LINEAR AND NON-LINEAR IMPACT OF INTEREST RATE ON SUSTAINABLE ENERGY CONSUMPTION IN NIGERIA

Ibrahim Abubakar
Department of Economics and Development Studies,
North Eastern University Gombe,
Gombe State-Nigeria
abubakaribrahim851@gmail.com

Shehu El-Rasheed, *Ph.D*
Department of Economics and Development Studies,
Federal University of Kashere,
Gombe State-Nigeria
selrasheed2017@gmail.com

Hassan Abdulwahab Yusuf, ***Ph.D***
Department of Economics and Development Studies,
Federal University of Kashere,
Gombe State-Nigeria

***Corresponding Author**
Ibrahim Abubakar
Department of Economics and Development Studies,
North Eastern University Gombe,
Gombe State-Nigeria
abubakaribrahim851@gmail.com

ABSTRACT

This study examined the impact of interest rate on renewable energy consumption in Nigeria from 1991–2021. The data for this study were obtained from World Bank Development Indicators, the Central Bank Statistical Bulletin, and the World Carbon Budget. The study employed Non-linear Autoregressive Distributed Lag (NARDL) model. Wald test result shows that an asymmetric relationship exists between the interest rate and renewable energy consumption in the long run. The empirical results reveal that interest rate exerts a negative and statistically significant impact on renewable energy consumption in both the short run and long run, implying that higher borrowing costs reduce investment in renewable energy technologies. The NARDL results further shows that increases in interest rate have a stronger negative impact on renewable energy consumption than equivalent decreases. Also, the long run result revealed that positive and negative changes are significant. It was observed that the impact of positive and negative change s were all negative as shown in their respective coefficients of -0.465768 and -0.410854, respectively. *The study concludes that Nigeria's transition towards sustainable energy is strongly influenced by the cost of capital associated with renewable energy investment. It therefore recommends that monetary authorities adopt interest-rate-supportive policies such as green-lending windows, subsidised credit, tax incentives, and renewable-energy financing schemes to enhance accessibility and accelerate clean-energy adoption. Strengthening renewable-energy financing frameworks will not only improve investment viability but also support national growth, energy security, and emission reduction commitments.*

Keywords**:** *Interest Rate, Renewable Energy Consumption, non-linear autoregressive distributed lag, green lending windows, Nigeria.*

1.0 Introduction

In Nigeria, energy plays a pivotal role across all sectors—from powering homes and businesses to supporting transportation, healthcare, and industrial activities. Yet, despite abundant natural energy resources, the country suffers from chronic electricity shortages, grid instability, and dependence on fossil fuels, which are environmentally and economically unsustainable (Oseni, 2011).

Consequently, the pursuit of sustainable energy—especially through renewable sources like solar, wind, and bioenergy—has become both a developmental necessity and a policy priority (Energy Commission of Nigeria [ECN], 2005).

Sustainable energy consumption, often proxied by renewable energy consumption (REC), is increasingly seen as an essential pathway for inclusive and long-term economic development in Nigeria. With projections suggesting that nearly 60% of Nigeria's energy demand in 2050 can be met by renewable energy sources, saving 40% in natural gas and 65% in oil needs (IRENA, 2023), understanding the economic factors that drive this transition becomes imperative.

Among the key macroeconomic factors influencing renewable energy consumption is the interest rate. Interest rate, as the price of borrowing capital, determines the affordability of investments in energy infrastructure—particularly in renewables, which are often capital-intensive and require long-term financing. In Nigeria, where renewable energy projects are largely financed through external borrowing or private investment, high interest rates serve as a significant deterrent (Oyedepo, 2012; Central Bank of Nigeria [CBN], 2023). Conversely, lower interest rates can stimulate investment by reducing the cost of capital, thereby enabling individuals, households, and businesses to adopt cleaner technologies such as solar panels, wind turbines, and bioenergy systems.

The Nigerian context is unique: the energy sector is underfunded, energy access remains low (especially in rural areas), and commercial bank lending rates are among the highest in Africa—averaging 23% as of 2023 (CBN, 2023). These high interest rates make renewable energy projects less attractive to investors and unaffordable to many potential users (Adenikinju, 2005). Additionally, monetary policy adjustments—particularly changes in the Monetary Policy Rate (MPR)—have ripple effects on commercial lending rates, further influencing the viability of renewable energy investments (Nwachukwu & Odigie, 2009).

Interest rates play a crucial role in determining the cost of borrowing for renewable energy projects in Nigeria (International Energy Agency, 2020). High interest rates can increase the cost of borrowing, making it more expensive for developers to finance renewable energy projects (Caglar, 2020). On the other hand, low interest rates can reduce the cost of borrowing, making it more attractive for developers to invest in renewable energy projects (World Economic Forum, 2024).

Empirical evidence suggests a mixed impact of interest rates on renewable energy adoption. While some studies posit a linear relationship—whereby lower rates directly stimulate investment—others argue that the effect may be nonlinear, particularly in developing economies with high financial market volatility (Narayan & Popp, 2012). For instance, renewable energy investment may respond only after interest rates fall below a certain threshold or may be more sensitive to sudden rate hikes than to gradual changes. This complexity underscores the need for a nonlinear analytical approach in addition to traditional linear models.

In this context, investigating the nonlinear impact of interest rate on renewable energy consumption in Nigeria provides a crucial step toward understanding how monetary policy can support or hinder the country's energy transition. It also provides insights into how interest rates can be managed to catalyze private sector involvement and improve access to clean energy technologies (World Bank, 2021).

This paper aims to examine the impact of interest rate on renewable energy consumption in Nigeria using a Non-linear Autoregressive Distributed Lag Model (NARDL). The study highlights the nonlinear relationship between interest rate and renewable energy consumption as a proxy for sustainable energy consumption, providing valuable insights. Section 2 offers an overview of renewable energy and interest rate in Nigeria, Section three covers the theoretical framework and literature review, Section 4 presents the model, Section 5 discusses the data and econometric results, and the concluding section highlights key inferences and policy implications.

2.0 Literature Review

2.1 Conceptual Review

2.1.1 Renewable Energy

Renewable energy consumption refers to the use of energy sourced from renewable and naturally replenishing resources, such as solar, wind, hydro, biomass, and geothermal energy. In the context of sustainability, it represents environmentally friendly energy use that minimizes carbon emission and environmental degradation (Boyle, 2012).

The types of renewable energy include: solar, wind, hydro, biomass, and geothermal. It is typically measured in terajoule, kilowatt hours, or as a percentage of total energy consumption (International Energy Agency, 2023). Renewable energy consumption is influenced by economic policies, financing options (interest rates), technological innovation, and macroeconomic variables such as Gross Domestic Product and Foreign Direct Investment. A favourable macroeconomic environment encourages investment in renewable energy infrastructure (International Renewable Energy, 2023).

2.1.2 Concept of Interest Rate

While Uchendu (1993) defines interest rate as "return or yield on equity or opportunity cost of deferring current consumption", a more nuanced understanding is crucial. Interest rates are a key economic variable that influence investment decisions across sectors, including renewable energy. As Uchendu (1993) and Esia (2005) point out, distinguishing between nominal and real interest rates is crucial. Real interest rates, adjusted for inflation, more accurately reflect the true cost of borrowing and significantly impact investment decisions. Higher real interest rates increase the cost of borrowing for renewable energy projects, potentially discouraging investment and slowing down the transition to a renewable energy-based economy. Conversely, lower interest rates can stimulate investment by reducing the cost of capital and making renewable energy projects more financially viable. Consumption behavior as discussed by economists like Mankiw (1981), Hansen and Singleton (1983), and Hall (1988), interest rates also influence consumer behavior. While the impact of interest rate changes on consumption may be relatively small, it can indirectly affect energy demand and, consequently the demand for renewable energy.

2.2 Theoretical Framework

2.2.1 The Intertemporal Choice Theory

Intertemporal Choice Theory explains how individuals, households, firms and governments allocate consumption and investment decisions across different time periods. The theory was formally developed by Fisher (1930) and later expanded by economists such as Ramsey (1928) and Samuelson (1937). The central proposition of the theory is that economic agents make consumption and investment decisions by comparing present consumption with future consumption subject to income, wealth and interest rate constraints.

The theory assumes that individuals derive utility from consumption in different periods and therefore attempt to maximize lifetime utility subject to an intertemporal budget constraint.

2.3. Empirical Literature Review

Empirical studies on renewable energy consumption (REC) have expanded significantly over the past two decades, reflecting global efforts toward sustainable development, environmental protection, and energy security. Interest rate remains one of the most critical but underexplored determinants of renewable energy consumption. Renewable energy projects are typically capital-intensive and rely heavily on long-term financing; therefore, interest rate fluctuations significantly influence investment decisions and energy consumption patterns.

Financial development plays a critical role in renewable energy investment due to the capital-intensive nature of renewable energy projects.

One of the pioneer studies to investigate to investigate this phenomena is Brunnschweiler (2010) which utilized a sample of 119 non-OECD nations between 1980 and 2006 and indicated a positive and significant connection between financial development and renewable energy consumption.

Caglar (2020) employed bootstrap ARDL techniques to examine the relationship between FDI, renewable energy consumption, and economic growth across selected countries. The study found evidence of long-run co-integration between FDI and renewable energy consumption in some countries, suggesting that foreign investment supports renewable energy expansion.

Population growth influences renewable energy demand through increased energy consumption requirements and environmental pressures. Rahman (2017) examined the relationship between population density, environmental quality, and energy consumption in selected Asian countries using dynamic ordinary least squares. The study found that population growth stimulates renewable energy consumption due to increased demand for sustainable energy alternatives.

Samour et al. (2022) examined the spillover effects of U.S. interest rates on renewable energy utilization in Turkey using bootstrap ARDL modeling. Their results revealed that U.S. interest rates significantly influence renewable energy consumption through domestic income and local interest rate transmission channels. The study also found that oil prices negatively affect renewable energy consumption through income effects. Mukhtar et al. (2020) investigated the effect of interest rate on household consumption in Nigeria using generalized method of moments. Their findings indicated that interest rate significantly influences consumption behavior, suggesting that borrowing costs affect investment and energy consumption decisions. Manasseh et al. (2018) examined the relationship between interest rate, inflation, and consumer spending using modified consumption models and Granger causality tests. The study revealed that interest rates significantly explain variations in consumption expenditure, highlighting the importance of monetary policy in consumption behavior.

Adegboye (2013) also found that real interest rate plays a significant role in determining private consumption expenditure in Nigeria, although its effect varies across model specifications.

Ishioro (2013) further emphasized the importance of the interest rate channel in monetary transmission mechanisms in Nigeria, suggesting that interest rate fluctuations influence investment and consumption decisions across sectors, including energy consumption.

3.0 Methodology

To achieve the objective of this study, annual time series data from 1990 to 2021 was employed. Data on renewable energy consumption, foreign direct investment, foreign exchange rates, growth rate and inflation rate were obtained from World development indicators. In contrast data on interest rate and carbon emission were obtained from Central Bank statistical Bulletin and World Carbon Budget respectively.

3.1 Model Specification

To examine the relationship between interest rate and renewable energy consumption in Nigeria, this study adapts the model by Mukhtar et.al (2020). The original model by Mukhtar et.al (2020) modified the traditional consumption function by incorporating macroeconomic variables such as interest rate, energy consumption and exchange rate.

The model specified by Mukhtar et.al (2020) is expressed as follows:

$$\text{HC} = B_0 + \beta INT_1 + \beta EC_2 + \beta EXR_3 + \varepsilon \qquad (1)$$

Where :

HC = Household Consumption

INT= refers to Interest Rate,

EC =indicates Energy Consumption

EXR = Exchange Rate.

3.2 Econometric form for the equation

However, in order to achieve the objectives of this study and better capture the determinants of renewable energy consumption in Nigeria, the above model is adapted and extended by incorporating additional macroeconomic variables such as Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Consumer Price Index (CPI) and Carbon Dioxide (CO_2) emissions.

$$REC_t = \beta_0 + \beta_1 INT_t + \beta_2 GDP_t + \beta_3 FDI_t + \beta_4 CPI_t + \beta_5 CO2_t + \mu_t \qquad (2)$$

Where:

REC_t = Renewable energy consumption
β_0 = constant parameter
β_i = coefficient of the explanatory variables I= 1, 2… 6.
U_t = stochastic disturbance term
INT_t = Interest rate
GDP_t = Gross Domestic Product
FDI_t = Foreign Direct Investment
CPI_t = Consumer Price Index
$CO2_t$ = Carbon dioxide emission
t = time subscript. β_1, β_2, and B_3 are expected to be negative, positive and positive respectively whereas, β_4 and β_5 are expected to be negative and negative respectively.

The NARDL model proposed by Shin et al. (2014) is an extension of Pesaran et al.'s (2001) ARDL model that provides a one-step estimation of both short-run and long-run coefficient estimates under which variables could be a purely I(0), I(1) or a combination of both.

Following Shin et al. (2014) interest rate shall be decomposed into two-time series variables. This new series includes positive changes, which shall be denoted by ΔINT_j^+ and negative changes to be denoted by ΔINT_j^-. They are constructed as positive and negative partial sums as follows:

$$INT_t^+ = \sum_{j=1}^{t} \Delta INT_j^+ = \sum_{j=1}^{t} \max(\Delta INT_j, 0) \quad (3)$$

$$INT_t^- = \sum_{j=1}^{t} \Delta INT_j^- = \sum_{j=1}^{t} \min(\Delta INT_j, 0) \quad (4)$$

ΔINT , in equation (3) is then replaced with ΔINT_{t-i}^+ and ΔINT_{t-i}^- as in equation (5):

$$\begin{aligned}\Delta REC_t = \alpha &+ \sum_{i=1}^{n1} b_i \Delta REC_{t-i} + \sum_{i=0}^{n2} c_i \Delta GDP_{t-i} + \sum_{i=0}^{n3} d_i \Delta FDI_{t-i} + \sum_{i=0}^{n4} e_i \Delta CPI_{t-i} + \sum_{i=0}^{n5} f_i \Delta CO2_{t-i} \\ &+ \sum_{i=0}^{n6} e_i \Delta INT_{t-i}^+ + \sum_{i=0}^{n7} f_i \Delta INT_{t-i}^- + \theta_0 REC_{t-i} + \theta_1 GDP_{t-i} + \theta_2 FDI_{t-i} \\ &+ \theta_3 CPI_{t-i} + \theta_4 CO2_{t-i} + \theta_5 INT_{t-i}^+ + \theta_6 INT_{t-i}^- \\ &+ \mu_t \quad (5)\end{aligned}$$

The introduction of partial sums makes Equation (5) a NARDL model, able to test whether interest rate affects renewable energy consumption asymmetrically either in the short-run, the long-run, or both.

When the NARDL model is estimated, some asymmetric assumptions would be tested. First, if $n6 \neq n7$ i.e. the partial sum variables take different lag orders, adjustment asymmetry is established implying that the time it takes for the renewable energy consumption to respond to positive shocks in interest rate is different than it takes to respond to negative shocks in interest rate. Second, given any lag order i, if estimate of e_i is different from f_i , short-run asymmetric effect of interest rate would be supported. Third, short-run cumulative or impact asymmetry effect will be established if the Wald test rejects the null hypothesis of $\sum e_i = \sum f_i$. Fourth, if the normalized long-run estimate obtained for the positive partial sum is different than the one obtained for negative partial sum, it is concluded that there is long-run asymmetric effect. Lastly, the F test is applied to determine asymmetry co-integration.

4.0 Results and Discussion

4.1. Unit Root Tests

The study performed the ADF and PP unit root tests to determine whether the time series data are stationary.

Table 4.1. Unit root tests of Variables

Variable	Augmented Dickey Fuller			Phillips Perron		
	AT LEVEL	**1st DIFF.**	**I(d)**	**AT LEVEL**	**1st DIFF.**	**I(d)**
REC	__	-4.309824***	I(1)	__	-4.309824***	I(1)
INT (MPR)	-3.218382*	-3.632896**	I(0)	-3.218382*	-4.309824**	I(0)
GDPR	_	-4.309824***	I(1)	___	-4.30982***	I(1)
FDI	__	-4.309824***	I(1)	___	-4.309824***	I(1)
CPI	__	-4.374307***	I(1)	__	-4.30982***	I(1)
CO2	__	-4.309824***	I(1)	__	-4.30982***	I(1)

Where *, **, *** indicates significance at 10%, 5% and 1% respectively.

Source: *Computed by the Author using Eviews 10*

The outcomes of the unit root tests performed on the variables are summarized in Table 4.1 for both ADF and PP testing. ADF test and unit root tests for all reveal that the variables are stationary at first difference. However, INTR (MPR) is stationary at level at 10% critical value.

4.2 Cointegration bound test

NARDL BOUND TEST

Following the confirmation that the series consisted of both integration of order 0 and1, a necessary condition for NARDL model estimation, the long-run bound test based on the NARDL technique is presented in table 4.2 below.

Test Statistic	Value	Significance Level	I (0)	I (1)
F-statistic	5.368022	10%	1.92	2.89
K	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

Table 4.2 shows the result of NARDL bounds test for co integration, that is, the NARDL equation. The estimated F-statistics (5.368022) exceeds the critical value of the upper bound I (1) at 5%. Hence the null hypothesis of no long-run relationship among variables in the equation is rejected. This implies that there is a long-run relationship in the asymmetric model.

Table 4.3 Long Run Asymmetric Test Result

Variables	Coefficient	Std. Error	t-Statistics	Prob.
INTR_POS	-0.465768	0.170274	0.170274	0.0141
INTR_NEG	-0.410854	0.107136	-3.834888	0.0013
GDPR_POS	-0.249889	0.127606	-1.958285	0.0668
GDPR_NEG	-0.818982	0.143405	0.007827	0.9938
FDI	0.839549	0.501778	1.673150	0.1126
CPI	0.027133	0.027875	0.973391	0.3440
CO2	-11.48072	5.374237	-2.136252	0.0475
C	96.97060	4.845196	20.01376	0.0000

The long run results of the estimates of the NARDL model for the impact of interest rate on renewable energy consumption in Nigeria indicate that the long run effect of positive change in interest rate on renewable energy consumption is negative and statistically significant at 5% level of significance. This implies that unit increase in interest rate decreases renewable energy consumption by 0.47%, also the negative change in interest rate on renewable energy consumption is negative and significant. This implies that a unit increase in interest rate will amount to a 0.41% decrease in renewable energy consumption.

The result of the long run estimates indicates non-significant impacts both for positive and negative changes of GDP growth rate on renewable energy consumption in Nigeria. This implies that for the positive change in GDP growth rate, a unit increase in interest rate will result in 0.24% decrease in renewable energy consumption while for the negative change in interest rate, a unit increase in GDP growth rate will lead to 0.81% decrease in renewable energy consumption.

Table 4.4: Short Run Asymmetric Test

Variable	Coefficient	Std. Error	t-Statistics	Prob.
D(INTR_NEG)	-0.407155	0.050877	-8.002789	0.0000
D(CPI)	-0.012612	0.011385	-1.107727	0.2834
D(CO2)	-13.49665	1.525764	-8.845829	0.0000
ECM(-1)	-0.549865	0.065235	-8.428959	0.0000
R-squared	0.842663			
Ajusted R-squared	0.823782			

The coefficient of ECM-1 shows the speed of adjustment back to the long-run back to the long-run equilibrium after a short-run shock. Here, it can be deduced that the disequilibrium that occurred in the short-run can revert to equilibrium in the long-run at the speed of -0.549865.The R^2 shows that the independent variables in the model particularly interest rate, inflation rate and carbon emission explain 82% of the variation in renewable energy consumption.

The short-run results reveal that a negative shock in interest rate will reduce renewable energy consumption by 41%.

4.5 NARDL Wald Test

Table 5:

Test Statistic	Value	Df	Probability
t-statistic	-3.645648	17	0.0020
F-statistic	13.29075	(1, 17)	0.0020
Chi-square	13.29075	1	0.0003

The results above suggest that there is a long-run asymmetric relationship between the dependent and independent variables.

4.6 NARDL Diagnostic Test Results

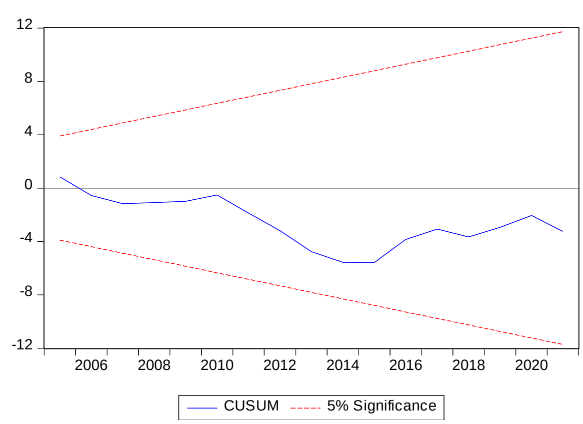
Table 6: Diagnostic Test Results

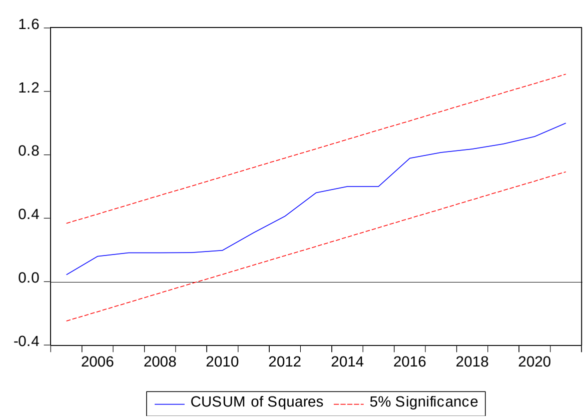
Test Statistics	Probability Value
χ^2Serial correlation LM test	0.3726
Heteroscedasticity	0.1753

Source: Author’s Computation using Eviews

Table 6 depicts the results of the diagnostic checks. The study examined the consistency of the coefficients of the estimates based on the chi-square and Lagrange Multiplier (LM) tests as well as the stability test using recursive residuals suggested by Brown et al. (1975). All test statistics on each null hypothesis could not be rejected at any conventional level of significance. Hence, there is no serial correlation, non-normality, or heteroscedasticity.

4.7 NARDL STABILITY TEST





The tests and results displayed in figure 1 and 2 are utilized in this investigation on the consistency of the Non-linear Autoregressive Distributed Lag (NARDL) model estimates. The graph of the CUSUM and CUSUMQ statistics for both equations fall comfortably within the bounds.

5.0 Conclusion and Recommendations

5.1 Conclusion

This study concludes that interest rate plays a critical role in shaping renewable energy consumption in Nigeria, particularly in the long run. The empirical findings reveal that higher interest rates significantly

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discourage investment in renewable energy projects by increasing the cost of capital. However, the absence of significant short-run effects and the presence of weak causality suggest that the transmission mechanism of monetary policy to the renewable energy sector remains inefficient. This inefficiency can be attributed to structural and institutional constraints that limit the responsiveness of the sector to macroeconomic signals.

Furthermore, the results indicate that key macroeconomic variables such as economic growth, foreign direct investment, and inflation do not significantly stimulate renewable energy consumption in Nigeria. At the same time, the persistence of carbon emissions reflects the country's continued dependence on fossil fuels. The evidence of asymmetric effects, as revealed by the NARDL model, underscores the importance of adopting non-linear policy approaches, since the impact of interest rate changes is not uniform. Overall, the findings suggest that Nigeria's renewable energy sector is underdeveloped and insufficiently integrated into the broader macroeconomic framework, thereby requiring deliberate, targeted, and well-coordinated policy interventions.

5.2 Recommendations

In light of the findings, it is recommended that monetary authorities pursue a stable and moderate interest rate regime to lower borrowing costs and encourage investment in renewable energy projects. High and volatile interest rates discourage long-term financing, which is essential for capital-intensive renewable energy investments. Therefore, maintaining a conducive financial environment will enhance private sector participation and improve the viability of renewable energy initiatives.

Given the asymmetric impact of interest rate changes on renewable energy consumption, policymakers should adopt flexible and targeted monetary policies that account for these non-linear dynamics. This implies that policy responses should be carefully calibrated, recognizing that increases in interest rates may have a more pronounced negative effect than the positive impact of reductions. In addition, complementary fiscal measures—such as green financing schemes, renewable energy funds, and credit guarantees—should be implemented to strengthen the transmission of monetary policy to the renewable energy sector.

The government should also ensure that economic growth is aligned with sustainable energy development by integrating renewable energy policies into national development strategies. This includes promoting investment through incentives such as tax reliefs, subsidies, and regulatory support targeted at both domestic and foreign investors. Strengthening institutional frameworks and improving the investment climate will help attract foreign direct investment specifically into renewable energy, thereby enhancing its contribution to economic growth.

Finally, efforts should be made to maintain price stability and enforce strict environmental regulations to support the transition to clean energy. Controlling inflation will reduce uncertainty and improve long-term investment planning, while policies such as carbon pricing, emission controls, and renewable energy mandates will discourage reliance on fossil fuels. Additionally, increased public investment in renewable energy infrastructure, technology, and human capacity development is essential to address the structural weaknesses of the sector and position it as a key driver of sustainable development in Nigeria.

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