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Renewable Energy Transition and Energy Security in Nigeria

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Abstract
This study examines the impact of the renewable energy transition on electricity access in Nigeria from 1990 to 2025. Using the Autoregressive Distributed Lag (ARDL) bounds testing approach, it analyses the relationship between electricity access, renewable energy use, GDP per capita, inflation, and population growth. The results confirm a long-run cointegrating relationship among the variables. In the long run, renewable energy use, population growth, and inflation exert a negative and significant effect on electricity access, while GDP per capita has a positive and significant effect. Specifically, a 1% increase in electricity from renewable sources reduces electricity access by 0.32%. The error correction term indicates that about 70% of short-run deviations from equilibrium are corrected within one year. Diagnostic and stability tests validate the robustness and stability of the estimated model. The findings suggest that expanding electricity access requires more than increasing renewable energy capacity. Policy efforts should also focus on raising household incomes, controlling inflation, and managing population pressures to ensure that renewable energy investments translate into improved access. Recommendations include trade openness in the renewable energy market, economic diversification, and managing population growth and inflation rates to improve energy access.

Keywords: Renewable Energy, Energy Security, Nigeria, ARDL Model, Transition

Introduction

Nigeria's reliance on crude oil, discovered in 1956, has driven economic growth but also led to environmental degradation and energy insecurity. Despite abundant renewable energy resources - solar irradiation averaging 5.5 KWh/m²/day (Adeyeye et al., 2022), wind speeds of 2-4 m/s (Ayodele & Ogunjuyigbe, 2021), and significant hydro power potential (IEA, 2020; Sambo, 2020) - the country faces acute energy poverty, with 90 million lacking grid access. Frequent outages and fossil fuel reliance (80% generation) plague the sector, impacting health, education, and economic opportunities (SE4ALL, 2020; World Bank, 2022). The Nigerian government has recently adopted the National Energy Transition Policy (NETP), marking a significant shift towards a cleaner and more sustainable energy future. With a commitment to achieve net-zero emissions by 2060, Nigeria aims to balance its national development priorities with the urgent need for climate action. This policy underscores the importance of energy security, job retention, and citizen welfare, while ensuring a just transition for vulnerable communities. Nigeria's government has set a target of 10 GW of renewable capacity by 2030 through policies like NETP 2022 (NETP, 2022). Reaching this goal is complicated by gaps in grid infrastructure, delays in policy rollout, and limited financing for projects (Adebayo et al., 2021; Sambo et al., 2021; Ogunlade et al., 2022). While assessments show Nigeria has strong potential for solar, wind, and hydro power, governance issues remain a barrier. Corruption, bureaucratic delays, and shifting political priorities have slowed implementation of transition plans in the past. This study therefore uses an ARDL model to test how renewable energy expansion affects energy security in Nigeria.

Renewable energy refers to power from sources that regenerate naturally. In the Nigerian context, solar potential is highest in the north due to high irradiance levels, making it suitable for off-grid systems in states like Katsina and Kano. Wind resources are also concentrated in these northern regions. For hydro, Nigeria relies on existing plants such as Kainji, Jebba, and planned projects like Mambilla to contribute to the national grid.

Energy Access: This means households and communities can obtain enough energy for basic services like lighting and cooking. A large share of rural households still depends on firewood and other traditional biomass, which signals a gap in modern energy access.

Energy Affordability: Energy affordability is about ensuring energy is priced reasonably, so households and businesses can pay for it without financial strain. In Nigeria, energy costs can be high for low-income households, making affordability a challenge. The government has implemented subsidies and tariff structures to make energy more affordable, but the effectiveness of these measures is often debated.

Energy Sustainability: Energy sustainability means meeting today's energy demand without depleting the resources needed for future use. In Nigeria, this is increasingly linked to expanding solar-based solutions in farming, such as solar-powered irrigation. Shifting toward these options can lower reliance on oil and gas, preserve natural resources, and reduce environmental damage.

Energy Transition: Energy transition describes the shift from conventional fossil fuels to lower-carbon energy sources. Nigeria's transition agenda includes reaching a 30% share of renewables in the energy mix by 2030 and cutting down on gas flaring. The goal is to create a more diverse energy system, strengthen supply security, and address climate-related risks.

Energy Security: Energy security refers to the uninterrupted availability of energy at an affordable cost. For Nigeria, it involves balancing domestic production, imports, and renewable capacity to reduce vulnerability to supply disruptions and price volatility.

This study is grounded in Energy Transition Theory. Energy Transition Theory explains the process of moving away from fossil fuels toward renewable energy sources to support long-term development and lower environmental harm. This theory was introduced by Vaclav Smil, a renowned energy analyst from the Czech Republic (Canada), in 2010. His work focused on energy transitions, energy policy, and sustainability. The theory was improved upon in 2012 by Arnulf Grubler from Austria (USA), an expert on energy transitions, technology, and climate change. He worked on energy transition history and prospects. This study is anchored on this theory because there is a need for Nigeria to move from oil, gas, and coal to environmentally friendly energy systems in line with the global push for decarbonization and climate change mitigation. Again, Nigeria's energy issues such as vulnerability to oil price drops, gas/fuel shortages, and climate impact (oil spills, gas flaring, which harm the environment/communities) can be reduced greatly. This transition to renewables will help the country in many ways, such as diversifying the energy mix, power rural areas, boosting the economy, reducing emissions, reducing gas flaring and meeting global climate goals. Nigeria requires a carefully coordinated shift toward renewable energy to ensure stable energy supply and long-term economic growth.

Ohunakin (2011), Ayodele et al. (2018), and Ayodele and Ogunjuyigbe (2021) report wind viability in Kano and other northern zones using Weibull analysis and GIS mapping. Ben et al. (2021) report the highest wind potential in Obudu among 13 central and southern cities, and classify most southern sites in power classes 1–4. Salisu et al. (2019), Elegeony and Ohunakin (2021), and Bawonda and Adefarati (2023) report LCOE below \$0.12/kWh and renewable fractions above 98% for PV/diesel/battery systems in Sokoto, Giri, and Gwagwalada using HOMER simulations. Zarmai et al. (2024) report an NPC of \$182,065.20, an LCOE of \$0.00198/kWh, and renewable fraction of 98.3% for a hybrid utility grid-diesel generator-solar PV mini-grid for the Faculty of Engineering and Technology, Nigerian Defence Academy, Kaduna. Ohunakin (2011) reports Katsina mean wind speed of 9.839 m/s and Kano power density of 368.92 W/m². Ben et al. (2021) report that the maximum likelihood method produced the most accurate wind

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parameter estimates among six methods tested. Fakehinde et al. (2019) report a positive relationship between hydropower, economic growth, and financial development in top hydroelectric countries from 1990 to 2020 using panel data techniques. Fasipe et al. (2021) report 18 sites in the Osse sub-basin with capacities between 677.485 kW and 7,622.877 kW and annual flow exceeding 92% using GIS and NRCS-CN modelling. Oyinna et al. (2023) use GIS and statistical tools to identify small hydropower sites in Yobe and Kebbi. Babatunde et al. (2022) report NPC of $9,096 for a standalone PV and battery system and NPC of $10,324 for a hybrid PV, fuel cell, wind, and battery system in Lagos using multi-criteria decision analysis. Ezekwem and Mothusam (2023) report an 87% reduction in energy cost for a PV-wind hybrid in Choba, Port Harcourt using HOMER Pro. Sambo et al. (2021) identify implementation gaps in renewable energy policy through interviews and recommend stronger regulatory frameworks and enforcement. Adeshina et al. (2024) conclude from a policy review that an overhaul is needed to increase renewable uptake. Nchege et al. (2024) report that renewable energy investment supports energy security and economic growth in Nigeria using an ARDL model. Aleshinloye (2026) reports that non-renewable energy consumption drives growth in Nigeria using Granger causality, VECM, and Johansen cointegration tests, and recommends a gradual shift to renewables. Adeyeye et al. (2022) assess solar, wind, and hydro resources and state that infrastructure and policy support are required.

Studies on wind energy potential in Nigeria have applied Weibull analysis, GIS mapping, and statistical methods. Ohunakin (2011) used Weibull analysis with 1971–2007 data across six northern sites and reported Katsina mean wind speed of 9.839 m/s, Kano power density of 368.92 W/m², and Kano annual energy of 3224.45 kWh/m², with lower values in Kaduna, Bauchi, and Potiskum. Ayodele et al. (2018) analysed 15 sites and identified Jos and Kano as commercially viable. Ben et al. (2021) applied six statistical methods to 13 central and southern cities, found Obudu with the highest potential and Mboko the most stable, and reported that the maximum likelihood method produced the most accurate wind parameter estimates. Ayodele and Ogunjuyigbe (2021) used GIS to map wind speed across Nigeria. Research on solar and hybrid systems has relied heavily on HOMER simulations. Salisu et al. (2019) modelled PV/diesel/battery systems for Giri village and reported LCOE of $0.110/kWh, NPC of $1.01M, renewable fraction of 98.3%, and GHG emissions of 2889.36 kg/year, with similar results for Gwagwalada. Elegeony and Ohunakin (2021) assessed a solar-battery-diesel mini-grid and reported positive financial indicators, 92% GHG reduction, a 4-year payback period, and 203 MWh/year of exportable energy. Bawonda and Adefarati (2023) used analytical and simulation mapping to highlight Sokoto's solar potential. Zarmai et al. (2024) applied HOMER Pro to design a hybrid grid-diesel-PV-converter mini-grid for the Nigerian Defence Academy in Kaduna, reporting NPC of $182,065.20, LCOE of $0.00198/kWh, renewable fraction of 98.3%, and annual energy production of 836,430 kWh/year. Hydropower and multi-resource studies have used GIS, panel data, and statistical tools. Fakehinde et al. (2019) used panel data for top hydroelectric countries from 1990 to 2020 and reported a positive relationship between hydropower, economic growth, and financial development. Fasipe et al. (2021) combined GIS and NRCS-CN modelling in the Osse sub-basin to identify 18 sites with capacities between 677.485 kW and 7,622.877 kW and annual flow exceeding 92%, and proposed a CDM framework including discharge estimates, turbine recommendations, and cost analysis. Oyinna et al. (2023) applied GIS and statistical tools to identify small hydropower sites in Yobe and Kebbi. Adeyeye et al. (2022) conducted qualitative and quantitative assessments of solar, wind, and hydro resources.

Studies on system optimisation, policy, and macroeconomic linkages have used MCDA, simulation, and econometric methods. Babatunde et al. (2022) applied MCDA to residential systems in Lagos and reported NPC of $9,096 for a standalone PV and battery system and NPC of $10,324 for a hybrid PV, fuel cell, wind, and battery system. Ezekwem and Mothusamy (2023) used HOMER Pro for Choba in Port Harcourt and reported an 87% reduction in energy cost for a PV-wind configuration relative to the baseline. Sambo et al. (2021) analysed policy and interviewed stakeholders, identified implementation gaps in renewable energy policy, and recommended stronger regulation and enforcement. Adeshina et al. (2024) reviewed energy policies and concluded that a comprehensive overhaul is needed to increase renewable uptake. Nchege et al. (2024) used an ARDL model to report that renewable energy investment supports energy security and economic growth in Nigeria. Emezirinwune et al. (2024) examined hybrid renewable systems in agriculture and reported that solar PV integration reduces carbon emissions and creates income streams for farmers. Aleshinloye (2026) applied Granger causality, VECM, and Johansen cointegration tests and reported that non-renewable energy consumption drives growth in Nigeria, recommending a gradual shift to renewables and inclusion of environmental regulations.

Existing studies have focused on resource potential, system optimisation, and policy review. This study examines the impact of renewable energy transition on Nigeria's energy security from 1990 to 2025 using an Auto Regressive Distributed Lag model. To address this gap, the study adopts an ARDL approach to examine the impact of renewable energy transition on Nigeria's energy security over the period 1990–2025, allowing for cointegration analysis and separation of short- and long-run effects.

Methodology

This study uses an ex post facto research design. Annual time series data covering 1990–2025 were compiled to examine the variables. The data were obtained from the World Bank Open Data portal, the U.S. Energy Information Administration, SE4ALL, IRENA, NREEEP, and the National Bureau of Statistics**.** To assess the relationship between the variables, this study applies an Autoregressive Distributed Lag (ARDL) approach. ARDL was selected for several reasons relevant to the data and research goal.

1. Data structure: The analysis uses annual time series data for Nigeria from 1995 to 2025 to evaluate how the renewable energy transition affects energy security.
2. Dynamic relationships: ARDL captures both short-run and long-run interactions between variables such as renewable energy uptake and energy security.
3. Integration flexibility: The method accommodates variables that are stationary at level I(0), first difference I(1), or a mix of both, reducing the need for extensive pre-testing.
4. Sample size: It performs reliably with limited observations, which fits the data constraints common in country-level studies.
5. Endogeneity concerns: ARDL addresses potential endogeneity among the explanatory variables.
6. Lag flexibility: The framework allows for different lag lengths for dependent and independent variables.

Given these properties, ARDL fits the objective of empirically testing the impact of renewable energy transition on energy security in Nigeria. The empirical procedure includes descriptive statistics, a correlation matrix, the KPSS unit root test, the ARDL bounds test for cointegration, estimation of long-run and short-run coefficients, and post-estimation diagnostic checks.

Model Specification

EA= f(EFR, GDPPCC, INFLR, POPGR) (1)

ECONOMETRIC MODEL

EA= β0 + β1EFR + β2GDPPCC + β3INFL+β4POPGR+ε (2)

Where: EA: Energy Access (Dependent variable; Proxy for energy security, measured with % of the population that has access to electricity in Nigeria)

EFR: Energy from Renewables (independent variable, measured with the percentage of energy from Renewables)

Control variables:

GDPPCC: GDP per Capita (current), INFLR: Inflation rate, POPGR: Population growth rate

β0 is the intercept or constant term, while β1, β2, and β3 are the coefficients corresponding to EFR, GDPPCC, and INFLR, respectively, reflecting their short-run effects on the dependent variable. ε represents the error term capturing unobserved factors.

Results

Table 1: Summary statistics

	EA	EFR	GDPPC	INFLR	POPGR
Mean	48.4083	30.1656	1654.572	18.4322	2.5597
Median	50.05	32.75	1767.9	12.95	2.6
Maximum	61.2	54.7	3189.8	72.84	2.8
Minimum	27.3	14.4	480.7	6.6	2.08
Std. Dev.	8.2840	9.7499	873.415	15.5752	0.2528
Skewness	-0.4908	0.2093	0.1233	2.1649	-0.9104
Kurtosis	2.5029	2.4267	1.7042	6.9295	2.4036
Jarque-Bera	1.8160	0.7560	2.6099	51.2823	5.5062
Probability	0.4033	0.6852	0.2711	0.0000	0.0637
Observations	36	36	36	36	36

Note: EA = energy access; EFR = renewable energy; GDPPC = GDP per capita; INFLR = inflation rate; POPGR = population growth rate

The descriptive results show that electricity access in Nigeria varied moderately over the period, rising from 27.3% to 61.2% of the population. Renewable electricity generation averaged 30.17%, ranging between 14.4% and 54.7%. GDP per capita remained relatively low, with a mean of US$1,654.57 and values fluctuating between US$480.7 and US$3,189.8. The high standard deviation of US$873.42 confirms this wide variation. Inflation averaged 18.43%, indicating persistently high price levels, with a minimum of 6.6% and a peak of 72.84% recorded during the study period. Population growth averaged 2.56% annually, reaching a maximum of 2.8%. The standard deviation values reveal that GDP per capita, inflation, renewable energy use, and electricity access exhibited greater variability compared to population growth. Normality tests further indicate that the series for energy access, renewable energy use, GDP per capita, and population growth follow a normal distribution.

Table 2: Correlation matrix

	EA	**EFR**	**GDPPC**	**INFLR**	**POPGR**
EA	1.0000				
EFR	-0.6527	1.0000			
GDPPC	0.7046	-0.6920	1.0000		
INFLR	-0.3329	0.20426	-0.2934	1.0000	
POPGR	-0.5001	0.4423	-0.3154	-0.0204	1.0000

Source: Author's Computation (2026)

This section assesses the pairwise correlations among the variables to confirm the robustness of the results. As shown in Table 2, inflation and population growth both exhibit a positive correlation with renewable energy use. Conversely, GDP per capita is negatively correlated with renewable energy use. Negative relationships are also observed between GDP per capita and inflation, GDP per capita and population growth, and population growth and inflation. Overall, the correlation coefficients suggest that multicollinearity is not a concern among the regressors used in the analysis.

Table 3: Unit Root Test

Variables	**KPSS**			**Decision I(d)**
	Level	**1st_diff.**	**Critical Value at 5%**	
EA_t	0.6926	0.4623**	0.4630	I(1)
EFR_t	0.5559	0.2034***	0.4630	I(1)
$lnGDPPC_t$	0.5406	0.1701***	0.4630	I(1)
$INFLR_t$	0.2692**	-	0.4630	I(0)
$POPGR_t$	0.4096**	-	0.4630	I(0)

Note: * means that the variable is significant at the 10% level, ** means the variable is significant at the 5% level, and *** means the variable is significant at the 1% level.
Source: Author's computation, 2026.

Regressing nonstationary variables without pretesting can produce spurious results due to inflated t-statistics, F-statistics, and R^2. To avoid this, the KPSS test of Kwiatkowski, Phillips, Schmidt, and Shin (1992) was applied. Results in Table 3 show that inflation and population growth rate are I(0), while electricity access, renewable energy use, and log GDP per capita are I(1). Given this mix of I(0) and I(1) variables, the ARDL bounds testing approach is appropriate for assessing cointegration and the effect of renewable energy on energy access, and is preferred over Engle-Granger (1987) and Johansen (1991) methods.

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Table 4: Bounds test co-integration result

Significant Level	l(0) Bound	l(1) Bound	Value
10%	2.2	3.09	F-Stats = 5.681747***
5%	2.56	3.49	k = 4
2.5%	2.88	3.87	
1%	3.29	4.37	

Note: K represents the number of regressors in the model. The null hypothesis states that no cointegration exists among the series. *, * *, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. This means the F-statistic is significant even at 1%. Source: Author's computation, 2026.

After establishing the stationarity properties of the variables using the KPSS test, the study tested for cointegration among renewable energy use, GDP per capita, population growth, inflation, and electricity access. The Pesaran et al. (2001) bounds testing approach was adopted because it accommodates variables that are a mix of I(0) and I(1). As shown in Table 4, the F-statistic of 5.681747 exceeds the 5% upper bound critical value of 3.49, leading to rejection of the null hypothesis of no cointegration. This confirms the existence of a long-run relationship between the variables. Given the mixed integration orders and evidence of cointegration, the long-run and short-run dynamics were estimated using the autoregressive distributed lag (ARDL) framework proposed by Pesaran et al. (2001).

Table 5: ARDL results

Dependent Variable: EA_t				
Long run results				
Variable	Coefficient	Std. Error	t-Stats	Prob
EFR_t	-0.3169**	0.1171	-2.7049	0.0150
$POPGR_t$	-8.8981**	3.1583	-2.8173	0.0119
$INFLR_t$	-0.2612***	0.0611	-4.2746	0.0005
$lnGDPPC_t$	13.9842***	4.5481	3.0747	0.0069
C	44.6259	20.2091	2.2082	0.0413
Short run results				
Variable	Coefficient	Std. Error	t-Stats	Prob
$D(EA_{t-1})$	-0.5240***	0.1158	-4.5222	0.0003
$D(EA_{t-2})$	-0.3271**	0.1283	-2.5498	0.0207
$D(EFR_t)$	-0.0142	0.0605	-0.2349	0.8170
$D(POPGR_t)$	27.4743***	6.7008	4.1001	0.0007
$D(POPGR_{t-1})$	21.6955**	7.9174	2.7402	0.0140
$D(INFLR_t)$	-0.0305	0.0372	-0.8204	0.4233
$D(INFLR_{t-1})$	0.1214***	0.0372	3.2617	0.0046
$D(INFLR_{t-2})$	0.0960**	0.0337	2.8465	0.0112
$D(lnGDPPC_t)$	6.2329**	2.4987	2.4944	0.0232
$D(lnGDPPC_{t-1})$	5.1000**	2.3368	2.1824	0.0434
ECM_{t-1}	-0.7012***	0.1055	-6.6420	0.0000
R^2 = 0.7781			Adjusted R^2 = 0.6773	

Note: ** and *** , indicate significance at 5%, and 1% levels, respectively.
Here, some variables are significant at 5% (indicated by **) and some at even 1% (hence the ***). There is no one * here because none of the variables is significant at 10%.
Source: Author's computation, 2026

Following the cointegration test, the ARDL model was estimated and the results are presented in Table 5, which reports both long-run and short-run effects on electricity access. In the long run, renewable energy use has a negative and significant impact, with a 1% increase in renewable electricity associated with a 0.32% decline in the share of the population with access. Population growth is also negative and significant at the 5% level, implying that a 1% rise in population growth reduces electricity access by about 8.90%. Inflation similarly constrains access, as a 1% increase lowers it by approximately 0.26%, consistent with the expectation that higher inflation erodes household purchasing power and limits investment in cleaner energy. Conversely, GDP per capita has a positive and significant effect, where a 1% increase raises electricity access by 13.98%, reflecting that higher incomes enable households to afford and install renewable energy systems like solar. In the short run, population growth becomes positive and significant at the 5% level, contributing to improved access. GDP per capita retains a positive effect, with contemporaneous and lagged impacts of 6.23% and 5.10%, respectively. The error correction term is negative and significant, confirming a cointegrating relationship, and indicates that roughly 70.12% of short-run disequilibrium is corrected annually, pointing to a strong and rapid adjustment to long-run equilibrium.

Table 6: Diagnostic Result

Test/Hypothesis (hypothesis is in null form)	Test type	Test-stats.	Prob.	Decision
Residual Normality (Residuals are Normally Distributed)	Jarque-Bera	0.2256	0.8932	Accept
Serial Correlation (Residuals are serially independent)	Breusch-Godfrey LM Test	6.8617	0.0764	Accept
Linearity (Model is linear)	Ramsey RESET	0.0532	0.8204	Accept
Heteroskedasticity (Residuals are homoscedastic)	ARCH	0.1669	0.6828	Accept

Source: Author's Computation (2026)

Several diagnostic tests were conducted to assess the robustness of the ARDL estimates. As shown in Table 6, the results indicate no evidence of heteroscedasticity or serial correlation in the residuals. In addition, the model's functional form is correctly specified, and the error terms follow a normal distribution. The stability of the estimated coefficients was further evaluated using CUSUM and CUSUM of Squares tests, presented in Figures 1 and 2. Both plots remain within the 5% critical bounds, confirming that the model parameters are stable over the sample period.

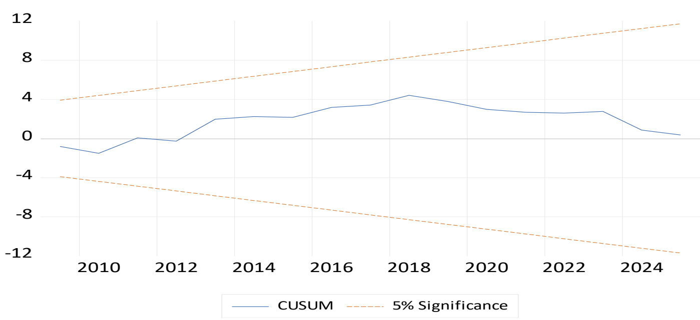

Figure 1: Plot of Cumulative Sum (CUSUM)

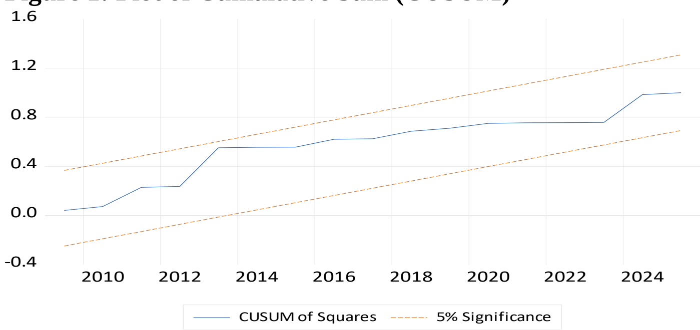

Figure 2: Plot of Cumulative Sum of Squares (CUSUM of Squares)

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Conclusion

This study concludes that energy from renewables, GDP per capita, inflation rate, and population growth significantly impacted energy access in Nigeria. Hence, renewable energy transition will help to reduce energy insecurity in Nigeria both in rural areas and urban centres. This is because Nigeria has renewable energy potential both in the north and in the south. This will make businesses thrive because steady power supply will boost their output, reduce their cost of production, and increase their profit margin, all things being equal. Again, the deaths caused by inhaling carbon monoxide emitted by vehicles, generator sets and diesel-powered plants will drastically reduce as renewable energy will become an alternative source of power to households and firms.

Recommendations

The study proposes the following for policy formulation and implementation:

1. Trade openness in the renewable energy market in Nigeria
2. Economic diversification to bring about inclusive growth that will create more jobs, increase national and per capita income, capable of increasing disposable income of consumers to be able to afford renewable energy installation in their homes and factories.
3. The Nigerian government should make an effort to reduce inflation in the country because it hinders energy access.

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