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POWERING INDUSTRIAL GROWTH: THE ROLE OF ENERGY ACCESS IN MANUFACTURING PERFORMANCE IN NIGERIA

Purpose. This study examines the impact of energy access on manufacturing performance in Nigeria with the access to electricity, electric power consumption and renewable energy consumption while Manufacturing value added was used as an indicator of manufacturing performance.
Design/methodology/approach. This study used Secondary data from the World Development Indicators (WDI) of World Bank which is available on an annual basis between the year 2000 and 2024. Autoregressive Distributed Lag (ARDL) bounds testing method is employed in estimating short-run and long-run relationships, which is backed by diagnostic tests to determine model reliability.
Findings. The long runs estimates showed that access to electricity and consumption of renewable energy had negative and statistically significant impacts on manufacturing value added, while the use of electric power had an impact that was statistically insignificant. Current value of access to electricity had positive but non-significant effect in short run, while the lagged values had positive and significant effect on the short run manufacturing performance. The short run effect of renewable energy consumption was negative and significant.
Originality. This study offers a disaggregated analysis of energy access by analyzing energy access in the form of electricity access, electric power consumption, and renewable energy consumption in one framework, ARDL, which is a different approach from the previous studies that mainly investigated the relationship between aggregate energy consumption and industrial output. The study adds new empirical facts to the energy–manufacturing link in Nigeria, using recent data from 2000 to 2024, to inform policies that seek to improve manufacturing performance through improved energy infrastructure and sustainable energy use.
Keywords: Energy access, Manufacturing performance, Access to electricity, Electric power consumption, Renewable energy consumption, ARDL, Nigeria.

Introduction

Energy is increasingly one of the most important factors in the transformation of industries and their sustainable economic development. Not only is it an input into production, energy influences the efficiency, competitiveness and technological progress of production activities. Sustained industrial growth has been the hallmark of those countries that have made continuous investments in stable energy supply infrastructure that can sustain productive sectors (Rezaee & Silva, 2026). As a result, the focus has changed from merely energy resources to energy systems that are available, accessible and efficient for industrial processes (Weldengus & Berhe, 2026). This change is the result of a realisation that the competitiveness of industry is not just a matter of energy supply quantity, but also of its reliability, affordability and sustainability.

With the rising attention on sustainable development, the connection between energy and industrialization has been redefined, and while conventional energy sources have become essential in industrial production, the growing environmental concerns have pushed the development of energy systems towards renewables and clean energy (Teng et al., 2026). This shift has sparked extensive discussion on the ability of renewables to deliver industrial productivity and environmental sustainability at the same time. For example, Rasheed et al. (2026) stated that the production of renewable energy is associated with sustainable industrial transformation without any reduction in industrial competitiveness, which reduces environmental degradation. Likewise, Maruta (2025) noted that energy development, especially electricity access and energy utilization, greatly boosts the industrialization process in the African economies. The studies revealed that energy development has been integrated into the industrial policy agenda and is no longer a production factor.

Even in the face of this agreement, the energy–industrial performance link is not unequivocal, especially in developing countries. Although access to electricity has been increasing over the past 20 years, issues remain in the productive use of available electricity infrastructure, its reliability, and its efficiency. Despite the improvements made in energy policies, energy infrastructure and energy utilization remain insufficient to boost industrial productivity in West Africa, as noted by Ogunsola and Zwane (2025). Similarly, Asinya & Ishua (2025) discovered that while energy use is a significant factor in industrial development, its impact is not always in accordance with theoretical predictions, thus, increases in energy availability may not guarantee increased industrial performance. The opposing results suggest that the impact of energisation isn't just about providing more energy, but it's also about using energy to do productive things.

Nigeria is one of the most striking examples of this paradox: The country has a high level of energy resources and has enacted a number of measures to increase its electricity generation capacity and promote the use of renewable energy, but the manufacturing industry still faces chronic energy shortages. The electricity supply continues to be precarious, with many manufacturing companies having to depend greatly on their own generation, which is at a much greater cost to the businesses. Nigeria's manufacturing industry is not competitive as a result of its reliance on self-generation using diesel (Olaoye, 2026), which has hampered productivity and hindered industrial growth. Likewise, Yetano Roche et al. (2020) reiterated the need to coordinate investments in Nigeria's electricity infrastructure with the development of renewable energy systems that can provide reliable and affordable energy supplies for productive activities.

The results from the empirical studies conducted so far are generally consistent with the importance of energy in industrial development, but the findings vary. Both Balogun (2024) and Asinya and Ishua (2025) observed that electricity access and consumption of renewable energy have positive effects on industrial production in Nigeria while energy related variables did not yield the expected results even though they are statistically significant. The impact of energy development also differs between economies in Africa and Asia, based on evidence. The disharmonies suggest that the correlation between energy access and manufacturing performance is context specific and could be explored further through empirical studies based on country evidence.

In light of this background, this study investigates the effect of energy access on manufacturing performance in Nigeria with particular focus on the energy access of electricity, electric power consumption and renewable energy consumption. The study uses manufacturing value added as a measure of manufacturing performance, instead of focusing only on industrial output or aggregate economic growth, as in previous studies. The study assesses the overall impact of the major energy indicators on manufacturing activities to give more empirical evidence which can be used in developing energy and industrial policies to boost the manufacturing sector and ensure sustainable industrial development in Nigeria.

The manufacturing sector is still a significant contributor to economic transformation via industrialisation, job creation, technology development and export development. But its operation is very reliant on the availability of reliable and efficient energy systems. Despite the many reforms and investments in the energy sector, Nigeria still faces the problem of low electricity supply, inefficient energy use, and low level of integration of renewable energy sources, which are limiting manufacturing activities. This has led to a question of whether gains in energy values have been reflected in meaningful gains in manufacturing performance.

The relationship between energy use and industrial performance is still not clear from the empirical evidence. Electricity access and use of RE have been observed to boost industrial performance by Balogun (2024) and Maruta (2025) respectively while Asinya and Ishua (2025) obtained results contrary to theoretical findings. Likewise, Ogunsola and Zwane (2025) highlighted that the inability to harness energy effectively and efficiently in the industrial sector hampers industrial productivity. These differences suggest that the effect of energy development on manufacturing performance are context dependent and warrant further investigation.

In Nigeria, manufacturing companies still experience intermittent power supply, high energy costs and reliance on alternative power sources, which make them less competitive. Furthermore, previous studies have concentrated in industrial production and economic growth, and few have examined manufacturing value added as a direct indicator of the performance of industrial sectors. The study therefore explored the influence of access to electricity, electric power use and renewable energy use on manufacturing performance in Nigeria as evidence for effective formulation of energy and industrial policy.

The main objective of this study is to examine the impact of energy access on manufacturing performance in Nigeria. other specific objective are to: analyze the impact of electricity availability on factories' productivity in Nigeria; investigate the impact of electric power use on the performance of manufacturing activities in Nigeria; and evaluate the impact of renewable energy use on production of manufacturing industry in Nigeria.

This study is significant to the study of energy economics and industrial development because it looks at the link between energy access and performance in manufacturing in Nigeria. It offers insights into the impact of electricity access, electricity consumption and renewable energy utilization. The results help policy makers make better decisions about the development of energy infrastructure and industrial policies, and aid manufacturing companies in their energy efficiency and renewable choices. The findings of the study will also be useful to scholars and researchers looking into energy and sectoral development.

Literature review

Energy Access

Energy access is defined as the availability, affordability, reliability and quality of energy services needed to sustain economic and social activities (Jiao & Tan, 2024). It's not just about the physical connection to electricity; productive areas need a reliable and adequate supply of electricity to function well. In the industrial equipment sector, the lack of access to energy leads to higher operating expenses, lower productivity and competitiveness. Poor energy access is a constraint on development outcomes as it hinders access to essential services and economic activities (Kwong et al. 2026), whereas increased energy access has a significant positive impact on industrialisation in African economies (Maruta 2025). But just access might not be enough in an industrial growth when there is disparity in energy supply and it is not reliable and efficient. This means that the extent of energy access is only the beginning and the ability to use existing energy systems in a productive manner is also important.

Access to Electricity

Access to electricity refers to the degree of access to reliable electricity services that can be used to ensure the provision of electricity for economic activities in households and productive sectors (Moloi, 2025). In fact, one of the most important aspects of manufacturing is the ability to access electricity, as the operations of the manufacturing processes rely on a steady and reliable supply of power which is also cost effective (Ejefobihi et al. 2025). But where electricity is unreliable or inadequate, availability doesn't necessarily mean industrial performance. Maruta (2025) provided the foundation that access to electricity is one of the critical factors in industrialization in African economies, while Balogun (2024) revealed that the access to electricity has a positive effect on industrial production in Nigeria. Olaoye (2026), however, said the poor supply of electricity made producers resort to alternative sources of energy, which is very expensive, thus making them less competitive. Thus, the extent of access to electricity should be measured not just based on connections but also on the reliability for its use and its capacity to power manufacturing processes.

Electric Power Consumption

Electric power consumption measures the amount of electricity used in an economy and can be used to gauge the level of energy consumption in productive activities (Kabeyi & Olanrewaju, 2021). For manufacturing, a sufficient use of electricity can make the production capacity stronger, increase operational efficiency and encourage industrial growth. But, efficiency in electricity use does not always translate to efficiencies in manufacturing if the energy is being used inefficiently or a power failure is an issue. The use of energy is important for development as Balogun, Ali, and Rozaini (2024) revealed that energy consumption has a positive effect on economic performance in Nigeria. Likewise, Maruta (2025) mentioned that energy consumption is a key factor in industrialization in the African economies. However, efficient energy use is important to safeguard productivity gains as noted by Ogunsola and Zwane (2025). Therefore, the productive effect of the use of electric power is dependent on the efficiency and reliability of energy systems.

Renewable Energy Consumption

Renewable energy consumption is the use of renewable energy sources, including sustainable energy such as solar, wind, hydro and other renewable sources, to enable economic activities (Mammadov et al., 2022). It is becoming more important in relation to the need of cleaner, more reliable and sustainable energy systems to support industrial development. The impact that renewable energy has on manufacturing performance, however, is dependent on how much is being adopted, how much is covered by infrastructure, and technology capacity. Rasheed et al. (2026) highlighted that renewable energy is a key driver of sustainable industrial transition, helping to ensure competitiveness while alleviating environmental pressures. Likewise, Balogun (2024) concluded that renewable energy consumption positively affects the industrial production in Nigeria. Yetano Roche et al. (2020) however, said that there is a need for coordinated policy actions and improved infrastructure to support Nigeria's transition to renewable energy. Thus, using renewable energy is a challenge and opportunity to enhance manufacturing performance.

Manufacturing Performance

Manufacturing performance is a measure of the capacity of the manufacturing industry to create economic value by engaging in efficient production processes and the use of resources. To get a more suitable measure of sectoral performance, manufacturing value added is used instead of manufactured value. The manufacturing value added is used in place of manufacturing value as it measures the net contribution of manufacturing activities to economic output. But external factors are increasingly becoming an influence on manufacturing performance, especially energy availability and reliability. Olaoye 2026 has reported that the insecurity of electricity supply contributes to high production costs and low competitiveness of industrial production, whilst Ogunsola and Zwane 2025 reported that a poor energy infrastructure limits industrial productivity. On the other hand, Balogun (2024) observed that good energy service boosts industrial production in Nigeria. The results indicate a strong correlation between manufacturing performance and the efficiency of energy systems.

Theoretical Framework

Energy-Led Growth Hypothesis

Kraft and Kraft (1978) presented their study "On the Relationship between Energy and GNP" that introduced the Energy-Led Growth Hypothesis. The theory suggests that energy is a key input to the production process where changes in energy availability and consumption affect economic productive capacity. The hypothesis suggests that industries with heavy production demands are highly energy-intensive and, thus, have a high dependence on energy availability, which may limit output growth and industrial development if energy is not reliable.

The rationale for the use of this theory in the present study is justified by the fact that without proper and sufficient energy system, manufacturing activities cannot run effectively. Electricity and other forms of energy are essential to power machinery, to keep production lines running and to increase efficiency in manufacturing. The betterment of access to electricity, electric power consumption and utilization of renewable energy are expected to lead to betterment of manufacturing value added by productive capacity.

The theory offers a solid background to the study of energy access and manufacturing performance in Nigeria since the Nigeria's manufacturing problem is directly linked to its energy problem. Nigeria has significant energy resources but the lack of reliable power supply and inefficient energy systems remains a challenge to the competitiveness of industries. This is in accordance with the views of Olaoye (2026) and Ogunsola and Zwane (2025) who noted that poor energy infrastructure results in low industrial productivity. Hence, the Energy-Led Growth Hypothesis gave the theoretical props for studying the effect of energy development indicators on the performance of manufacturing industry in Nigeria.

Empirical review

Metershak Rasheed along with Yuhuan, Haseeb, Ahmed and Saud (2026) explored the correlation between green energy generation, industrial competitiveness, industrialization and environmental sustainability for 14 Asian emerging economies between 1992 and 2021. The study used the ARDL-PMG, ARDL-DFE, FMOLS and ARDL-ECM estimation techniques. The results showed that production of renewable energy resulted in environmental sustainability, while industrial competitiveness and industrialization resulted in higher carbon emissions in the long run. The study found that Sustainable industrial transformation is only possible with the use of renewable energy and concluded that the investment in renewable energy, the promotion of green industrial policies and implementing low carbon industrial production strategies will lead to industrial growth while also being environmentally sustainable.

Kwong, Bailis, Daouda, Gill-Wiehl, Mutiso, Pillarisetti, et al. (2026) discussed the significance of energy access and its impact on health outcomes in low- and middle-income countries and explored the connection between energy poverty, health care delivery, and sustainable development. The study cited available evidence on access, reliability, and quality of energy; and health and socioeconomic issues. The results showed that the lack of clean and reliable energy creates negative health impacts, restricts access to health care, and leads to higher disease burdens. The study concluded that universal access to clean and reliable energy is vital in improving public health, and advocated that greater investments should be made in sustainable energy infrastructure, supportive policies, and financing channels to bring energy to the low- and middle-income countries.

Balogun (2024) investigated the linkages between access to energy, use of renewable energy and industrial production in Nigeria for 1990-2023 period of data. Autoregressive Distributed Lag (ARDL) model was used to analyse the relationship between the variables. The results showed that access to electricity, consumption of renewable sources of energy had positive effects in both the short and long run and foreign direct investment exerted a positive effect only in the long run on industrial output. The study found that increasing energy access and use of renewable energy improves industrial productivity and recommended industrial electricity infrastructure expansion, expanding electricity supply through renewable energy technologies, and supportive government policies to increase energy access and enhance industrial performance.

Using annual data from 1990 to 2023, Asinya and Ishua (2025) analyzed the relationship between energy and industrial development and economic growth in Nigeria. This study used Ordinary Least Squares (OLS), Augmented Dickey-Fuller (ADF) unit root test, and cointegration analysis in the study of the long run relationship between the variables. The results showed that industrial investment and foreign direct investment were statistically significant variables and their impact was strong on economic growth, energy consumption utilization and industrial output were statistically significant variables but they did not have the expected sign as per a priori. The study concluded that energy and industrial development play a crucial role in sustainable economic growth and recommended the extension of energy access, development of renewable energy, development of energy efficient technologies and energy diversification and industrial diversification through the encouragement of favorable government policies.

Olaoye (2026) investigated the contribution of industrial energy systems to competitiveness in manufacturing industry in Nigeria. This study was qualitative, using examples of Nigeria and experiences from China, Europe and South East Asia. The results indicated that most manufacturers are forced to rely on costly diesel-powered self-generation of electricity, thus making production costs higher and less competitive. The study found that a reliable industrial energy infrastructure is crucial for the growth of manufacturing and indicated that investments in captive power plants, hybrid RE systems, industrial energy clusters and supportive government policies will yield industrial productivity and competitiveness.

In West Africa, Ogunsola and Zwane (2025) analyzed the impact of energy efficiency policies on the growth of industries in 16 countries over a period of 24 years from 2000 to 2023. Stochastic frontier and random effects models were used to study relationships between energy intensity, carbon emission efficiency, renewable energy efficiency, energy infrastructure and industrial growth. The results showed that weak energy intensity of production and lack of infrastructure hindered industrial development, and good governance and cityization boosted productivity. The study found that energy efficiency policies play a significant role in industrial development and identified three governance, energy infrastructure, and energy efficiency policy recommendations to improve energy efficiency in industries and sustainable development in West Africa.

Balogun, Ali and Rozaini (2024) analyzed the effect of energy consumption on economic growth of Nigeria for the period of 1980 to 2022. Empirical time-series analysis and forecasting techniques were used to assess energy consumption–economic performance relationship. The results showed that the energy consumption had a significant positive effect on the economic growth in both short run and long run, and inflation and population growth had negative effects on the long run growth. Finally, the study concluded that the reliable use of energy is a key factor in sustainable economic development and suggested that adjustment of energy infrastructure, attracting foreign investment, maintaining macroeconomic stability, as well as coordinated energy and economic policies, are important issues for development in the long-term.

Maruta (2025) studied the effect of energy development on industrialisation in African economies across the panel data of 1990-2017. Fixed effects, two-stage least squares (2SLS), and system

Generalized Method of Moments (System-GMM) methods were used to examine the connection between energy development and industrial development. The results showed that energy development (electrical energy and energy use) had a significant and positive effect on industrialization with the highest influence being the access to electricity. The study showed that energy development is one of the most important drivers of industrialization and recommended a better provision of electricity access, strengthening energy infrastructure, and the development of good energy policies for sustainable industrial development in Africa.

Yetano Roche et al., (2020), however, investigated transition pathways to sustainable electricity access and decarbonization of power sector in Nigeria by 2030. Three alternative scenarios of electricity demand, generation and transmission were developed for the study, based on published data and stakeholder interviews. It was found that Green Transition scenario would enable Nigeria to attain universal access to electricity and surpass Nigeria's decarbonization targets but only partial targets in renewable energy are met. The study showed that coordinated policy activities could achieve energy transition that is sustainable, and it was recommended to increase the use of renewable energy, consolidate the electricity supply chain and decrease the use of fossil fuels-based electricity backup generation.

Methodology

In this study, ex post facto research design was employed. The design is appropriate because the effect of energy services on manufacturing performance was studied without influencing the variables of interest in Nigeria using historical time-series data. In this study, data of secondary information was used for each year from 2000 to 2024. Information about manufacturing value added, electricity access, electric power consumption and renewable energy consumption was obtained from World Development Indicators (WDI) by the World Bank.

Model Specification

For this study the model is defined as the impact of energy access on manufacturing performance in Nigeria. This functional relationship is written as:

$$MVA = f(AEP, EPC, REC) \tag{1}$$

The econometric model is specified as:

$$MVA_t = \beta_0 + \beta_1 AEP_t + \beta_2 EPC_t + \beta_3 REC_t + \mu_t \tag{2}$$

Since the study employed the Autoregressive Distributed Lag (ARDL) technique, the ARDL model is specified as:

$$\begin{aligned} MVA_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i MVA_{t-i} + \sum_{j=0}^{q_1} \beta_j AEP_{t-j} + \\ + \sum_{k=0}^{q_2} \delta_k EPC_{t-k} + \sum_{l=0}^{q_3} \phi_l REC_{t-l} + \varepsilon_t \end{aligned} \tag{3}$$

The Error Correction representation of the ARDL model is specified as:

$$\begin{aligned} \Delta MVA_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta MVA_{t-i} + \sum_{j=0}^{q_1} \beta_j \Delta AEP_{t-j} + \\ + \sum_{k=0}^{q_2} \delta_k \Delta EPC_{t-k} + \sum_{l=0}^{q_3} \phi_l \Delta REC_{t-l} + \lambda ECT_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

where:

MVA = Manufacturing Value Added (% of GDP)

AEP = Access to Electricity (% of population)

EPC = Electric Power Consumption (kWh per capita)

REC = Renewable Energy Consumption (% of total final energy consumption)

β_0 (or α_0) = Intercept

β_1–β_3 = Long-run slope coefficients

ECT = Error Correction Term

ε = Stochastic error term

Δ = First difference operator

t = Time period

The study used the ARDL estimation method proposed by Pesaran, Shin and Smith (2001). The ARDL method is appropriate because it fits variables that are integrated of order zero and one but not two, I(0) and I(1). It also displays good performance in small sample settings, and estimates the short run dynamics as well as the long run equilibrium relationship between the variables. The Bounds cointegration test was employed to determine the presence of the long-run relationship, Error Correction Model (ECM) to measure the rate of convergence from the short-run disequilibrium to the long-run equilibrium, and diagnostic tests following the estimation was used to examine the robustness and stability of the estimated model.

Results and discussion

Table 1
Descriptive Statistics

	MVA	AEP	EPC	REC
Mean	9.419877	52.68506	142.844	83.00514
Median	8.928929	53	139.4709	82.9
Maximum	13.9334	61.2	219.2447	88.1
Minimum	6.552817	43.2	95.55121	79.84625
Std. Dev.	1.845162	5.489873	28.32361	2.517465
Skewness	1.136502	-0.10574	0.919384	0.338229
Kurtosis	3.850936	1.95276	4.093018	1.876842
Jarque-Bera	6.136087	1.188991	4.766409	1.790709
Probability	0.046512	0.551841	0.092254	0.408463
Sum	235.4969	1317.126	3571.101	2075.128
Sum Sq. Dev.	81.71097	723.3289	19253.45	152.1031
Observations	25	25	25	25

Source: Authors' research (2026)

The descriptive statistics of manufacturing value added (MVA), access to electricity (AEP), electric power consumption (EPC) and renewable energy consumption (REC) in Nigeria for the period 2000 to 2024 are shown in Table 1. The results reveal that the average values of all the variables observed were positive over the period of the study indicating that manufacturing activity and energy related indicators in Nigeria are on the increase over the study period.

The mean value of manufacturing value added (MVA) was 9.4199, with a maximum of 13.9334 and a minimum of 6.5528 showing that the contribution of manufacturing sector to the economy fluctuated during the study period. Access to electricity (AEP) had an average value of 52.6851%, ranging from 43.2% to 61.2%, indicating gradual improvement in electricity access. In a similar way, the mean value of electric power consumption (EPC) was 142.8440 kWh per capita, with ranges between 95.5512 and 219.2447, indicating the variations in the consumption of electricity. Renewable energy consumption (REC) had the highest average of 83.0051%, ranging from 79.8462% to 88.1% suggesting the continued dominance of renewable energy sources in Nigeria's total final energy consumption.

The standard deviation shows that the amount of electric power consumption (EPC) has the highest variability (28.3236), indicating more fluctuations over the study period, and manufacturing value added (MVA) has the lowest variability (1.8452), which means that there are relative stable fluctuations in EPC over the study period. The Jarque–Bera statistics also reveal that the probability values for AEP, EPC, and REC are >0.05 which means that they are normally distributed, while the probability value for MVA is <0.05, suggesting some deviation from normal distribution. In general, the descriptive statistics show that the variables have appropriate statistical characteristics to be used in the empirical analysis.

After the descriptive analysis, the study moved on to the degree of association between the variables through the use of correlation analysis and the result is shown in Table 2.

Table 2
Correlation Matrix

	MVA	AEP	EPC	REC
MVA	1	-0.50389	-0.403	0.049482
AEP	-0.50389	1	0.57064	-0.76539
EPC	-0.403	0.57064	1	-0.60155
REC	0.049482	-0.76539	-0.60155	1

Source: Authors' research (2026)

The correlation matrix in Table 2 displays the level of association among the manufacturing value added (MVA), access to electricity (AEP), electric power consumption (EPC), and renewable energy consumption (REC). The findings show moderate negative correlation between manufacturing value added (MVA) and access to electricity (AEP) (r = -0.5039), and electric power consumption (EPC) (r = -0.4030) and very weak positive correlation between manufacturing value added (MVA) and renewable energy consumption (REC) (r = 0.0495).

The correlation between the explanatory variables shows a reasonable positive association between the use of electricity (AEP) and electric power consumption (EPC) (r = 0.5706). In contrast, there is a negative correlation between renewable energy consumption (REC) and access to electricity (AEP) (r = -0.7654) and electric power consumption (EPC) (r = -0.6015). The highest correlation coefficient is 0.7654, and it is still less than the common threshold 0.80 which means that there is no serious multicollinearity among the explanatory variables.

The correlation results indicated that all variables in the study have an acceptable level of independence to be used simultaneously in the regression model. In the first step of examining the degree of association among the variables, the study conducted the Augmented Dickey-Fuller (ADF) unit root test on the variables, and it is presented in Table 3.

Table 3
Augmented Dickey–Fuller (ADF) Unit Root Test

Variables	ADF Statistic	5% Critical Value	P-value	Stationarity	Order of Integration
MVA	-3.5456	-2.9981	0.0158	Stationary	I(0)
AEP	-1.0890	-2.9981	0.7021	Non-stationary	
D(AEP)	-5.4437	-3.0207	0.0003	Stationary	I(1)
EPC	-2.3601	-2.9919	0.1629	Non-stationary	
D(EPC)	-5.2195	-2.9981	0.0003	Stationary	I(1)
REC	-1.3031	-2.9919	0.6110	Non-stationary	
D(REC)	-5.7209	-2.9981	0.0001	Stationary	I(1)

Source: Authors' research (2026)

The results of the Augmented Dickey–Fuller (ADF) unit root test for manufacturing value added (MVA), access to electricity (AEP), electric power consumption (EPC), and renewable energy consumption (REC) are displayed in Table 3. The results suggest that manufacturing value added (MVA) is stationary at level, I(0), because the absolute value of the ADF is larger than the critical value and the probability value is less than 0.05.

Also, results indicate that access to electricity (AEP), electric power consumption (EPC), and renewable energy consumption (REC) are non-stationary at level but are stationary after first differencing. This suggests that all three variables are integrated of order one (I(1)) because their first difference ADF statistics are significant at the 5 percent level.

The overall results indicate the presence of I(0) and I(1) variables, but do not show the presence of any I(2) variable. This is because this combination fulfills the condition of applying the ARDL estimation method. After demonstrating the stationarity characteristics of the variables in the study, the study then examined whether there is a long run relationship between the variables using ARDL Bounds cointegration test, the result of which is presented in table 4.

Table 4
ARDL Bounds Cointegration Test

Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	7.2998	10%	2.676	3.586
K = 3	5%	3.272	4.306	
	1%	4.614	5.966	

Source: Authors' research (2026)

The Bounds test results obtained from the ARDL test to check the presence of long-run relationship among the manufacturing value added (MVA), access to electricity (AEP), electric power consumption (EPC), and renewable energy consumption (REC) in Nigeria are shown in Table 4. This estimated F-statistic is greater than the upper bound critical values at the 10%, 5% and 1% levels of significance.

The estimated F-statistic is higher than the upper bound critical value of 5.966 at the 1 percent significance level, so we reject the null hypothesis of no long-run relationship. This validates the presence of a stable long run relationship between manufacturing performance and the chosen energy indicators during the study period. Given that there is a long-run relationship among the variables, the ARDL study moved on to estimating the long-run ARDL coefficients, which is presented in Table 5.

Table 5
Long-Run ARDL Estimates

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
AEP(-1)	-0.34518	0.073291	-4.70971	0.000175
EPC	-0.01234	0.008204	-1.50371	0.150001
REC(-1)	-0.82451	0.135574	-6.08163	0.0000
C	96.7168	14.67057	6.592571	0.0000

Source: Authors' research (2026)

The estimated long run ARDL coefficients for the relationship between manufacturing value added (MVA) and the selected energy variables in Nigeria are presented in table 5. As shown in the results, the access to electricity (AEP) variable is negatively correlated and with a statistically significant probability value of 0.0002, with the manufacturing value added variable. This means that, in the long run, more electricity leads to less manufacturing value added. The significance level of the coefficient shows that access to electricity plays an important role in the manufacturing performance in the period covered.

The result also illustrates that consumption of electric power (EPC) is not statistically significant and the impact is negative. The negative coefficient of -0.0123 and probability of 0.1500 indicate that a change in electric power consumption does not have a statistically significant long run impact on manufacturing performance. This suggests that while there may be an economy wide increase in electricity use, it is not enough to account for the increase in the manufacturing sector's share of the economy.

In the same way, the consumption of renewable energy (REC) has a negative and statistically significant impact on the manufacturing value added. This shows that a positive increase in renewable energy usage is linked with a negative effect on manufacturing value added in the long run with a coefficient of value (-0.8245) and a probability value of 0.0000. This further indicates that the use of renewable energy has a significant impact on the manufacturing performance during the study period. Given the long-run elasticities of the explanatory variables on manufacturing performance, the study went on to estimate the short-run elasticities and the related error correction mechanism, which are reported in Table 6.

Table 6
Short-Run/Error Correction Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-0.5418	0.078423	-6.90867	0.0000
D(AEP)	0.032334	0.028072	1.151813	0.26534
D(AEP(-1))	0.177706	0.037027	4.799299	0.00020
D(AEP(-2))	0.129001	0.029363	4.393252	0.000397
D(REC)	-0.32359	0.06509	-4.97149	0.0001
R-squared	0.79746	Mean dependent var		-0.14339
Adjusted R-squared	0.749804	S.D. dependent var		0.743426
S.E. of regression	0.371859	Akaike info criterion		1.056111
Sum squared resid	2.350741	Schwarz criterion		1.304075
Log likelihood	-6.61722	Hannan-Quinn criter.		1.114523
F-statistic	16.73355	Durbin-Watson stat		2.054947
Prob(F-statistic)	0.00001			

Source: Authors' research (2026)

The short run ARDL error correction model (ECM) estimates of the relationship between manufacturing value added (MVA) and the selected energy variables for Nigeria is presented in Table 6. The coefficient of the error correction term [COINTEQ (-1)] is significant and negative, -0.5418 and a probability value of 0.0000. This substantiates the presence of a stable LT equilibrium relationship between the variables. The coefficient also suggests that around 54.18% of any short-run manufacturing performance disequilibrium is corrected in one year, which denotes a rapid convergence towards the LR equilibrium.

The short-run results indicate that the access to electricity [D(AEP)] has a positive, but statistically insignificant effect on the value added in manufacturing. But the first and second lagged access to electricity (D(AEP(-1)) and D(AEP(-2)) positively and statistically significantly affect manufacturing value added. This means that enhancing access to electricity does not have an immediate effect on manufacturing performance but after one and two years begins to impact positively.

The outcome also suggests that the use of renewable energy [D(REC)] is negatively and statistically significant in the short run on the value added of manufacturing sector. This implies that the more renewable energy is used, the less the manufacturing performance is during the time period considered.

The model's fitness is at an acceptable level. The R-squared value is 0.7975, which means that 79.75% of the variations in manufacturing value added are explained by the explanatory variables in the model, and the adjusted R-squared value is 0.7498, which means that the model has a high explanatory power after adjustment for the number of explanatory variables. Additionally, the F-statistic of 16.7335 has a probability value of 0.0000 which indicates that the model is jointly significant, and the Durbin–Watson statistic is 2.0549, indicating no serious first-order autocorrelation in the estimated model. The study further performed a series of post-estimation diagnostic tests to determine the reliability and adequacy of the estimated ARDL model and the result of the test is presented in Table 7.

Table 7
Diagnostic Test Results

Diagnostic Test	Test Statistic	Probability	Decision
Breusch–Godfrey Serial Correlation LM Test	F = 1.1814	0.3430	No serial correlation
Breusch–Pagan–Godfrey Heteroskedasticity Test	F = 0.4829	0.8475	No heteroskedasticity
Ramsey RESET Test	F = 0.0885	0.7712	Model is correctly specified
Jarque–Bera Normality Test	JB = 1.5506	0.4606	Residuals are normally distributed

Source: Authors' research (2026)

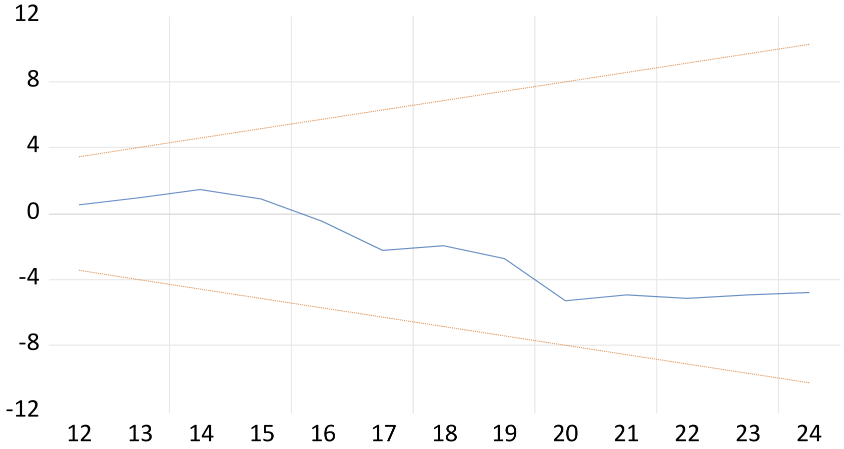
The post-estimation diagnostic tests have been performed using the estimated ARDL model and presented in Table 7 to evaluate the reliability and adequacy of the estimated model. The Breusch-Godfrey Serial Correlation LM test gave a test probability of 0.3430 which is greater than the 5 percent significance level. This means that the null hypothesis of no serial correlation cannot be rejected, suggesting that the residuals are not serially correlated.

The Breusch–Pagan–Godfrey test for heteroskedasticity gave a probability value of 0.8475, which means the residuals are homoskedastic. This indicates that the variance of the error term is constant over the estimation period, and thus meets one of the important assumptions of the regression model. In turn, the Ramsey RESET test gave a probability value of 0.7712, which was interpreted as indicating that the estimated model was correctly specified and that there was no functional form or omitted variable bias.

In addition, Jarque-Bera normality test gave a probability value of 0.4606, which is higher than the 5 percent significance level, meaning that the residuals are normally-distributed. In general, the results of the diagnostic tests indicate that the estimated ARDL model is statistically reliable, stable, and appropriate for empirical inference.

After the diagnostic evaluation, the stability of the estimated model was revisited using the CUSUM and CUSUM of Squares (CUSUMSQ) stability procedures and the results are shown in Figure 1.

Figure 1
CUSUM Stability Test



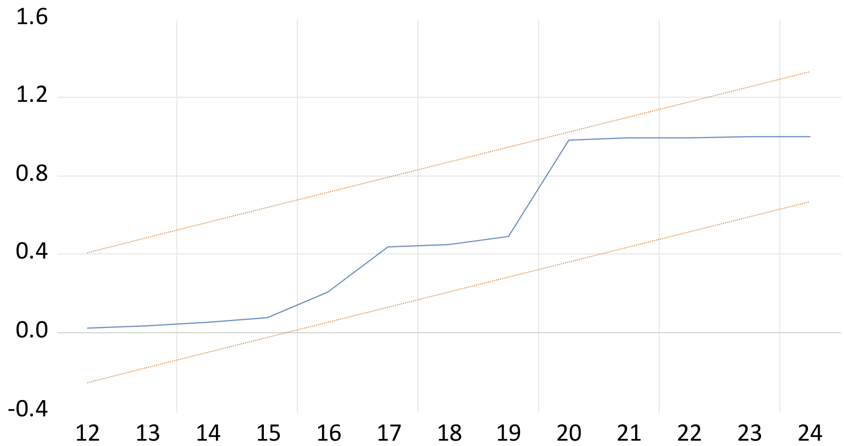
Source: Authors' research (2026)

The estimated ARDL model is presented to be tested for stability using the CUSUM test shown in figure 1. The outcome is a CUSUM line that stays in the 5% significance lines during the investigation period. This suggests that the parameters of the model are estimated to be stable and the relationship between manufacturing value added and the energy variables included in the model is not suspected of being structurally unstable.

The stability of the CUSUM lines in the limits provide confidence in the reliability of the estimated ARDL model for making statistical inferences and that the ARDL model coefficients do not change over the sample period.

The result of the CUSUM stability test is presented in Figure 2 following the CUSUM stability test the stability of the model was further checked from the results of the CUSUM of Squares (CUSUMSQ) test.

Figure 2
CUSUM of Squares (CUSUMSQ) Stability Test

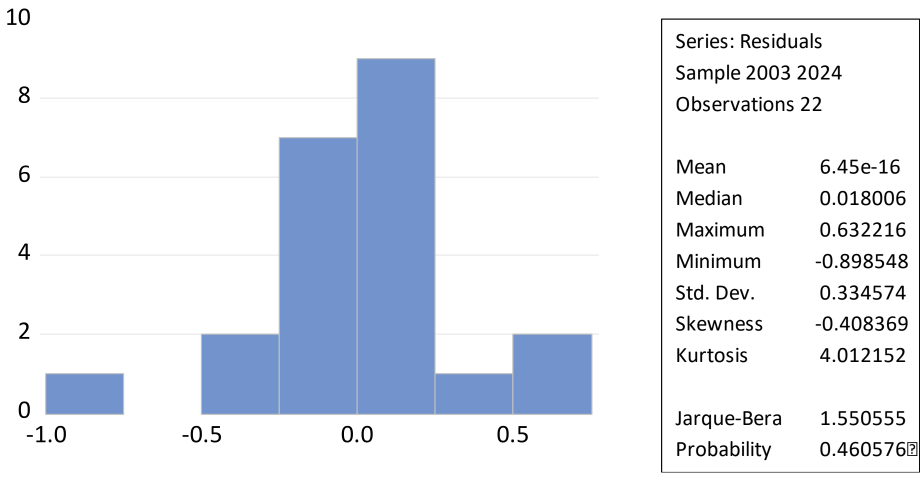


Source: Authors' research (2026)

To test the stability of the estimated ARDL model, the CUSUM of Squares (CUSUMSQ) test is used and presented in Figure 2. The result shows that the CUSUMSQ line stays within the 5% significance limits over the entire study period, but is currently close to the upper limit of the 5% around the later years of the sample.

This suggests the variance of the model residuals is not changing over time and that there are no significant structural changes in the estimated manufacturing value added relationship with the energy variables. Thus, the estimated ARDL model is deemed to be stable and reliable for policy inferences over the period of investigation.

Figure 3
Residual Normality Test



Source: Authors' research (2026)

The normality test of the model residuals by Jarque-Bera is given in Figure 3. The result shows a Jarque–Bera statistic of 1.550555 with a probability value of 0.460576, which is greater than the 5% significance level. This implies that the residuals are normally distributed, which means that the estimated ARDL model meets the normality assumption. Thus, the conclusions drawn from the regression results are considered reliable for statistical inferences.

Discussion of Findings

The results of this study show that the access to electricity has negative and statistically significant long run effect on manufacturing performance in Nigeria. This means that despite improvements in electricity access, there has not been a corresponding improvement in manufacturing output over the time period considered. An explanation that has been suggested is that providing more electricity does not guarantee a more stable and reliable supply of electricity for industrial production. The increased benefits of increased electricity access could have been dampened by the frequent power outages, voltage fluctuations, and ongoing reliance on electricity generation from their own assets by manufacturing companies. This is an opposite result to the study conducted by Balogun (2024) which found that access to electricity positively improved industrial output in Nigeria. It also goes against the findings of Maruta (2025) which established that access to electricity was positively associated with industrialisation in African economies. However, the findings are similar to that of Olaoye (2026) who opined that companies are compelled to utilise alternative energy sources which are expensive to supply, thereby affecting the competitiveness and performance of industries owing to the inadequate and unreliable electricity supply.

The study also reveals that the long run impact of electric power consumption on manufacturing performance is negative but statistically insignificant. This implies that electricity consumption is not significantly contributing to the economy of Nigeria as a result of its variations in consumption. The negligible effect could be due to either inadequate quantity of electricity being used for productive industrial processes or its use being mainly outside industry. This result is consistent with most of the other findings of Asinya and Ishua (2025) who concluded that energy consumption was statistically significant however did not follow the theoretical predictions of industrial development. Another finding is that simply increasing electricity usage is not enough to drive factory development if the quality, efficiency and reliability of electricity are lacking.

The results also indicate that in the long-run, the use of renewable energy negatively affects the performance of manufacturing. This has shown that the use of renewable energy has not positively affected the manufacturing sector in Nigeria yet. It is likely that this is due to the fact that renewable energy technologies are still underdeveloped for large-scale industrial use and are mainly used in domestic and small-scale applications. Therefore, the current renewable energy development may not be enough to support energy demand of the manufacturing sector. This agreed with both Balogun (2024) and Rasheed et al. (2026) who observed that renewable energy is an enabler of industrial performance and sustainable industrial development. However, this outcome could be due to the fact that the energy sector is still dominated by conventional sources in Nigeria, with only a small proportion of renewable energy sources being used in industrial production.

The results show that, in the short run, the present value of access to electricity has no significant impact on manufacturing performance, while the first and second lagged value of access to electricity have positive and significant impacts. This means that future gains in access to electricity should take some time for their effect to be seen in manufacturing operations. The delayed effect implies that perhaps it takes time for companies to adapt their production processes, increase production capacity or make complementary investments before improvements in electricity access are reflected in increased manufacturing performance. Additionally, the short-run evidence does not support the long-run results, which showed a negative and significant impact of consuming RE on manufacturing sector growth in Nigeria, thereby confirming that use of RE as yet has not become a significant force in the manufacturing sector growth in Nigeria. The overall results indicate that increasing the availability of energy is not enough to improve the performance of manufacturing activities without having proper infrastructure for electricity, energy saving, and distributing energy efficiently among the industries.

Conclusion

The aim of this study was to assess the influence of energy access on manufacturing performance in Nigeria, based on the data obtained from 2000 to 2024. Specifically, the study examined the impact of access to electricity, electric power consumption and renewable energy consumption on manufacturing value added in ARDL framework. The results confirmed the existence of long-run equilibrium relationship between the variables implying that access to energy continues to play a significant role in manufacturing performance in Nigeria. The findings also indicate that the quality, reliability and effective use of energy is more important for manufacturing advances than simply access to energy. Thus, the study concludes that for the improvement of manufacturing performance, a holistic approach is needed which involves sufficient power resources, efficient energy consumption and sustainable utilization of renewable resources. While Nigeria has been able to achieve significant gains in access to electricity, existing gaps in the energy infrastructure system continue to hinder competitiveness and productive efforts of the manufacturing sector. This means that policies aimed at enhancing energy infrastructure, electricity reliability, and increased integration of renewables into industrial production systems will be essential for sustainable industrial growth. The study results led to the following recommendations: Government should increase the consistency and reliability of electricity supplies to the manufacturing sector to ensure that greater electricity access leads to better manufacturing performance; Relevant authorities should boost electricity generation and distribution system, in order to increase the productive use of electricity in manufacturing activity; To enhance industrial productivity, government should support the use of renewable energy technologies in manufacturing sector by developing policies and providing investment incentives.

Implications

This study has implications for policy, management and academia. The study shows, from a policy perspective, that increasing electricity access without increased electricity reliability and energy efficiency is not enough to stimulate manufacturing growth. This implies that government policy should be focused on developing electricity generation, transmission and distribution infrastructure and incentivize uptake of renewable energy on an industrial scale. On the management side, the manufacturing companies must diversify their energy supply by adopting renewable energy and energy saving technologies to minimise manufactory costs from unreliable public electricity supply. Such investments would help to make operations more efficient and make them more competitive in the long term.

Academically, the study adds to an expanding body of research on energy economics by empirical evidence, showing that the multiple dimensions of energy access, as opposed to electricity access, affect the performance of manufacturing. It also broadens the application of the Energy-Led Growth Hypothesis in the context of Nigeria's manufacturing sector to provide a basis for future empirical studies on sustainable industrial development in Nigeria.

Limitations and Future Research

Although this study has made a contribution, it has some limitations. First, the analysis was conducted only in Nigeria, which may limit the generalisability of the results to other countries that have different institutional and energy market frameworks. Second, manufacturing value added was used as the sole measure of manufacturing performance, and three measures of energy access used. These factors were sufficient to measure the aims of the study but other indicators of energy performance and industrial development might contribute to the understanding. Comparative panel analyses with several African or emerging economies should be undertaken to see whether the relationships observed are country-specific or regionally consistent, in the future. The researchers can also add other energy-related variables, like energy prices, energy efficiency, energy transmission losses, energy investment, or energy security. Additionally, future studies could explore how institutional quality, technological innovation, or digital infrastructure might help to mediate the relationship between energy access and manufacturing performance.

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Conflicts of Interest

The authors have no conflict of interest that will bias the interpretation or writing of this article. The authors also state that no financial or commercial relationships are present that could have affected the design, analysis, interpretation of the data, or reporting of the results for this study.

Author Contributions

Conceptualization: A. A. A.; Methodology: A.A.A.; Software: A.A.A.; Validation: A.A.A. and E.V.A.; Formal Analysis: A.A.A.; Investigation: A.A.A.; Resources: E.V.A.; Data Curation: A.A.A.; Writing – Original Draft Preparation: A.A.A.; Writing – Review & Editing: A.A.A. and E.V.A.; Visualization: A.A.A.; Supervision: E.V.A.; Project Administration: E.V.A.

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