Energy Access, Quality, and Affordability as Drivers of Sustainable Economic Development in West Africa: A Panel Data Analysis

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Abstract

The pursuit of sustainable economic development across West Africa may be shaped by the degree and quality of energy access. Reliable and affordable electricity can potentially facilitate industrial activities, support small and medium-sized enterprises, and improve human capital development by powering education and healthcare services. It may also contribute to poverty reduction by stimulating income-generating opportunities and enhancing agricultural value chains. However, the regional energy landscape remains heterogeneous, with some areas benefiting from grid connectivity while others depend on off-grid renewable or informal sources. Such diversity may influence economic trajectories differently across rural and urban contexts, requiring policy approaches tailored to local conditions. This study examines the potential associations between electricity access, reliability, affordability, and efficiency, and their implications for sustainable economic development in West Africa. Using panel data estimations, including fixed effects models, the analysis suggests that enhanced energy access may be linked with higher development outcomes, although institutional capacity, infrastructure quality, and affordability may mediate this relationship. These findings indicate that energy policy in West Africa could benefit from a dual strategy of expanding access and improving quality while integrating governance, education, and spatial planning considerations.

Keywords: Energy Access, Sustainable Development, West Africa, Electricity Reliability, Renewable Energy, Economic Growth

1. Introduction

The pursuit of sustainable economic development across West Africa may be significantly influenced by the degree of energy access. Access to reliable and affordable energy can facilitate industrial activities, support small and medium enterprises, and improve human capital development by powering education and healthcare services (Adetunji et al., 2022). It may also contribute to poverty reduction, as greater energy availability can stimulate income-generating opportunities and enhance agricultural processing (Osei & Mensah, 2021). As such, a nuanced understanding of how energy access intertwines with sustainable economic growth is essential for policy formulation.

Parallel to this, the region's energy landscape is characterized by heterogeneity, some areas benefit from grid electrification while others remain off-grid and rely on renewable or informal energy sources. This diversity may affect how energy influences economic trajectories differently across rural and urban contexts. For example, renewable off-grid solutions may catalyze grassroots-level economic engagement in remote communities, whereas grid extension may bolster manufacturing and service sectors (Kamara & Conteh, 2023). Understanding these dynamics may help tailor interventions to specific local needs.

Within this context, one might postulate that the degree of energy access is positively associated with indicators of economic development, such as GDP per capita growth, employment rates, and improvements in quality-of-life measures. However, this relationship may be mediated by institutional capacity and infrastructure quality; regions with weak governance or poor maintenance regimes may not fully capitalize on new energy investments (Akinyele et al., 2020). Thus, we approach the relationship cautiously, acknowledging that energy access may not translate into development outcomes uniformly.Building on these insights, the first hypothesis (H1) can be proposed that: *Regions in West Africa with enhanced access to electricity, either via grid extension or off-grid renewable solutions, may exhibit higher rates of sustainable economic development compared to regions with limited energy access.*

Moreover, the nature of energy access might matter. Off-grid renewables, by virtue of being decentralized, may disproportionately benefit remote communities by stimulating micro-enterprises and reducing time spent on fuel gathering, thereby indirectly contributing to

household income and human capital development (Yeboah & Agyeman, 2024). Consequently, a second hypothesis*(H2) arises that:Economic impacts attributable to off-grid renewable energy access may differ substantively from those associated with grid-based electricity, potentially resulting in more equitable development outcomes in underserved areas.*

Additionally, the efficiency and sustainability of energy use may influence the magnitude of development outcomes. Even where energy access is present, if consumption is constrained by high costs, unreliable supply, or inefficient end-use technologies, its developmental potential may be curtailed. Therefore, we introduce the third null (H3) that: *Among regions with comparable levels of energy access, those with more affordable and reliable energy servicesmay experience greater sustainable economic development.*

2. Methodology

This study draws upon panel data compiled for regions across West Africa over the period 2010–2024. The dataset integrates regional indicators of electricity access (e.g., percentage of households with grid connection, number of off-grid installations) from the World Bank's *World Development Indicators* and the IEA Access Database. Economic development outcomes are proxied by measures such as regional per capita GDP, poverty headcount ratio, and industrial output sourced respectively from national statistical offices and the World Bank (Blimpo & Cosgrove-Davies, 2019; IEA, 2023). Additional control variables include education levels, population density, and institutional quality (Amegah & Agyei-Mensah, 2024; Khandker et al., 2022). The analytical sample comprises sub-national units (regions/provinces) within West African countries for which all requisite variables are available, yielding N observations across T time periods, and allowing for both cross-section and time variation. To test $\mathbf{H_1}$, we estimate the following baseline fixed-effects panel data model:

$$\text{EconDev}_{it} = \alpha_i + \lambda_t + \beta_1 \,\text{ElecAccess}_{it} + \gamma' \mathbf{X}_{it} + \varepsilon_{it}, \quad (1)$$

where EconDev_{it} denotes sustainable economic development in region i at time t; α_i and λ_t are region and year fixed effects; ElecAccess_{it} captures electricity access (grid and off-grid combined); $\mathbf{X}_{it}$ is a vector of control variables; and ε_{it} is the error term.

To assess $\mathbf{H_2}$, we decompose electricity access into two orthogonal components:

$$\text{EconDev}_{it} = \alpha_i + \lambda_t + \beta_2 \,\text{GridAccess}_{it} + \beta_3 \,\text{OffGridAccess}_{it} + \gamma' \mathbf{X}_{it} + \varepsilon_{it}, \quad (2)$$

where GridAccess_{it} and $\text{OffGridAccess}_{it}$ denote grid-based and off-grid renewable access, respectively. Comparison of β_2 and β_3 allows us to explore differential impacts.

For **H₃**, we introduce measures of reliability (Reliability_{it}), affordability (Price_{it}), and technology adoption (Efficiency_{it}), and employ interaction terms:

$$\begin{aligned}\text{EconDev}_{it} = {} & \alpha_i + \lambda_t + \beta_4\,\text{ElecAccess}_{it} + \beta_5\,\text{Reliability}_{it} + \beta_6\,\text{Price}_{it} + \beta_7\,\text{Efficiency}_{it} \\ & + \delta_1(\text{ElecAccess}_{it} \times \text{Reliability}_{it}) + \delta_2(\text{ElecAccess}_{it} \times \text{Price}_{it}) \\ & + \delta_3(\text{ElecAccess}_{it} \times \text{Efficiency}_{it}) + \gamma' \mathbf{X}_{it} + \varepsilon_{it}\end{aligned} \quad (3)$$

where interaction terms allow us to test whether comparable levels of electricity access yield higher development outcomes when service quality and efficiency are enhanced.

The primary estimation method is a fixed-effects panel regression, which controls for unobserved time-invariant heterogeneity across regions and global shocks (Wooldridge, 2010). This method is suitable when unobserved region-specific factors might correlate with electricity access and development outcomes (Blimpo & Cosgrove-Davies, 2019). Year fixed effects capture broader macro shocks (e.g., commodity price fluctuations across years).

To address dynamic effects, we estimate models including lagged dependent variables (dynamic panel specification), though such models may introduce bias in short panels; these are estimated using the system GMM estimator (Arellano & Bover, 1995), which is robust for "small T, large N" panels. Endogeneity of electricity access is further addressed by IV estimation, where the instruments may include distance to transmission infrastructure or timing of electrification policy interventions, subject to validity tests (first-stage F-statistics, overidentification tests) (Dinkelman & Mqubela, 2022).

Table 1. Variable Definitions and Data Sources

Variable	Description	Source
EconDev	Regional per capita GDP, poverty headcount, industrial output composite	World Bank, national statistical offices
ElecAccess	% households with electricity (grid or off-grid)	World Bank WDI, IEA Access Database
GridAccess	% households connected to national grid	IEA Access Database
OffGridAccess	% households with solar home systems or mini-grid access	IEA Access Database, REN21 country reports
Reliability	Average hours of supply per day or frequency of outages	National utilities, Afrobarometer surveys
Price	Average residential electricity tariff (PPP-adjusted)	National regulatory agencies, World Bank

Variable	Description	Source
Efficiency	Proxy index: share of efficient appliances (e.g., LED lighting)	National surveys, pilot program datasets
Control Variables (X)	Education enrollment, institutional quality index, population density, urbanization	UNESCO, World Governance Indicators, UNDP

Source: Author

3. Results

Table 2 provides the Pearson correlation coefficients between the dependent variable and the explanatory variables. The results suggest that ElecAccess exhibits a strong positive correlation with EconDev (0.650), indicating that higher electricity availability is associated with better development outcomes in West African contexts. This aligns with findings by Mensah et al. (2021), who reported similar positive relationships in panel data from multiple Sub-Saharan countries. Reliability also shows a strong positive correlation with EconDev (0.680), consistent with the assertion that the stability and quality of electricity supply significantly influence economic activities (Kumi, 2023). Efficiency records the highest correlation with EconDev, underscoring the role of energy use optimization in driving productivity (Nwachukwu & Akinwale, 2020).

Conversely, Price is negatively correlated with EconDev (-0.350), supporting prior evidence that high energy costs can constrain industrial competitiveness and household welfare (Adom et al., 2019). Interestingly, OffGridAccess has a slightly negative correlation (-0.180), which might suggest that off-grid adoption in the region often occurs in less economically vibrant areas, where market and institutional conditions are weaker (Pueyo et al., 2022). The correlation among explanatory variables reveals potential collinearity concerns, particularly between ElecAccess and GridAccess (0.880), and between ElecAccess and Efficiency (0.770). These high inter-correlations necessitate robust econometric strategies to mitigate multicollinearity risks (Wooldridge, 2021).

The fixed-effects (within) regression results in Table 3 provide a more rigorous estimation of the relationship between electricity-related factors and sustainable economic development, controlling for unobserved heterogeneity across regions. The coefficient for ElecAccess suggests that a 1% increase in electricity access is associated with a 0.073 unit increase in sustainable economic development, holding other variables constant. This reinforces empirical findings from cross-country studies that improved energy access significantly boosts development outcomes

(Lee et al., 2020). Reliability has the largest positive coefficient, highlighting that beyond access, the dependability of electricity supply is a crucial driver of economic transformation (Mensah et al., 2021). Efficiency also emerges as a statistically significant factor, corroborating arguments that energy-efficient technologies can increase productivity and reduce costs (Acheampong et al., 2021). Price exhibits a negative and significant coefficient, supporting the notion that high tariffs can undermine industrial competitiveness and household energy affordability (Alam et al., 2022). Similarly, Population Density shows a small but significant negative effect, possibly due to urban congestion effects or infrastructure strain (Oyebanji et al., 2021). The positive coefficients for Education and Institution emphasize the complementary roles of human capital and governance in translating energy access into sustainable development gains (Blimpo & Cosgrove-Davies, 2019). Lastly, Urbanization suggests that urban expansion, when supported by adequate infrastructure, can amplify development benefits (Gollin et al., 2021). The findings confirm that both the quantity and quality of electricity supply, alongside socio-economic enablers, significantly influence sustainable economic development in West Africa.

Table 2. Pearson correlation matrix

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
EconDev [1]	1.000	0.650	0.605	-0.180	0.680	-0.350	0.740	0.610	0.460	-0.110	0.520
ElecAccess [2]	0.650	1.000	0.880	-0.050	0.720	-0.350	0.770	0.600	0.420	-0.080	0.630
GridAccess [3]	0.605	0.880	1.000	-0.300	0.690	-0.300	0.700	0.580	0.400	-0.120	0.570
OffGridAccess [4]	-0.18	-0.00	-0.300	1.000	-0.120	0.220	-0.100	-0.140	-0.050	0.120	-0.20
Reliability [5]	0.680	0.720	0.690	-0.120	1.000	-0.300	0.750	0.540	0.420	-0.070	0.600
Price [6]	-0.35	-0.35	-0.300	0.220	-0.300	1.000	-0.360	-0.300	-0.210	0.030	-0.22
Efficiency [7]	0.740	0.770	0.700	-0.100	0.750	-0.360	1.000	0.650	0.460	-0.090	0.610
Education [8]	0.610	0.600	0.580	-0.140	0.540	-0.300	0.650	1.000	0.470	-0.050	0.490
Institution [9]	0.460	0.420	0.400	-0.050	0.420	-0.210	0.460	0.470	1.000	-0.020	0.360
PopDensity [10]	-0.11	-0.08	-0.120	0.120	-0.070	0.030	-0.090	-0.050	-0.020	1.000	-0.04
Urbanization [11]	0.520	0.630	0.570	-0.200	0.600	-0.220	0.610	0.490	0.360	-0.040	1.000

Source: Author

Table 3. Fixed-Effects (Within) estimation - main specification (Equation 1)

Variable	coef	std_err	t	pval
const	0.001	0.012	0.083	0.934
ElecAccess	0.073	0.010	7.300	0.000
Reliability	0.482	0.045	10.711	0.000
Price	-0.298	0.056	-5.321	0.000
Efficiency	0.058	0.012	4.833	0.000
Education	0.019	0.005	3.800	0.000
Institution	0.028	0.007	4.000	0.000
PopDensity	-0.001	0.000	-2.000	0.045
Urbanization	0.039	0.009	4.333	0.000

Source: Author

The findings from this study hold substantial implications for energy and development policy in West Africa. The positive and statistically significant relationship between electricity access and sustainable economic development suggests that governments and development agencies should prioritize expanding both grid and off-grid solutions. Grid extension can be critical for urban and peri-urban areas with higher population densities, while decentralized renewable energy systems, such as solar mini-grids, can address rural electrification gaps. This dual approach may ensure that regions with varying demographic and geographic characteristics benefit equitably from energy investments (Aklin et al., 2020; Lee et al., 2020).

The strong association between electricity reliability and economic performance underscores the importance of improving the operational efficiency of existing infrastructure. Investment in grid maintenance, smart-grid technologies, and energy storage solutions could significantly enhance service stability. Unreliable electricity supply can increase transaction costs for firms, reduce productivity, and discourage both domestic and foreign investment (Mensah et al., 2021; Bazilian & Pielke, 2020). Therefore, interventions that strengthen reliability are likely to produce long-term economic dividends.

The negative coefficient for electricity price implies that affordability remains a major barrier to maximizing development benefits. High tariffs can disproportionately affect low-income households and small enterprises, limiting their ability to invest in productive activities. Policymakers could explore targeted subsidies, progressive tariff structures, and increased competition in the energy market to reduce consumer costs while maintaining utility solvency (Blimpo & Cosgrove-Davies, 2019; Wolfram et al., 2021).

Efficiency improvements also emerged as a critical determinant of development outcomes. This suggests that simply expanding access is insufficient—energy systems must be technologically and operationally optimized. Promoting the adoption of energy-efficient appliances, enforcing building energy codes, and incentivizing industrial efficiency measures could help achieve higher economic returns per unit of energy consumed (Bhattacharyya, 2020; Sovacool et al., 2020).

Education and institutional quality also play complementary roles in ensuring that the economic benefits of energy access are fully realized. Educational investments can enhance human capital, enabling individuals to leverage energy access for income generation and improved productivity.

Likewise, strong institutions can facilitate transparent governance, reduce corruption in energy sector projects, and promote stable investment environments (Andersen & Dalgaard, 2020; Ouedraogo, 2020). This suggests that energy policy should be integrated with broader human capital and governance reforms.

Finally, population density and urbanization dynamics indicate that spatial planning and urban policy must be considered alongside energy strategies. High-density urban areas may require different technological and infrastructural approaches compared to dispersed rural communities. Integrated planning that aligns energy investments with demographic trends may yield more sustainable and inclusive growth outcomes (Kumi, 2021; Acheampong et al., 2021).

4. Conclusion

This study underscores the multifaceted role of electricity access, reliability, affordability, and efficiency in shaping sustainable economic development across Sub-Saharan Africa. The empirical evidence suggests that improving access to modern energy services may yield substantial socio-economic benefits, particularly when such access is complemented by affordability measures and reliability enhancements. However, the analysis also reveals that the economic dividends of electrification are not automatic; they depend on the interplay between energy infrastructure, institutional quality, human capital, and spatial development dynamics (Blimpo & Cosgrove-Davies, 2019; Andersen & Dalgaard, 2020).

The results indicate that policy interventions should adopt an integrated approach, combining grid extension with decentralized renewable energy systems to address the persistent urban–rural divide. Furthermore, ensuring electricity affordability through progressive tariff structures and targeted subsidies could expand productive energy use among households and small businesses (Wolfram et al., 2021). At the same time, strengthening institutional capacity and governance mechanisms is essential to ensure that investments in the energy sector translate into long-term economic gains (Ouedraogo, 2020).

Given the heterogeneity in demographic and geographic characteristics across the region, energy policies should be tailored to context-specific needs. Urban areas with high population densities may require investments in high-capacity transmission systems and energy storage, while sparsely populated rural areas may benefit more from cost-effective mini-grids and off-grid solar

solutions (Kumi, 2021). In addition, embedding energy policy within broader socio-economic frameworkscan create synergies that amplify development outcomes (Acheampong et al., 2021).

Looking forward, future research could deepen the understanding of sectoral linkages by examining how electrification influences productivity in agriculture, manufacturing, and services over time. Longitudinal studies with high-frequency data may help disentangle the causal mechanisms linking energy access to socio-economic outcomes, while cross-country comparative analyses could identify best practices adaptable to diverse national contexts (Aklin et al., 2020). Further work could also assess the resilience of energy systems to climate change impacts, exploring how adaptive infrastructure and renewable integration can mitigate supply risks in vulnerable regions (Sovacool et al., 2020).

Ultimately, sustainable energy transitions in Sub-Saharan Africa will require coordinated efforts among governments, the private sector, and international development partners. By aligning energy policy with social inclusion, economic diversification, and environmental sustainability goals, the region can leverage electricity as a catalyst for broad-based and resilient development.

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