**DOES ENERGY POVERTY UNDERMINE ENVIRONMENTAL SUSTAINABILITY? EVIDENCE FROM NIGERIA**

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**ABSTRACT**

This study explores the nexus between energy poverty and environmental sustainability in Nigeria using annual data from 1995-2024 sourced from the World Development Indicators. Environmental sustainability was measured through institutional policy ratings, while energy poverty served as the core explanatory variable, complemented by access to electricity, electricity consumption per capita, fossil fuel use, and access to clean fuel as threshold variables. Foreign direct investment, urbanisation, and per capita income were included as controls. Employing the autoregressive distributed lag (ARDL) approach, the results confirmed long-run cointegration among the variables. The short-run estimates revealed largely insignificant effects, though access to electricity and clean fuel exhibited contractionary tendencies. In the long run, access to electricity and urbanisation significantly improved environmental sustainability, whereas energy poverty, fossil fuel dependence, foreign direct investment, and per capita income exerted adverse effects, reflecting structural inefficiencies and enclave-type investment practices. Post-estimation diagnostics confirmed the robustness of the model. From a policy perspective, the findings underscore the need to reduce energy poverty through broader electricity access and clean energy adoption, promote sustainable urbanisation with adequate infrastructure, and restructure foreign investment to maximise domestic spillovers. Failure to address fossil fuel dependence risks undermining Nigeria’s long-run environmental sustainability agenda.

**Keywords**: Energy poverty, Environmental sustainability, Fossil fuel consumption, Clean energy

**JEL Codes: Q56, Q41**

**1. INTRODUCTION**

Energy poverty remains a critical impediment to sustainable development across advanced, emerging and developing economies. Globally, the failure to guarantee reliable, affordable and clean energy for all undermines human well-being, constrains economic productivity and complicates efforts to meet international sustainability commitments embodied in the Sustainable Development Goals (SDGs), particularly SDG7 (affordable, reliable and modern energy) and SDG13 (climate action). Despite modest gains in electricity access, hundreds of millions still lack reliable supply, forcing dependence on costly and polluting alternatives such as kerosene, diesel generators and inefficient biomass, with severe health and environmental consequences (IEA, 2024). This persistent exclusion creates tensions between development imperatives and environmental sustainability.

In West Africa, these challenges are intensified by rapid population growth, urban–rural disparities in grid penetration, weak institutional capacity, inadequate electrification finance, and dependence on fossil-fuel exports, which disincentivize clean energy investments. Power systems in the region are characterised by low generation capacity, high transmission and distribution losses, and financial shortfalls that perpetuate reliance on biomass and small-scale fossil fuels, aggravating environmental degradation and public health risks (Adewuyi et al., 2020).

Nigeria exemplifies these dynamics. Despite vast oil, gas and renewable resources, it has one of the largest global electricity access deficits. Millions either lack grid connection or endure erratic supply, resorting to diesel generators and traditional biomass. This situation yields a three-fold problem: deprivation of socio-economic benefits from reliable electricity, environmental damage through deforestation and pollution and constraints on productivity and poverty alleviation (World Bank, 2023). Structural barriers include chronic underperformance across generation, transmission and distribution; institutional fragmentation and regulatory uncertainty; demographic pressures that outpace electrification gains and governance issues in fossil-fuel resource management (NBS, 2022).

Environmentally, energy poverty accelerates deforestation, drives indoor air pollution, and increases greenhouse gas emissions from dispersed, small-scale sources such as diesel generators. These processes undermine ecosystem services, intensify climate vulnerabilities, and create feedback loops between poverty and environmental degradation (Adewuyi et al., 2020; Ndukwu et al., 2021). While distributed renewables, modern cooking solutions and energy efficiency measures offer viable clean-access pathways, realising their potential in Nigeria requires addressing financing, regulatory, and integration challenges (IEA, 2023).

Policy reforms since the early 2000s have promoted privatisation, renewables and off-grid solutions, yet implementation gaps persist due to misaligned subsidy and tariff structures, fiscal constraints and regulatory uncertainty (IEA, 2022; NBS, 2022). Energy poverty disproportionately affects rural, low-income and female-headed households, exacerbating gender inequalities, limiting educational outcomes and constraining micro-enterprise productivity (Ogwumike & Ozughalu, 2015).

Despite a growing body of research, important gaps remain. In the first instance, many studies focused narrowly on access or on environmental outcomes in isolation. Also, fewer studies rigorously quantify linkages between household energy deprivation and measurable environmental indicators at sub-national scales. The country’s large absolute numbers without reliable electricity, the persistence of polluting fuel use, systemic power sector deficiencies and the twin imperatives of poverty reduction and climate mitigation converge to motivate this study so as to investigate the interactions between energy access and environmental sustainability. This study therefore aims to empirically examine intricate interrelationship between energy poverty and environmental sustainability in Nigeria.

**2. LITERATURE REVIEW**

Energy poverty is broadly conceptualised as a multidimensional deprivation encompassing accessibility, affordability, reliability, adequacy, quality, and sustainability of energy services, with its core impact extending beyond economic constraints to human capability development (Sadath & Acharya, 2017; Hassan et al., 2022, Oyedele & Oluwalaiye, 2023).). Operational approaches define it through measurable thresholds for modern energy use (Chen et al., 2023; Sy & Mokaddem, 2022) and multidimensional frameworks linking high costs, low income, and inefficient infrastructure (Tundys et al., 2021). In Nigeria, persistent reliance on traditional biomass fuels such as firewood and charcoal (Ogwumike & Ozughalu, 2015; Nduka, 2021) reflects significant deficits in economic, environmental and social performance (Ehsanullah et al., 2021). Scholars emphasise that clean energy adoption is essential for reducing socio-economic vulnerability and fostering environmental sustainability (Papadopoulou et al., 2019; Ashagidigbi et al., 2020; Amer & Kareem, 2025). Economic measurement tools, including the 10% income expenditure threshold (Ceglia et al., 2022) and the Low-Income High Costs framework (Jové-Llopis & Trujillo-Baute, 2024), highlight intervention pathways through income enhancement, cost reduction and energy efficiency improvement.

**2.1 Theoretical Literature**

This study is anchored in the Sustainable Development Theory, rooted in the Brundtland Commission (1987), which advocated the simultaneous pursuit of economic growth, poverty alleviation, and environmental protection. Integrated with the Environmental Kuznets Curve (EKC) hypothesis (Khan, 2020), it highlights Nigeria’s dual challenge of expanding energy access to address poverty while reducing environmental degradation from fossil fuel dependence. Oyetepo’s (2012) Three Pillars Model reinforces the need to balance economic, social, and environmental objectives, with renewable energy adoption offering a pathway to achieve these goals concurrently. Similarly, Ogwumike and Ozughalu (2015) stress that clean, modern energy access enhances environmental quality, drives economic progress, and promotes social equity. Tundys et al. (2021) extend these perspectives by situating energy poverty within environmental governance and climate policy frameworks, underscoring the interdependence between equitable energy access and ecological preservation.

2.2 Empirical Literature

Empirically, many scholars have attempted to address energy poverty and its multi-dimensional implications for environmental sustainability. In advanced economies, Ehsanullah et al. (2021) assessed the interplay between energy insecurity, energy poverty, and climate concerns across the G7, applying a composite Energy Performance Index (EPI) derived from Data Envelopment Analysis-like methods integrated with Multi-Criteria Decision Analysis. Results revealed substantial disparities in energy-environmental efficiency, with Canada outperforming peers while the United States lagged in environmental performance despite economic strength. Abdullahi et al. (2025) used the ARDL framework approach to examine the impact of renewable energy and energy efficiency on environmental pollution in Nigeria. Using annual time series data on renewable energy, energy equity, energy efficiency, and environmental pollution, the results revealed renewable energy and energy efficiency significantly reduce environmental pollution. Conversely, the results revealed that energy equity increase environmental pollution. The study suggest that the adoption of cleaner energy will reduce emission and promote environmental sustainability in Nigeria. Similar study by Anwar et al. (2025) examined the environmental implications of adaptation technologies and energy poverty in the five most polluted economies namely China, India, Japan, Russia and the United States, using panel quantile regression over 2000–2020. Findings indicated that green technological adaptation improves ecological outcomes, while mitigating energy poverty is essential for sustainability. A study by Bello (2025) investigated the relationship between natural resources, carbon emissions (CO2), renewable energy, oil exports, foreign direct investment, and economic growth in four major oil exporting countries of Nigeria, Gabon, Angola, and Democratic Republic of Congo. Utilising the generalized method of moments, the findings revealed that natural resources and renewable energy significantly enhance economic growth while carbon emissions and foreign direct investment are not significant. The study confirm the importance of clean energy in promoting sustainable development in African countries.

 Pauline et al. (2025) investigated the impact of renewable energy consumption on economic growth in Nigeria. Employing ARDL bound test estimation technique, the findings from the study revealed that renewable energy consumption has significant negative impact on economic growth in the long run. However, the causality test revealed a unidirectional relationship from renewable energy to economic growth.

The conceptual linkage between energy poverty and environmental sustainability rests on the principle that equitable access to clean, efficient and modern energy services can reduce ecological footprints, mitigate deforestation and greenhouse gas emissions, and build climate resilience (Khan, 2020). In Nigeria, where traditional biomass fuels dominate rural and semi-urban energy use, the environmental consequences, such as deforestation, biodiversity loss, and air pollution are severe, reinforcing a feedback loop between poverty, environmental degradation and unsustainable practices. Adaji et al. (2025) examine the effect of terrorism and international tourism on environmental sustainability in Africa. The study found that international tourism significantly increases Co2 emission while terrorism insignificantly increase Co2 emission in Africa. This implies that international terrorism and terrorism have adverse effect on environmental sustainability in African countries.

Hassan et al. (2022) analysed BRICS countries (1989–2016), employing CUP-FM, CUP-BC, CCEMG, and AMG estimators to account for cross-sectional dependence. The study found that economic growth, income inequality, and energy poverty exacerbate environmental degradation, whereas education and globalisation help alleviate both emissions and energy deprivation. Extending this approach, Khan (2020) focused on developing Asia, revealing a bidirectional poverty–environment trade-off, wherein ecological degradation can sometimes coincide with poverty reduction, a finding that raises normative policy dilemmas. Oyedele and Oluwalaiye (2023) used panel Var model to examine the relationship between energy consumption, Co2 emission and population health in Sub-Saharan African countries. Under five mortality rate and life expectancy at birth were employed as a measure for population health. The results revealed that fossil fuel consumption shock had a negative impact on life expectancy and greatest impact on Co2 emission. This implies that fossil fuel consumption had adverse effect on environmental sustainability and harmful to human health. This is not surprising since fossil fuel account for highest percentage source of energy consumption in most sub-saharan African countries.

In Europe, Tundys et al. (2021) identified stark disparities in energy poverty between “old EU,” “new EU,” and non-EU states, attributing variations to income levels, building energy efficiency, and climate policy execution. Complementing this, Jové-Llopis and Trujillo-Baute (2024) used Spanish Household Budget Survey microdata to compare income-transfer schemes and energy-efficiency measures, concluding that structural interventions, such as building retrofits, offer far greater reductions in energy poverty (up to 64%) than palliative subsidies. Ceglia et al. (2022) further demonstrated the capacity of photovoltaic-based Renewable Energy Communities in Italy to lower both operating costs and CO₂ emissions while reducing household energy poverty by 12–16%. In Greece, Papadopoulou et al. (2019) highlighted public willingness to transition from lignite to PV energy despite cost and infrastructure barriers, signaling strong societal support for renewable energy adoption as a poverty-alleviation strategy.

In West Africa, Amer and Kareem (2025) constructed an Energy Poverty Gap index for ECOWAS nations (2004 - 2020) using Method of Moments Quantile Regression. They found that green finance, technological innovation, and income growth significantly mitigate energy poverty, while dependence on natural resource rents and certain FDI inflows exacerbate it. This aligns with Adjei-Mantey et al. (2024), who, using an instrumental variable approach in Ghana, demonstrated that environmental consciousness significantly influences household adoption of clean cooking fuels, thereby reducing energy poverty.

In Nigeria, multiple studies converge on the persistence of high energy poverty rates despite abundant renewable resources. Ogwumike and Ozughalu (2015), using the 2004 Nigeria Living Standard Survey, found over 75% of households were energy poor, with determinants including education, household size, and regional disparities. Ashagidigbi et al. (2020), analysing 2018 NDHS data, confirmed severe rural–urban gaps, with rural households scoring an average MEPI of 0.38. Jack et al. (2018) and Nwozor et al. (2019) linked biomass reliance to deforestation and biodiversity loss, arguing for urgent renewable energy investment.

Oyedepo (2012) documented untapped solar and wind potentials, estimating solar capacity sufficient to generate electricity 23 times Nigeria’s projected 2030 demand. Ugwoke et al. (2020) noted fragmentation in Nigerian energy planning and called for integrated multidisciplinary frameworks. Nduka (2021) showed rural willingness to pay for pico-PV and improved cookstoves, projecting household savings of USD 60 annually. Yetano Roche et al. (2024) modelled clean cooking transitions to 2060, finding that ambitious adoption of clean energy could reduce premature deaths by 7% and avert CO₂ emissions resulting from fossil fuel energy consumption.

In India, Sadath and Acharya (2017) applied the Multidimensional Energy Poverty Index within a capability approach, revealing strong overlaps between energy poverty, income deprivation, and social marginalisation, with disproportionate burdens on women. In rural China, Chen et al. (2023) employed a mixed-method approach during COVID-19 to show that solar energy is the most viable renewable option for alleviating multidimensional energy poverty, despite structural barriers to adoption. Sy and Mokaddem (2022) synthesised global literature on energy poverty measurement using the SALSA framework, identifying three main indicator types namely single, dashboard and composite, while emphasising the need for harmonised definitions and better data to track SDG 7 progress.

Across contexts, a consistent finding is that renewable energy adoption, whether through PV systems in Europe (Ceglia et al., 2022; Papadopoulou et al., 2019, Adaji, et al 2025), solar in rural China (Chen et al., 2023), or clean cooking in West Africa (Adjei-Mantey et al., 2024; Yetano Roche et al., 2024), plays a dual role in alleviating energy poverty and mitigating environmental degradation. However, divergences arise in the effectiveness of income growth as a mitigating factor; while Amer and Kareem (2025) report its positive impact in ECOWAS, Khan (2020) and Hassan et al. (2022) caution that unregulated economic expansion may exacerbate ecological harm. Another divergence is in policy emphasis, European studies tend to focus on structural efficiency measures, while African and Asian contexts highlight infrastructural access and behavioural adoption barriers.

**3. METHODOLOGY**

In order to investigate the impact of energy poverty on environmental sustainability, the study explored a time series dataset to examine the relationship between the dependent variable and explanatory variables. The study used the rating of institutional policy on environmental sustainability as a proxy for environmental sustainability, the dependent variable, energy poverty measured by fossil fuel energy consumption FFE (% of total population) as the independent variable, and access to electricity, electricity consumption per capita, and access to clean energy as threshold variables. The control variables include foreign direct investment, urbanization and per capita income as explored in the work of Sa’ad & Bugaje (2016) and Wang et al. (2025). Descriptive statistics were conducted on the data for clear understanding of the overall distribution and variation of the data before analysis. The dataset also undergoes stationarity tests before analysis to avoid spurious time-series results. The study employed autoregressive distributive lag (ARDL) estimation technique to ascertain short run and long run relationship among the variable. This is to investigate the extent to which energy poverty affect environmental sustainability in Nigeria.

**3.1 Theoretical Framework**

This study is anchored in the Sustainable Development Theory, rooted in the Brundtland Commission (1987), which advocated the simultaneous pursuit of economic growth, poverty alleviation, and environmental protection. Integrated with the Environmental Kuznets Curve (EKC) hypothesis (Khan, 2020), it highlights Nigeria’s dual challenge of expanding energy access to address poverty while reducing environmental degradation from fossil fuel dependence.

The regression model is adapted from the work of Wang et al. (2025) which investigated the relationship between energy transition and environmental sustainability.

**3.2 Model Specification**

The model is modified and represented by the following equation:

ESr = f(FFE, AE,ECP,ACF,URP, FDI,PCI) (1)

Equation 1 is a mathematical expression of the functional relationship between environmental sustainability and energy poverty proxied by fossil fuel energy consumption (FFE), other independent variables include; access to electricity, electricity consumption per capita, access to clean fuel, unrbanisation, per capita income, and foreign direct investment.

The econometric form of the regression model is stated as follows:

 ESr = 𝛽0+𝛽1FFE+𝛽2A*E*+𝛽3ECP+𝛽4*ACF*+𝛽5URP+𝛽6FDI+𝛽7PCI+μt (2)

in equation 2, ESr captures the environmental sustainability measured by the index rating of institutional policy on environmental sustainability, while the basic independent variables measured by fossil fuel energy consumption (% of total population), and its parameter estimate is represented by 𝛽1, 𝛽0 indicates the intercept, 𝛽2, 𝛽3, 𝛽4, 𝛽5, 𝛽6 and 𝛽7 representthe parameter estimates of various control variables, and μt represents the error term. The regression model includes the relationship between the environmental sustainability and fossil fuel energy consumption (FFE), control variables vis a visaccess to electricity AE, electricity consumption in KWt per capita ECP, access to clean fuel energy for cooking (% of total population) ACF, foreign direct investment (net inflow of foreign capital investment), per capita income (PCI) measured by GNP per capita expressed in local currency, and urban population (% of total population). The estimation focuses on the sign of the coefficients of independent variables and their corresponding values.

To determine the long-run estimate of the coefficient of ARDL, it is necessary to determine the𝜌 maximum lag order of the ARDL model (p1,q1,q2,q3,q4). The long-run model for Yt(ESrt) was estimated as:

$ESr = δ\_{0}$+$\sum\_{ρ=1}^{ρ}δ\_{1}ESrt\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{2}FFE\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{3}AE\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{4}ECP\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{5}ACF\_{\begin{array}{c}ρ\_{=1}\\\end{array}}$+$\sum\_{ρ=1}^{ρ}δ\_{6}URP\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{7}FDI\_{ρ=1}$+$\sum\_{ρ=1}^{ρ}δ\_{8}PCI\_{ρ=1}$+𝜀t  **(3)**

However, to obtain the short-run dynamic parameters by estimating an error correction model associated with the long-run estimates, the model is specified as:

$ΔES\_{r}$=𝜶+$δ\_{1}\sum\_{ρ=1}^{}ΔFFE\_{ρ}\_{=1}$+$β\_{1}\sum\_{ρ=1}^{}ΔAE\_{ρ}\_{=1}θ\sum\_{ρ=1}^{}ΔECP\_{ρ}\_{=1}$+$ϕ\sum\_{ρ=1}^{}ΔACF\_{ρ}\_{=1}$+$ω\sum\_{ρ=1}^{}ΔURP\_{ρ}\_{=1}$+$α\sum\_{ρ=1}^{}ΔFDI\_{ρ}\_{=1}$+σ$\sum\_{ρ=1}^{}ΔPCI\_{ρ}\_{=1}$+𝜷1ECMt-1+𝜀t (4)

Where 𝜟 implies the differences of the variables.

In equation 4, **ECMt-1** is the lagged error correction term which is the speed of adjustment, while 𝝷,𝝍,𝝎,𝝓,𝝈, and 𝜷 are the short-run dynamic coefficients of the model’s convergence to the point of equilibrium. The appropriate lag structure of ECM is determined by the Akaike information criteria (AIC).

The data on the variables were sourced from the World Bank development indicators for Nigeria from 1995 to 2024.

**Table 1 Description of Variables**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Code | Definition | Source |
| Rating of environmental sustainability | ESr | Index of institutional policy rating of environmental sustainability | WDI |
| Access to electricity | AE | Access to electricity (% of total population) | WDI |
| Electricity consumption per capita | ECP | the electricity consumption in KWt per capita | WDI |
| Fossil fuel energy consumption | FFE | the fossil fuel energy consumption (% of population) | WDI |
| Access to clean fuel | ACF | the access to clean fuel energy source (% of total population). | WDI |
| Urbanisation | URP | Urban population (% of total population) | WDI |
| Foreign direct investment | FDI | Net foreign investment inflow | WDI |
| Per capita income | PCI | Per capita GNP in constant local currency | WDI |

Source: Authors’ computation, 2025

**4. RESULTS AND DISCUSSION OF FINDINGS**

The research investigates how energy poverty influences environmental sustainability, while controlling for variables such as foreign direct investment and urbanization. The preliminary tests result and the linear regression estimates are presented in the following figures.

**Table 2: Descriptive Statistics of variables**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | ECP | AE | ACF | ES | FFE | FDI | PCI | URP |
|  Mean |  139.0585 |  47.91340 |  11.87160 |  3.360000 |  49.81080 |  1.140357 |  271361.3 |  45.46398 |
|  Median |  138.2902 |  46.11000 |  6.900000 |  3.500000 |  49.48000 |  0.893526 |  271635.3 |  46.11800 |
|  Maximum |  219.2345 |  62.67000 |  45.35000 |  3.500000 |  58.89000 |  4.282088 |  365972.7 |  57.67900 |
|  Minimum |  95.55121 |  37.81000 |  0.900000 |  3.000000 |  42.39000 | -1.150856 |  196440.0 |  32.20500 |
|  Std. Dev. |  28.32347 |  6.855603 |  11.77928 |  0.226779 |  4.764533 |  0.951153 |  60896.96 |  7.076101 |
|  Skewness |  1.216280 |  0.430260 |  1.046932 | -0.979958 |  0.104548 |  0.719991 |  0.066530 | -0.270541 |
|  Kurtosis |  4.447442 |  2.131738 |  3.266425 |  1.960317 |  1.899136 |  4.162964 |  1.380471 |  2.025126 |
|  |  |  |  |  |  |  |  |  |
|  Jarque-Bera |  16.69257 |  3.113278 |  9.281760 |  10.25460 |  2.615880 |  7.137567 |  5.501206 |  2.589891 |
|  Probability |  0.000237 |  0.210844 |  0.009649 |  0.005933 |  0.270376 |  0.028190 |  0.063889 |  0.273913 |
|  |  |  |  |  |  |  |  |  |
|  Sum |  6952.927 |  2395.670 |  593.5800 |  168.0000 |  2490.540 |  57.01787 |  13568066 |  2273.199 |
|  Sum Sq. Dev. |  39308.72 |  2302.965 |  6798.826 |  2.520000 |  1112.338 |  44.32993 |  1.82E+11 |  2453.489 |
|  |  |  |  |  |  |  |  |  |
|  Observations |  50 |  50 |  50 |  50 |  50 |  50 |  50 |  50 |

Source: Authors’ computation via E-view 9, 2025

The descriptive statistics indicate structural disparities in energy access, environmental sustainability, and economic outcomes. Electricity consumption per capita (ECP) averages 139.06 KWh with moderate variation and significant non-normality, while access to electricity (AE) is limited at 47.9% but relatively stable and normally distributed. Access to clean fuel (ACF) remains very low (11.87%) with high dispersion and significant deviation from normality, underscoring unequal distribution. The environmental sustainability rating (ESr) is relatively stable (mean = 3.36) with low variability, though negatively skewed. Fossil fuel consumption (FFE) dominates at nearly 50% of total energy use, showing limited variation and symmetry, whereas foreign direct investment (FDI) displays high volatility with skewness and leptokurtosis. Per capita income (PCI) is the largest variable in magnitude but also highly dispersed, while urbanisation (URP) averages 45.5% with modest variation. Overall, the data highlight uneven access to modern energy, persistent reliance on fossil fuels, and variable economic conditions, with ECP, ACF, and FDI deviating significantly from normality, suggesting the need for robust estimation techniques in empirical modelling.

**Table 3: Unit root results**

|  |  |  |
| --- | --- | --- |
| Test integration |  | Augmented Dickey Fuller (ADF)  |
| OrderVariable | **Level**  |  **1st difference**  |
|  | t-stat  | Prob | t-stat  | Prob |  |
| ESr  | -3.867 | 0.004\* | -5.767 | 0.000\* | I(0) |
| AE | -1.499 | 0.526 | -9.173  | 0.000\* | I(1) |
| ACF | -0.591 | 0.988  | -5.389  | 0.000\*  | I(1) |
| ECP  | 2.779  | 0.069  | 7.687  | 0.000\*  | I(1) |
| FFE  | 2.604  | 0.099  | 7.686  | 0.000\*  | I(1) |
| FDI  | 4.049  | 0.002\*  | 11.159  | 0.000\*  | I(0) |
| PCI  | 1.141  | 0.629  | 4.597  | 0.001\*  | I(1) |
| URP  | 1.224  | 0.657  | .943  | 0.000\*  | I(1) |

Source: Authors’ computation via E-view 9, 2025

Note: \*,\*\*,\*\*\* indicate significant level at (1%),(5%) and (10%) respectively.

The Augmented Dickey–Fuller (ADF) unit root test results in Table 3 indicate that ESr and FDI are stationary at level, I(0), while AE, ACF, ECP, FFE and PCI become stationary only after first differencing, I(1). This mix of I(0) and I(1) stationarity, validates the suitability of the ARDL bounds testing framework for examining potential long-run relationships among the series.

**Table 4: Bound test results**

Model F-statistics Bounds Remark

 Upper Lower

Environmental sustainability 6.24 2.33 \*\*\* 3.15\*\*\* cointegration

 (ESr) 2.32\*\* 3.51\*\*\*

 2.96\* 4.26\*

Note:\*,\*\*, and \*\*\* indicates 1%, 5% and 10% statistical level of significance respectively.

The results of the bounds test, presented in Table 4, indicate the existence of a long-run relationship between the variables under consideration. Specifically, the calculated F-statistic (6.24) exceeds the critical upper bound values at the 1%, 5%, and 10% levels of significance. This outcome confirms the presence of cointegration in the environmental sustainability (ESr) model, implying that the variables move together in the long run despite potential short-term fluctuations.

**Table 5: ARDL Short-run Estimates of Coefficients**

Variables Coefficient Std. Error T-Stat. prob

D(AE) - 0.011 0.065 -2.422 0.035\*

D(ECP) -0.001 0.001 1.275 0.231

D(FFE) 0.001 0.069 0.035 0.972

D(ACF) -0.013 0.004 -3.033 0.322

D(PCI) 0.039 0.237 0.163 0.874

D(FDI) 0.204 0.012 1.722 0.116

D(URP) -0.033 0.021 -1.607 0.139

CointEq(-1) -2.132 -0.273 -0.323 0.042

R2 0.909 0.174 46.7 0.006

Adjusted R2 0.781

Source: Authors’ computation via E-View 9

The table 5 above shows the results of the ARDL short-run coefficients test of access to electricity, electricity consumption per capita, fossil fuel consumption and access to clean fuel energy source in Nigeria. The results revealed that in the short run, access to electricity has negative significant impact on environmental sustainability with coefficients value of (-0.012). This indicate a 1% increase in access to electricity will reduce the rating of environmental sustainability by 0.012%. This implies that increase access to electricity will negatively affect the environment which is against the *aprior*i expectation of positive impact of access to electricity on environmental sustainability.

However, other variables show insignificant short-run effects, but the significant negative error correction term confirms a stable long-run equilibrium, with the model explaining about 91% of the variation and demonstrating strong overall robustness.

**Table 6: ARDL Long-run Estimates of Coefficients**

Variables Coefficient Std. Error T-Stat. prob

ACF -0.008 0.002 -1.679 0.004\*

AE 0.005 0.002 2.902 0.016\*

ECP 0.001 0.001 0.449 0.662

FFE -0.021 0.004 -4.941 0.001\*

PCI -0.251 0.064 -3.936 0.003\*

FDI -0.041 0.013 -3.106 0.011\*

URP 0.013 0.005 2.767 0.019\*

R2 0.935 0.174 46.7 0.006

Adjusted R2 0.895

Log likelihood 36.68

Source: Authors’ computation via E-view 9

From the ARDL Long-run Estimates, access to electricity is significantly and positively related to environmental sustainability in Nigeria. Thus, a unit improvement in access to electricity will increase leads to 0.005 % increase in environmental sustainability rating of Nigeria in the long-run. ARDL-based evidence of a long-run electricity–growth link and growth gains from electricity pricing/subsidy reforms and infrastructure quality supports the AE result (Nwagu et al., 2025) Urbanisation’s favourable contribution also accords with ARDL evidence that urbanisation raises output, with more recent work showing the effect strengthens when human capital is high (Jemiluyi & Jeke, 2024). On the other hand, the model results show that fossil fuel energy consumption has a negative and significant relationship with environmental sustainability in the long-run. Thus, a unit increase in fossil fuel energy consumptions leads to 0.021 decrease in environmental sustainability rating of Nigeria. This result provides a support to the work of Oyedele and Oluwalaiye (2023) who found that fossil fuel consumption has negative impact on Co2 emission in Sub-Saharan African countries. The negative FDI coefficient is plausible in enclave-type settings: classic and newer Nigerian evidence finds FDI can be insignificant or harmful overall (limited spillovers, repatriation), though sectoral studies show manufacturing FDI can raise growth—hence your estimate may be capturing composition effects (Emako et al., 2022, Usman et al., 2024). However, the result shows that per capita income has negative and significant relationship with environmental sustainability in the long-run. Thus, a unit increase in per capita income leads to 0.251% decrease in environmental sustainability rating of Nigeria in the long-run. This result indicates the limited access to clean energy in Nigeria. Finally, the insignificant ECP effect is consistent with evidence that generation capacity does not translate into output because of grid bottlenecks and losses, and the per-capita-income “negative” echoes the well-documented Nigerian “growth without development” paradox, where rising averages mask structural inefficiencies (Edet, 2015).

**Table 7: Post-Estimation Diagnostic Tests**

| Test | Statistic | df | Probability | Inference |
| --- | --- | --- | --- | --- |
| **Breusch-Pagan-Godfrey (Heteroskedasticity)** | F = 0.902 | (35,10) | 0.617 | No heteroskedasticity detected |
|  | Obs\*R² = 34.94 | (35) | 0.471 |  |
|  | Scaled Explained SS = 1.024 | (35) | 1.000 |  |
| **Breusch-Godfrey LM (Serial Correlation)** | F = 4.334 | (2,8) | 0.053 | No serial correlation (supported by DW statistic) |
|  | Obs\*R² = 23.92 | (2) | 0.000 |  |
| **Ramsey RESET (Model Specification)** | t = 2.594 | (9) | 0.029 | Correct functional form, coefficients stable |
|  | F = 6.731 | (1,9) | 0.029 |  |

The post-estimation diagnostics confirm the robustness and reliability of the estimated ARDL model. The Breusch-Pagan-Godfrey test indicates the absence of heteroskedasticity, validating the efficiency of the estimated coefficients. Similarly, the Breusch-Godfrey LM test suggests no serial correlation, further reinforced by the Durbin-Watson statistic, thereby confirming the independence of residuals. Finally, the Ramsey RESET test validates model stability and correct specification, as the test statistics fall within the 5% significance threshold. Succinctly put, these results demonstrate that the estimated model is well-specified, stable and suitable for reliable policy inference.

**5. CONCLUSION AND POLICY RECOMMENDATIONS**

This study investigated the impact of energy poverty on environmental sustainability in Nigeria using the ARDL approach and time-series data from 1995–2024. The results confirm the existence of a long-run relationship among the variables, with the diagnostics affirming model stability and reliability. Empirical evidence shows that access to electricity and urbanisation significantly enhance environmental sustainability, while dependence on fossil fuels, limited access to clean energy, declining per capita income, and foreign direct investment (FDI) inflows exert significant negative effects. Electricity consumption per capita, however, was found to be insignificant, reflecting infrastructural inefficiencies and transmission losses.

The policy implications are clear. First, expanding reliable and affordable electricity access is critical, particularly through renewable energy investments, decentralized off-grid systems and strengthened rural electrification. Second, the negative role of FDI highlights the need to redirect foreign capital into productive, green-oriented sectors such as renewable technologies and manufacturing, rather than extractive industries with limited domestic spillovers. Third, addressing fossil fuel dependence and weak clean fuel access requires stronger regulatory frameworks, subsidy reforms, and incentives for households and firms to adopt cleaner energy alternatives.

Urbanisation’s positive effect suggests that well-managed urban growth can drive sustainable outcomes. Integrated urban planning, investment in green infrastructure, and low-carbon technologies in housing, transport, and energy systems are therefore essential. Finally, the negative effect of per capita income reinforces the “growth without development” paradox in Nigeria, signalling the need for structural reforms that foster inclusive growth, reduce inequality and ensure that economic gains translate into environmental improvements. In a nutshell, Nigeria’s transition towards environmental sustainability depends on aligning energy policy with broader development strategies. Prioritising renewable energy adoption, reforming investment incentives, embedding sustainability in urban development, and addressing structural inefficiencies will be fundamental in achieving the Sustainable Development Goals and a resilient low-carbon growth trajectory.

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