Economics and Statistics Research Journal (ESRJ)
Volume.16, Number 2; February-2025;
ISSN: 2836-8398 | Impact Factor: 9.97
https://zapjournals.com/Journals/index.php/esrj
Published By: Zendo Academic Publishing

THE IMPACT OF SOLAR ENERGY FINANCING ON ELECTRICITY GENERATION IN NIGERIA. AN ARDL APPROACH

[1]Lawal, Ibrahim Ozomata, [2]Bernard, Ojonugwa Anthony, [3]Mustapha, Muktar, [4]Alfa, Yakubu and [5]Oyefabi, Ilemobola

Correspondence: lawalib2003@gmail.com

JEL Code: Q42 G30 L94 C32 C51

Article Info

Keywords: Solar Energy, financing, electricity generation, ARDL

DOI
10.5281/zenodo.14916729

Abstract

This study used Auto Regressive Distributed Lag (ARDL) estimation techniques to explore the dynamic relationship between solar energy financing and electricity generation in Nigeria using data from 1985 to 2022. Solar energy financing by the Rural Electrification Agency of Nigeria is the primary independent variable, alongside control variables, such as government expenditure on the electricity sector, renewable energy financing by commercial banks, foreign aid for renewable energy, and labour employed in the electricity sector. The results demonstrate that increases in financing from the Rural Electrification Agency, government spending, commercial bank investments, and foreign aid positively impact electricity generation in both the short and long term. Additionally, labour employed in the sector significantly contributes to the improvement of electricity generation. These findings emphasize the importance of enhancing funding for solar energy projects, diversifying government allocations to the electricity sector, and fostering a supportive environment for foreign aid and investments. Beyond enriching existing literature and theoretical frameworks, this research offers practical insights for policymakers, industry stakeholders, and researchers aiming to promote renewable energy investments for sustainable electricity generation in Nigeria.

1. Introduction

The foundation of socioeconomic development is electricity, especially in developing nations like Nigeria where there is a growing need for reliable and sustainable energy. As the worldwide push for greener energy intensifies,

[1,4,5]Department of Economics, Nigerian Defence Academy, Kaduna, Nigeria
[2] Department of Economics, Air Force Institute of Technology, Kaduna, Nigeria.
[3] Department of Economics, Bayero University, Kano

Nigeria’s drive for affordable and efficient electricity depends on renewable energy sources, underscoring the crucial role that energy financing plays in this shift.

In addition to being relevant in driving the industrial activities of any economy, electricity is also important in achieving most development policies (Ajaelu & Okereke, 2020). Supporting alternative energy sources for electricity generation can enhance productive activities in the manufacturing sector, encourage the service sector to deliver efficient services, and improve the welfare of households in any economy.

In a statement by the Energy Commission of Nigeria (ECN), Nigeria's energy landscape encompasses various sources, including hydroelectricity, solar energy, wind power, and biomass (ECN, 2014). Despite relying on hydroelectric power for decades, the nation has struggled to meet its escalating electricity demand. While electricity generation is derived from both renewable and nonrenewable sources, harnessing renewable sources efficiently holds the promise of sustainable electricity generation, addressing the challenges of fossil fuels, such as emissions and pollution (ECN, 2014).

A report by the National Electricity Regulatory Commission of Nigeria (NERC) shows that Nigeria needs to improve its electricity infrastructure. Compared with the 4,922.26MW recorded in 2023/Q4, the average available generation capacity across all electricity-generating plants during the quarter was 4,249MW a -13.68% drop of 673.16MW (NERC, 2024). However, this is significantly less than the projected 45,662MW to meet current demands (Punch, 2024). Consequently, the persistent energy deficit adversely affects industries, employment, and business costs, worsening the unemployment rate and hindering technical education enrollment.

The country's energy struggles have remained despite various reforms and policies, including the 2003 national energy policy, energy sector privatization, and the 2023 Electricity Act. These initiatives have been accompanied by government and private sector financial interventions; however, challenges persist, primarily due to overreliance on fossil fuels and their environmental repercussions.

Acknowledging the vast potential of renewable energy for socioeconomic advancement, in a report by the Energy Commission of Nigeria (ECN, 2014), Nigeria introduced a renewable energy master plan (REMP) in 2005. However, implementing renewable energy projects remains financially demanding and requires substantial support from governmental, commercial, and foreign funding sources. Notably, through foreign aid initiatives such as Power Africa, technical assistance provided to distribution companies in Nigeria has led to a significant revenue increase of over $250 million (ECN, 2014). This infusion of funds can be directed toward enhancing the distribution network, thereby improving service quality and expanding electricity access. Despite these efforts, the Nigerian power sector has faced various challenges, including regulatory uncertainty, gas supply and transmission system constraints, and power sector planning deficiencies (USAID, 2023), which have hindered its commercial viability.

While funding for renewable energy projects in Nigeria has increased, electricity generation output has yet to align with these financial commitments. This raised a growing concern among researchers; Giartkasari and Nikensari (2022), Rashed et al. (2022), Onabote et al. (2021), Adenuga and Idoko (2021), Mesagan et al. (2021), Atchike et al. (2020), Longe et al. (2020), Onayemi et al. (2020). This incongruence necessitates a thorough examination of the efficacy of financial investments, specifically in solar energy, to advance Nigeria’s electricity generation landscape.

The dynamics of solar energy finance and its effects on Nigeria's electrical industry are examined in this paper. This study aims to contribute to existing knowledge and envision how solar energy financing could shape Nigeria’s energy future by examining financial mechanisms, policy frameworks, and their interaction with solar energy deployment. Nigeria possesses significant renewable energy resources capable of substantially addressing its energy needs, and further research and investment in alternative energy sources, particularly financing, are crucial for enhancing electricity generation. Understanding the various impacts and challenges of solar energy financing by the government, private sector, and foreign aid is essential for guiding Nigeria toward a more sustainable, accessible, and resilient energy landscape.

There are five sections in this research. The study's context is established in the introduction. A synopsis of the relationship between energy funding and electricity generation can be found in Section 2. The data and techniques used to evaluate the impact of renewable energy financing on Nigeria's electricity generation are described in Section 3. The research findings are presented and examined in Section 4. Section 5 summarizes the investigation and makes suggestions considering the results.

2. Literature Review

2.1. Conceptual Review

Renewable Energy

Renewable energy includes all energy sources that come directly or indirectly from the sun, including biomass, solar, wind, hydro, marine, and geothermal. These sources are sustainable and perpetually available because nature renews them regularly (Akuru & Okoro, 2005). They generally do not cause much harm except when harnessed and caused by human activity.

Solar Energy

One renewable energy source is solar energy, which is the energy that is transformed by the sun. Visible light and infrared radiation constitute the majority of sunlight once it enters the Earth's atmosphere (Byjus, 2023). This energy is then transformed into electrical power via solar cell panels (Byjus, 2023). Using sunlight to generate electricity is known as solar energy adoption. Concentrating solar power, or CSP, is a straightforward method that generates electricity by heating water or enclosed areas (solar collectors) using solar radiation (Nadabo, 2010).

Solar Energy Financing

Solar energy financing refers to various methods and mechanisms to fund solar energy projects. Given the high initial costs associated with installing solar panels and equipment, financing is essential for making solar power accessible to individuals, businesses, and communities. This can be financed by the government, private organizations, and individuals. Solar energy financing is categorized into upfront payments, loans, power purchase agreements, solar leases, government incentives and rebates, crowd funding, and grants (Adel et al., 2019).

In Nigeria, end consumers or solar energy enterprises can obtain solar energy financing directly from government-owned institutions like the Bank of Industry (BOI) or indirectly through Deposit Money Banks (DMBs) or Microfinance Banks (MFBs) (Enerdatics, 2023). The Bank of Industry (BOI) provided a N852 million loan to six up-and-coming energy companies in 2021 to promote renewable energy. A more recent development is the expected ₦6 billion solar energy fund by the Bank of Industry (BOI, 2022), which will allow different end-user categories to purchase dependable solar solutions.

Electricity Generation

Electricity generation is defined as electricity generated from fossil fuels, nuclear power plants, hydropower plants (excluding pumped storage), geothermal systems, solar panels, biofuels, and wind (Emodi & Boo, 2015; Lutz, 1997). Nigeria can generate electricity in two ways, according to reports from the International Energy Administration (IEA, 2022): either by capturing the energy of natural forces like the sun, wind, or flowing water, or by using the heat from burning fuels or nuclear reactions to create steam (thermal power) (IEA, 2022). However, natural gas accounts for more than 75% of Nigeria's total energy generation (IEA, 2022).

Empirical Literature

Copious literature has been published on the issues of renewable and nonrenewable energy development, financing, and contribution to national development, especially electricity performance. Some of these studies can be traced to the work of Andonov and Rauh (2024), who found that international firms, institutional investors, and private equity all contributed significantly to the energy transition's funding. Compared with incumbents, newcomers have a twofold higher chance of building power plants. As of 2020, it controlled 34% of the electricity generated from natural gas, 47% from solar, and 58% from wind. Most ownership transfers occur in deregulated wholesale markets, which draw in more money from new investors to build natural gas and renewable energy plants, buy out existing ones, and hasten the decommissioning of coal-fired power plants. Although there are occasional leakage when DLCs sell fossil fuel plants to foreign businesses, private equity decommissions plants are usually at a rate comparable to incumbents. The efficiency of the acquired plants is increased, and more efficient power plants with lower heating rates are produced by the new ownership types. Our findings also point to a significant compromise when introducing fresh funding options for the electrical industry. Foreign companies and private equity firms sell electricity under contracts with shorter durations, shorter increment pricing, and greater peak-period sales, resulting in an average price per MWh that is $2.59 higher.

Hondroyiannis et al. (2024) used data from 19 OECD economies from 1990 to 2020 to examine the effect of hazards on sustainable energy consumption. The results of a quantile regression analysis, MG estimators, Panel OLS, and a local projection technique showed that political, economic, and financial risks have a considerable impact on energy consumption from renewable sources. Strong but contradictory implications about reducing the climate financing gap are drawn from the relationship between finance indicators and sustainable energy consumption. Their results highlight how oil prices, economic growth, economic openness, and human capital development significantly improve the use of sustainable energy. It is further demonstrated that the main goals of legislation for promoting environmental sustainability should be lowering carbon emissions and reducing the cost of renewable energy. A multi-lever technique is needed when creating environmental policies, but distributional variability should also be considered.

The relationship between the output of renewable energy (RE) and three significant variables—GDP, CO2 emissions, and oil prices—for 10 developed and 16 emerging countries during the 1976–2018 period was examined by Elmassah (2024) using a panel autoregressive distributed lag model. The results show both long-term elasticity between RE and GDP and a short-term link between RE and CO2 emissions and oil costs in developed countries. On the other hand, in the rising nations group, there were long-term relationships between RE and GDP, CO2 emissions, and oil prices.

Giartkasari and Nikensari (2022) examined how consumption, economic welfare, renewable energy, and foreign direct investment (FDI) interact in six ASEAN nations. To investigate the connections between these variables, their methodology used a causality test and an Error Correction Model (ECM). The results point to a one-way causal relationship between GDP per capita and FDI as well as a bidirectional relationship between FDI and renewable energy consumption. The report calls on governments to prioritize renewable energy, but it fails to consider how renewable energy affects living standards.

Olanrele and Fuinhas (2022) used panel ARDL analysis and content description to investigate the factors that influence the adoption of renewable electricity generation in sub-Saharan African (SSA) nations. According to the study's findings, the region's most established renewable electricity source is hydroelectric power. Despite their enormous potential, nonhydro renewable electricity sources are not being quickly deployed. The negative correlation between renewable electricity generation and the introduction of policies in SSA further suggests that regulations are inefficient in promoting the adoption of renewable electricity.

The relationship between foreign direct investment (FDI) in the renewable electricity sector, renewable electricity production, and economic growth in Africa was examined by Rashed et al. (2022). They discovered a unidirectional causal relationship between economic growth and renewable electricity production using panel vector autoregression (PVAR) and a static panel data model. The report advised African politicians to prioritize renewable electricity generation, highlighting the possibility that development may not be fully represented by economic growth alone.

Bekun and Alola (2022) study focused on 12 agrarian sub-Saharan African economies and examined the factors that influence renewable energy use. A panel ARDL model was used in the study, and the dataset covered the years 1990–2014. According to their findings, SSA economies are hampered by economic expansion. Additionally, the production of power from fossil fuels drastically reduces the use of clean energy. Silva et al. (2018) used the same period, 1990–2014, and discovered that the growth of renewable energy was explained by both economic development (measured by GDP per capita) and rising energy use.

Onabote et al. (2021) conducted a time series study on Nigeria's energy sustainability, financing, and economic growth. Using the Johansen Co-integration technique, the researchers identified long-run co-integration among variables related to economic growth, sustainable energy, and financing options. The study recommends appropriate policies to encourage diverse avenues for financing energy generation in Nigeria.

Adenuga and Idoko (2021) employed the ARDL estimation technique to examine the impact of government expenditures on electricity supply in Nigeria from 1990 to 2017. Their study revealed that government expenditure, GDP, gross capital formation, inflation, and labor contributions contributed to electricity supply.

Da-Silva (2018) used a panel data approach, specifically the panel-ARDL model, to examine panel data on sub-Saharan African nations from 1990 to 2014. The results show that economic development (per capita GDP) and increased energy demand promote the development of renewable energy, whereas population growth impedes it. This report also examines Sub-Saharan Africa's current renewable energy situation and its potential for the future. According to this study, the region has not yet reached its full potential for the development of renewable energy sources like wind, biomass, solar, and hydropower, which are dispersed throughout the continent, although many resources are easily accessible and show significant economic potential.

The literature revealed a paucity of knowledge regarding the relationship between renewable energy financing and electricity generation. Nevertheless, the literature reviewed provides valuable insights into the relationships between government expenditure, electricity supply, electricity consumption, FDI, economic growth, and structural breaks within the energy sector. However, they do not include or explore causal relationship analysis in their empirical investigations, limiting a comprehensive understanding of the interconnectedness among these variables. Above all, this study reviewed a neglected empirical investigation on the significance of financing renewable energy for electricity generation in an emerging economy like Nigeria. To bridge these gaps, future research on solar energy financing and electricity generation in Nigeria should focus on conducting detailed impact analyses, exploring causal relationships among different variables, and extending the scope of empirical investigations to capture a broader understanding of the energy sector's dynamics and its implications on national development.

3. Methodology

Model Specification

The study investigated how financing for solar energy has affected Nigeria's ability to generate electricity. The endogenous growth theory (Burgess & Barbier, 2001) served as the model's methodological foundation to accomplish this goal. This theory clarifies how capital functions in the production process. This type of capital can be the money required to pay for the energy needed for production. The following production function was suggested by endogenous growth theory:

$$Y = f(T, K, L) \quad 1$$

Y is aggregate output; K, capital stock; L, labor; and T, technological advancement. However, it is worth noting that T is based on the investment and funding of research technology. Equation 1 further expresses that a marginal change in A, K, and L brings about a change in Y. However, by adopting the endogenous growth theory as a methodological framework, the Nigerian electricity generation function takes the following form:

$$ELG = TKL \quad 2$$

$$ELG = f(TKL) \quad 3$$

where ELG stands for an economy's total electricity generation. K is the stock of capital; L is the stock of labor, and T is the technology (also known as energy plants or machinery). Equation 3 assumes that technology remains constant and that Nigeria’s total solar energy expenditure represents its capital stock. The technology required to power solar energy, which helps Nigeria generate electricity, is financed through this solar energy funding. The overall workforce in Nigeria was used as a proxy for labor in this analysis because of the dearth of data on the labor employed by the Nigerian power sector.

The general form of the model is thus specified as follows:

$$ELG_t = f(SEF_t, LAB_t) \quad 4$$

Where: ELG_t is the electricity generated over time in Nigeria, SEF_t is the total solar energy financing in Nigeria, and LAB_t is the total workforce in the electricity sector over time. Here, t is the period from 1985 to 2022.

Estimation Technique

This study adopts the ARDL estimation technique, which was used by Adenuga and Idoko (2021), who analyzed the impact of government expenditure on electricity supply in Nigeria. The model estimated by Idoko is stated as

$$ELS = f(GOE, INC, INV, INF, LAB) \quad 5$$

In its linear functional form using the variable in its log form, Equation 4 is transformed as in Equation 6:

$$lnELSt = \alpha + \beta 1lnGOEt + \beta 2lnINCt + \beta 3lnINVt + \beta 4lnINFt + \beta 5lnLABt + Uit \quad 6$$

where ELS stands for Nigerian electricity supply, which is represented by electricity generation. GOE stands for government expenditure, INC for income (as measured by GDP), and INV for investment (as measured by Nigeria's gross fixed capital formation). LAB stands for labor, which represents the entire workforce that may have an impact on power sector operations, and Uit is the error term over time. INF is used as a stand-in to explain the impact of general price increases, which may include the rate of change in capital costs. The intercept and slope coefficients are represented by α and βs, the periods by t, and the natural logs of the variables by ln.

To provide policy guidance, this study focuses specifically on solar energy financing. Therefore, in addition to government expenditure on the national grid electricity (CBN, 2022), solar energy financing has been integrated into the model. Nigeria's government in its budgetary allocation to the electricity sector has funded solar energy as a renewable energy source through yearly budgetary allocations to organizations like the Rural Electricity Agency (REAN, 2021), foreign aid from the World Bank (REAN, 2021), the African Development Bank (AfDB, 2013), and Nigerian commercial banks (CBN, 2022). Consequently, the modified form of equation 6 is as follows:

$$ELG = f(SEF, GEF, CEF. FEF, LAB) \quad 7$$

$$ELG = \beta_0 + \beta_1 SEF + \beta_2 GEF + \beta_3 CEF + \beta_4 FEF + \beta_5 LAB + \mu \quad 8$$

Where ELG, SEF, GEF, CEF, FEF, and LAB are Electricity generation in Nigeria, solar energy financed by the Rural Electrification Agency of Nigeria, government expenditure on the electricity sector, Commercial banks' energy financing, foreign aid energy financing and labor. β_1 to β_5 are parameters to be estimated and μ is the white noise.

Equations 7 and 8 were estimated using ARDL estimation techniques. The decision to employ the estimation technique was influenced by the fractionally integrated nature of the underlying regressors, which oscillate between levels and Integrated series. The ARDL bound test confirmed the co-integration among variables, which is consistent with the conditions outlined by Pesaran and Smith (2001) for autoregressive distributed lag estimation.

The chosen estimation method aligns with the arguments put forth by Narayan and Smyth (2005), emphasizing the superior small sample properties of the bounds testing approach over multivariate co-integration. By altering the Autoregressive Distributed Lag (ARDL) framework, this method successfully resolves the issues caused by the presence of I (0) and I(1) regressors in a Johansen-type framework.

The ARDL specification for equation 8 is presented as

$$\Delta lELG_t = \alpha_0 + \sum_{i=1}^{p} \phi_i \Delta lELG_{t-i} + \sum_{j=1}^{q_1} \beta_1 \Delta lSEF_{t-j} + \sum_{k=0}^{q_2} \beta_{2k} \Delta lGEF_{t-k} + \sum_{l=0}^{q_3} \beta_{3l} \Delta lCEF_{t-l} + \sum_{m=0}^{q_4} \beta_{4m} \Delta lFEF_{t-m} + \sum_{n=0}^{q_5} \beta_{4n} \Delta lLAB_{t-n} + \delta ECT_{t-1} \quad 9$$

$$lELG_t = \lambda_0 + \lambda_1 lELG_{t-1} + \lambda_2 lSEF_{t-2} + \lambda_3 lGEF_{t-3} + \lambda_4 lCEF_{t-4} + \lambda_5 lFEF_{t-5} + \lambda_6 lLAB_{t-6} + \mu_t \quad 10$$

Δ indicates first-differencing (to account for the short-run influence), The λ's capture the long-run relationships and $p, q_1, q_2, q_3, q_4, q_5$ are considered the lags for the variables. The variables in equations 9 and 10 are specified as logs. This step standardizes the variables and interprets the elasticity.

The long-run relationship is derived from the level terms as follows:

$$ELG_t = -\frac{\lambda_2}{\lambda_1} lSEF - \frac{\lambda_3}{\lambda_1} lGEF_t - \frac{\lambda_4}{\lambda_1} lCEF_t - \frac{\lambda_4}{\lambda_1} lFEF_t - \frac{\lambda_6}{\lambda_1} lLAB_t + \mu_t \quad 11$$

Here, the coefficients $\frac{\lambda_2}{\lambda_1}, \frac{\lambda_3}{\lambda_1}, \ldots$ represent the long-run elasticities.

The short-run dynamics are represented by the coefficients of the first-differenced terms, i.e $\phi_i, \beta_{1j}, \beta_{2k}, \beta_{3l}, \beta_{4m}$ *and* β_{5n}.

In ARDL, the Error Correction Term (ECT_{t-1}) measures the speed of adjustment back to equilibrium. It is derived from the long-run equation and is included in the short-run model. The δ in equation 9 is the coefficient of the ECT_{t-1}. The speed of adjustment parameter ($0 < \delta < -1$). If δ is negative ($\delta<0$) it means, the system corrects back toward long-run equilibrium and $|\delta|<1$ ensures that the adjustment happens gradually (not overshooting or exploding).

Justification of Variable and Data Sources

The time series data were sourced from 1985 to 2022. This covers significant economic periods, such as the structural adjustment program (SAP) and global economic shocks from the COVID-19 pandemic. Nigeria faced energy crises during this period because of fluctuating crude oil prices, volatility in petroleum pump prices, and inadequate budget allocations to the energy sector. The period of energy reforms, which includes the Nigerian Energy Policy of 2003 and 2005 and the Renewable Energy Master Plan of 2005, were captured.

Data for electricity generation were obtained from the World Development Indicator (WDI, 2024). In contrast, solar energy financing data were obtained from the Rural Electrification Agency of Nigeria (REAN, 2021). The REAN is responsible for providing off-grid electricity to rural communities. The major source of electricity for this agency is solar power. The Rural Electrification Fund (REF) was created under Section 88(II) of the Electric Power Industry Reform Act (EPSRA) of 2005 to aid in the development of off-grid and on-grid energy solutions to improve the power industry. According to Section 88(12), the Nigeria Electricity Regulatory Commission (NERC) collects fines, statutory remittances, grants, and loans from development financial institutions, and a percentage of licensees' yearly earnings as financing sources for rural electrification. According to Section 91, the Rural Electrification Agency (REA) is responsible for conducting electrification projects in rural areas. According to REAN (2022) and REAN (2021), the Federal Government of Nigeria (FGN) spent about ₦100.89 billion between 2020 and 2022 on off-grid rural electrification, with solar energy serving as the main energy source. In addition, The World Bank has provided the Federal Government of Nigeria with funding to help cover the cost of the Nigeria Electrification Project (NEP) and the Rural Electrification Agency (AFDB, 2013). A portion of the credit's earnings is used by the implementation agency to settle the contract for consultation services. To support these goals and offer financial and technical support for independent solar solutions to rural areas that have little to no potential for reliably, affordably, and sustainably receiving electricity from conventional power systems, the World Bank approved a $350 million low-cost loan to the FGN through the REA in June 2018 (REAN, 2021). Similarly, the Minister of Power, Adebayo Adelabu, disclosed that $750mill was approved by the World bank to finance distributed access through the Renewable Energy Scale-up (DARES) program (REAN, 2023). However, the Power Holding Company of Nigeria (PHCN) and its predecessor, the National Electric Power Authority (NEPA), were mostly in charge of rural electrification projects before the creation of the Rural Electrification Agency (REA) in Nigeria in 2005.

Therefore, data for government energy finance and commercial banks' renewable energy finance were sourced from the Central Bank of Nigeria Statistical Bulletin (CBN, 2022), and data for energy financing from foreign (African Development Banks and World Bank) were sources from CBN (2022) and the Federal Ministry of Budget and Economic Planning (FMBEP, 2023). Data for Labor were sourced from the World Development Indicator (WDI, 2024). Labor Data are generated from World Bank population estimates and ILO estimates of the labor force participation rate.

4. Presentation and Discussion of Results

4.1 Data Analysis

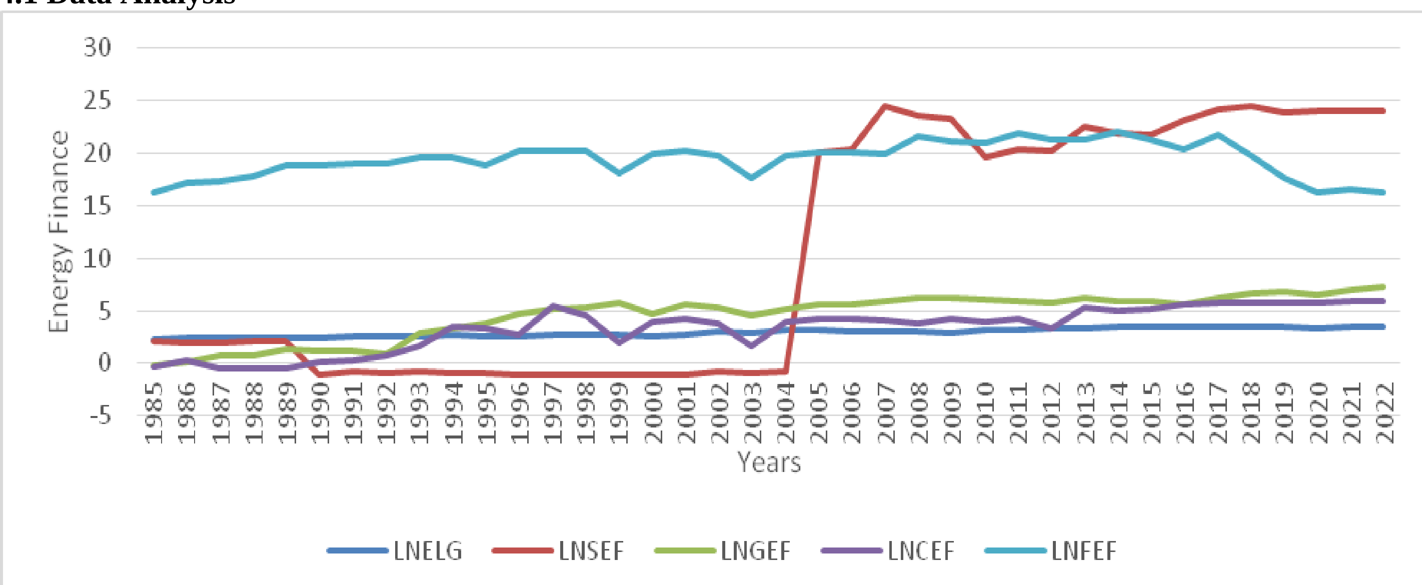

Figure 1. Electricity Generation and Energy Finance variables in Nigeria (1985 – 2022)

Source: ***Source:*** Researcher's Computations Using Eviews 10.

Figure 1 illustrates the electricity generation trends and various energy finance factors from 1985 to 2022. Although electricity generation remained relatively stable over this period, showing limited growth in Nigeria, the energy finance variables exhibited fluctuating patterns. Notably, solar energy finance experienced a significant increase from N421.3 billion to N1.38 trillion between 2003 and 2009, followed by a decline to approximately N315 billion in 2010, remaining volatile until 2022. A unit root test was carried out to evaluate the stationarity of the variables considering the observed volatility; the results are shown in Table 2.

4.2. Stationary Test
Table 1
Unit Root Test (ADF Test Result)

Variables	ADF Levels	Critical Values	ADF 1st Diff	Critical Values	Order of Integration
LnELG	-3.271	-3.540	-7.359	-3.540	I(1)
LnSEF	-2.074	-3.540	-6.267	-3.540	I(1)
LnGEF	-1.855	-3.540	-6.994	-3.540	I(1)
LnCEF	-3.440	-3.537	-7.431	-3.540	I(1)
LnFEF	-6.866	-2.946	-	-	I(0)
LnLAB	-1.709	-3.540	-4.788	-3.540	I(1)

***Source:* Researcher's Computations Using Eviews 10.**
The unit root test in Table 1 shows that the variables are stationarity at the first difference, except for the LNFEF, which is stationary at the level. I(0) and I(1) are both present in the variables. As a result, these variables have traits that make them appropriate for the ARDL model, indicating that there is a long-term relationship between them.

4.3 Optimal Lag Selection
Table 2
Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-160.502	NA	0.004	11.483	11.766	11.572
1	-33.844	192.172	7.981	5.231	7.211*	5.851
2	13.627	52.381*	5.151	4.440	8.117	5.591
3	78.595	44.806	2.181*	2.442*	7.817	4.125*

***Source:* Researcher's Computations Using Eviews 10.**
Table 2 presents the criteria by which the lag length of our model variables was selected. All two criteria (AIC and HQIC) indicate the selection of a maximum of three (3) lags, while SBIC indicates a maximum of one (1) lag to be included in our model, as shown by the asterisk (*) along the three lags. Based on the selection criteria, lag 3 was the most frequently chosen optimal lag, and the AIC with the minimum value was selected.

4.4. Cointegration Test
The next goal of the study is to determine long-term links between the variables because they show integration of orders one and zero. The long-term linkages between them were determined using the ARDL-bound testing technique. Table 3 presents the results of the co-integration test:

Table 3: *Result of ARDL Bounds Test for Co-integration*

Null Hypothesis: No Long-run relationships exist.		
Test Statistic	Value	K
F-Statistic	7.446	5
Critical Value Bounds		
Significance	Lower Bound	Upper Bound
5%	2.62	3.79

***Source:* Researcher's Computations Using Eviews 10.**

The results of the co-integration test show that at the 5% significance level, the F-statistic (7.446) exceeds both the lower and upper bound critical values. At the 5% significance level, the null hypothesis, which states that no long-term relationship exists, is thus rejected. This suggests that cointegration exists among the variables.

Table 4: *ARDL Long-Run Estimated Result*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNSEF	0.017	0.006	2.928	0.013
LNGEF	0.129	0.026	5.078	0.000
LNCEF	0.011	0.016	0.740	0.473
LNFEF	0.101	0.021	4.880	0.000
LNLAB	2.877	0.363	7.933	0.000

***Source:* Researcher's Computations Using Eviews 10.**

4.5. ARDL Error Correction Model

Considering the co-integration connection between the dependent variable and the regressors, this study calculates the error correction ARDL model. The outcomes of these estimations are displayed in Table 5.

Table 5: *Results of the Estimated ARDL Error Correction Electricity Generation Model*

Dependent Variable: D(LNELG)

ECM Regression
Case 3: Unrestricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNSEF(-1))	0.013	0.003	3.960	0.002
D(LNGEF(-1))	0.092	0.022	4.236	0.001
D(LNCEF)	0.028	0.009	3.140	0.009
D(LNFEF(-1))	0.072	0.015	4.678	0.000
D(LNLAB(-1))	3.511	1.041	3.374	0.006
CointEq(-1)*	-0.582	0.121	-4.777	0.000

R-squared	0.982	Mean dependent var	3.075
Adjusted R-squared	0.958	S.D. dependent var	0.317
S.E. of regression	0.065	Akaike info criterion	-2.695
Sum squared resid	0.050	Schwarz criterion	-2.129
Log likelihood	51.074	Hannan-Quinn criter.	-2.518
F-statistic	41.392	Durbin-Watson stat	2.008
Prob(F-statistic)	0.000		

* p-value incompatible with t-Bounds distribution.

***Source:* Researcher's Computations Using Eviews 10.**

Tables 4 and 5 present the results of the Autoregressive Distributed Lag (ARDL) model, revealing positive coefficients for all variables in both the short run and long run. Despite limited attention in existing literature, these findings align with both empirical expectations and theoretical predictions, supporting the tenets of endogenous growth theory. Besides commercial banks' energy finance variable that is statistically insignificant in the long run, solar energy financing, government expenditure on electricity, and labour show positive and statistically significant coefficients, indicating their contributions to electricity generation in Nigeria. Specifically, a 1% increase in solar energy finance leads to a 0.01% increase in electricity generation, while government expenditure on electricity and commercial banks' energy finance contribute to about 0.13% and 0.11%, respectively, to electricity generation in the long run. Foreign aid renewable energy finance and labour contributed about 0.10% and 2.88% of electricity generation in the long run. However, the long-run result revealed that the total labour employed contributes more to electricity generation in Nigeria.

Similarly, the estimated coefficient of solar energy financing, government expenditure on electricity, commercial banks' energy finance, renewable energy finance from foreign aid and total labour employed shows a positive and statistically significant estimate in the short run, contributing to changes in electricity generation. That is, a 1% increase in solar energy finance contributes to about a 0.01% increase in electricity generation in Nigeria. Also, a 1% increase in government expenditure, commercial energy finance, and energy finance from foreign aid and labour contributed to about 0.09%, 0.03%, 0.07% and 3.51 percent of electricity generation in Nigeria. However, energy finance from foreign aid exhibits a negative and significant coefficient, implying a decrease in electricity generation with each unit of foreign intervention. The short-run result further revealed that labour employed contributes more to electricity generation in Nigeria.

With about 58% of the disequilibria from the prior year convergent to their long-run equilibrium in the present period, the coefficient of the Error Correction term validates a long-term link between the variables. With explanatory variables accounting for almost 98% of the variance in the dependent variable, the short-run model shows a good fit. Furthermore, the lack of serial correlation between error terms is confirmed by the Durbin-Watson statistic of 2.

4.6. Diagnostic Test of the ARDL Model

Table 6 presents diagnostic tests conducted to ensure the robustness and validity of our model and the variables employed in this study.

Table 6

Result of the Diagnostic Test.

Heteroskedasticity Test			
F Statistics	0.647	Prob	0.795
Serial Correlation LM Test			
F Statistics	1.080	Prob	0.376
Normality Test			
Jarque-Bera	0.590	Prob	0.745

***Source:* Researcher's Computations Using Eviews 10**

Post-estimation tests were performed in this work to guarantee the accuracy of the estimation analysis. Normality, serial correlation, and heteroscedasticity tests were conducted. The model is free from heteroscedasticity because the p-value of 0.80 is above the 0.05 cut-off. Similarly, with a p-value of 0.38, no serial association was discovered. Additionally, the p-value of 0.75 from the normality test was above the 0.5% criterion and showed a normal distribution of residual values. These diagnostic test results provide confidence in the validity of the estimation and confirm that the estimation analysis is robust.

4.7. Policy Implication of Findings

The outcomes of this research have considerable implications for Nigeria's energy policy. The following highlight some key policy considerations:

Increasing investment in renewable energy projects through the Rural Electrification Agency of Nigeria, especially solar projects, may have a positive impact on electricity generation in Nigeria, according to the positive and statistically significant relationship between solar energy financing in both short- and long-term models. Similarly, the positive and statistically significant coefficient associated with government expenditure on the electricity sector indicates that augmenting spending in this area could result in substantial improvements in electricity generation.

The positive and statistically significant coefficient linked to commercial banks' energy finance implies that the involvement of commercial banks in financing energy projects could yield benefits for electricity generation. The World Bank and African Development Bank's involvement in energy financing may also have a major impact on Nigeria's electricity generation, as indicated by the significant coefficient given to foreign aid energy financing in both the short and long term.

Moreover, the positive and significant coefficient associated with total labor employed underscores the crucial role of the workforce in electricity generation. In summary, increasing manpower with the requisite skills and expertise is essential for maintaining and enhancing electricity generation capacity.

Additionally, the negative and significant Error Correction term, which shows a long-term relationship between dependent and independent variables, emphasizes how critical it is to correct short-term imbalances to eventually achieve sustainable electricity generation.

5. Conclusion and Recommendations

It is crucial to acknowledge the critical role that electricity plays in Nigeria's economic development and prosperity, as well as the significance of financing renewable energy. However, research on energy economics has not yet given much emphasis to the particular facet of energy financing and its relationship to electricity generation. This study explores the importance of solar energy finance in terms of power generation in Nigeria, taking into account this vacuum in the literature. The Autoregressive Distributed Lag (ARDL) model estimate technique was used in the study, along with pre-estimation tests on time series data.The variables considered were electricity generation (dependent variable) and solar energy financing, government expenditure on the electricity sector, commercial bank renewable energy financing, renewable energy financing from foreign aid, and total employment in the electricity sector (independent variables). The findings reveal that solar energy financing, government expenditure on the electricity sector, commercial bank renewable energy financing, and energy financing from foreign interventions in renewable energy spur electricity generation in Nigeria. Total employment's importance in the production of electricity is highlighted by its inclusion as an explanatory variable, which is consistent with the theoretical prediction that higher output results from increasing labor and capital stock.

From the above findings, the study suggests the following:

Given the significant contribution of solar energy finance to electricity generation, policymakers should encourage and facilitate investments in renewable energy ventures, particularly solar energy projects, to enhance energy diversity and security. The Rural Electrification Agency could be a key player in effectively managing these investments.

Considering the substantial impact of government expenditures on electricity generation in the sector, policymakers should prioritize directing resources toward maintaining, expanding, and modernizing electricity infrastructure to meet Nigeria's increasing demand for electricity. The Federal Ministry of Power could effectively manage these resources.

While acknowledging the role of commercial banks in supporting the power sector, policymakers should create an enabling environment for banks to provide financial support to energy ventures by offering favorable loan terms, incentives, and regulatory support tailored for electricity purposes.

Lastly, to ease structural limitations and investment obstacles in the energy sector and to ease the transition to a sustainable or balanced power supply, policymakers and industry stakeholders should take these steps into place.

REFERENCES

Adel, A., Yuliya, G. T., Zhanara, P. S., Anastasia, A. K., and Aleksei, A. S. (2019). Government Policy and Financing Options for Solar Energy: World Prospects. *International Journal of Energy Economics and Policy, 9*(6), 131-145.

Adenuga O.S. & Idoko, C. (2021). Impact of government expenditure on electricity supply in Nigeria: 1990–2017. *Journal of Humanities and Social Sciences Research, 4*(1), 64–74.

African Development Bank (2013). Financing Rural Electrification at the Global Conference on Rural Energy Access. Retrieved from https://sdgs.un.org

Ahmed, A., Tyurina, Y. G., Smailova, Z. P., Kurilova, A. A., & Shulus, A. A. (2019). Government Policy and Financing Options for Solar Energy: World Prospects. *International Journal of Energy Economics and Policy, 9*(6), 131–145. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/8212.

Ajaelu, H. & Okereke, R. (2020). Assessment of Nigeria's renewable energy potential and energy poverty: Challenges and prospects. *PM World Journal*, IX(VI), pp. 1-19.

Akuru, U.B. & Okoro, O.I. (2005). Renewable energy investment in Nigeria: a review of the renewable energy master plan. *Energy South Afr. 25* (30).

Andonov, A. & Rauh, J. D. (2024). Shifting the Finance of Electricity Generation. Stanford University Graduate School of Business Research Paper No. 4287123, Available at http://dx.doi.org/10.2139/ssrn.4287123

Atchike, D. W.; Zhao, Z.; Bao, G. (2020). Relationship between electricity consumption, foreign direct investment, and economic growth. *International Journal of Energy Economics and Policy 10*(4), 507–515.

Bank of Industry (2022). Renewable Energy Fund (https://www.boi.ng/renewable-energy/).

Bekun, F. V., & Alola, A. (2022). Determinants of renewable energy consumption in agrarian sub-sahar african economies. *Energy, Ecology, and Environment*, 7, 227–235.

Burgess, J. C., and Barbier, E. B. (2001). Sustainable development. In *International encyclopedia of the social & behavioral sciences* (15329–15335). Elsevier. https://doi.org/10.1016/B0-08-043076-7/04164-4

Byjus, (2023). What is Solar Energy? Retrieved from https://byjus.com/physics/solar-energy-project/

Da Silva, P. P., Cerqueira, P. A., & Ogbe, W. (2018). Determinants of renewable energy growth in Sub-Saharan Africa: Evidence from panel ARDL. *Energy 156, 45–54.* Doi: 10.1016/j.energy.2018.05.068

ECN (2022). National Energy Policy. Retrieved from https://energy.gov.ng/Energy_Policies_Plan.

Elmassah, S. (2024). Determinants of renewable energy production in emerging and developed countries, International Journal of Energy Sector Management, 18(5), 1014-1040. https://doi.org/10.1108/IJESM-08-2021-0031

Emmanuel P. A., Collins O. E., Thomas O. M., Armstrong O. N., Chris M. E. & Hitler, L. (2021). Solar energy: A panacea for the electricity generation crisis in Nigeria. *Helyon, 7*, e07016. https://doi.org/10.1016/j.heliyon.2021.e07016.

Emodi, N. V., & Boo, K. J. (2015). Sustainable energy development in Nigeria: Current status and policy options. *Renewable and Sustainable Energy Reviews*, 51, 356-381.

Emodi, N.V. & Ebele, N. E. (2016). Policies enhancing renewable energy development and implementations in Nigeria. *Sci. Educat. Publ. 4* (1), 7-6.

Energetics (2023). Financing solutions for solar energy projects. Retrieved from https://enerdatics.com/

Energy Commission of Nigeria (2014). National Renewable Energy And Energy Efficiency Policy. Retrieved from https://energy.gov.ng/Energy_Policies_Plan.

Federal Ministry of Budget and Economic Planning (2024). Finance and Account. Retrieved from https://nationalplanning.gov.ng

Giartkasari, G & Nikensari, S.I. (2022). Causal relationship between renewable energy Consumption, economic welfare, and foreign direct investment in 6 ASEAN countries. *Jurnal Pendidikan Ekonomi, Perkantoran Dan Akuntansi, 7*(4), 120-128. DOI: doi.org/10.21009/JPEPA.007. x.x.

Giwa, A; Alabia, A; Yusuf, A. & Olukanb, T. (2017). A comprehensive review of biomass and solar energy for sustainable energy generation in Nigeria. *Renewable and Sustainable Energy Reviews, 67,* 620–641. http://dx.doi.org/10.1016/j.rser.2016.11.160

Hindi, I. (2023). Nigeria Needs 33,000MW For Stable Power Supply–Discos. Punch News Paper, 7 May. Retrieved from https://punchng.com/.

Hondroyiannis, G., Papapetrou, E. and Tsalaporta, P. (2024). Sustainable energy consumption and finance in the presence of risks: Toward a green economy. Renewable Energy, 237, Part A, doi:10.1016/j.renene.2024.121565

International Energy Agency. (2022). *Sources of electricity generation.* Retrieved from https://www.iea.org.

IRENA (2023), Renewable Energy Roadmap: Nigeria, International Renewable Energy Agency, Abu Dhabi.

Isah, A.; Dioha, M.O.; Debnath, R; Abraham-Dukuma, M.C & Butu H. M. (2023). Financing renewable energy: policy insights from Brazil and Nigeria. *Energy, Sustainability and Society*, *13*,2. https://doi.org/10.1186/s13705-022-00379-9.

Krupa, J., Harvey, L. D. D. (2017). Renewable electricity finance in the United States: A state-of-the-art. *Energy*, 135, 913-929. https://doi.org/10.1016/j.energy.2017.05.190

Longe, A. E., Adebayo, E. O., Shehu, M., and Adelokun, O. O. (2020). Energy consumption and foreign direct investment in Nigeria: *A structural break analysis. Economic Themes, 58*(2), 187–201. https://doi.org/10.2478/ethemes-2020-0011

Lutz, M. (1997). German electricity reform attempts: Reforming co-optive networks. In European electricity systems in transition: A comparative analysis of policy and regulation in Western Europe (pp. 231–252). Elsevier. (Global Energy Policy and Economics Series)

Mazzucato, M. & Gregor, S. (2018). Financing renewable energy: Who is financing what and why it matters. Technological forecasting and social change. *127*, 8-22. https://doi.org/10.1016/j.techfore.2017.05.021

Mesagan, E., Ajide, K., & Vinh, X. (2021). Dynamic heterogeneous pollution reduction analysis in SANEM countries: Lessons from the energy-investment interaction. *Environment Science and Pollution Research*, *6*(2), 66-79.

Nadabo, S. L. (2010). Renewable Energy as a Solution to the Nigerian Crisis, University of Applied Sciences.

National Electricity regulatory Commission (2024). NERC Quarterly Reports, First Quarter, 2024. Retrieved from https://nerc.gov.ng/

Olanrele, I.A. and Fuinhas, J. A. (2022). Assessment of renewable electricity adoption in sub-Saharan Africa, Energy & Environment, 35(2), doi:10.1177/0958305X221118878

Onabote, A., Jolaade, A., Osabohien, R.., Otobo, O., Ede, C., & Okafor, V. (2021). Energy sustainability, energy financing, and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, *11*(1), 22–45.

Onayemi, S., Olomola, P., Alege, P., & Onayemi, O. (2020). Foreign direct investment, electricity supply, and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, *10*(5), 243–247.

Ozoegwu, C.G., Mgbemene, C.A. & Ozor, P. A. (2017). The status of solar energy integration and policies in Nigeria. *Sustain. Energy Rev. 70*, 457–471.

Rashed, A., Yong, C., & Soon, S. (2022). The nexus of foreign direct investment in renewable electricity, renewable electricity production, and economic growth in Africa. *Powerful Economic and Finance*, *10*(1), 56–78.

Rural Electrification Agency of Nigeria (2021). Exploring sources of funding for off-grid rural electrification. Retrieved from https://rean.org.ng

Rural Electrification Agency of Nigeria (2021). The World Bank approves $350 million for REA off-grid projects. Retrieved from https://rea.gov.ng/wbank.

Rural Electrification Agency of Nigeria (2021). World Bank loan facility. Retrieved from https://nep.rea.gov.ng/worldbank-nep/

The Rural Electrification Agency of Nigeria (2023). World Bank Approves $750m to Boost renewable Energy in Nigeria. Retrieved from https://nep.rea.gov.ng

Statista Research Department (2023). Renewable energy share of electricity capacity in Nigeria 2011-2022. Retrieved from https://www.statista.com/statistics/1278245/

US Energy Information Administration (2023). Electricity Generation. Retrieved from https://www.eia.gov

USAID (2023). Nigerian Power Africa Fact Sheet. Retrieved from https://www.usaid.gov/powerafrica/nigeria.

World Development Indicator (2024) Nigeria, Electricity Production. Retrieved from https://databank.worldbank.org/

World Development Indicator (2024) Nigeria, Total Labor. Retrieved from https://databank.worldbank.org/