ENERGY CONSUMPTION PATTERNS IN MOZAMBIQUE: BALANCING ECONOMIC GROWTH WITH ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

This study investigates the dynamic relationship between energy consumption patterns and economic growth in Mozambique from 1990 to 2023, focusing on the interaction between carbon dioxide emissions (CO_2), GDP growth (GDP), fossil fuel energy consumption (FFEC), and renewable energy output (REO). The study employed the ARDL approach to examine both the long- and short-run relationships among the variables. The findings reveal that both carbon dioxide emissions and energy consumption from fossil fuels negatively affect GDP. The analysis showed long-run negative impacts of CO2 emissions from the electricity sector (-183%), renewable electricity output (-78%), and fossil fuel consumption (-134%) on GDP. In the short run, the error correction term indicated a speed of adjustment of 140% towards equilibrium. Granger causality tests confirmed that renewable electricity output influences economic growth, fossil fuel energy consumption contributes to CO2 emissions, and fossil fuel use impacts renewable energy output, suggesting heavy reliance on fossil fuels despite their negative effects on growth. The policy recommendations include the need for a targeted energy transition strategy that promotes investment in renewable energy infrastructure, particularly hydropower and solar, which are abundant in Mozambique. Strengthening regulatory frameworks, incentivising private sector participation, and integrating environmental concerns into national development plans are essential steps. Furthermore, the promotion of energy efficiency and regional cooperation in clean energy projects can improve sustainability. The study contributes to the limited empirical literature on the energy environment and country-specific economic insights over a comprehensive data range. It highlights the feasibility of decoupling economic growth from environmental harm through sustainable energy practices in a low-income, yet resource-rich context. Limitations include data quality and availability issues, particularly regarding disaggregated renewable energy statistics and non-CO_2 greenhouse gases. Additionally, the study does not account for institutional, political, or social variables that may influence the implementation of energy policy. Future research could explore sector-specific energy impacts, incorporate climate adaptation metrics, or apply scenario-based modelling to evaluate the long-term effects of various energy policies under climate uncertainty. A regional comparative analysis within Southern Africa could also yield valuable policy insights.

Keywords: GDP, Climate Change and Renewable Energy, Fossil Fuels.

1. INTRODUCTION

During the past three decades, Mozambique has experienced a gradual but notable transformation in its economic landscape, characterised by post-conflict reconstruction, investment in infrastructure, and increased industrial activity (Mahumane and Mulder, 2019). However, this progress has been accompanied by rising energy demands and environmental concerns. Mozambique is endowed with vast natural energy resources, including significant hydropower potential, coal reserves, and recent offshore natural gas discoveries (de Almeida et al., 2022). Despite this, energy access remains limited for large segments of the population, and fossil fuels continue to dominate the country's primary energy consumption mix (Mahumane and Mulder, 2019).

Globally, the tension between economic growth and environmental sustainability has prompted developing countries to reassess their energy strategies. Mozambique, like many sub-Saharan African nations, faces the dual challenge of promoting economic development while addressing the environmental implications of increased carbon emissions and overreliance on non-renewable energy sources (Cristóvo et al., 2021). Therefore, understanding the historical patterns of energy consumption and their implications for economic and environmental outcomes is critical for evidence-based policymaking (Cristóvo et al, 2021).

Although Mozambique's economic growth has shown resilience and potential, it has relied significantly on carbon-intensive energy sources. The implications of this trend for long-term sustainability are underexplored. Existing literature on energy-economic-environmental interactions in Sub-Saharan Africa often lacks country-specific longitudinal insights, especially for nations like Mozambique with a unique energy and development profile (Come Zebra et al., 2021). There is an urgent need to assess whether Mozambique's energy consumption trajectory supports a balanced path toward sustainable development or exacerbates environmental degradation.

The objective of this study is to examine the relationship between economic growth and energy consumption patterns in Mozambique, focussing on the roles of fossil fuel consumption, renewable energy production, and carbon dioxide emissions.

This research contributes to the empirical discourse on sustainable development by offering a comprehensive, data-driven assessment of the energy-economic-environment nexus of Mozambique. It informs policy debates on energy transition, climate action, and green growth in low-income and resource-abundant countries. The findings will be valuable to policymakers, development agencies and academics interested in sustainable energy strategies, particularly in the context of the Sustainable Development Goals (SDGs) of the United Nations, specifically SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action).

The motivation for this study stems from the critical need to provide context-specific insights into how Mozambique can navigate the global sustainability agenda. Given the vast renewable energy potential of the country, rapid economic growth, and vulnerability to climate change, there is a pressing opportunity and responsibility to chart a sustainable energy future. The scarcity of in-depth longitudinal analyses on Mozambique's energy consumption patterns and their economic-environmental implications underscores the relevance and urgency of this research. By shedding light on these interconnections, the study seeks to support more informed and proactive policymaking in a pivotal period of Mozambique's development.

2. LITERATURE REVIEW

2.1 Theoretical and Conceptual Background

This study is grounded in a green transition theory that emphasises long-term ecological values over short-term human interests (Sharma et al., 2022). Green transition theory forms part of a broader sustainability-related inquiry focusing on environmental justice, ecological modernisation, zero growth, and socially sustainable economics (Amoah et al., 2025). Low-carbon energy systems are becoming increasingly prominent in post-growth societies.

2.2 Empirical Review and Hypothesis Development

Empirically, the study examines scholarly discussions on the country's dependence on fossil fuels versus renewable energy, government policies influencing sustainable energy transitions, and socio-economic factors driving consumption patterns. Furthermore, it considers global perspectives on sustainable development and how Mozambique's energy policies align with international environmental commitments.

2.2.1 Carbon dioxide emission (CO2) and GDP growth

Kumari et al. (2025) examined the relationship between urbanisation, economic growth, renewable energy consumption, and carbon emissions in India, focusing on the effects of rapid urban population growth. The findings reveal the complexities of balancing economic development and environmental preservation, illustrating a two-way causal relationship between urbanisation, economic growth, and carbon emissions.

Despite India’s lower per capita emissions, the study underscores the political challenges in promoting sustainability through renewable energy investments to mitigate carbon emissions. It stresses the importance of international collaboration for access to clean energy technologies to support India’s sustainable growth.

Similarly, Chen (2025) examined the relationships between energy consumption, CO2 emissions, and economic growth. The study investigated three pairwise linkages: CO2 emissions and economic growth, CO2 emissions and energy consumption, and economic growth and energy consumption in various quantiles. The results indicate that energy consumption significantly increases both CO2 emissions and economic growth, while economic growth significantly increases CO2 emissions.

2.2.2 Fossil Fuel Energy Consumption and Environmental Sustainability

IDai et al. (2025) explored the impact of uncertainty in energy policy on energy consumption patterns within G7 countries, focusing on fossil fuels, renewables, and total energy use. The study highlights the need for stable energy policies to increase investor confidence and support the development of renewable energy, providing information for the formulation of strategic policies to facilitate a sustainable energy transition.

Similarly, Miao et al. (2025) highlight the importance of renewable energy in promoting sustainable development amidst growing environmental challenges. The results indicate that fossil fuel consumption negatively affects green economic growth both domestically and in neighbouring countries through negative spatial spillovers, while renewable energy consumption has positive spillover effects, improving sustainability regionally. The study underscores the need for regional cooperation and policy interdependence, offering guidance in line with international agreements like COP28 and the Sustainable Development Goals.

2.2.3 Renewable energy output and GDP growth

Sahlian (2021) analysed whether increased use of renewables contributes to GDP growth. It found that renewable energy can mitigate the impacts of greenhouse gases (GHGs) while supporting economic growth. The study findings revealed that economic growth correlates positively with renewable energy production, GHG per capita, and GHG intensity per GDP.

Lastly, (Come Zebra et al., 2021) evaluates Mozambique's Renewable Energy Feed-in Tariff (REFIT) within the framework of its nationally determined contributions (NDCs) under the Paris Agreement to limit global temperature rise. Using the LEAP model to project greenhouse gas (GHG) impacts, it concludes that REFIT could reduce emissions by 0.34 MtCO2eq (0.6% of the electricity sector's NDC target) by 2030 compared to a business-as-usual scenario. Enhanced REFIT implementation could increase this reduction to 2.54 MtCO2eq (4.3% of the sector's target). The study emphasises the importance of a robust measurement, reporting, and verification system to track climate policy progress and ensure transparency with the United Nations Framework Convention on Climate Change (UNFCCC).

3. DATA AND RESEARCH METHODOLOGY

The study used the autoregressive distributed lags (ARDL) bound test method to investigate the influence of energy consumption patterns in Mozambique. The ARDL model, initially introduced by Pesaran, Shin, and Smith (1999), represents a time series approach that enables the integration of lagged variables and error correction terms within a dynamic framework. The ARDL panel data methodology serves as a valuable tool for analysing economic panel data due to its capacity to capture both short- and long-term effects, account for individual and time-specific variations, and address issues such as serial correlation and cross-sectional dependence.

1.1 Study data

The study used data from an annual time series ranging from 1990 to 2023. Data were collected from the World Bank database (https://data.worldbank.org/). Table 1 below presents a brief explanation of the variables.

Table 1. Explanation of the variables

Variable	Description	Source
GDPG	GDP growth (annual%)	World Bank database
CO_2	Carbon dioxide (CO2) emissions from the power industry (energy) (Mt CO2e)	World Bank database
FFEC	Fossil fuel energy consumption (% of total output)	World Bank database
REO	Renewable electricity output (% of total electricity output)	World Bank database

Source: calculated by the author

1.2 Model Specification

Based on the variables given in Table 3 above, the model of this study has been specified as follows.

$$GDPG_t = \beta_0 + \beta_1 CO_2 + \beta_2 FFEC + \beta_3 REO + \mu \text{.......} 1$$

In Equation (1) above, GDPG represents annual GDP growth, CO2 represents carbon dioxide (CO2) emissions from the power industry, FFEC represents fossil fuel energy consumption, and REO represents renewable electricity production between 1990 and 2023. Similarly,

$t = time$, β_0 constant, $\beta_1, \beta_2 and \beta_3 = Coefficients$ and $\mu = error - term$

Furthermore, the fundamental prerequisite for implementing the ARDL approach lies in the requirement that a selection of variables must exhibit stationarity at I (0) while others must display stationarity at I (1) (Pesaran, Shin and Smith, 1999). This ARDL methodology serves a pivotal role in encompassing the complex influences of heteroskedasticity as well as the intricate patterns of autocorrelation (Pesaran, Shin, and Smith, 1999). The equation embodying the ARDL approach is meticulously outlined in the following.

$$\Delta GDPG_t = \beta_o + \sum_{i=1}^{m} \beta_1 \Delta GDPG_{t-1} + \sum_{i=1}^{m} \beta_2 \Delta CO_{2t\text{-}1} + \sum_{i=1}^{m} \beta_3 \Delta FFEC_{t\text{-}1} + \sum_{i=1}^{m} \beta_4 \Delta REO_{t\text{-}1} +$$
$$\alpha_1 \Delta GDPG_{t\text{-}1} + \alpha_2 \Delta CO_{2t\text{-}1} + \alpha_3 \Delta FFEC_{t\text{-}1} + \alpha_4 \Delta REO_{t\text{-}1} + \mu_t \text{.......} 2$$

Where β to denote the short-run dynamics of the model, whilst α To denote the long-run part of the model. The Δ is the first difference between the operator and the μ is a term for the disturbance of white noise. Based on equation 1, the null hypothesis is given as denotes that there is no cointegration among the variables. The alternative hypothesis is formulated as $H_1 \neq \beta_0 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$ This denotes the presence of cointegration among the variables.

Furthermore, the error correction model of the ARDL is formulated as follows.

$$\Delta GDPG_t = \beta_0 + \sum_{i=1}^{m} \beta_1 \Delta GDPG_{t-1} + \sum_{i=1}^{m} \beta_2 \Delta CO_{2t-1} + \sum_{i=1}^{m} \beta_3 \Delta FFEC_{t-1} + \sum_{i=1}^{m} \beta_4 \Delta REO$$
$$+\lambda ECT_{t-1} + \mu_t \text{.......} 3$$

Where λ The coefficient of the *ECT* (Error Correction Term), which captures the reversion and speed of adjustment to reach equilibrium (Pesaran et al. 2001).

4. RESULTS AND DISCUSSION

This section of the study presents statistical and econometric findings, including descriptive statistics, unit root tests, diagnostic tests, and ARDL estimation results. It aims to enhance the understanding of energy consumption patterns in Mozambique, thereby informing policy decisions. Table 2, below, presents the descriptive statistical results.

Table 2. Descriptive statistics results

	GDPG	CO2	FFEC	REO
Mean	6.044406	0.421103	11.63735	86.25819
Std. Dev.	4.206337	0.658701	7.221508	24.10358
Skewness	-0.940423	1.197332	0.568339	-2.781582
Kurtosis	4.552150	2.513172	1.834483	10.33549
Jarque-Bera	8.424559	8.459506	3.754825	120.0740
Probability	0.014813	0.014556	0.152985	0.000000
Sum Sq. Dev.	583.8780	14.31828	1720.956	19172.42

Source: calculated by the author

Based on Table 2 above, GDPG, CO2, FFEC and REO the $H_0 = There - is - no - relationship - between\, \text{var}\, iables$. Therefore, the P-values following the Jarque-Bera test indicate that all four variables have P-values of greater than 5% significance level, meaning the variables are related. Therefore, we accept the null hypothesis that the data is normally distributed. Table 3, below, presents the Unit root test results.

Table 3. Unit root test results

Variable	Model	T-stats	P-value.	Order
ADF unit root test				
GDPG	Intercept	-4.535***	0.001	I (1)
	Trend & intercept	-5.152***	0.001	I (0)
CO2	Intercept	-3.735***	0.008	I (1)
	Trend & intercept	-3.796***	0.033	I (1)
FFEC	Intercept	-4.456***	0.002	I (0)
	Trend & intercept	-5.421***	0.001	I (1)
REO	Intercept	-5.414***	0.000	I (0)
	Trend & intercept	-3.929***	0.023	I (1)

*Source: calculated by the author (***; ** and * represent significant at the 10% level,5% level, and 1% level, respectively)*

The unit root test results presented in Table 3 above indicate that the variables are integrated of order zero, I (0), and I (1). Therefore, the stationarity test outcome above justifies the application of the autoregressive distributed lag (ARDL) framework (Pesaran et al., 2001).

Table 4, below, presents the ARDL bound test results.

Table 4. ARDL bound test results

F-statistic				6.773351		
	10%		5%		1%	
Sample Size	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
30	2.676	3.586	3.272	4.306	4.614	5.966
35	2.618	3.532	3.164	4.194	4.428	5.816
* I (0) and I (1) are respectively the stationary and non-stationary bounds.						

Source: calculated by the author

The bound test presented in Table 4 illustrates the ARDL bound test that was performed on four variables, categorised into two groups: integration of order zero and integration of order one. The F statistics exceed critical values at significance levels of 10%, 5% and 1%, suggesting the existence of cointegration. Consequently, the null hypothesis of no cointegration is rejected as the F-statistic value exceeds the upper bound critical value. Table 5, below, presents ARDL Long-Run results.

Table 5. ARDL Long-Run results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDPG (-1) *	-1.396228	0.569770	-2.450513	0.0306
CO2 (-1)	-18.38594	7.491030	-2.454394	0.0303
D (FFEC (-3))	-1.344611	0.601604	-2.235043	0.0452
D (REO (-3))	-0.780581	0.224129	-3.482732	0.0045

Source: calculated by the author

Similarly, the long-run ARDL results presented in Table 5 reveal that a percentage increase in carbon dioxide (CO2) emissions from the electricity industry negatively impacts the gross domestic product by 183%. Similarly, a percentage change in the renewable electricity output negatively affects the gross domestic product by -78%. This is because renewable energy is not put to good use, hence affecting economic growth. Lastly, a percentage change in Fossil fuel electricity consumption affects the gross domestic product by -134%. This is because fossil fuels produce carbon dioxide, hence affecting the gross domestic product. Table 6, below, presents ARDL Short-Run and ECM Results.

Table 6. ARDL Short-Run and ECM Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-1.396228	0.223298	-6.252768	0.0000
D (GDPG (-3))	0.311040	0.137046	2.269606	0.0384
D (FFEC (-3))	-1.344611	0.442893	-3.035975	0.0083
D (CO2 (-1))	13.25094	3.533816	3.749753	0.0019
D (REO (-1))	0.519737	0.118769	4.376035	0.0005

Source: calculated by the author

Furthermore, the findings presented in Table 6 suggest that, in the short run, the coefficient for the error correction term of (CointEq (-1) -1.396) is negative and significant, indicating that the economic growth model demonstrates a speed of adjustment of approximately 140%. Similarly, a percentage change in Fossil fuel energy consumption impacts GDP by -134% due to intense carbon dioxide emissions when changing the fossil fuels into energy. Furthermore, a percentage change in carbon dioxide emissions impacts GDP by 132. Lastly, a percentage change in renewable electricity output has an impact on GDP by 52. Table 7, below, presents Diagnostic test Results.

Table 7. Diagnostic test results

Diagnostic Analysis	Test	Null hypothesis	P-value	Conclusions
Normality	Jarque-Bera	Data are normally distributed.	0.000	Fails to reject H_0 because the P-value is greater than 5%
Serial correlation	Breusch-Godfrey Serial Correlation LM Test	No serial correlation.	0.712	Fails to reject H_0 Because the P-value is greater than the level of significance. at 5%

Heteroskedasticity	Breusch-Pagan-Godfrey	Homoskedasticity	0.718	Fails to reject because the P-value is greater than the level of significance at 5%.

Source: calculated by the author

The diagnostic tests presented in Table 7 above demonstrate that the study does not reject the null hypothesis in three diagnostic tests, as the p-values exceed the significance level of 5%.

This result indicates that the model meets the criteria for the ARDL model. Figure 1 and 2 below presents the CUSUM test and the CUSUM of squares test results.

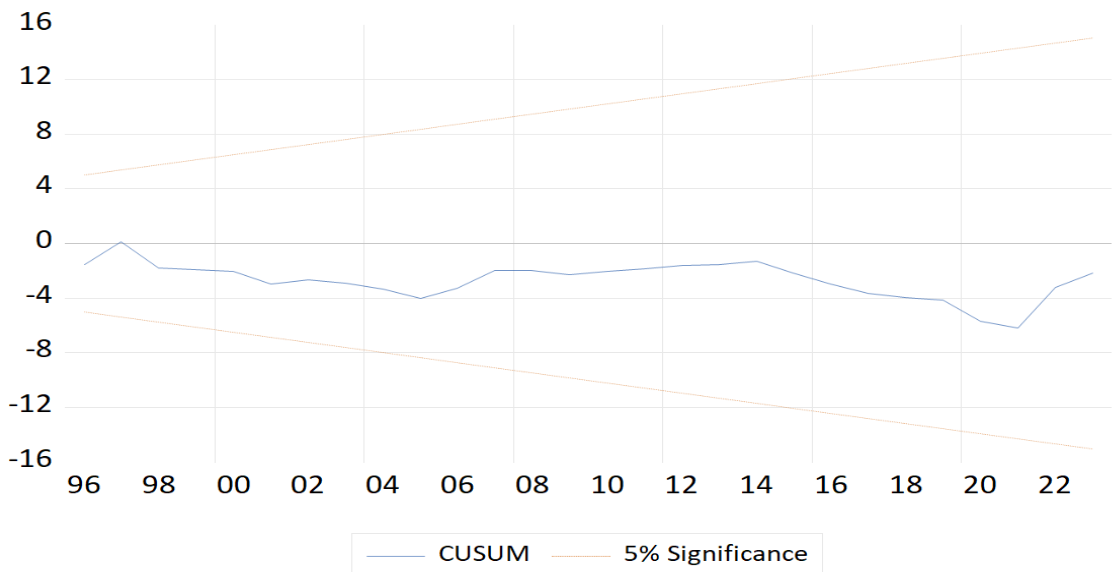

FIGURE 1
CUSUM TEST RESULTS.

(SOURCE: CALCULATED BY THE AUTHOR)

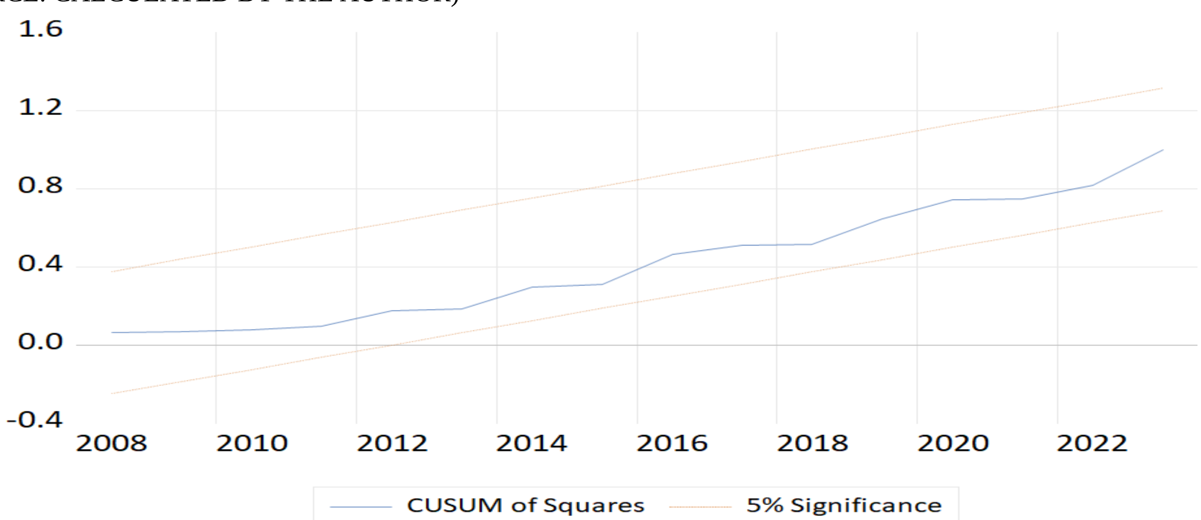

FIGURE 2
CUSUM OF SQUARES TEST RESULTS
(SOURCE: CALCULATED BY THE AUTHOR)

As evidenced by the results depicted in Figures 1 and 2, both the CUSUM and CUSUM square test plots remain within the established control limits. This observation suggests that the model parameters, as well as the variance of the residuals, exhibit stability. Consequently, there are no substantial structural changes or variance alterations within the model over time, thus demonstrating the reliability and consistency of the model. Table 8 below, presents the Granger causality test results.

Table 8. Granger causality test results

Null Hypothesis:	F-Statistic	Prob.	Decision
CO2 does not Granger Cause GDPG	2.67593	0.0871	Accept the H_0
GDPG does not Granger Cause CO2	0.04385	0.9572	Accept the H_0
FFEC does not Granger Cause GDPG	2.50441	0.1005	Accept the H_0
GDPG does not Granger Cause FFEC	0.09756	0.9074	Accept the H_0
REO does not Granger Cause GDPG	3.84128	0.0340	Reject the H_0
GDPG does not Granger Cause REO	1.78652	0.1868	Accept the H_0
FFEC does not Granger Cause CO2	7.09813	0.0033	Reject the H_0
CO does not Granger Cause FFEC	1.17287	0.3248	Accept the H_0
REO does not Granger Cause CO2	0.31704	0.7310	Accept the H_0
CO does not Granger Cause REO	3.00058	0.0666	Accept the H_0
REO does not Granger Cause FFEC	118.994	4.E-14	Accept the H_0
FFEC does not Granger Cause REO	4.46040	0.0212	Reject the H_0

Source: calculated by the author

The Granger causality results in Table 8 show that the study does not reject the null hypothesis that REO does not Granger cause Granger GDPG. The probability of 0.0340 is less than the 0.05 % significance level; therefore, renewable electricity output (REO) has a causal relationship with economic growth. Consequently, the null hypothesis that FFEC does not Granger cause Granger to CO2 was rejected, meaning that Fossil fuel energy consumption (FFEC) has a causal relationship with carbon dioxide emission. Lastly, the null hypothesis that FFEC does not Granger-cause REO was rejected, meaning that Fossil fuel energy consumption (FFEC) has a causal relationship with renewable energy output. People are dependent on fossil fuels than renewable energy, regardless of the negative effect it has.

5. CONCLUSIONS

This study provides empirical insights into the intricate nexus between energy consumption patterns and economic growth in Mozambique from 1990 to 2023. The ARDL bound test results show that there is cointegration among the variables analyzed, as the F statistics exceed critical values. The study finds that an increase in CO2 emissions from the electricity industry and fossil fuel consumption negatively affects GDP, while the renewable electricity output is inversely related to GDP growth due to inefficient use. The short-run model indicates significant results with an error correction term showing a 140% speed of adjustment. Granger causality tests reveal causal relationships: renewable electricity output affects economic growth, and fossil fuel energy consumption influences both carbon dioxide emissions and renewable energy output. Furthermore, the findings suggest a dependency on fossil fuels despite their negative impact.

This confirms the role of renewables in mitigating environmental degradation without compromising economic performance. In general, the study highlights the feasibility of decoupling economic growth from environmental harm through a strategic shift towards sustainable energy sources.

3.1 Policy Recommendations

Mozambique should invest in renewable energy, focusing on hydropower and solar, using its natural resources. Similarly, financial incentives and subsidies can attract investment. There is also a need to develop regulatory policies to expand renewables and reduce fossil fuel dependence. Additionally, the country needs to simplify approvals, enhance transparency, and cut bureaucracy. There is also a need to encourage public-private partnerships in clean energy with tax breaks or low-interest loans to reduce risks and boost confidence. Moreover, there is a need to integrate sustainability and climate resilience into national strategies. Lastly, the country needs to foster regional energy integration through the Southern African Power Pool, reducing energy insecurity and environmental stress.

3.2 Future Research Directions

Future studies could divide energy consumption by sector (e.g. agriculture, industry, residential) to better understand the drivers of energy demand and emissions in each segment. Incorporating variables such as governance quality, policy implementation capacity, public perception, and political stability could enrich the analysis of energy policy effectiveness. Conduct comparative studies with other Southern African countries to identify shared challenges and transferable policy solutions. This can help benchmark Mozambique's performance and promote regional learning. Assess the socio-economic impacts of a green energy transition, especially in terms of employment, income distribution, and social equity. Research should focus on designing inclusive energy policies that benefit vulnerable populations.

REFERENCES

1. Amoah, A., Amoah, B., Kwablah, E., & Asiama, R. K. (2025). Renewable energy transition and climate finance nexus in sub-Saharan Africa. *Global Environmental Change Advances*, *4*, 100013.
2. Chen, T. H., Chang, H. W., Mikhaylov, A., & Chang, T. (2025). Revisit energy consumption, economic growth and carbon dioxide emissions links in transition countries using a new developed Quantile_on_Quantile approach. *Applied Economics*, *57*(6), 583-599.
3. Come Zebra, E. I., Mahumane, G., Canu, F. A., & Cardoso, A. (2021). Assessing the greenhouse gas impact of a renewable energy feed-in tariff policy in Mozambique: towards NDC ambition and recommendations to effectively measure, report, and verify its implementation. *Sustainability*, *13*(10), 5376.
4. Cristóvão, L., Chichango, F., Massinga, P., & Macanguisse, J. (2021). The potential of renewable energy in Mozambique: an overview. *Journal of Energy Technologies and Policy*, *11*(2), 30-37.
5. Dai, J., Farooq, U., & Alam, M. M. (2025). Navigating energy policy uncertainty: Effects on fossil fuel and renewable energy consumption in G7 economies. *International Journal of Green Energy*, *22*(2), 239-252.
6. de Almeida, A., Quaresma, N., & Biosse, E. (2022). The role of energy efficiency and renewable energies to accelerate sustainable energy access—a perspective case study of Mozambique. *Energy Efficiency*, *15*(6), 36.
7. Kumari, D., Shashwat, S., Verma, P. K., & Giri, A. K. (2025). Examining the nexus between carbon dioxide emissions, economic growth, fossil fuel energy use, urbanization and renewable energy towards achieving environmental sustainability in India. *International Journal of Energy Sector Management*, *19*(3), 731-746.
8. Mahumane, G., & Mulder, P. (2019). Expanding versus greening? Long-term energy and emission transitions in Mozambique. *Energy Policy*, *126*, 145-156.

9. Miao, Y., Bukhari, A. A. A., Bukhari, W. A. A., Ahmad, S., & Hayat, N. (2025). Why fossil fuels stifle green economic growth? An environmental management perspective in assessing the spatial spillover impact of energy consumption in South Asia. *Journal of Environmental Management*, *373*, 123471.
10. Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American statistical Association*, *94*(446), 621-634.
11. Sahlian, D. N., Popa, A. F., & Creţu, R. F. (2021). Does the increase in renewable energy influence GDP growth? An EU-28 analysis. *Energies*, *14*(16), 4762.
12. Sharma, G. D., Verma, M., Shahbaz, M., Gupta, M., & Chopra, R. (2022). Transitioning green finance from theory to practice for renewable energy development. *Renewable Energy*, *195*, 554-565.