important variables from earlier research and talk about how they relate to the model.

Access to Electricity: According to the Sustainable Development Goals (SDGs), one of the most important indicators for sustainable development is access to electricity, which is calculated as the proportion of the population that has power.

Total Energy Consumption: There are conflicting findings from empirical research on Nigeria's energy use and economic expansion. Adegbemi et al. (2013) showed a substantial positive link between aggregate energy consumption and economic growth, but Ekeocha et al. (2020) concluded that energy consumption had a minor impact on growth. This discrepancy emphasises how intricate and uncertain the relationship between overall energy use and sustainable growth is.

Electricity Production: Adegbemi et al. (2013) and Antai et al. (2015) found a positive correlation between Nigeria's economic growth and energy usage. While Antai et al. showed a direct and reciprocal association between energy usage and GDP growth, Adegbemi et al. observed a long-term relationship between economic expansion and energy use.

Renewable energy consumption: Consuming renewable energy is anticipated to eventually accelerate economic growth, according to Nkoro et al. (2019).

Gross National income: Uzokwe and Onyije (2020) estimate that rising energy consumption will support economic expansion.

3.2. Data Source

The World Bank Development Indicators, the International Energy Agency, and the World Energy & Climate Statistics Yearbook (ENERDATA) provided the data used in the study for the years 1990–2024.

3.3. Model Specification

This work is a component of a larger empirical study that estimated a system of connected equations using the Seemingly Unrelated Regression (SUR) model. When modelling several dependent variables at once and their error terms are contemporaneously associated, SUR is appropriate. Compared to estimating each equation independently, this method increases estimate efficiency. By enabling information sharing across equations via the error covariance matrix, the SUR framework improves estimate efficiency. In complex energy-environment-development systems, where economic, environmental, and infrastructure factors interact dynamically, this is particularly pertinent. Four structurally different but theoretically connected equations made up the entire model:

1. Greenhouse Gas Emissions = f(Energy Consumption)
2. Sustainable Development = f(Greenhouse Gas Emissions)
3. Energy Efficiency = f(Renewable Energy Consumption)
4. Sustainable Development = f(Energy Consumption)

However, only the fourth equation—which looks at how energy usage affects sustainable development is shown and examined in this work. To enable a more thorough examination of each theme goal, the remaining equations are covered in distinct studies.

In order to investigate the relationship between energy consumption and sustainable development, the model used the following indicators as fundamental variables: gross national income per capita (GNIPC), electricity production (ELP), the share of renewable energy in energy production (SREP), total energy consumption (TEC), and access to electricity (ATE). The specification is as follows:

$$ATE_t = \alpha_0 + \alpha_1 TEC_t + \alpha_2 ELP_t + \alpha_3 SREP_t + \alpha_4 GNI_t + \ell_t \qquad 1$$

3.4. Estimation procedures

The Augmented Dickey-Fuller (ADF) test was used to check for stationarity in all variables. To attain stationarity, transformations were used where needed. Seemingly Unrelated Regression, which takes contemporaneous correlation across the system's error term into consideration, was used to estimate the SUR system. Even though the SUR system was calculated collaboratively, only equation 4's results are reported and interpreted in this research, which directly addresses the study's goal of assessing how energy use affects Nigeria's sustainable development.

4. Empirical Results

4.1. Descriptive Statistics and Analysis of Model estimations

Access to Electricity (ATE) has a median of 50% and a mean of 48.5%, with a virtually symmetric distribution despite a slight left skew (-0.35) indicating certain places with lesser access. With a standard deviation of 8.67% and a range of 27.3% to 62.3%, electricity availability varies greatly, suggesting that infrastructure development and policy execution are not uniform. With a mean of 27.9%, substantial variability (SD = 8.93%), and a broad range of 14.3% to 41.9%, renewable energy's share of electricity generation is more erratic than the steady trends in electricity production and overall energy consumption. The left-skewed distribution of the Log of Gross National Income (LGNI) is probably caused by income disparity or economic downturns. All variables pass normality tests in spite of this. The trustworthiness of these results is, however, constrained by the small sample size (35 observations). All things considered; the dataset seems appropriate for employing parametric statistical techniques to simulate the effects of energy on development.

Table 1: Descriptive statistics for: ATE, LTEC, LELP, SREP, GNIPC

	ATE	LTEC	LELP	SREP	LGNI
Mean	48.50454	4.704348	3.145025	27.89700	11.84284
Median	50.00000	4.700480	3.135494	27.10000	12.31842
Maximum	62.33300	5.161592	3.688879	41.90000	13.77822
Minimum	27.30000	4.189655	2.564949	14.27150	8.500545
Std. Dev.	8.666934	0.317681	0.368506	8.926626	1.579246
Skewness	-0.346060	-0.083565	0.017131	-0.013723	-0.616913
Kurtosis	2.399632	1.545001	1.544939	1.488876	2.210357
Jarque-Bera	1.224232	3.128057	3.089298	3.331197	3.129381
Probability	0.542202	0.209291	0.213387	0.189078	0.209153
Sum	1697.659	164.6522	110.0759	976.3950	414.4993
Sum Sq. Dev.	2553.935	3.431319	4.617092	2709.278	84.79665
Observations	35	35	35	35	35

Source: Eviews 9, 2025

Only Access to Electricity (ATE) is stationary at level (I(0)), according to the results of the Augmented Dickey-Fuller test (Table 2). The remaining variables, which are integrated of order one (I(1)), are non-stationary at level but become stationary after first differencing (LTEC, LELP, SREP, and LGNI).

Table 2: ADF unit root test: ATE, LTEC, LELP, SREP, LGNI

Series	Test Statistic	CV@5%	CV@10%	Remarks
	Trend and Intercept (Series at Levels)			
ATE	-6.887875	-3.548490	-3.207094	I(0)
LTEC	-1.783631	-3.548490	-3.207094	NS
LELP	-3.240699	-3.548490	-3.207094	NS
SREP	-3.529001	-3.548490	-3.207094	NS
LGNI	-1.503725	-3.548490	-3.207094	NS
	Trend and Intercept (Series at First Differencing)			
LTEC	-5.713736	-3.552973	-3.209642	I(1)
LELP	-7.389009	-3.552973	-3.209642	I(1)
SREP	-6.957233	-3.552973	-3.209642	I(1)
LGNI	-4.666709	-3.552973	-3.209642	I(1)

CV=Critical Value, ADF=Augmented Dickey Fuller, NS=Non Stationary
Source: Eview 9, 2025

The study used the Bound Test Cointegration approach to investigate possible long-term correlations between the variables because of the mixed integration orders (I(0) and I(1)). The necessity to ascertain if steady-state correlations exist in spite of varying integration orders motivated this choice.

The mixed integration orders made the ARDL model appropriate. The null hypothesis is rejected and a long-term relationship between ATE, LTEC, LELP, SREP, and LGNI is indicated by the computed F-statistic (9.248296), which is greater than the lower and upper bound critical values. This implies that these factors will likely move in tandem over time, suggesting a close relationship between Nigeria's sustainable development and energy consumption. According to Table 3's findings, nigeria's energy consumption and sustainable variables move together over the long run with an adjustment speed of 101%, suggesting a strong trend towards equilibrium restoration.

Table 3: ARDL bounds test: ATE, LTEC, LELP, SREP, LGNI

Test Statistic	Value	k		
F-statistic	9.248296	4		
Critical Value Bounds				
Significance	I0 Bound	I1 Bound		
10%	2.45	3.52		
5%	2.86	4.01		
2.5%	3.25	4.49		
1%	3.74	5.06		
Variable	Coefficient	Std. Error	t-Statistic	Prob.
CointEq(-1)	-1.015137	0.152172	-6.670980	0.0000

Null Hypothesis: No long-run relationships exist; Sample: 1990 2024
Source: Eviews 9, 2025

This study investigates the impact of energy use on sustainable development using seemingly unrelated regression, the findings of which are provided in Table 3. The model shows a positive association between access to electricity (ATE) and total energy consumption (LTEC), with a 1% rise in LTEC resulting in a 26% increase in ATE, however reliance on fossil fuels raises sustainability issues. Furthermore, the proportion of renewable energy in electricity production (SREP) has a favourable effect on ATE, with a 1% rise in SREP resulting in a 0.26% increase in ATE, highlighting renewable energy's benefits for long-term access to electricity.

Table 4.: SUR_ analysis estimations

Estimation Method: Seemingly Unrelated Regression
Total system (balanced) observations 139
Linear estimation after one-step weighting matrix

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(16)	-97.70282	21.87839	-4.465722	0.0000
C(17)	26.16374	7.299540	3.584300	0.0005
C(18)	-3.732595	3.984139	-0.936864	0.3507
C(19)	0.265827	0.102313	2.598175	0.0106
C(20)	2.317620	0.878363	2.638567	0.0094

Determinant residual covariance **1.05E-11**

ATE = C(16) + C(17)*LTEC + C(18)*LELP + C(19)*SREP + C(20)* LGNI
R-squared 0.945977 Adjusted R-squared 0.938774 Durb-W 1.895522

Source: Eviews 9, 2025

Table 4 shows that gross national income (LGNI) has a positive effect on access to electricity (ATE), with a 1% increase in LGNI translating into a 2.31% increase in ATE. However, ATE is negatively impacted by electricity production (LELP); a 1% rise in LELP causes a 3.73% drop in ATE, most likely as a result of inefficiencies. The energy consumption variables (LTEC, SREP, and LGNI) and sustainable development in Nigeria are significantly correlated, and the model has a high explanatory ability (R-square = 0.94).

Complex links between Nigeria's economic growth, electricity access, energy consumption, and adoption of renewable energy are revealed by the Toda Yamamoto VAR Granger Causality test (Table 5). The findings indicate that access to electricity (ATE) is greatly impacted by gross national income (LGNI), indicating that economic expansion propels ATE improvements through investments in energy infrastructure. In order to address issues with electricity access, the combined significance of all variables emphasises the necessity of equal energy distribution, balanced economic growth, and infrastructure modernisation. Furthermore, while electricity generation (LELP) and renewable energy share (SREP) have no direct effect on ATE, total energy consumption (LTEC) only slightly contributes to it.

Table 5: VAR granger causality (model 4)

Dependent variable: ATE			
Excluded	Chi-sq	df	Prob.
LTEC	3.106150	1	0.0780
LELP	0.627772	1	0.4282
SREP	1.232194	1	0.2670
LGNI	6.160310	1	0.0131
All	39.78102	4	0.0000
Dependent variable: LTEC			
Excluded	Chi-sq	df	Prob.
ATE	3.033164	1	0.0816
LELP	1.019382	1	0.3127
SREP	0.019677	1	0.8884

LGNI	5.724453	1	0.0167
All	7.799426	4	0.0992
Dependent variable: LELP			
Excluded	Chi-sq	df	Prob.
ATE	0.000494	1	0.9823
LTEC	6.787280	1	0.0092
SREP	0.052497	1	0.8188
LGNI	0.845156	1	0.3579
All	14.06502	4	0.0071
Dependent variable: SREP			
Excluded	Chi-sq	df	Prob.
ATE	1.216310	1	0.2701
LTEC	0.019680	1	0.8884
LELP	0.698496	1	0.4033
LGNI	0.006848	1	0.9340
All	19.57312	4	0.0006
Dependent variable: LGNI			
Excluded	Chi-sq	df	Prob.
ATE	1.783492	1	0.1817
LTEC	0.022962	1	0.8796
LELP	0.355810	1	0.5508
SREP	0.485759	1	0.4858
All	4.158659	4	0.3850

Source: Eviews 9, 2025

A feedback loop that favours fossil fuels can be seen in the dynamics of energy production and consumption. Total energy consumption (LTEC), which reflects Nigeria's energy-intensive industrialisation and urbanisation, is driven by economic growth (LGNI). Electricity production (LELP), which is mostly derived from fossil fuels, is then driven by total energy consumption, sustaining carbon-intensive energy systems. The systemic relevance of renewable energy share (SREP) implies that its implementation requires coordinated policies rather than isolated initiatives, even while it lacks individual drivers.

Among the economic tests of significance computed in the larger study are the system residual normality test, system residual portmanteau test for autocorrelation, correlation matrix, and covariance matrix.

Autocorrelation in residuals is evaluated using the Ljung-Box test (Portmanteau test), and because of the study's high sample size, the Q-Stat is favoured above the Adj Q-Stat. In order to validate the model's performance, the test results, which are shown in Table 6, will ascertain whether the residuals exhibit considerable autocorrelation.

Table 6: System residual portmanteau tests for autocorrelations

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	23.92893	0.0911	24.65405	0.0762	16
2	44.87010	0.0650	46.90404	0.0433	32
3	55.28534	0.2188	58.32720	0.1460	48
4	72.98720	0.2066	78.38932	0.1065	64
5	87.96337	0.2539	95.94758	0.1080	80
6	99.56917	0.3812	110.0403	0.1550	96
7	107.3085	0.6077	119.7862	0.2901	112
8	119.4444	0.6933	135.6562	0.3048	128
9	129.9427	0.7931	149.9339	0.3504	144
10	141.9461	0.8443	166.9387	0.3374	160
11	151.8496	0.9058	181.5786	0.3708	176
12	164.3626	0.9265	200.9169	0.3149	192
Null Hypothesis: no residual autocorrelations up to lag h					

Source: Eviews 9, 2025
The test is valid only for lags larger than the System lag order.
df is degrees of freedom for (approximate) chi-square distribution

The statistics reveal no significant autocorrelation in the residuals, suggesting that they are distributed randomly and devoid of any discernible patterns, as the p-values from lags 1 through 12 are greater than 0.05. Consequently, it implies that the model has caught the fundamental relationships and that the residuals are white noise.
The system normality tests establish whether the residuals, or errors, of a regression model are distributed normally. The 0.05 probability value benchmark was used to determine whether the null hypotheses are accepted or rejected. The null hypothesis states that residuals are distributed normally.

Table 6: System residual normality tests

Component	Skewness	Chi-sq	df	Prob.
1	-0.378357	0.835066	1	0.3608
2	-0.089672	0.046906	1	0.8285
3	-0.052477	0.016064	1	0.8991
4	-0.140448	0.115066	1	0.7344
Joint		1.013103	4	0.9078
Component	Kurtosis	Chi-sq	df	Prob.
1	3.128086	0.023925	1	0.8771
2	3.057364	0.004799	1	0.9448
3	2.208350	0.913953	1	0.3391
4	2.748355	0.092349	1	0.7612
Joint		1.035026	4	0.9044
Component	Jarque-Bera	df	Prob.	

1	0.858992	2	0.6508
2	0.051705	2	0.9745
3	0.930017	2	0.6281
4	0.207416	2	0.9015
Joint	2.048129	8	0.9795

Null Hypothesis: residuals are multivariate normal

Source: Eviews 9, 2025

The results of the Jarque-Bera, skewness, and kurtosis tests all have p-values greater than 0.05, suggesting that the residuals have a normal distribution. This implies that the results are trustworthy and that the model's assumptions are met.

4.2. Economic Interpretation of Results

Access to electricity (ATE) is positively impacted by total energy consumption (LTEC) and renewable energy share (SREP), according to this study, which looks at the relationship between sustainable development and energy consumption. These results corroborate modernisation theories (Rostow, 1960) that emphasise the contribution of energy infrastructure to economic growth and Sachs and Warner's (1995) focus on sustainable energy transitions for long-term development, especially in resource-rich countries.

In line with Wolde-Rufael's (2009) research on transmission constraints in African countries, the study discovered that electricity production (LELP) had a detrimental effect on access to electricity, most likely as a result of inefficiencies such grid losses and irregular supply. With a high adjustment speed (101%) towards equilibrium, the cointegration test shows a long-term relationship between energy consumption and sustainable development, bolstering the Energy Ladder Hypothesis (Leach, 1992), which holds that as countries advance, they switch to more sustainable and efficient energy sources.

The study demonstrates the role of economic growth (LGNI) in boosting access to electricity and overall energy usage. The absence of a clear causal relationship between the use of renewable energy and the availability of electricity, however, points to the necessity of policy-driven incentives to increase the impact of renewables. The need for pro-growth policies that support sustainable energy expansion is highlighted by this finding, which supports Pachauri and Spreng's (2011) contention that targeted government interventions are required to encourage the adoption of renewable energy and guarantee fair energy distribution in developing nations.

5. Conclusion and Recommendations

Using sound econometric techniques, this study investigated the intricate connections between energy use and sustainable development in Nigeria. The results offer insightful information about how energy, the environment, and development interact, highlighting the necessity of careful policy changes to move towards a sustainable energy economy that strikes a balance between environmental preservation and economic growth.

According to the study, a 1% rise in total energy consumption (LTEC) results in a 26% increase in electricity access (ATE), indicating that rising access to electricity in Nigeria is mostly driven by total energy consumption. This demonstrates how crucial it is to develop energy infrastructure in order to electrify. Furthermore, access to power is greatly enhanced by a larger share of renewable energy production (SREP), underscoring the possibility of a sustainable energy transition. The need to update Nigeria's grid and address structural inefficiencies is highlighted by the fact that electricity production (LELP) has a detrimental effect on access, most likely as a result of transmission losses, poor infrastructure, and erratic supply.

The study's conclusions highlight the necessity of focused legislative actions to solve Nigeria's energy-related problems. Grid efficiency and distribution must be enhanced to guarantee that energy expansion results in appreciable increases in access to electricity. To reduce transmission losses, the Nigerian Electricity Regulatory Commission ought to set strict efficiency guidelines. The government should also establish policies that prioritise renewable energy sources in power purchase agreements and foster private sector involvement in renewable energy projects and system expansions.

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