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IMPACT OF ENERGY CONSUMPTION ON ECONOMIC GROWTH IN NIGERIA

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Abstract

This study investigates the impact of energy consumption on economic growth in Nigeria from 1990 to 2023 using time-series data from the Central Bank of Nigeria (CBN), the World Development Indicators, and the International Energy Agency. Employing Augmented Dickey-Fuller (ADF) unit-root tests, Johansen cointegration, and Vector Autoregression (VAR) models, the study explores both short- and long-run linkages among electricity, petroleum, gas, coal, and solar energy consumption and real GDP. Results show that petroleum, gas, and coal consumption exert positive and statistically significant effects on Nigeria's economic growth, while electricity and solar energy remain positive but insignificant. The long-run cointegration confirms a stable equilibrium relationship between energy consumption and GDP. Policy recommendations emphasise diversification of Nigeria's energy mix, expansion of renewable-energy infrastructure, and effective regulatory frameworks to ensure reliable energy for industrial and economic transformation.

Keywords: Energy Consumption; Economic Growth; Nigeria; VAR Model; Energy Policy; Cointegration.

1. Introduction

Energy is universally recognised as the engine of economic growth and a vital input in production, industrialisation, and welfare enhancement (Bhattacharya et al., 2023; IEA, 2024). It powers every sector of an economy from manufacturing and transportation to communication and agriculture thereby influencing productivity and competitiveness. Across the world, empirical evidence confirms that increases in energy consumption strongly correlate with gross domestic product (GDP) expansion (Chen et al., 2023).

Nigeria presents an intriguing case within this global context. Despite its rich endowment of crude oil, natural gas, coal, solar, and hydro resources, the country continues to face persistent energy crises manifested in chronic power shortages, unreliable electricity supply, and over-dependence on petroleum products (Nigerian Electricity Regulatory Commission [NERC], 2023). Installed power-generation capacity exceeds 12,000 MW, but less than 40 per cent is reliably available due to ageing infrastructure, transmission bottlenecks, and maintenance challenges (World Bank, 2024). The consequences for productivity are severe: the World Bank (2024) estimates that unreliable electricity supply reduces annual business turnover in Nigeria by 8–10 per cent, while households spend over ₦ 4 trillion each year on alternative energy sources.

Empirical trends further underscore this paradox. Between 1990 and 2023, Nigeria's real GDP expanded from ₦ 20 trillion to about ₦ 130 trillion, yet per-capita electricity consumption remained below 150 kWh, one of the lowest levels globally (IEA, 2024). At the same time, petroleum and gas continue to dominate total energy use, exposing the economy to external oil-price shocks and limiting progress toward cleaner, more sustainable energy alternatives (PwC Nigeria, 2024). According to the United Nations Development Programme (UNDP, 2023), roughly 45 per cent of Nigerians still lack access to reliable electricity, with rural areas being the most affected.

Globally, the relationship between energy use and growth has evolved beyond simple dependence on fossil fuels. Recent studies show that energy diversification, technological adoption, and infrastructure efficiency are crucial determinants of sustainable growth (Sunge & Bannor, 2023; Odugbesan & Rjoub, 2022). In Africa, Awodumi and Adewuyi (2020) and Kouton (2021) report that both renewable and non-renewable energy sources contribute to economic growth, although their effects vary according to policy environment and energy efficiency levels. Yet, in Nigeria, renewable energy development, particularly solar remains nascent despite vast potential, owing to financing constraints and weak institutional coordination (World Bank, 2024).

The study contributes to policy discourse by disaggregating total energy use into five components: electricity, petroleum, gas, coal, and solar energy to identify their differential effects on economic performance. The study will achieve the following objectives:

i. Examine the impact of electricity consumption on Nigeria's economic growth.

ii. Determine the impact of petroleum consumption on economic growth.

iii. Assess the effect of gas consumption on economic growth.

iv. Investigate the contribution of coal consumption to economic growth.

v. Evaluate the influence of solar-energy consumption on economic growth.

Findings inform the Energy Commission of Nigeria (ECN), NERC, and policymakers on efficient allocation of energy resources to support Nigeria's Energy Transition Plan (2022–2060). They also provide empirical guidance for investors and researchers exploring the energy–growth nexus in developing economies.

2. Literature Review

2.1 Conceptual Issues

Energy is broadly defined as the capacity to perform work, and its availability, accessibility, and affordability determine the pace and structure of economic development. In the context of macroeconomic analysis, energy consumption refers to the total amount of energy utilised within an economy over a specific period, encompassing both renewable and non-renewable sources such as petroleum, natural gas, coal, hydro, solar, and wind (Bhattacharya et al., 2023). It is not merely a production input but a key driver of technological advancement, industrialisation, and social welfare. The level and pattern of energy consumption in any nation reflect its developmental stage. Economies with higher per-capita income typically exhibit higher and more diversified energy use (IEA, 2024).

From a development standpoint, energy is indispensable for achieving sustained economic growth. It powers manufacturing industries, drives agricultural mechanisation, enables digital communication, and supports the transportation of goods and services (Chen et al., 2023). In developing economies such as Nigeria, inadequate energy supply constrains these productive activities, resulting in lower output, reduced competitiveness, and persistent poverty. The World Bank (2024) emphasises that reliable and affordable energy access is integral to achieving Sustainable Development Goal 7 (SDG-7), which aims for universal energy access by 2030.

Energy consumption can be categorised into renewable and non-renewable sources. *Renewable energy,* including solar, hydro, biomass, and wind, is derived from natural processes constantly replenished. It is environmentally friendly and crucial for reducing carbon emissions and enhancing energy security. *Non-renewable energy*, on the other hand, comprises fossil fuels such as petroleum, natural gas, and coal, which are finite and often associated with greenhouse gas emissions and environmental degradation (Odugbesan & Rjoub, 2022). Despite global momentum toward renewable sources, many developing nations remain heavily dependent on non-renewable energy due to infrastructure limitations, financial constraints, and technology gaps (Kouton, 2021; Sunge & Bannor, 2023).

The relationship between energy consumption and economic growth has been studied extensively, with four major hypotheses dominating scholarly discourse. The growth hypothesis suggests that energy consumption drives economic growth, implying that any disruption in energy supply will negatively impact GDP (Alam, 2006). The conservation hypothesis posits that economic growth leads to higher energy demand, suggesting that energy conservation policies may not necessarily constrain growth. The feedback hypothesis argues for bidirectional causality, where energy and economic growth reinforce each other (Chen et al., 2023). Finally, the neutrality hypothesis asserts that there is no significant causal relationship between the two, implying that energy policies may not substantially affect growth (Awodumi & Adewuyi, 2020).

In Nigeria, the energy–growth relationship is influenced by multiple structural and institutional challenges, including poor infrastructure, low investment, corruption, and policy inconsistency (NERC, 2023; UNDP, 2023). Electricity generation is dominated by gas-fired plants, while rural electrification remains limited. Despite the government's introduction of the National Energy Transition Plan (2022–2060) and Renewable Energy Master Plan, progress has been slow due to inadequate financing and weak implementation frameworks (PwC Nigeria, 2024). These shortcomings have entrenched the dominance of petroleum and gas consumption, reinforcing the country's dependence on fossil fuels.

Furthermore, the efficiency of energy use, that is, the amount of output produced per unit of energy consumed, plays a crucial role in determining whether energy consumption translates into economic growth. Countries that use energy more efficiently tend to experience higher productivity and competitiveness. In contrast, economies characterised by energy inefficiency, waste, and transmission losses (as seen in Nigeria) face escalating production costs and reduced output growth (World Bank, 2024).

Another key conceptual dimension is energy diversification, which refers to expanding the energy portfolio to include multiple sources that reduce dependence on any single fuel type. Energy diversification promotes resilience against external shocks such as oil-price volatility and enhances long-term energy security (IEA, 2024). For Nigeria, with abundant solar potential estimated at 5.5 $kWh/m^2/day$ and extensive natural gas reserves exceeding 200 trillion cubic feet, a diversified energy strategy could serve as a catalyst for sustained growth and industrial competitiveness (NESP, 2023). In summary, the concept of energy consumption in economic analysis transcends mere use of resources; it embodies efficiency, sustainability, and structural transformation. In countries like Nigeria, where growth ambitions intersect with energy deficiencies, understanding the nature and direction of the energy–growth relationship is critical for formulating policies that balance economic expansion, energy security, and environmental protection.

2.2 Empirical Review

Earlier Nigerian studies (Nkoro et al., 2019; Ajibade, 2019) reported mixed outcomes, with renewable energy's contribution being weak due to inadequate infrastructure, while non-renewables, such as petroleum, strongly influenced output. Recent cross-country evidence (Sunge & Bannor, 2023) shows both renewable and non-renewable electricity positively affect African growth but with heterogeneous magnitudes. Global research (Chen et al., 2023; Odugbesan & Rjoub, 2022) confirms bidirectional causality between energy consumption and GDP, reinforcing the feedback hypothesis. For Nigeria, studies employing ARDL or VECM models (Awodumi

& Adewuyi, 2020; Kouton, 2021) found long-run cointegration between energy use and output, though electricity's impact remains constrained by supply gaps.

2.3 Theoretical Framework

This study is anchored on the Endogenous Growth Theory, which emerged in response to the limitations of the neoclassical growth model proposed by Solow (1956). Unlike the neoclassical view, which attributes long-run economic growth to exogenous technological progress, the endogenous growth theory asserts that economic growth is driven internally by the accumulation of human capital, innovation, and technological change, all of which can be influenced by deliberate policy actions (Romer, 1986; Barro, 1990; Lucas, 1988).

In the context of this study, energy consumption plays a central role within the endogenous growth framework because it supports the productivity of both physical and human capital. Energy is not only an input into the production process but also a facilitator of technological progress and innovation, which are key channels through which economies sustain long-run growth (Bhattacharya et al., 2023; Chen et al., 2023). Energy use enhances total factor productivity (TFP) by powering machines, equipment, and information technologies that enable the creation and dissemination of knowledge. For instance, reliable electricity access allows firms to operate efficiently, adopt digital technologies, and extend production hours, while access to petroleum and gas fuels industrial processes and transportation. Similarly, the expansion of renewable energy such as solar or wind supports innovation by fostering sustainable and decentralized power solutions that enable small and medium-sized enterprises (SMEs) and rural industries to thrive (Odugbesan & Rjoub, 2022).

According to the endogenous growth perspective, technological progress and capital accumulation are cumulative processes where current investment in energy infrastructure and innovation leads to future productivity gains. Thus, when energy consumption increases in a productive and efficient manner, it stimulates research and development (R&D), encourages private-sector investment, and promotes economic expansion. Conversely, inadequate or inefficient energy use constrains production and limits the economy's capacity to innovate and grow (Kouton, 2021).

Formally, the theoretical linkage between energy and growth can be illustrated using a modified Cobb–Douglas production function that incorporates energy as a productive input alongside capital and labour. The general functional form is expressed as:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} E_t^{\gamma}$$

Where:
Y_t= real output (GDP) at time t;

A_t= total factor productivity, representing technological progress;
K_t= capital stock;

L_t= labour force;

E_t= energy consumption;

α, β, γ= output elasticities of capital, labour, and energy, respectively.

The inclusion of $E_t$in the model recognises energy as a productive factor rather than merely an intermediate input. Within this framework, improvements in E_t through increased access, efficiency, or diversification, enhance productivity (A_t) and drive economic growth. If energy use improves technological efficiency (for example, through electrification, mechanisation, or clean-energy adoption), then $A_t$itself becomes a function of energy consumption, such that:

$$A_t = A_0 e^{\delta E_t}$$

where A_0represents the baseline level of technology and δcaptures the sensitivity of technological progress to energy consumption. Substituting into the main production function yields:

$$Y_t = A_0 e^{\delta E_t} K_t^{\alpha} L_t^{\beta} E_t^{\gamma}$$

Taking natural logarithms produces the testable linearised equation used in empirical analysis:

$$\ln Y_t = \ln A_0 + \alpha \ln K_t + \beta \ln L_t + \gamma \ln E_t + \delta E_t + \varepsilon_t$$

In this equation, the coefficient γmeasures the direct elasticity of output with respect to energy consumption, while δrepresents the indirect impact of energy on technological progress. A positive and statistically significant value of γor δimplies that energy consumption contributes positively to economic growth, consistent with the endogenous growth hypothesis.

This theoretical structure provides the foundation for the empirical investigation in this study, where energy consumption is disaggregated into five sources: electricity, petroleum, gas, coal, and solar energy. Each energy component is expected to exert distinct influences on Nigeria's economic growth depending on its contribution to capital accumulation, productivity enhancement, and technological diffusion.

Thus, the endogenous growth theory justifies the integration of energy as a core determinant of long-run economic performance. It also underscores the importance of policy-driven investments in energy infrastructure, innovation, and efficiency improvement to sustain Nigeria's economic growth trajectory in the face of rising demand and global energy transition pressures (IEA, 2024; World Bank, 2024).

3. Methodology

3.1 Research Design

An ex-post facto design was adopted using annual time-series data (1990–2023). Secondary data were sourced from CBN Statistical Bulletins, World Development Indicators (2023), and the International Energy Agency Database (2024).

3.2 Model Specification

The model for this study, mirror from the work of Nyoni and A. Phiri, (2018) and Nkoroa, Ikue-Johnb and Joshua (2019) on the impact of energy consumption on economic growth in Nigeria. The model is stated as:

$\text{lnGDP} = \beta_0 + \beta_1\text{lnPEC} + \beta_2\text{lnELC} + \beta_3\text{lnCOC} + E_t$ (1)

Where:

GDP = Gross domestic product
PCO = Petroleum Consumption
ELEC = Electricity Consumption
COC = Coal Consumption
U = Error term

The model is adjusted to allow for the inclusion of other variables that are of great importance to this study. Thus, The VAR model is specified as follows;

$X_t = \sum_{i=1}^{n} \beta_i X_{t-i} + \text{ч}_t$ ………………………………………………..……………………… (2)

GDPt = f(ELC, PCOt, GACt, COCt, SECt) ……………...……………..………………… (3)

$\text{GDP}_t = \alpha_{10} + \sum_{i=1}^{n} \alpha_{11i}\text{GDP} + \sum_{i=1}^{n} \alpha_{12i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{13i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{14i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{15i}\text{COC}_{t-i} + \sum_{i=1}^{n} \alpha_{16i}\text{SEC}_{t-i} + \text{ч}_{1t}$ ………………………………………………… (4)

$ELC_t = \alpha_{16} + \sum_{i=1}^{n} \alpha_{17i}\text{GDP} + \sum_{i=1}^{n} \alpha_{18i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{19i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{20i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{21i}\text{COC}_{t-i} + \sum_{i=1}^{n} \alpha_{21i}\text{SEC}_{t-i} + \text{ч}_{1t}$ ………………………………………………… (5)

$\text{PCO}_t = \alpha_{23} + \sum_{i=1}^{n} \alpha_{24i}\text{GDP} + \sum_{i=1}^{n} \alpha_{25i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{26i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{27i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{28i}\text{COC}_{t-i} + \sum_{i=1}^{n} \alpha_{28i}\text{SEC}_{t-i} + \text{ч}_{1t}$ ……………………..………………………… (6)

$\text{GAC}_t = \alpha_{30} + \sum_{i=1}^{n} \alpha_{31i}\text{GDP} + \sum_{i=1}^{n} \alpha_{32i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{33i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{34i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{35i}\text{COC}_{t-i} \sum_{i=1}^{n} \alpha_{35i}\text{SEC}_{t-i} + \text{ч}_{1t}$ …………………………………………………… (7)

$\text{COC}_t = \alpha_{37} + \sum_{i=1}^{n} \alpha_{38i}\text{GDP} + \sum_{i=1}^{n} \alpha_{39i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{40i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{41i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{42i}\text{SEC}_{t-i} + \text{ч}_{1t}$ (8)

$\text{SEC}_t = \alpha_{37} + \sum_{i=1}^{n} \alpha_{38i}\text{GDP} + \sum_{i=1}^{n} \alpha_{39i}\text{ELC}_{t-i} + \sum_{i=1}^{n} \alpha_{40i}\text{PCO}_{t-i} + \sum_{i=1}^{n} \alpha_{41i}\text{GAC}_{t-i} + \sum_{i=1}^{n} \alpha_{42i}\text{SEC}_{t-i} + \text{ч}_{1t}$ (9)

Where:

Ln = Logarithm;

GDP_t = Gross domestic product at time t;
ELC_t = Electricity Consumption at time t;
PCO_t = Petroleum Consumption at time t;
GAC_t = Gas Consumption at time t;
COC_t = Coal Consumption at time t;
SEC_t = Solar Energy Consumption at time t;
β_0 = Intercept of the regression model;
$\beta_1 - \beta_5$ = Coefficients of the explanatory variables; and
U = Error term.
The model a priori expectations becomes $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, > 0$

3.3 Estimation Techniques

Descriptive Statistics – to summarise data distribution.

ADF Unit Root Tests – to confirm stationarity.

Johansen Cointegration Test – to detect long-run equilibrium.

VAR Model Estimation – to capture dynamic relationships.

Granger Causality Tests – to examine the direction of influence.

Post-Estimation Diagnostics – serial-correlation (LM) and stability (CUSUM).

3.4 Definition and Measurement of Variables

Table 1: Measurement of Variable

Variable	Definition / Measurement	Expected Sign
GDP	Real GDP (constant 2010 US$)	—
ELC	Electricity consumption (GWh per capita)	+
PCO	Petroleum consumption (barrels per day)	+
GAC	Gas consumption (million cubic meters)	+
COC	Coal consumption (metric tons)	+
SEC	Solar-energy consumption (GWh)	+

Source: Authors Computation 2025

3.5 Pre-Estimation Results (Summary)

Table 2: ADF Unit Root Tests

Variable	Level	1st Diff.	Order of Integration
GDP	–1.88	–4.76***	I(1)
ELC	–2.12	–5.03***	I(1)
PCO	–2.95	–3.95**	I(1)
GAC	–2.54	–4.97***	I(1)
COC	–1.63	–5.14***	I(1)
SEC	–2.28	–4.55***	I(1)

Notes: *** $p < 0.01$, ** $p < 0.05$. All variables stationary at first difference or level.

Source: Authors Computation 2025

Table 3: Johansen Cointegration Results

Hypothesis	Trace Stat.	Critical Value (0.05)	Prob.	Inference
None *	114.3	95.75	0.01	Reject H_0 → Cointegration
At most 1	69.2	69.8	0.07	Accept H_0
At most 2	33.6	47.9	0.32	—

Source: Authors Computation 2025

Result confirms at least one long-run cointegrating vector.

3.6 VAR Lag Order Selection

Akaike and Schwarz criteria selected lag 2 as optimal (AIC = –5.23).

3.7 Post-Estimation Diagnostics

CUSUM plots and LM tests show model stability (no serial correlation, $p > 0.05$).

4. Results and Discussion

4.1 Descriptive Statistics

Table 4: Summary Statistics (1990–2023)

Variable	Mean	Std. Dev.	Min	Max
GDP (₦ trillion, real)	55.62	32.41	19.60	130.45
ELC (GWh per capita)	143.25	23.11	102.3	186.8
PCO (barrels/day $\times10^3$)	512.64	87.93	367.0	674.5
GAC (million m^3)	325.13	69.20	213.4	452.6
COC (tons $\times10^3$)	58.11	11.22	36.8	73.9
SEC (GWh)	5.37	2.04	1.03	8.45

Source: Authors Computation 2025

The mean GDP growth of ₦55.62 trillion reflects an upward trend coinciding with industrial expansion and modest diversification since 2010. Petroleum and gas remain the dominant energy sources, while solar energy shows a slow but steady increase since 2015, corresponding to national renewable energy initiatives (NESP, 2023).

4.2 Regression Results

Table 5: VAR Model Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Inference
C	0.845	0.211	4.01	0.001	Significant
ELC	0.027	0.018	1.50	0.145	Positive, insignificant
PCO	0.218	0.073	2.98	0.006	Positive, significant
GAC	0.182	0.061	2.98	0.007	Positive, significant
COC	0.111	0.045	2.46	0.019	Positive, significant
SEC	0.031	0.026	1.19	0.235	Positive, insignificant
$R^2 = 0.82$	Adj. $R^2 = 0.78$	$F(5,28) = 21.46$ ($p < 0.01$)	DW = 1.89	—	

Source: Authors Computation 2025

The VAR regression reveals that petroleum, gas, and coal consumption have statistically significant positive impacts on Nigeria's real GDP, implying that these traditional energy sources remain pivotal to output growth. Electricity and solar energy show positive but insignificant effects, reflecting persistent supply instability, transmission losses, and limited renewable-energy penetration (NERC, 2023; World Bank, 2024).

The high R^2 (0.82) indicates that over 80% of GDP variation is explained by energy-consumption variables, validating the energy–growth nexus in Nigeria.

4.3 Granger Causality Results

Table 6: Pairwise Granger Causality (p-values)

Null Hypothesis	F-Stat.	Prob.	Direction
ELC → GDP	3.21	0.054	Unidirectional
PCO → GDP	5.33	0.011	Unidirectional
GAC → GDP	4.95	0.016	Bidirectional
COC → GDP	3.99	0.021	Unidirectional
SEC → GDP	2.14	0.112	None

Source: Authors Computation 2025

Results suggest a feedback relationship between gas consumption and GDP, while petroleum and coal Granger-cause economic growth without reverse causation. This supports the *energy-led growth hypothesis* (Kouton, 2021; Sunge & Bannor, 2023).

4.4 Policy Discussion

The dominance of petroleum and gas implies that Nigeria's economy remains carbon-intensive, vulnerable to oil-price volatility, and inconsistent with net-zero aspirations. Electricity's insignificance indicates infrastructural bottlenecks in generation and transmission. Solar energy's weak impact reveals untapped renewable potential despite abundant insolation (≈5.5 kWh/m²/day).

These findings align with international evidence that energy access drives inclusive growth when accompanied by institutional efficiency and infrastructure (Chen et al., 2023; IEA, 2024). For Nigeria, a stable energy supply could add 3–4% to annual GDP by 2030 (PwC, 2024).

5. Conclusion and Policy Recommendations

This study empirically established that energy consumption significantly influences Nigeria's economic growth between 1990 and 2023. Petroleum, gas, and coal consumption exert statistically significant positive effects, while electricity and solar energy contribute positively but insignificantly. Cointegration confirms a long-run equilibrium relationship among energy sources and GDP. The causal results affirm both energy-led and feedback hypotheses, highlighting the bidirectional relationship between gas use and growth. Overall, energy consumption remains a strong determinant of Nigeria's productive capacity. However, dependence on fossil fuels poses sustainability and environmental challenges.

Based on the findings, the study recommends:

A comprehensive transformation of Nigeria's energy landscape requires deliberate diversification of the national energy mix. Policymakers should prioritise an accelerated shift toward renewable sources, particularly solar, wind, and mini-hydro, through targeted incentives, research grants, and favourable tariff regimes. Diversification will not only cushion the economy against fossil-fuel volatility but also align with the global decarbonisation pathway under the Paris Agreement. Establishing clear feed-in tariffs, tax holidays, and low-interest green bonds will attract private investment and deepen domestic manufacturing of renewable-energy technologies.

Modernising and expanding the electricity-supply infrastructure is equally essential. Investment in generation, transmission, and distribution networks should focus on reducing technical losses, improving frequency stability, and expanding off-grid electrification for peri-urban and rural communities. Government and private-sector partnerships can deploy independent power projects (IPPs) and micro-grid solutions under transparent regulatory frameworks. In parallel, the Transmission Company of Nigeria and state-level utilities need performance-based contracts that emphasise service reliability and financial accountability.

The gas sub-sector holds immense potential for industrial transformation. Beyond export, natural gas should be positioned as a transitional fuel for domestic power generation, fertiliser production, and transportation. Effective implementation of the "Decade of Gas Initiative" demands streamlined licensing, transparent pricing, and elimination of infrastructural bottlenecks such as pipeline vandalism. Expanding compressed natural gas (CNG) networks for public transport and manufacturing will reduce dependence on petrol, lower emissions, and stimulate employment in gas-related industries.

Strengthening institutional governance and regulatory efficiency remains a prerequisite for sustainable energy development. Agencies such as the Nigerian Electricity Regulatory Commission (NERC), the Energy Commission of Nigeria (ECN), and the Rural Electrification Agency (REA) should operate within harmonised policy frameworks to avoid overlaps and delays. Transparent procurement procedures, data-driven monitoring, and predictable regulatory enforcement will foster investor confidence and reduce policy uncertainty. Digitalisation of regulatory processes and regular publication of sector-performance dashboards will further enhance accountability.

Fiscal and financial instruments must be re-engineered to support innovation and green investment. The Central Bank of Nigeria, Bank of Industry, and Development Bank of Nigeria could expand renewable-energy credit facilities and introduce risk-sharing mechanisms to encourage private lending. Establishing an Energy-Innovation Fund devoted to start-ups developing off-grid and energy-efficiency technologies will stimulate local value chains and reduce import dependency. Blended-finance approaches combining concessional public finance with private equity can mobilise the estimated US $20 billion investment gap in Nigeria's clean-energy sector.

Enhancing energy efficiency across industries and households is also vital. Adopting minimum-energy-performance standards for appliances, promoting energy-audit programmes for manufacturing firms, and enforcing building codes that incorporate insulation and lighting efficiency can significantly lower energy intensity. Public awareness campaigns through schools, media, and community platforms should emphasise conservation behaviour as an integral component of national energy security.

Regional and international cooperation can amplify domestic reforms. Strengthening Nigeria's participation in the Economic Community of West African States (ECOWAS) Regional Electricity Market and the West African Gas Pipeline will improve cross-border energy trade and reliability. Collaborative research with development partners such as the International Renewable Energy Agency (IRENA) and the African Development Bank should be directed toward capacity-building, data harmonisation, and technology transfer. Such cooperation will accelerate Nigeria's integration into the continental clean-energy value chain envisioned by the African Union's Agenda 2063.

Finally, coherent long-term planning and political commitment are indispensable. The federal government should institutionalise periodic energy-policy reviews that align with fiscal strategy, climate commitments, and industrialisation goals. Establishing a National Energy Planning Council with representation from academia, industry, and civil society would ensure evidence-based decision-making and continuity across political cycles. Embedding these reforms in law through an Energy Transition Act would guarantee policy stability and provide a credible roadmap for achieving universal energy access and sustained economic prosperity by 2060.

Limitations and Suggestions for Further Research

The study's reliance on aggregate national data limits sectoral insights into industrial, agricultural, and residential energy use. Future research should apply panel data across Nigerian states and incorporate environmental indicators such as CO_2 emissions and energy efficiency indices to support Nigeria's SDG-7 and SDG-13 goals.

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