# The Linkage between Renewable Energy Consumption and Kenya's Services Sector: Energizing the Service Economy

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## ABSTRACT

This study sought to examine the influence of renewable energy consumption on the growth of Kenya's services sector. It covered the period from 1987 to 2023. Using the ARDL and ECM approaches, the analysis investigates both short-run and long-run dynamics while controlling for non-renewable energy consumption, labour and gross capital formation. The results reveal that immediate and lagged changes in renewable energy consumption have limited short-run effects on service sector output. However, the first lag of renewable energy consumption exhibits a positive and statistically significant impact in the ECM framework, thereby suggesting delayed benefits from the consumption of renewable energies. On the other hand, lagged non-renewable energy consumption consistently exerts negative and significant effects, thus highlighting the negative short-run influence of non-renewable energy consumption on the growth of the service sector. Labour and gross capital formation show mixed effects, with delayed positive contributions, thus reflecting gradual absorption of workforce and capital into the economy's productive processes. The ECM term is negative and highly significant, confirming a stable long-run equilibrium relationship with approximately 33.6% of deviations from equilibrium corrected each period. The Post-estimation diagnostics show the robustness of the model throughout the study period. Therefore, the results of this study suggest that Kenya's services sector exhibits low immediate reliance on energy inputs but benefits from lagged improvements in renewable energy consumption, capital investment and labour integration. The study emphasizes the importance of promoting renewable energy adoption in energizing Kenya's service economy. This adoption will also accelerate the attainment of Vision 2030's dreams of a globally competitive economy and achieving SDGs 7 and 8 of clean energy and sustained growth. This study therefore recommends anchoring the service sector's renewable energy transition within Kenya's Vision 2030 and the national green growth agenda, emphasizing targeted incentives for clean energy use in ICT, transport and hospitality. By aligning service sector electrification with ongoing energy reforms and digital infrastructure expansion, Kenya can enhance efficiency, reduce operational costs and also foster inclusive, sustainable growth.

**Keywords:** renewable energy consumption, service sector growth, service economy

## INTRODUCTION

The services sector has experienced an exponential growth worldwide, with a contribution of over 78.7 % of the global GDP. The important sector is mainly motivated by innovations in Information and Communication Technology, finance and healthcare (World Bank, 2021).

According to the World Bank. (2023), the services sector in Kenya has, over time, proved to be a key contributor to economic growth, employment and structural transformation in the society. Sectors such as financial services, ICT, hospitality and retail contribute significantly to GDP, yet their expansion is increasingly influenced by energy availability and reliability. With the ever-rising demand for electricity and a growing emphasis on sustainable development, renewable energy sources such as solar, wind, hydro and biomass have attracted attention as potential enablers of service sector growth and productivity.

Despite the gains associated with the consumption of renewable energies in Kenya, the services sector has remained relatively low in energy intensity compared to manufacturing. Hence, the contemporaneous impacts of renewable energy consumption on service sector output may be limited, while benefits may come along gradually through efficiency gains, reduction in operational costs and improved service reliability. On the other hand, the overdependence on non-renewable energy may introduce inefficiencies, environmental costs and volatility that suppress service sector growth.

Empirical evidence on the existing association between renewable energy consumption and service sector growth in Kenya is scarce. This study, therefore, seeks to address this gap by investigating both short-run and long-run effects while incorporating labour and gross capital formation as moderating factors and also employing the robust ARDL and ECM methodologies. Thus, this study provides important insights into how renewable energy adoption and consumption can energize the service economy while supporting sustainable economic development in Kenya.

## LITERATURE REVIEW

Apergis and Payne (2014) investigated the factors influencing renewable energy consumption per capita across seven Central American nations from 1980 to 2010. Using dynamic panel data models, its analysis revealed a long-term cointegrated relationship between renewable energy consumption per capita, real GDP per capita, carbon emissions per capita, real coal prices and real oil prices, with positive and statistically significant coefficients. However, the study acknowledged that the effects differed based on the countries' levels of development and energy infrastructure. One of the study's limitations was the inconsistency in data quality across the nations, which could potentially impact the reliability of the results. This study comes in handy to address the shortcomings of Apergis and Payne (2014) by exploring sufficient and econometrically plausible data sets from the EIA, WDI and KNBS for the period 1980-2023. There was also a need to specifically do a study that focuses on the services sector exclusively.

Sadorksy (2009) conducted one of the early studies on the relationship between renewable energy uptake and economic growth, focusing on the G7 nations: Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. Using panel data from 1980 to 2005, the study applied a panel cointegration method to assess how renewable energy generation impacts economic growth. The results indicated that, over the long term, real GDP per capita and $CO_2$ per capita were significant contributors to the consumption of renewable energy per capita. However, the study also noted that the effect was stronger in countries with more developed financial markets, suggesting that financial development could enhance the benefits derived from renewable energy generation. A notable limitation of the study was its relatively short data span, which may not fully capture longterm trends, potentially making the econometric conclusions less robust. This study exploited a sufficient 19802023 data set.

Guja-Huseynli (2023) aimed to investigate the relationship between energy consumption and the export of goods and services within Italy's service sector in Mediterranean countries, using data from 1997 to 2021. It made use of the panel data analysis method, which examines the relationship between the variables by evaluating data across multiple cross-sections and time periods to capture both individual and overall effects. The study found that a 1% rise in energy consumption resulted in a 27% boost in the output of the commercial services sector. The study, apart from being from a non-representative population compared to Kenya, treated energy consumption as an aggregate variable and by not isolate the effect of the renewables from the non-renewables. This study also sought to cure this geographical and economic stage-related heterogeneity.

In its analysis of the impact of renewable energy consumption on the productivity of transport service activities, Asvanyi *et al.* (2017), in Hungary, established the existence of a causality flowing from renewable energy usage to the output of the tourism services sector. The study exploited a content analysis method to systematically review and synthesize existing research publications on the use of renewable energy in the tourism industry. The analysis does not focus on a specific data period but examines literature available up to the time of the study. The study, however, was done in a country that possesses different economic and social conditions compared to Kenya. This study sought to mitigate these regional heterogeneities for the ease of replicability of the study outcomes to Kenya and its neighbours in the region.

Huseynli (2023), a panel analysis of the Mediterranean countries, with special attention to Italy, with a 19972021 dataset, established a strong positive correlation between energy usage and the export of commercial services at

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the 5% probability level. The study sought to establish the effects of exports of goods and services and energy consumption in Italy's service sector. The study also determined that a 1% increase in the consumption rate increased the service exports by approximately 27%. The study, though it tried to establish the magnitudes of the association between the variables, harbours the problem of first-degree aggregation. The study treated energy as an aggregate variable, making it harder to isolate the impact of renewable energy in particular. This body of knowledge exploited disaggregated data for Kenya to address the problem of aggregation of impacts.

Sadorsky (2011), in its quest to determine the relationship between financial development and energy consumption in Central and Eastern European frontier economies, established a significant correlation between financial sector growth and energy uptake. The study used a dynamic panel data approach with the generalized method of moments regression technique to analyze the impact of financial development on energy consumption in nine Central and Eastern European frontier economies over the period 1996 to 2006. A methodological limitation is that, while the panel GMM approach addresses endogeneity, the relatively short time span and limited number of countries may reduce the generalizability of the findings. In addition to coming from a country with a different level of economic and social development compared to Kenya, the study has issues of firstdegree aggregation. The study considered energy consumption as a collective measure, but it became clear that a more detailed breakdown was necessary to analyze the specific impact of each form of renewable energy separately. This study will also employ a robust methodology that will enable it to determine the magnitudes of the associations, an attribute that is lacking in Sadorsky (2011). This study, apart from seeking to mitigate the geographical heterogeneities, employed robust econometric tools to aid in determining the magnitudes of the interactions.

Farhani and Ozturk (2015), in its analysis of the Cause-and-effect relationship existing between Carbon emissions, real GDP, energy usage, financial services development, market openness and the level of urban development in Tunisia over the 1971-2012 period, established a significant cause-and-effect association flowing from energy usage and trade openness and financial services. The study employed the auto-regressive distributed lag bounds testing approach to cointegration and the error correction method to analyze the long-run and short-run relationships between $CO_2$ emissions, economic growth, energy consumption, financial development, trade openness and urbanization in Tunisia, providing a robust framework for capturing both immediate and lagged effects among the variables. Despite coming from an African economy that could be replicated in Kenya, the study treated energy as an aggregate variable. The magnitudes and intensities of the associations were also not established. The ARDL framework that was adopted by this study mitigated this problem.

Ali *et al.* (2015), in its investigation of the dynamics of the relationship among financial development, economic expansion, energy costs and energy usage in Nigeria, using a dataset for the 1972-2011 period while exploiting the ARDL framework, found a favourable link between energy consumption and the development of financial services. This set of findings is in consonance with the study results of Chang (2015), research that was done in 53 counties using data for the period 1999-2008. The studies, however, harbour the problem of first-degree aggregation as energy consumption was treated as an aggregate variable and not disaggregated into renewable and nonrenewable to establish their individual effects. The studies also did not determine the magnitudes of the association between the variables. This study exploited sector-specific data to alleviate the problem of aggregating the impacts.

## RESEARCH METHODOLOGY

For service sector growth, this study linearized and operationalized the Solow Swan's Cobb-Douglas function to yield;

$$Ln(SER_t) = LnA + \alpha_1 Ln(REC_t) + \alpha_2 Ln(NREC_t) + \alpha_3 Ln(K_t) + \alpha_4 Ln(L_t) + \beta_1 Ln(REC_{t-1}) + \beta_2 Ln(NREC_{t-1}) + \beta_3 Ln(K_{t-1}) + \beta_4 Ln(L_{t-1}) + \varepsilon_t \ldots\ldots\ldots (3.1)$$

$LnSER_t$ is the log of service sector output at time *t*, $Ln(REC_t)$ is logged renewable energy consumption at time *t*, $Ln(NREC_t)$ is logged non-renewable energy consumption at time *t*, $Ln(K_t)$ is logged capital at time *t*, $Ln(L_t)$ is logged labour at time *t*, $Ln(REC_{t-1})$ is lagged renewable energy consumption, $Ln(NREC_{t-1})$ is lagged nonrenewable energy consumption,$Ln(K_{t-1})$ is lagged capital, $Ln(L_{t-1})$ is lagged labour $\varepsilon_t$ is the error term while $LnA$ is logged total factor productivity.

# RESULTS AND DISCUSSION

## 4.1 Descriptive statistics

**Table 4:1 -Descriptive Statistics**

| | SER(“000000”) | REC | NREC(“000000”) | L(“{000000”) | GCF(“OF_GDP”) |
|---|---|---|---|---|---|
| Mean | 2210887. | 19791.70 | 0.137666 | 13.54270 | 20.09076 |
| Median | 1702686. | 16115.00 | 0.117500 | 12.73076 | 19.73131 |
| Maximum | 6244359. | 46600.00 | 0.242000 | 23.18485 | 25.44904 |
| Minimum | 384533.0 | 6000.000 | 0.072000 | 5.341202 | 15.00382 |
| Std. Dev. | 1796011. | 10732.72 | 0.057575 | 5.556273 | 2.956138 |
| Skewness | 0.667653 | 0.900081 | 0.577631( | 0.205444 | 0.087421 |
| Kurtosis | 2.159982 | 2.769333 | 1.841721 | 1.682008 | 2.157324 |
| Jarque-Bera | 4.562566 | 6.038611 | 4.906443 | 3.494208 | 1.357899 |
| Probability | 0.102153 | 0.048835 | 0.086016 | 0.174278 | 0.507149 |
| Sum | 97279025 | 870835.0 | 6.057312 | 595.8787 | 883.9934 |
| Sum Sq. Dev. | 1.39E+14 | 4.95E+09 | 0.142540 | 1327.503 | 375.7664 |
| Observations | 44 | 44 | 44 | 44 | 44 |

(Source: Author,2025)

Table 4:1 highlights the descriptive statistics for the study variables, highlighting Kenya’s economic dynamics across the services sector, energy consumption, gross capital formation and labour. The services sector recorded the highest average output of 2.21 trillion with large variability, reflecting strong but uneven growth driven by telecommunications, finance and tourism. Renewable energy consumption averaged 19791.70 kilowatt-hours, showing gradual expansion tied to geothermal and hydropower investments, while non-renewable consumption averaged 137666.2 kilowatt-hours, indicating continued dependence on non-renewable energies. Labour steadily expanded from 5.34 million to 23.18 million, supporting sectoral productivity and gross capital formation remained stable at about 20% of GDP, signifying sustained investment in infrastructure. The statistics portray Kenya’s structural transformation, where service-led growth, renewable energy expansion, demographic momentum and steady capital investment collectively shape the country’s economic performance.

**Stationarity Test Results: The Augmented Dickey-Fuller (ADF)**

**Table 4:2-ADF Results**

Null hypothesis: Variable has a unit root Lag length: Automatic based on AIC, maximum lags of 10

| | ADF | | |
|---|---|---|---|
| | Level | First Difference | CONCLUSION |
| Variable | Trend & Intercept | Trend & Intercept | |
| SER | -0.027932 (0.9946) | -6.415405 ( 0.0000) | I (1) |
| REC | -2.148084 (0.5053) | -5.148163 (0.0008) | I (1) |
| NREC | -2.591905 (0.2858) | -6.793060 (0.0000) | I (1) |
| L | -3.558792 (0.0494) | -2.925557 ( 0.1665) | I (0) |
| GCF____OF_GDP | -2.754643 (0.2212) | -5.703648 (0.0002) | I (1) |

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(Source: Author, 2025)

Table 4.2 displays the ADF stationarity test results, which were conducted to confirm the suitability of the data for ARDL modelling. The test, based on trend and intercept specifications with lag lengths selected automatically using the AIC criterion, shows that services sector output, renewable and non-renewable energy consumption and gross capital formation are non-stationary at level but become stationary after first differencing, indicating they are integrated of order one. Labour, however, is stationary at level and therefore integrated of order zero. This combination of I(0) and I(1) variables meets the key requirement for ARDL analysis, confirming that the dataset is appropriate for further modelling and cointegration testing.

**Lag Length Determination**

Lag length selection was automatically determined in the ARDL framework using the AIC, enabling EViews to identify and retain optimal lags for both long-run and short-run estimations that balanced model fit, simplicity and captured essential time series dynamics.

**ARDL Analysis: Influence of Renewable Energy Consumption on the growth of the service sector in Kenya, ARDL Test**

**Table 4:3-Influence of renewable energy consumption on the growth of the service sector in Kenya, ARDL Results**

| | | | | |
|---|---|---|---|---|
| Dependent Variable: SER | | | | |
| Method: ARDL | | | | |
| Date: 07/08/25 Time: 18:19 | | | | |
| Sample (adjusted): 1987 2023 | | | | |
| Included observations: 37 after adjustments | | | | |
| Maximum dependent lags: 1 (Automatic selection) | | | | |
| Model selection method: Akaike info criterion (AIC) | | | | |
| Dynamic regressors (7 lags, automatic): REC NREC L GCF | | | | |
| Fixed regressors: C | | | | |
| Number of models evaluated: 4096 | | | | |
| Selected Model: ARDL(1, 2, 7, 6, 7) | | | | |
| Variable | Coefficient | Std. Error | t-Statistic | Prob.* |
| SER(-1) | 0.664213 | 0.089307 | 7.437408 | 0.0000 |
| REC | -0.047690 | 0.062948 | -0.757614 | 0.4681 |
| REC(-1) | -0.062553 | 0.062446 | -1.001705 | 0.3427 |
| REC(-2) | -0.086788 | 0.066445 | -1.306153 | 0.2239 |
| NREC | 0.062975 | 0.147262 | 0.427638 | 0.6790 |
| NREC(-1) | 0.038844 | 0.163764 | 0.237194 | 0.8178 |
| NREC(-2) | 0.001930 | 0.159423 | 0.012107 | 0.9906 |
| NREC(-3) | 0.187063 | 0.113291 | 1.651183 | 0.1331 |
| NREC(-4) | 0.104352 | 0.104412 | 0.999423 | 0.3437 |
| NREC(-5) | 0.052797 | 0.126997 | 0.415736 | 0.6873 |
| NREC(-6) | 0.147830 | 0.137450 | 1.075523 | 0.3101 |
| NREC(-7) | 0.180283 | 0.137074 | 1.315221 | 0.2210 |
| L | -1.697547 | 1.683587 | -1.008292 | 0.3397 |
| L(-1) | 3.461967 | 2.248152 | 1.539917 | 0.1580 |
| L(-2) | -2.400143 | 2.715268 | -0.883944 | 0.3997 |
| L(-3) | 2.596697 | 3.164367 | 0.820605 | 0.4331 |
| L(-4) | -5.098466 | 3.014654 | -1.691228 | 0.1250 |
| L(-5) | 7.471600 | 3.766419 | 1.983741 | 0.0786 |

| | | | | |
|---|---|---|---|---|
| L(-6) | -4.125360 | 2.016190 | -2.046117 | 0.0711 |
| GCF | -0.163212 | 0.087559 | -1.864013 | 0.0952 |
| GCF(-1) | 0.093203 | 0.086100 | 1.082496 | 0.3072 |
| GCF(-2) | -0.195631 | 0.104918 | -1.864612 | 0.0951 |
| GCF(-3) | -0.004875 | 0.092609 | -0.052645 | 0.9592 |
| GCF(-4) | -0.085174 | 0.078270 | -1.088203 | 0.3048 |
| GCF(-5) | -0.040588 | 0.085333 | -0.475640 | 0.6457 |
| GCF(-6) | -0.069592 | 0.087297 | -0.797181 | 0.4459 |
| GCF(-7) | -0.216104 | 0.093541 | -2.310266 | 0.0462 |
| C | 0.938226 | 1.418640 | 0.661356 | 0.5250 |
| R-squared | 0.999725 | Mean dependent var | | 28.26516 |
| Adjusted R-squared | 0.998898 | S.D. dependent var | | 0.842175 |
| S.E. of regression | 0.027951 | Akaike info criterion | | -4.216902 |
| Sum squared resid | 0.007031 | Schwarz criterion | | -2.997829 |
| Log likelihood | 106.0127 | Hannan-Quinn criter. | | -3.787121 |
| F-statistic | 1210.116 | Durbin-Watson stat | | 2.509992 |
| Prob(F-statistic) | 0.000000 | | | |
| *Note: p-values and any subsequent tests do not account for model selection. | | | | |

(Source: Author, 2025)

The ARDL model in Table 4:3 for the service sector was estimated using 37 adjusted observations spanning from 1987 to 2023. Model selection was based on the AIC Criterion, resulting in an optimal ARDL (1, 2, 7, 6, 7) structure. This includes one lag of the service sector output, two lags of renewable energy consumption, seven lags of non-renewable consumption, six lags of labour and seven lags of gross capital formation.

The lag of service sector output, SER (-1), has a coefficient of 0.664213, a standard error of 0.089307, a t-statistic of 7.437408 and a p-value of 0.0000. This coefficient is statistically significant at the 1% level and implies that a 1% increase in past service output results in a 0.664% increase in current output. This strong positive inertia suggests that the service sector in Kenya exhibits persistent growth patterns, possibly driven by repeat consumption, business continuity and recurring service contracts.

Renewable energy consumption enters the model with three terms. The contemporaneous coefficient of REC is -0.047690, a standard error of 0.062948, a t-statistic of -0.757614 and a p-value of 0.4681. This is statistically insignificant, implying that current renewable energy use has no immediate effect on service sector output. The first lag, REC (-1), has a coefficient of -0.062553, a t-statistic of -1.001705 and a p-value of 0.3427, also statistically insignificant. The second lag, REC (-2), shows a slightly stronger negative coefficient of -0.086788, a standard error of 0.066445, a t-statistic of -1.306153 and a p-value of 0.2239, but it too is statistically insignificant. These results imply that changes in renewable energy consumption, whether current or up to two years' prior, do not significantly affect Kenya's service sector output in the short or medium term. This may be due to the relatively lower energy intensity of services compared to manufacturing or due to widespread reliance on non-renewable power sources in service-based businesses.

Non-renewable energy consumption enters with eight terms, none of which are statistically significant. The contemporaneous coefficient of NREC is 0.062975 with a p-value of 0.6790, while the most impactful lag, NREC (-3), has a coefficient of 0.187063 and a t-statistic of 1.651183 but a p-value of 0.1331, falling short of conventional significance levels. The remaining lags, from NREC (-1) to NREC (-7), all have p-values above 0.2. These findings indicate that non-renewable energy consumption does not significantly influence service sector output in either the short or lagged terms. One possible explanation is that most service-based activities in Kenya, such as retail, communication, hospitality and financial services are less dependent on heavy energy inputs and more reliant on ICT, human capital or small-scale infrastructure.

Labour appears with seven lagged terms. The contemporaneous effect of L is -1.697547, with a standard error of 1.683587, a t-statistic of -1.008292 and a p-value of 0.3397, which is statistically insignificant. Most lags remain insignificant, except for L(-5), which has a coefficient of 7.471600, a standard error of 3.766419, a tstatistic of 1.983741 and a p-value of 0.0786. This is marginally significant at the 10% level and suggests that a 1% increase in labour input five years ago raises current service sector output by approximately 0.747%. While the delayed effect is notable, it could reflect long-term capacity-building, institutional hiring cycles or skill development periods before labour becomes fully productive in service delivery.

Labour lag six, L(-6), is also marginally significant with a coefficient of -4.125360, a standard error of 2.016190,a t-statistic of -2.046117 and a p-value of 0.0711. This implies that a 1% increase in labour input six years ago led to a 0.412% decline in current service output. The conflicting effects between L(-5) and L(-6) suggest the presence of structural inefficiencies, mismatch in skills or overstaffing challenges common in public service or informal sector employment.

Gross capital formation is included with eight terms. The contemporaneous effect, GCF, has a coefficient of 0.163212, a standard error of 0.087559, a t-statistic of -1.864013 and a p-value of 0.0952, statistically significant at the 10% level. This suggests that a 1% increase in gross capital formation this year leads to a 0.163% decline in service output, possibly due to capital being allocated toward fixed assets or sectors that don’t immediately generate service returns.

The second lag, GCF (-2), shows similar magnitude and significance, with a coefficient of -0.195631, a t-statistic of -1.864612 and a p-value of 0.0951. These short-run negative effects may indicate that capital investments are being diverted into longer-term projects with delayed productivity. However, the seventh lag, GCF (-7), is statistically significant at the 5% level, with a coefficient of -0.216104, a standard error of 0.093541, a t-statistic of -2.310266 and a p-value of 0.0462. This suggests that a 1% increase in gross capital formation seven years ago is associated with a 0.216% decrease in current service sector output, which could reflect misaligned investments, crowding out of operational spending or overinvestment in underutilized service infrastructure.

The constant term is 0.938226 with a standard error of 1.418640, a t-statistic of 0.661356 and a p-value of 0.5250, indicating statistical insignificance.

Generally, the model exhibits high explanatory power. The R-squared is 0.999725 and the adjusted R-squared is 0.998898, meaning that 99.9% of the variation in service sector output is explained by the model. The Fstatistic is 1210.116 with a p-value of 0.000000, confirming joint significance. The D-W statistic of 2.509992 indicates no autocorrelation. The standard error of regression is 0.027951.

The ARDL results indicate that neither renewable nor non-renewable energy consumption exerts a significant short or medium-term influence on service sector output, consistent with the relatively low energy intensity of service-based activities, which rely more on human capital and technology than on direct energy inputs. Labour demonstrates only weak lagged significance, suggesting that employment effects take time to materialize, possibly due to skill mismatches or slow integration into service activities. Gross capital formation displays delayed negative effects, which may reflect structural rigidities, misallocation of resources or inefficiencies in translating investments into service sector growth. These findings underscore the sector’s limited dependence on energy while highlighting challenges in labour and capital absorption.

**Influence of renewable energy consumption on the growth of the service sector in Kenya, ARDL Error Correction Regression**

**Table 4:4-Influence of renewable energy consumption on the growth of the service sector in Kenya, ARDL Error Correction Regression**

| | | |
|---|---|---|
| ARDL Error Correction Regression | | |
| Dependent Variable: D(SER) | | |
| Selected Model: ARDL(1, 2, 7, 6, 7) | | |

| | | | | |
|---|---|---|---|---|
| Case 3: Unrestricted Constant and No Trend | | | | |
| Date: 07/08/25 Time: 18:20 | | | | |
| Sample: 1980 2023 | | | | |
| Included observations: 37 | | | | |
| ECM Regression | | | | |
| Case 3: Unrestricted Constant and No Trend | | | | |
| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
| C | 0.938226 | 0.122995 | 7.628143 | 0.0000 |
| D(REC) | -0.047690 | 0.034674 | -1.375399 | 0.2023 |
| D(REC(-1)) | 0.086788 | 0.034456 | 2.518834 | 0.0328 |
| D(NREC) | 0.062975 | 0.078117 | 0.806156 | 0.4409 |
| D(NREC(-1)) | -0.674256 | 0.141492 | -4.765326 | 0.0010 |
| D(NREC(-2)) | -0.672326 | 0.117618 | -5.716162 | 0.0003 |
| D(NREC(-3)) | -0.485263 | 0.116880 | -4.151800 | 0.0025 |
| D(NREC(-4)) | -0.380910 | 0.109201 | -3.488171 | 0.0068 |
| D(NREC(-5)) | -0.328113 | 0.104593 | -3.137047 | 0.0120 |
| D(NREC(-6)) | -0.180283 | 0.099407 | -1.813586 | 0.1031 |
| D(L) | -1.697547 | 0.964991 | -1.759132 | 0.1124 |
| D(L(-1)) | 1.555674 | 1.082359 | 1.437299 | 0.1845 |
| D(L(-2)) | -0.844470 | 1.378133 | -0.612764 | 0.5552 |
| D(L(-3)) | 1.752227 | 1.392838 | 1.258026 | 0.2400 |
| D(L(-4)) | -3.346240 | 1.432182 | -2.336463 | 0.0443 |
| D(L(-5)) | 4.125361 | 1.455708 | 2.833920 | 0.0196 |
| D(GCF) | -0.163212 | 0.051174 | -3.189370 | 0.0110 |
| D(GCF(-1)) | 0.611964 | 0.087589 | 6.986739 | 0.0001 |
| D(GCF(-2)) | 0.416333 | 0.086574 | 4.808997 | 0.0010 |
| D(GCF(-3)) | 0.411458 | 0.084154 | 4.889331 | 0.0009 |
| D(GCF(-4)) | 0.326284 | 0.082421 | 3.958757 | 0.0033 |
| D(GCF(-5)) | 0.285696 | 0.073996 | 3.860941 | 0.0038 |
| D(GCF(-6)) | 0.216104 | 0.062301 | 3.468689 | 0.0071 |
| CointEq(-1)* | -0.335787 | 0.042573 | -7.887352 | 0.0000 |
| R-squared | 0.917138 | Mean dependent var | | 0.068172 |
| Adjusted R-squared | 0.770535 | S.D. dependent var | | 0.048550 |
| S.E. of regression | 0.023257 | Akaike info criterion | | -4.433118 |
| Sum squared resid | 0.007031 | Schwarz criterion | | -3.388198 |
| Log likelihood | 106.0127 | Hannan-Quinn criter. | | -4.064735 |
| F-statistic | 6.255935 | Durbin-Watson stat | | 2.509992 |
| Prob(F-statistic) | 0.000684 | | | |
| * p-value incompatible with t-Bounds distribution. | | | | |

(Source: Author, 2025)

The ECM results for the services sector, estimated under ARDL (1, 2, 7, 6, 7), are as reported in Table 4:4. The constant term has a coefficient of 0.938226 with a standard error of 0.122995, a t-statistic of 7.628143 and a probability value of 0.0000. This coefficient is positive and statistically significant, implying that, even after accounting for the explanatory variables, there exists an underlying positive drift in short-run changes of service sector output during the sample period. This suggests that the service sector exhibits a consistent upward momentum beyond the energy, labour and capital factors included in the model.

With respect to renewable energy consumption, the contemporaneous change D(REC) has a coefficient of 0.047690 with a standard error of 0.034674, a t-statistic of -1.375399 and a probability value of 0.2023. This result is statistically insignificant, implying that immediate changes in renewable energy consumption do not exert a reliable short-run influence on the growth of the services sector. However, the one-period lagged change D(REC(-1) carries a coefficient of 0.086788, a standard error of 0.034456, a t-statistic of 2.518834 and a probability of 0.0328. This lagged coefficient is statistically significant at the 5% level, suggesting that renewable energy consumption exerts delayed positive effects on service output. The implication is that increases in renewable energy usage may take time to diffuse through the economy, eventually supporting service activities in the subsequent period through enhanced efficiency, reduced costs or improved energy reliability.

Turning to non-renewable energy consumption, the current change D(NREC) yields a coefficient of 0.062975, with a standard error of 0.078117, a t-statistic of 0.806156 and a probability value of 0.4409. This is not statistically significant, indicating no immediate short-run effect of non-renewable consumption on the services sector. On the other hand, several lagged terms are both negative and significant. D(NREC(-1) has a coefficient of -0.674256, a standard error of 0.141492,a t-statistic of -4.765326, a probability of 0.0010, while D(NREC(2) records a coefficient of -0.672326, standard error of 0.117618,a t-statistic -5.716162 and a probability of 0.0003. Both effects are strongly negative and highly significant, showing that past increases in non-renewable energy consumption hinder subsequent growth in services. Similarly, D(NREC(-3) is -0.485263 with a probability of 0.0025, D(NREC(-4) is -0.380910 with a probability of 0.0068 and D(NREC(-5) is -0.328113 with a probability of 0.0120, all negative and statistically significant. These results reveal a consistent pattern where higher non-renewable energy consumption in earlier periods reduces the service sector's short-run growth performance. By the sixth lag, D(NREC(-6) is -0.180283 with a probability of 0.1031, which is not statistically significant, suggesting the delayed negative effect gradually diminishes. The observed pattern may be attributed to the higher costs, environmental externalities and structural inefficiencies associated with heavy reliance on fossil fuels, which undermine the dynamism of the services sector after short time lags.

Labour dynamics in the short run show a more mixed effect. The contemporaneous change D(L) is -1.697547 with a standard error of 0.964991, a t-statistic of -1.759132 and a probability of 0.1124, which is statistically insignificant. Similarly, the first lag D(L(-1) of 1.555674 with a probability of 0.1845, the second lag D(L(-2) of -0.844470 with a probability of 0.5552 and the third lag D(L(-3) of 1.752227 and a probability of probability 0.2400 are all insignificant. However, significant effects emerge at longer lags. The fourth lag D(L(-4) records 3.346240 with a probability of 0.0443, indicating a statistically significant negative impact on service sector growth, possibly due to mismatches or inefficiencies in labour allocation that surface with delay. On the other hand, the fifth lag D(L(-5) carries a positive coefficient of 4.125361, a t-statistic of 2.833920 and a probability of 0.0196, making it statistically significant. This suggests that service sector growth benefits from earlier labour changes once the workforce has been absorbed, trained or better utilized.

Gross capital formation exhibits contrasting short-run effects. The contemporaneous change D(GCF) is 0.163212 with a probability of 0.0110, which is statistically significant and negative. This suggests that immediate increases in capital investment may temporarily disrupt service activities, possibly due to adjustment costs or diversion of resources into long-term projects. In contrast, the lagged terms are consistently positive and highly significant. D(GCF(-1) is 0.611964 with a probability of probability 0.0001, D(GCF(-2) is 0.416333 with a probability of 0.0010, D(GCF(-3) is 0.411458 with a probability of 0.0009, D(GCF(-4) is 0.326284 with a probability of probability 0.0033, D(GCF(-5) is 0.285696 with a probability of 0.0038 and D(GCF(-6) is 0.216104 with a probability of 0.0071. These results indicate that capital investment exerts strong positive effects on service output after one to six periods, highlighting the delayed productivity gains from infrastructural projects and capital expansion in the sector.

The ECM term CointEq(-1) is -0.335787 with a standard error of 0.042573, a t-statistic of -7.887352 and a probability of 0.0000. This is negative and highly significant, confirming the existence of long-run equilibrium relationships among the variables. The coefficient indicates that approximately 33.6% of any deviation from the long-run equilibrium is corrected in each period. This moderate speed of adjustment suggests that shocks in the service sector converge back to equilibrium over three to four periods.

The overall goodness of fit of the model is strong, with an R-squared value of 0.917138 and an adjusted Rsquared

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of 0.770535. This means that about 91.7% of the variation in service sector growth is explained by the model and even after adjusting for degrees of freedom, the explanatory power remains high at 77.1%. The standard error of regression is 0.023257, indicating that residuals are tightly distributed around the fitted values. The F-statistic of 6.255935, with an associated probability of 0.000684, confirms that the model is jointly significant. The D-W statistic of 2.509992 suggests that the model is free from serious autocorrelation problems, strengthening the reliability of the estimates.

**Influence of renewable energy consumption on the growth of the service sector in Kenya, F-Bounds Test**

**Table 4:5-Influence of renewable energy consumption on the growth of the service sector in Kenya, F-Bounds Test**

| F-Bounds Test | | Null Hypothesis: No levels relationship | | |
|---|---|---|---|---|
| Test Statistic | Value | Signif. | I(0) | I(1) |
| F-statistic | 8.613738 | 10% | 2.45 | 3.52 |
| K | 4 | 5% | 2.86 | 4.01 |
| | | 2.5% | 3.25 | 4.49 |
| | | 1% | 3.74 | 5.06 |

(Source: Author, 2025)

The ARDL bounds test in Table 4:5 reports an F-statistic of 8.613738, which is well above the 1% upper critical value of 5.06. This confirms a long-run cointegrating relationship between services output and the explanatory variables, validating the use of ARDL and ECM frameworks.

**Post Diagnostic Tests**

**Test for Normality**

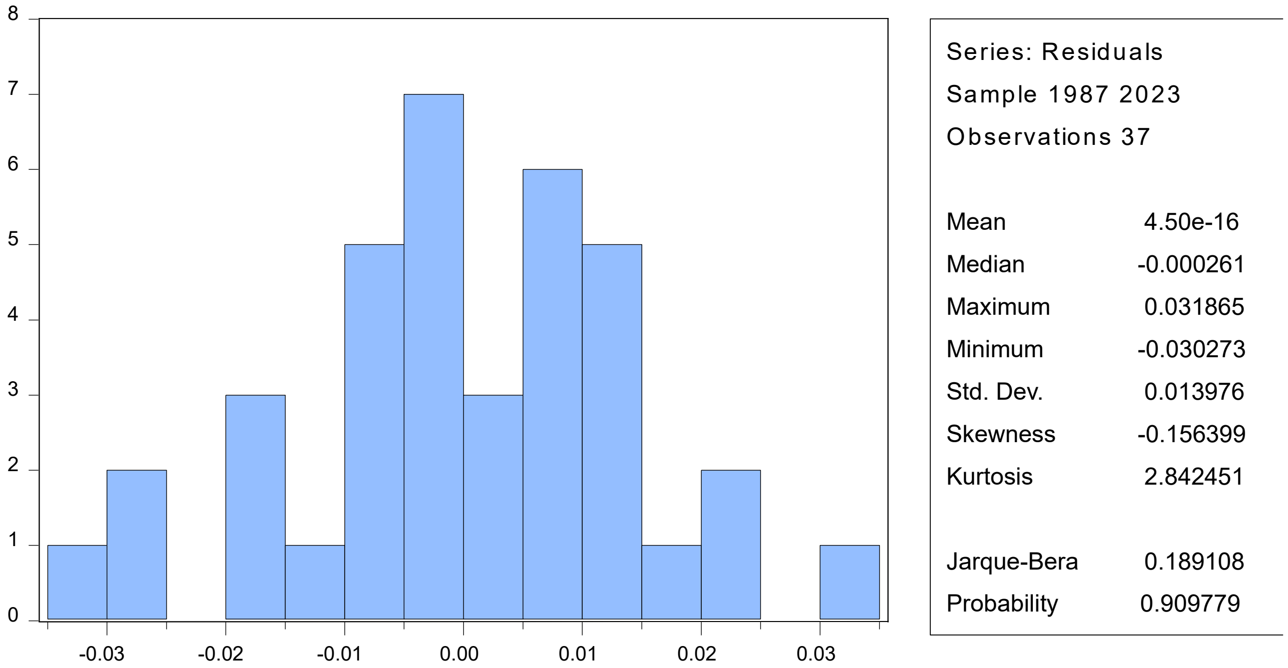


**Figure 4:1-Influence of renewable energy consumption on the growth of the service sector in Kenya, J-B Normality Test**

(Source: Author, 2025)

As per the results in Figure 4:1, with a p-value of 0.909779, it was concluded that the residuals were normally distributed.

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### 4.7.2 Test for Serial Correlation

**Table 4:2-Influence of renewable energy consumption on the growth of the service sector in Kenya, Breusch Godfrey serial Correlation LM Test**

| Breusch-Godfrey Serial Correlation LM Test: | | | |
|---|---|---|---|
| F-statistic | 1.503499 | Prob. F(2,7) | 0.2863 |
| Obs*R-squared | 11.11811 | Prob. Chi-Square(2) | 0.0039 |

(Source: Author, 2025)

The Breusch-Godfrey LM test in Table 4:42 has an F-statistic of 1.503499 and a p-value of 0.2863, indicating no significant serial correlation. However, the observed R-squared statistic shows a p-value of 0.0039, which may raise caution. Nonetheless, the D-W value of 2.51 supports the absence of autocorrelation in practice.

### 4.7 .3 Test for Heteroskedasticity

**Table 4:6-Influence of renewable energy consumption on the growth of the service sector in Kenya, Heteroskedasticity Test: Breusch-Pagan-Godfrey**

| Heteroskedasticity Test: Breusch-Pagan-Godfrey | | | |
|---|---|---|---|
| F-statistic | 0.964648 | Prob. F(27,9) | 0.5623 |
| Obs*R-squared | 27.49807 | Prob. Chi-Square(27) | 0.4372 |
| Scaled explained SS | 1.498821 | Prob. Chi-Square(27) | 1.0000 |

(Source: Author, 2025)

The Breusch-Pagan-Godfrey test in Table 4:6 indicates no heteroskedasticity, with an F-statistic of 0.964648 and a p-value of 0.5623 and Chi-square p-values above 0.4372. Residual variance appears stable.

Cumulative Sum of Recursive Residuals (CUSUM) Stability Test

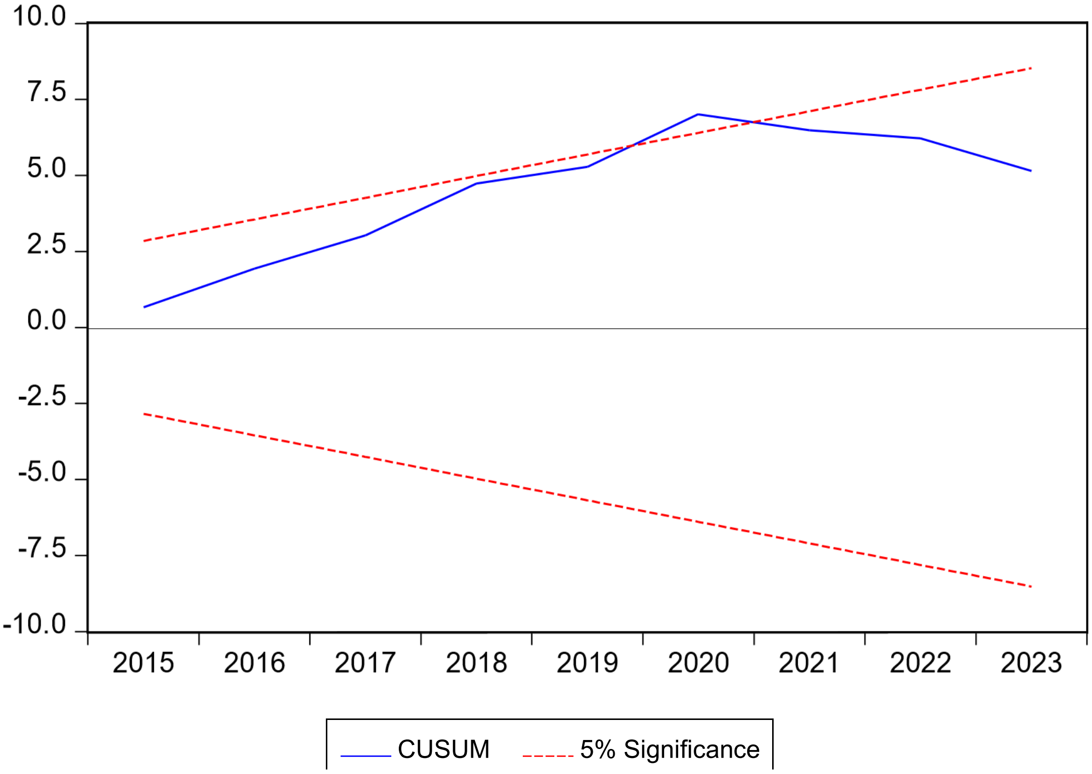


**Figure 4:2-Influence of renewable energy consumption on the growth of the service sector in Kenya, CUSUM Stability Test**

(Source: Author, 2025)

The CUSUM test results in Figure 4:2 show that recursive residuals stay within the 5% confidence bands, confirming structural stability of the model across the study period.

## CONCLUSION AND POLICY IMPLICATIONS

In the services sector, renewable energy consumption does not affect output immediately but exhibits a delayed positive contribution after one year. This finding reflects the time required for renewable energy investments to diffuse into service delivery systems, such as telecommunications or finance, where operational benefits manifest gradually. On the other hand, non-renewable energy consumption exerts persistently negative lagged effects across multiple periods, confirming that non-renewable energy dependence undermines service performance through higher costs, inefficiencies and environmental constraints. Labour effects are mixed, with mostly insignificant coefficients, though delayed positive contributions suggest that skill absorption and retraining eventually improve productivity. Gross capital formation initially suppresses service growth, likely due to adjustment costs, but delivers strong and consistent positive impacts across several lags, highlighting its role as a delayed driver of productivity once infrastructural projects mature. The service sector corrects about 34% of disequilibrium each year, implying a slower speed of adjustment compared to agriculture and manufacturing, though still sufficient to ensure eventual rebalancing.

Policy interventions should prioritize integrating renewable energy into Kenya's service sector through targeted fiscal incentives, improved grid reliability and decentralized clean energy systems that support ICT, finance, transport and tourism. Aligning these initiatives with Vision 2030 and the National Energy Policy will not only lower operational costs but also enhance productivity, sustainability and competitiveness in a sector that increasingly drives Kenya's economic transformation.

## LIMITATIONS OF THE STUDY

This body of knowledge was limited by its reliance on secondary time series data, which may not fully capture informal renewable energy use and other unrecorded service sector activities.

## AREAS FOR FURTHER RESEARCH

This study sought to make it possible to have sector-specific energy interventions. More areas of research could imply future studies exploring panel data of the East Africa region so as to inform a common energy policy for the region since many of the energy dynamics in the region are the same.

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