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Renewable and Non-Renewable Energy Consumption and Economic Growth in Africa: Regional Insights for Sustainable Energy Planning

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ABSTRACT

Effective long-term planning becomes essential as Africa strives to expedite its shift to sustainable energy systems and comprehends how energy consumption and economic growth interact. This study examines the effects of total energy consumption, renewable energy consumption, and non-renewable energy consumption on economic growth in eight regional economic communities in Africa— Arab Maghreb Union (AMU), Community of Sahel-Saharan States (CEN-SAD), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Economic Community of Central African States (ECCAS), Economic Community of Western African States (ECOWAS), Intergovernmental Authority on Development (IGAD), and Southern African Development Community (SADC)—between 1996 and 2022. Using panel data from the African regions, the Mean Group and Pooled Mean Group were utilised where applicable as indicated by the Hausman Test. The findings reveal that while both renewable and non-renewable energy consumption influence economic growth, their impacts vary across regions. Total energy consumption has a negative impact on economic growth in AMU, CEN-SAD, COMESA, ECCAS, and SADC blocs, but a positive impact on economic growth in ECOWAS and IGAD blocs, and an insignificant impact on the EAC bloc. While non-renewable energy consumption has a negative impact on economic growth in the AMU, COMESA, ECCAS, IGAD, and SADC blocs and a positive impact on economic growth in the EAC bloc, renewable energy consumption has a positive impact on economic growth in the AMU, COMESA, ECCAS, IGAD, and SADC blocs. These findings highlight the necessity of unique, region-specific energy planning approaches that give system resilience and investments in renewable energy top priority. Specifically, policymakers should expand energy access to underserved areas for the blocs experiencing positive impact of energy consumption, while those blocs experiencing negative impact should put in place policies to reduce energy waste and control energy prices to avoid volatility.

Keywords

Regional economic communities;
energy consumption;
economic growth;
renewable energy;
sustainable energy systems

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1. Introduction

Rapid population increase, urbanization, and the urgent need to achieve Sustainable Development Goal 7—ensuring that everyone has access to modern, affordable, sustainable, and dependable energy—all highlight how urgent Africa's energy transition is [1]. However, there are still significant regional differences in economic performance, consumer trends, and energy availability. These differences call for a planning-based strategy that considers future demand trends and resource potentials in addition to current deficiencies [2].

The rapid growth of economic activity, urbanisation, technological innovation, and population increase are all contributing to the rapidly increasing need for energy in developing countries around the world. Right now, Africa needs much more power. Just 24% of Africans in sub-Saharan Africa have access to electricity, and the continent's total power generation capacity (which excludes South Africa) is only 28 gigawatts. Inadequate infrastructure results in poor energy availability and consumption. Those that are connected to the grid typically experience power interruptions for 15% of the year [3].

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Study that separates energy use into non-renewable and renewable sources is essential. Most previous research has either just examined total energy consumption [4,5], or only renewable energy [6] or non-renewable energy consumption [7]. Very few studies have jointly analysed renewable and non-renewable energy consumption alongside total energy use, which limits understanding of the distinct and combined roles of energy sources in shaping economic growth. In addition, prior work rarely considers the regional heterogeneity across Africa's officially recognised Regional Economic Communities (RECs), even though energy resources, consumption patterns, and infrastructure vary widely. These omissions restrict the ability of policymakers to design evidence-based, region-specific strategies for achieving energy transition and sustainable development. This study advances the literature in two ways. First, it offers an integrated analysis of total, renewable, and non-renewable energy consumption on economic growth in Africa, examined jointly rather than in isolation. Second, it employs a comparative framework across the eight Regional Economic Communities (RECs)—Arab Maghreb Union (AMU), Community of Sahel-Saharan States (CEN-SAD), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Economic Community of Central African States (ECCAS), Economic Community of Western African States (ECOWAS), Intergovernmental Authority on Development (IGAD), and Southern African Development Community (SADC)—to reveal the heterogeneity of the energy–growth nexus. Together, these contributions provide deeper empirical insights and region-specific evidence crucial for Africa's energy transition, investment strategies, and sustainable development.

Building on these gaps, this study makes two key contributions. First, it provides the comprehensive assessment of total, renewable, and non-renewable energy consumption on economic growth in Africa, analysed both separately and jointly. Second, by adopting a comparative framework across the eight Regional Economic Communities (RECs), the study highlights the heterogeneity of the energy–growth relationship, offering region-specific insights that are critical for guiding Africa's energy transition. To achieve these aims, the study specifies three objectives: (i) to determine the dependence of economic growth on total energy consumption, (ii) to examine the separate effects of renewable and non-renewable energy consumption on economic growth, and (iii) to assess their joint impact within a single framework.

The countries in each of the REC is listed in the Appendix. Given that Africa's energy landscape is complex, with many areas having distinct energy resources and consumption patterns, this was required to strengthen the study and thoroughly identify potential for investment and development. The paper is structured as follows: Section 2 shows the literature review, Section 3 elaborates the methodology, and Section 4 elicits the results and discussions, followed by the conclusions in Section 5.

2. Literature Review

Energy consumption reflects the total amount of primary energy used within an economy before it is transformed into end-use fuels. As defined by the [8], it is measured as domestic energy output plus imports and changes in stock, minus exports and fuels used by ships and aircraft engaged in international travel. Closely linked to this is the concept of economic growth, which represents the sustained increase in a country's productive capacity over time. It is generally captured through growth in Gross Domestic Product (GDP), serving as a central indicator of development progress and the extent to which an economy expands its output of goods and services [8].

Within the broader energy mix, renewable and non-renewable sources play distinct roles. Renewable energy refers to natural resources that replenish faster than they are consumed—such as solar, wind, hydro, geothermal, biomass, biogas, marine energy, and waste-to-energy. These resources are increasingly valued for their role in mitigating climate change, reducing exposure to volatile fossil fuel prices, and lowering long-term energy costs. By contrast, non-renewable energy consists of finite resources like coal, oil, natural gas, and petroleum products, which cannot be replenished quickly enough to meet demand. The reliance on these sources raises concerns of depletion, environmental degradation, and vulnerability to global price shocks [8].

The energy supply, consumption, and resources of a few Southern African Development Community (SADC) member nations in 2005 were examined by [9]. Angola, Botswana, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe's energy usage is projected until 2030 using the Long-Range Energy Alternatives Planning (LEAP) model. According to the report, there should be a considerable increase in consumption in these countries, especially for power and biomass.

Using a different approach and scope than the aforementioned, [4] examined the dynamic causal relationships between energy consumption, energy prices, and growth, as well as the relationship between electricity consumption, prices, and growth for fifteen ECOWAS countries. The three stages of the study included panel unit root tests, panel cointegration tests, and Granger causality. The variables in this study, which covers the years 1980–2008, include GDP per capita, energy use per capita, and energy costs. The results indicate that GDP and electricity, as well as GDP and energy consumption, move in unison over the long run. The results demonstrate that the causal relationship is inverse in the short term, from GDP to energy consumption, and in the long term, from GDP to energy consumption.

The influence of renewable and non-renewable energy consumption on sustainable development in 16 emerging markets and developing economies (EMDEs) in Latin America and the Caribbean was studied by [10].The research analyses the data using a multivariate technique and incorporates annual data from 1990 to 2014. The results show that economic growth in the selected countries is positively impacted by the use of both renewable and non-renewable energy sources, as well as other elements like government spending, gross fixed capital formation, trade openness, and financial development.

For the Bloomberg Top Emerging Countries from 1980 to 2015, [11] investigated the connection between economic openness and the consumption of renewable and non-renewable energy. The authors examine the long-term link between the panels using the Pesaran CCE-MG cointegration estimator, the Westerlund panel cointegration test with multiple structural breakdowns, and the Dumitrescu-Hurlin panel causation test. Based on the results, it was found that one of the main causes of the rise in business transparency is the use of non-renewable energy. Furthermore, it was found that a major factor in reducing the degree to which these growing nations were open to trade was an increase in the use of renewable energy.

[12] emphasised that sustainable energy planning must move beyond aggregate technical indicators to include local energy system transitions, spatial carbon factors, community ownership, trust, and household-level energy practices which are highly relevant for African contexts, where energy challenges are deeply shaped by regional diversity, institutional trust, and social acceptance of energy projects.

[13] investigated the moderating role of institutions in the relationship between energy consumption and economic growth across African RECs. Their findings revealed that institutional quality significantly impact the extent to which energy consumption contributes to economic growth, suggesting that stronger governance frameworks and effective institutional arrangements enhance the energy-growth nexus.

Complementing this perspective, [14] explored the transition from coal-based systems towards sustainable renewable district heating. Their study demonstrated that integrating renewable heating supply with energy-saving demand measures is critical for phasing out coal dependence, enhancing sustainability, and promoting resilient energy systems.

[15] explored energy consumption efficiency behaviours and attitudes at the community level, underscoring the role of socio-cultural dynamics in shaping sustainable energy transitions. Their findings emphasized that while technological interventions are critical, the absence of behavioural alignment and adequate community awareness often undermines policy effectiveness. Extending this perspective, [16] examined the nexus between renewable energy and inclusive economic development in Africa, showing that renewable energy adoption not only addresses environmental challenges but also fosters social inclusion, poverty reduction, and equitable growth. Together, these studies highlight that sustainable energy systems in Africa must be driven by a dual focus: behavioural and attitudinal shifts at the grassroots level, alongside renewable energy strategies that directly promote inclusive economic development.

3. Methodology

3.1 Model Specification

The neoclassical economic growth theory [17] and the biophysical growth model's [18] serve as the foundation for the following models. The first objective seeks to determine the extent to which economic growth depends on total energy consumption across the eight Regional Economic Communities (RECs) in Africa. This relationship is specified in Equation (1), which serves as the benchmark model.

$$\left(\frac{\Delta Y}{Y}\right)_{it} = \beta_0 + \beta_1 GCF_{it} + \beta_2 LAB_{it} + \beta_3 TEN_{it} + \beta_4 CEM_{it} + \beta_5 FDI_{it} + \beta_6 INF_{it} + U_{it} \quad (1)$$

The second objective focuses on examining the distinct effects of renewable energy consumption (REN) and non-renewable energy consumption (NRE) on economic growth within the RECs. To achieve this, Equation (1) is extended by disaggregating total energy consumption (TEN) into its renewable and non-renewable components, resulting in Equations (2) and (3).

$$\left(\frac{\Delta Y}{Y}\right)_{it} = \beta_0 + \beta_1 GCF_{it} + \beta_2 LAB_{it} + \beta_3 REN_{it} + \beta_4 CEM_{it} + \beta_5 FDI_{it} + \beta_6 INF_{it} + U_{it} \quad (2)$$

$$\left(\frac{\Delta Y}{Y}\right)_{it} = \beta_0 + \beta_1 GCF_{it} + \beta_2 LAB_{it} + \beta_3 NRE_{it} + \beta_4 CEM_{it} + \beta_5 FDI_{it} + \beta_6 INF_{it} + U_{it} \quad (3)$$

Finally, the third objective investigates the joint impact of renewable (REN) and non-renewable energy consumption (NRE) within a single framework, as specified in Equation (4).

$$\left(\frac{\Delta Y}{Y}\right)_{it} = \beta_0 + \beta_1 GCF_{it} + \beta_2 LAB_{it} + \beta_3 REN_{it} + \beta_4 NRE_{it} + \beta_5 CEM_{it} + \beta_6 FDI_{it} + \beta_7 INF_{it} + U_{it} \quad (4)$$

where $\left(\frac{\Delta Y}{Y}\right), GCF, LAB, TEN, REN, NRE, CEM, FDI, INF$ denotes economic growth, capital stock growth, labour force growth, total energy consumption, renewable energy consumption, non-renewable energy consumption, carbon dioxide emissions, foreign direct investment and inflation, respectively, and β_1 to β_7 are the coefficients of the interaction variables in Equations 1 through 4.

3.2 Data

Capital stock growth was taken into consideration in order to account for the impact of investment on productivity and economic growth. It was measured using private investment flows in constant 2015 international dollars. The inclusion of this variable aligns with neoclassical theory. In order to account for the impact of demographic changes on economic development, *labour force growth* was included. Labour force growth was computed as the annual percentage change in the total labour force. Specifically, the value of the labour force in year *t* was compared to its value in year *t–1*, and the difference was expressed as a percentage of the base year (*t*–1). The inclusion of this variable aligns with neoclassical theory.

Renewable energy is one of the best sources for addressing the issue of rising energy costs. It was measured as percentage total final energy consumption. The growing competitiveness of solar and wind energy leads to significant growth in renewable energy. The inclusion of this variable was informed by past studies like [11]. *Non-renewable energy* was measured as percentage total final energy consumption. This study included this variable as a major input, building on the work of authors such as [19].

Total energy consumption was included to reflect the impact of energy on economic growth. One kilogram of oil per capital was the unit of measurement. The inclusion of this variable aligns with the biophysical growth concept. *Carbon dioxide emissions* were included as a variable to gauge the environmental impact of economic activity in accordance with [20] study. It was measured as the percentage of total fuel combustion.

Foreign direct investment was taken into consideration to account for capital accumulation and technological progress, as stated by [21]. It was measured as a proportion of GDP. Excessive *inflation* has been identified as an issue because it might deter investment and consumption and hinder economic growth. It was calculated using the annual percentage change in the consumer price index. [22,23] used inflation as a predictor.

Panel data covering the 54 African countries for the period between 1990 and 2023 sourced from World Bank, World Development Indicators [24] were used for the study.

3.3 Estimation Technique

The empirical analysis begins with descriptive statistics and correlation analysis to provide an overview of regional energy consumption patterns and their association with economic growth. Before estimation, cross-sectional dependency test was conducted using the BreuschPagan LM test, followed by panel unit root tests, using Pesaran's cross-sectionally augmented dickey fuller (PESCADF), was conducted to establish the stationarity properties of the series. Once stationarity is confirmed, the Kao panel cointegration test was applied to determine whether a long-run equilibrium relationship exists between economic growth and the different forms of energy consumption.

Following this, the study proceeds with model estimation with three techniques (viz: Pooled Mean Group [PMG], Mean Group [MG] and Dynamic Fixed Effect [DFE]) to capture the baseline relationship between energy consumption and growth across the Regional

Economic Communities. Optimal lag lengths for each variable were determined using the Akaike Information Criterion (AIC), ensuring model efficiency and comparability. The Hausman test is then used to determine the more appropriate estimator among them.

4. Results and Discussion

4.1 Descriptive Analysis

The results from Table 1 show that the mean score for the economic growth was 3.18% indicating a moderate expansion. The standard deviation of 10.78% suggests relatively stable growth. The minimum and maximum growth rate were -50.34% and 86.83% respectively. The average score for capital stock growth was 2.88% indicating a moderate increase in investments. The standard deviation was 13.51% suggesting some volatility while with minimum and maximum values were -69.12% and 76.01% respectively.

Labour force growth averaged 1.58% indicating a relatively slow expansion. The standard deviation of 1.0% suggests some stability. The minimum and maximum growth rate were -5.28% and 3.13% respectively. Inflation had a mean of 4.05% indicating a moderate increase in prices with standard deviation of 4.41% suggesting some volatility. The minimum and maximum values were -9.79% and 25.85% respectively.

Total energy consumption averaged 1,483.99kWh, indicating a relatively moderate level of energy usage. The standard deviation of 908.58kWh suggests some variability. The minimum and maximum consumption were 363.49kWh and 3,243.82kWh respectively. Renewable energy consumption averaged 13.12%, indicating a moderate level of renewable energy usage while the standard deviation of 12.8% suggests some stability. The minimum and maximum consumptions were 0.06% and 46.01%. Non-renewable energy consumption averaged 94.45% showing a relatively high level of non-renewable energy usage. The standard deviation of 12.8% suggests some variability while the minimum and maximum consumptions were 81.49% and 99.98%, respectively.

The mean of carbon dioxide emission was 10.98% indicating a relatively moderate level of emissions with standard deviation of 3.34% suggesting some variability. The minimum and maximum emissions were 3.36% and 16.14% respectively. Foreign direct investment averaged 2.95% indicating a small amount of foreign investment in the region. The standard deviation of 4.18% suggests moderate variability in FDI inflows while the minimum and maximum inflows were -11.19% and 27.65%, respectively.

4.2 Correlation Analysis

The correlation matrix is shown in Table 2. Since the correlation coefficients stay within acceptable parameters, the results provide no indication of significant multicollinearity among the variables. This implies that there no significant correlations between the independent variables,

Table 1: Descriptive Statistics for Sustainable Energy Planning in Africa.

Variable	Mean	Std. Dev.	Min	Max	Obs
$\left(\frac{\Delta Y}{Y}\right)$	3.185	10.784	–50.339	86.827	135
GCF	2.885	13.51	–69.124	76.014	135
LAB	1.581	1.002	–5.28	3.135	135
INF	4.051	4.406	–9.798	25.854	135
TEN	1483.995	908.578	363.491	3243.823	135
REN	13.121	12.801	0 .06	46.01	135
NRE	94.446	6.169	81.49	99.978	135
CEM	10.98	3.345	3.361	16.139	135
FDI	2.947	4.179	–11.192	27.652	135

Note. $\left(\frac{\Delta Y}{Y}\right), GCF, LAB, INF, TEN, REN, NRE, CEM \text{ and } FDI$ represent economic growth, capital stock growth, labour force growth, inflation, total energy consumption, renewable energy consumption, non-renewable energy consumption, carbon dioxide emission and foreign direct investment, respectively. *Obs* is the number of observations.

Source: Authors' computation (2025).

Table 2: Correlation Matrix for Sustainable Energy Planning in Africa.

Variable	$\left(\frac{\Delta Y}{Y}\right)$	GCF	LAB	INF	TEN	REN	NRE	CEM	FDI
$\left(\frac{\Delta Y}{Y}\right)$	1.000								
GCF	–0.035	1.000							
	(0.685)								
LAB	–0.104	–0.267	1.000						
	(0.229)	(0.002)							
INF	–0.063	0.075	–0.139	1.000					
	(0.466)	(0.390)	(0.108)						
TEN	–0.010	0.081	0.008	–0.170	1.000				
	(0.913)	(0.350)	(0.925)	(0.048)					
REN	0.019	0.118	–0.057	0.121	0.148	1.000			
	(0.828)	(0.174)	(0.510)	(0.164)	(0.086)				
NRE	–0.028	0.014	0.054	–0.141	0.725	–0.073	1.000		
	(0.746)	(0.874)	(0.531)	(0.102)	(0.000)	(0.402)			
CEM	0.060	–0.172	0.045	0.032	–0.758	–0.231	–0.242	1.000	
	(0.491)	(0.046)	(0.605)	(0.709)	(0.000)	(0.007)	(0.005)		
FDI	0.031	0.095	–0.086	0.054	0.204	0.411	0.092	–0.213	1.000
	(0.722)	(0.271)	(0.319)	(0.536)	(0.018)	(0.000)	(0.290)	(0.013)	

Source: Authors' computation (2025).

guaranteeing the validity and reliability of the regression analysis.

4.3 Results of the ADF Unit Root Test

Both first-generation and second-generation unit root tests were used in this investigation, the selection criterion was based on the outcome of the cross-sectional dependency analysis conducted. The Pesaran's cross-sectionally augmented dickey fuller (PESCADF) is used when a variable exhibits cross-sectional dependency, otherwise, the Im-Pesaran-Shin (IPS) unit root test is used.

Table 3 shows that while certain variables, such as $\left(\frac{\Delta Y}{Y}\right)$, *GCF, LAB, INF, TEN, REN, and NRE,* were stationary at the 5% significance level, others, such as CEM and FDI, were only stationary at the first difference. Therefore, to determine whether there is a long-run relationship between the variables, co-integration testing was required.

4.4 Panel Cointegration Test

The long-term connection between the dependent and independent variables was examined using the Kao co-integration test approach. If the probability value of the t-statistic is less than or equal to the selected 5% critical value, the null hypothesis is rejected; if not, the hypothesis is accepted, and a long-term association is concluded.

Table 4 shows that the p-value was 0.000 in every instance, which is below the 0.05 significance level. Consequently, it was concluded that there was a long run relationship between the dependent and independent variables, and the null hypothesis was rejected. Therefore, the Panel ARDL technique was employed to estimate all of the equations.

4.5 Estimates of the Regression Equations

Tests were first conducted to assess the relative suitability of the three methods of estimating with PARDL regressions—the dynamic fixed effect (DFE), mean group

Table 3: Results of the Unit Root Tests for Sustainable Energy Planning in Africa.

Variables	Stationary	t-Stat	p-values	Order of Integration	Generation	Conclusion
$\left(\frac{\Delta Y}{Y}\right)$	At Level	–6.099	0.000	I(0)	First	Stationary or I(0) at the level form
GCF	At Level	–4.908	0.000	I(0)	First	Stationary or I(0) at the level form
LAB	At Level	–1.763	0.000	I(0)	First	Stationary or I(0) at the level form
INF	At Level	–3.622	0.001	I(0)	Second	Stationary or I(0) at the level form
TEN	At Level	–4.318	0.000	I(0)	Second	Stationary or I(0) at the level form
REN	At Level	–3.091	0.000	I(0)	Second	Stationary or I(0) at the level form
NRE	At Level	–6.100	0.000	I(0)	Second	Stationary or I(0) at the level form
CEM	At Level	–2.221	0.144	I(1)	Second	Unit root or I(1) at the first difference
	At First Difference	–4.697	0.000	I(0)		
FDI	At Level	–2.177	0.168	I(1)	Second	Unit root or I(1) at the first difference
	At First Difference	–4.373	0.000	I(0)		

Source: Authors' computation (2025)

(MG), and pooled mean group (PMG)—before the Hausman test was applied to choose the best fit for the panel data-based models. The MG and PMG are the most appropriate, according to the Hausman test findings, which are not displayed for conciseness.

4.5.1 Effects of Total Energy Consumption on Economic Growth

As shown in Table 5a, the coefficients of total energy consumption (TEN) were -0.003 and -0.004 with p-values of 0.039 and 0.040 in AMU and CEN-SAD blocs respectively, implying that the coefficient was negative and statistically significant. In ECOWAS, IGAD and SADC blocs, the coefficients of total energy consumption (TEN) were 0.004, 0.006 and 0.000 with p-values of 0.019, 0.042 and 0.001 implying that the coefficient was positive and statistically significant while it was insignificant in COMESA, EAC and ECCAS blocs.

The coefficients of gross capital formation (GCF) were positive and statistically significant in ECCAS, ECOWAS, IGAD and SADC blocs being 0.042, 0.019, 0.028 and 0.165 with p-values less than 0.05 in each case while being insignificant in other blocs. The coefficients of labour force growth (LAB) were negative and statistically significant in AMU and SADC blocs being -3.087 and -1.258 with p-values of 0.040 and 0.013 respectively while its coefficients were positive and statistically significant in CEN-SAD, COMESA, EAC, ECCAS and ECOWAS blocs being 0.901, 1.544, 0.972, 2.256 and 2.614 with p-values less than 0.05 in each case.

The coefficients of Inflation (INF) were negative and statistically significant in EAC and ECCAS blocs being -0.090 and -0.021 with p-values of 0.011 and 0.000 respectively while being insignificant in other blocs. The coefficients of carbon dioxide emissions (CEM) were negative and statistically significant in AMU, EAC and ECOWAS blocs being -1.084, -0.136 and -0.142 with p-values less than 0.05. Also, its coefficient was positive and statistically significant in ECCAS bloc being 0.076 with a p-value of 0.026 while being insignificant in other blocs. The coefficient of foreign direct investment (FDI) was negative and statistically significant in AMU bloc being -1.501 with a p-value of 0.001 while being insignificant in other blocs.

4.5.2 Separate Effects of Renewable and Non-renewable Energy on Economic Growth

As shown in Table 5b, the coefficients of renewable energy consumption (REN) were 0.290, 0.127, 0.091,

Table 4: Results of the Cointegration Tests for Sustainable Energy Planning in Africa.

Equation 1		Equation 2		Equation 3		Equation 4	
T-stat	P-value	T-stat	P-value	T-stat	P-value	T-stat	P-value
–6.320	0.000	–6.823	0.000	–6.840	0.000	–6.370	0.000

Source: Authors' computation (2025)

Table 5a: Panel ARDL Estimates of the Regression Equations for Total Energy Consumption.

	AMU			CEN-SAD			COMESA			EAC		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	0.081	0.98	0.329	–0.005	–0.68	0.494	0.002	0.38	0.701	–0.035	–1.32	0.187
LAB	–3.087	–2.06	0.040	0.901	2.80	0.005	1.544	5.46	0.000	0.972	4.89	0.000
INF	–0.157	–0.73	0.468	–0.054	–1.30	0.194	–0.007	–0.62	0.537	–0.090	–2.54	0.011
TEN	–0.003	–2.06	0.039	–0.004	–2.06	0.040	4.641	0.00	0.996	–0.001	–0.77	0.442
CEM	–1.084	–1.96	0.050	–0.280	–1.29	0.197	–0.079	–0.75	0.452	–0.136	–4.21	0.000
FDI	–1.501	–3.46	0.001	0.012	0.17	0.869	–0.080	–1.34	0.179	0.230	1.49	0.137
χ2	10.76		0.000	60.87		0.000	45.09		0.000	60.76		0.000
Method of Estimation	PMG			PMG			PMG			PMG		
	ECCAS			**ECOWAS**			**IGAD**			**SADC**		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	0.042	2.63	0.008	0.019	2.73	0.006	0.028	2.49	0.013	0.165	8.59	0.000
LAB	2.256	6.07	0.000	2.641	6.14	0.000	–0.137	–0.48	0.631	–1.258	–2.49	0.013
INF	–0.021	–5.42	0.000	0.055	1.21	0.228	–0.013	–1.48	0.140	–0.000	–0.16	0.871
TEN	–0.000	–0.21	0.835	0.004	2.35	0.019	0.006	2.03	0.042	0.000	3.40	0.001
CEM	0.076	2.23	0.026	–0.142	–2.95	0.003	0.128	1.42	0.155	0.089	1.60	0.110
FDI	–0.015	–0.31	0.760	0.053	1.50	0.133	0.017	0.31	0.755	–0.018	–0.43	0.667
χ2	30.76		0.000	70.76		0.000	40.76		0.000	80.76		0.000
Method of Estimation	PMG			PMG			PMG			PMG		

Source: Authors' computation (2025)

0.097 and 0.050 with p-values of 0.000, 0.001, 0.029, 0.007 and 0.000 in AMU, COMESA, ECCAS, IGAD and SADC respectively implying that the coefficients were positive and statistically significant while it was not significant in other blocs. The coefficients of gross capital formation (GCF) were positive and statistically significant in ECCAS, IGAD and SADC blocs being 0.043, 0.024 and 0.190 with p-values less than 0.05 in each case while being insignificant in other blocs.

The coefficient of labour force growth (LAB) was negative and statistically significant in AMU bloc being -6.311 with a p-value of 0.030 while its coefficients were positive and statistically significant in COMESA, EAC, ECCAS and ECOWAS blocs being 0.707, 1.279, 1.580 and 2.183 with p-values less than 0.05 in each case while being insignificant in other blocs. The coefficient of Inflation (INF) was negative and statistically significant in EAC bloc being -0.023 with a p-value of 0.000 while being insignificant in other blocs.

The coefficient of carbon dioxide emissions (CEM) was negative and statistically significant in EAC bloc being -0.135 with a p-value of 0.000 while being insignificant in other blocs. The coefficient of foreign direct investment (FDI) was negative and statistically significant in AMU bloc being -1.120 with a p-value of 0.002 while being positive and statistically significant in ECOWAS bloc being 0.116 with a p-value of 0.002. Its coefficient was not insignificant in other blocs.

From Table 5c, the coefficients of non-renewable energy consumption (NRE) were -0.316, -0.091, -0.075, -0.173 and -0.002 with p-values less than 0.05 in AMU, COMESA, ECCAS, IGAD and SADC respectively implying that the coefficients were negative and statistically significant. However, in the EAC bloc, the coefficient was 0.083 with a p-value of 0.003 showing that the coefficient was positive and statistically significant. The coefficient was not significant in CEN-SAD bloc.

The coefficients of gross capital formation (GCF) were positive and statistically significant in ECCAS, ECOWAS, IGAD and SADC blocs being 0.044, 0.015, 0.024 and 0.164 with p-values less than 0.05 in each case. Also, its coefficient was negative and statistically significant in

Table 5b: Panel ARDL Estimates of the Regression Equations for Renewable Energy Consumption.

	AMU			CEN-SAD			COMESA			EAC		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	–0.027	1.30	0.195	0.003	0.45	0.652	0.007	1.40	0.160	–0.021	–0.71	0.479
LAB	–6.311	–2.12	0.034	0.433	1.42	0.156	0.707	2.52	0.012	1.279	6.22	0.000
INF	–0.563	–1.16	0.246	–0.062	–1.51	0.130	–0.009	–0.71	0.479	–0.051	–1.71	0.087
REN	0.290	–5.07	0.000	0.020	1.92	0.055	0.127	3.44	0.001	0.017	1.15	0.250
CEM	0.730	0.78	0.437	0.063	0.65	0.516	–0.103	–1.01	0.314	–0.135	–5.23	0.000
FDI	–1.120	–2.47	0.002	–0.043	–0.62	0.535	–0.077	–1.26	0.208	0.090	0.56	0.575
χ^2	17.09		0.000	75.09		0.000	67.08		0.000	57.09		0.000
Method of Estimation	PMG			PMG			PMG			PMG		
	ECCAS			**ECOWAS**			**IGAD**			**SADC**		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	0.043	2.58	0.010	0.009	1.47	0.141	0.024	2.55	0.011	0.190	11.31	0.000
LAB	1.580	5.98	0.000	2.183	4.31	0.000	–0.006	–0.02	0.981	–0.357	–1.00	0.317
INF	–0.023	–6.64	0.000	0.032	0.69	0.488	0.008	0.90	0.366	–0.001	–0.36	0.721
REN	0.091	2.19	0.029	0.002	0.09	0.930	0.097	2.72	0.007	0.050	4.16	0.000
CEM	0.012	0.31	0.756	–0.074	–1.84	0.066	–0.010	–0.12	0.906	0.004	0.11	0.911
FDI	0.027	0.69	0.493	0.116	3.13	0.002	–0.055	–1.06	0.288	–0.034	–0.83	0.405
χ^2	27.09		0.000	77.09		0.000	87.09		0.000	77.09		0.000
Method of Estimation	PMG			PMG			PMG			PMG		

Source: Authors' computation (2025)

EAC bloc being -0.080 with a p-value of 0.000 while being insignificant in other blocs. The coefficient of labour force growth (LAB) was negative and statistically significant in AMU bloc being -6.311 with a p-value of 0.034. Also, its coefficients were positive and statistically significant in COMESA, ECCAS and ECOWAS blocs being 1.501, 1.525 and 2.439 with p-values less than 0.05 in each case while being insignificant in other blocs.

The coefficients of Inflation (INF) were negative and statistically significant in CEN-SAD, EAC, ECCAS and IGAD blocs being -0.101, -0.095, -0.025 and -0.022 with p-values less than 0.05 in each case while being insignificant in other blocs. The coefficients of carbon dioxide emissions (CEM) were negative and statistically significant in COMESA, EAC and ECOWAS blocs being -0.442, -0.133 and -0.116 with p-values less than 0.05 in each case while being insignificant in other blocs. The coefficient of foreign direct investment (FDI) was positive and statistically significant in ECOWAS bloc being 0.078 with a p-value of 0.023. Its coefficient was not insignificant in other blocs.

Results from the total energy consumption coefficients were not quite consistent. While the positive impact is due to increased productivity, which can be attributed to energy-efficient technologies and lead to economic growth, the negative impact of total energy consumption in some blocs may be caused by fluctuations in energy prices, income level [25] which can create uncertainty and influence investment and consumption decisions. While the negative results are supported by earlier empirical study like [26], the significant positive results are consistent with findings from earlier empirical studies like [27] and [28].

Similarly, in some blocs, the coefficients of renewable energy consumption were statistically significant and positive, while in other blocs, they were not. The significant positive finding is consistent with the results of earlier empirical studies, including those of [11,13]. The positive effect may stem from the fact that it fosters innovation by supporting clean technology research and development, but the lack of impact on other blocs may be the consequence of structural changes in the

Table 5c: Panel ARDL Estimates of the Regression Equations for Non-renewable Energy Consumption.

	AMU			CEN-SAD			COMESA			EAC		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	0.652	1.30	0.195	–0.000	–0.12	0.905	–0.000	–0.18	0.860	–0.080	–3.56	0.000
LAB	–8.793	–2.12	0.034	0.517	1.76	0.078	1.501	5.72	0.000	1.196	5.78	0.000
INF	–2.956	–1.16	0.246	–0.101	–2.39	0.017	–0.004	–0.30	0.710	–0.095	–3.24	0.001
NRE	–0.316	–5.07	0.000	–0.067	–0.52	0.606	–0.091	–5.00	0.000	0.083	2.95	0.003
CEM	0.519	0.78	0.437	0.048	0.40	0.687	–0.442	–4.30	0.000	–0.133	–6.52	0.000
FDI	–0.384	–0.60	0.550	–0.031	–0.39	0.696	–0.088	–1.55	0.121	0.204	1.59	0.111
χ^2	58.19		0.000	56.34		0.000	67.87		0.000	67.19		0.000
Method of Estimation	MG			MG			MG			MG		
	ECCAS			**ECOWAS**			**IGAD**			**SADC**		
Variables	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**	**Coeff.**	**Z-Stat**	**P-value**
GCF	0.044	2.73	0.006	0.015	2.69	0.007	0.024	2.50	0.013	0.164	8.42	0.000
LAB	1.525	5.71	0.000	2.439	5.23	0.000	–0.283	–1.01	0.311	–0.710	–1.64	1.000
INF	–0.025	–6/95	0.000	0.037	0.83	0.406	–0.022	–2.38	0.017	0.003	0.87	0.387
NRE	–0.075	2.95	0.009	0.025	0.93	0.351	–0.173	–3.08	0.002	–0.002	–3.25	0.001
CEM	0.004	0.10	0.917	–0.116	–2.90	0.004	–0.141	–0.94	0.349	–0.069	–1.20	0.231
FDI	–0.056	–1.15	0.252	0.078	2.27	0.023	–0.015	–0.29	0.774	–0.037	–0.82	0.411
χ^2	68.19		0.000	68.19		0.000	48.19		0.000	58.19		0.000
Method of Estimation	MG			MG			MG			MG		

Source: Authors' computation (2025)

economy, wherein changes in economic sectors may offset the benefits of renewable energy.

In some blocs, the non-renewable energy consumption coefficients were statistically significant and negative, whereas in other blocs, they were statistically significant and positive, and in yet others, they were statistically insignificant. The significant positive finding is consistent with the results of earlier empirical research, including [7] findings. Environmental deterioration, which fuels climate change, air pollution, and water contamination, may be the cause of the adverse consequence. Positive impacts might result from energy security, which is reinforced by a steady supply of energy, while the no effect could result from global energy market patterns, where local effects of renewable energy may be overshadowed by fluctuating global energy costs.

5. Conclusion

This study analysed how Africa's economic growth is impacted by total energy consumption, renewable energy consumption, and non-renewable energy consumption across eight regional economic communities in Africa. The findings establish that while both energy types contribute to growth, their effects vary significantly depending on regional energy structures and policy environments. The study establishes that total energy consumption has a negative and significant impact in AMU, and CEN-SAD blocs, but a positive and significant impact in ECOWAS, IGAD and SADC blocs and a negligible impact in COMESA, EAC and ECCAS blocs. While non-renewable energy consumption has a negative impact on economic growth in the AMU, COMESA, ECCAS, IGAD, and SADC blocs and a positive impact on economic growth in the EAC bloc, renewable energy consumption has a positive impact in the AMU, COMESA, ECCAS, IGAD, and SADC blocs.

The study's conclusions have important implications for Africa's sustainable energy planning. First, the fact that renewable energy boosts economic growth in several regions emphasises how urgent it is to increase renewable investments, especially in places with unrealised solar, wind, and hydro potential. For instance, regions with established renewable infrastructure, such as AMU, COMESA, ECCAS, IGAD, and SADC, exhibit stronger energy-growth linkages, indicating that sustained economic benefits can be achieved through ongoing infrastructure development and stable policies.

Second, the energy-growth connection exhibits regional variation, indicating that "one-size-fits-all" approaches to energy policy would not work. Regionally specific energy planning is required, considering institutional capabilities, development goals, and local resource endowments.

The study also underscores the importance of regional policies in enhancing energy access, infrastructure, and investment in cleaner energy sources. Policymakers should prioritise strategies that integrate renewable energy expansion with economic growth objectives while addressing regional disparities in energy availability. Since total energy consumption affects various regional economic communities in both positive and negative ways, those that benefit should expand energy access to underserved areas, while those that were negatively impacted should have policies in place to reduce energy waste and control energy prices to avoid volatility. In regional economic blocs where non-renewable energy has a detrimental impact, officials should set industry energy efficiency requirements and implement stringent environmental laws.

While this study provides new insights into the relationship between energy consumption and economic growth across African Regional Economic Communities, some limitations should be acknowledged. First, while the comparative regional framework captures broad patterns, it may overlook intra-regional and country-specific differences. Second, institutional and political economy dynamics are not fully incorporated. These limitations highlight areas for future research, including micro-level analyses, broader data coverage, and integration of institutional and technological dimensions. Also, future research should explore the role of technological advancements and financial mechanisms in accelerating Africa's transition towards a more sustainable energy mix.

References

[1] United Nations. Transforming our world: the 2030 Agenda for Sustainable Development. 2015. Available from: https://sdgs.un.org/2030agenda

[2] International Renewable Energy Agency (IRENA). Renewable energy market analysis: Africa and its regions. 2022. Available from: https://www.irena.org/publications

[3] International Energy Agency (IEA). Africa energy outlook 2019: World energy outlook special report. 2019. Available from: https://www.iea.org/reports/africa-energy-outlook-2019

[4] Ouedraogo NS. Energy consumption and economic growth: Evidence from the economic community of West African States (ECOWAS). Energy Econ. 2013; 36:637–647. https://doi.org/10.1016/j.eneco.2012.11.011

[5] Ozcan B, Tzeremes PG, Tzeremes NG. Energy consumption, economic growth and environmental degradation in OECD countries. Econ Model. 2020; 84:203–213. https://doi.org/10.1016/j.econmod.2019.04.010

[6] Uzar U. Political economy of renewable energy: Does institutional quality make a difference in renewable energy consumption? Renew Energy. 2020; 155:591–603. https://doi.org/10.1016/j.renene.2020.03.172

[7] Nadeem S, Munir K. Disaggregate energy consumption and economic growth in Pakistan: A sectoral analysis. Int J Energy Econ Policy. 2022;12(1):296–306.

[8] World Bank. Energy. 2024. Available from: https://www.worldbank.org/en/topic/energy

[9] Merven B, Hughes A, Davis S. An analysis of energy consumption for a selection of countries in the Southern African Development Community. J Energy South Afr. 2010;21(1):11–24. https://doi.org/10.17159/2413-3051/2010/v21i1a3246

[10] Le HP, Bao HHG. Renewable and non-renewable energy consumption, government expenditure, institution quality, financial development, trade openness, and sustainable development in Latin America and Caribbean emerging market and developing economies. Int J Energy Econ Policy. 2020;10(1):242–248. https://doi.org/10.32479/ijeep.8506

[11] Zeren F, Akkus HT. The relationship between renewable energy consumption and trade openness: New evidence from emerging economies. Renew Energy. 2020; 147:322–329. https://doi.org/10.1016/j.renene.2019.09.006

[12] Østergaard, PA, Duic, N. Sustainable Energy Planning and Management with focus on local energy system transition, spatial carbon factors, community ownership, trust, and household energy management. International Journal of Sustainable Energy Planning and Management. 2025; 46, 1–3. https://doi.org/10.54337/ijsepm.10682

[13] Biala MI, Aromasodun OM, Shitu AM. Institutional roles in moderating energy-led growth in African Regional Economic Communities. Academia Green Energy. 2025; 2(3). https://doi.org/10.20935/AcadEnergy7817.

[14] Dragusha B, Drilon M, Selimaj R, Sahiti N. How sustainable renewable district heating supply and heat saving demand support the transformation of coal energy systems. Int J Sustain

Energy Plan Manag. 2025; 46:24-40. 2025; 46, 24-40. https://doi.org/10.54337/ijsepm.10004

[15] Bishoge, OK, Kombe, GG, Mvile, BN. Energy Consumption Efficiency Behaviours and Attitudes among the Community. International Journal of Sustainable Energy Planning and Management. 2021; 31, 175–188. https://doi.org/10.5278/ijsepm.6153

[16] Yuni, DN, Ezenwa, N, Urama, NE, Tingum, EN, Mohlori-Sepamo, K. Renewable Energy and Inclusive Economic Development: An African Case Study. *International Journal of Sustainable Energy Planning and Management*. 2023; *39*, 23–35. https://doi.org/10.54337/ijsepm.7413

[17] Solow, RM. A contribution to the theory of economic growth. *Quarterly Journal of Economics*. 1956; 70(1). https://doi.org/10.2307/1884513

[18] Ayres, RU. The minimum complexity of endogenous growth models: The role of physical resource flows. *Energy.* 2001; 26(9), 817-838. https://doi.org/10.1016/S0360-5442(01)00031-7

[19] Lotfalipour MR, Falahi MA, Ashena M. Economic growth, CO2 emissions, and fossil fuels consumption in Iran. Energy. 2010;35(12):5115–5120. https://doi.org/10.1016/j.energy.2010.08.004

[20] Mensah IA, Sun M, Gao C, Omari-Sasu AY, Zhu D, Ampimah BC, Quarcoo A. Analysis on the nexus of economic growth, fossil fuel energy consumption, CO2 emissions and oil price in Africa based on a PMG panel ARDL approach. J Clean Prod. 2019; 228:161–174. https://doi.org/10.1016/j.jclepro.2019.04.281

[21] Wang Z, Bui Q, Zhang B. The relationship between biomass energy consumption and human development: Empirical evidence from BRICS countries. Energy. 2020; 194:116906. https://doi.org/10.1016/j.energy.2020.116906

[22] Zamani M. Evaluating the relationship between the energy consumption and the macroeconomic indicators. Res J Environ Earth Sci. 2012;4(12):1025–1032.

[23] Mahadevan R, Asafu-Adjaye J. Energy consumption, economic growth and prices. A reassessment using panel VECM for developed and developing countries. Energy Policy. 2007; 35:2481–2490. https://doi.org/10.1016/j.enpol.2006.08.019

[24] World Bank World Development Indicator. Retrieved from: https://databank.worldbank.org/indicator/BN.KLT.DINV.CD/1ff4a498/Popular-Indicators#

[25] Biala MI, Aromasodun OM, Shitu AM. Energy-Growth Nexus: A Systematic Review of Empirical Evidence and Policy Implications. Afr J Environ Sci Renew Energy. 2025;18(1):178–197. https://doi.org/10.62154/ajesre.2025.018.010656.

[26] Soytas U, Sari R. The relationship between energy and production: Evidence from Turkish manufacturing industry. Energy Econ. 2007;29(6):1151–1165. https://doi.org/10.1016/j.eneco.2006.05.019

[27] Ghali KH, El-Sakka MIT. Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ. 2004;26(2):225–238. https://doi.org/10.1016/S0140-9883(03)00056-2

[28] Wolde-Rufae Y. Energy consumption and economic growth: The experience of African countries revisited. Energy Econ. 2009; 31:217–224. https://doi.org/10.1016/j.eneco.2008.11.005

Appendix

Officially Recognised African Regional Economic Communities

1. Arab Maghred Union (AMU): AMU aims to promote economic integration, cooperation and solidarity among North African countries. Member countries include Algeria, Libya, Mauritania, Morocco and Tunisia.
2. Community of Sahel-Saharan States (CENSAD): Founded in 1998, CENSAD promotes economic cooperation and sustainable development among Sahel-Saharan countries. It consists of 25 countries, viz: Algeria, Benin, Burkina Faso, Central African Republic, Chad, Comoros, Cote d'Ivoire, Djibouti, Egypt, Eritrea, Gambia, Guinea, Guinea-Bissau, Libya, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Togo and Tunisia.
3. Common Market for Eastern and Southern Africa (COMESA): is Africa's largest regional economic organisation, with 19 member states and a population of about 390 million. COMESA has a free trade area, with 19 member states, and launched a customs union in 2009. COMESA countries include Burundi, Comoros, D.R. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia, and Zimbabwe.
4. East African Community (EAC): Founded in 1999, EAS promotes regional development among East African countries and include Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda.
5. Economic Community of Central African States (ECCAS): Established in 1983, ECCAS aims to promote regional stability among Central African countries and includes 10 countries, namely, Angola, Burundi, Cameroon, Central African

Republic, Chad, Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon and Sao Tome and Principle.

6. Economic Community of West African States (ECOWAS): Founded in 1975, ECOWAS promotes economic cooperation and regional security among West African countries consisting of 15 members which are Benin, Burkina Faso, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo.
7. Intergovernmental Authority on Development (IGAD): established in 1986, IGAD promotes economic cooperation and humanitarian assistance among Horn of Africa and surrounding countries. The members include Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda.
8. Southern African Development Community (SADC): Founded in 1994, SADC promotes regional stability among Southern African countries and comprises of 16 member-states which are Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe.