# Original Research Article

# Renewable Energy Consumption and Economic Growth in Uganda

This paper concerns itself with the relationship of renewable energy consumption on economic growth in Uganda using data of 1990-2015. Uganda is gifted with renewable energy resources and should be exploring the possibility of meeting the Sustainable Development Goal 7.
This paper uses autoregressive distributive lag, the augmented Dickey Fuller test for stationarity while for cointegration the Johansen, Phillips and Perron tests were used. The Granger Wald test was used to test for causality between the variables of interest.
The findings indicate a negative relationship between renewable energy and economic growth. While a positive relationship exist between Gross Domestic Product and gross capita formation, electricity trade Foreign Direct Investment and Trade Openness that are taken as controls of this model.
In conclusion therefore, Uganda need to pursue clean energy policies, while expanding its electricity trade in the East African community in order to absorb the excess electricity supply over peak domestic consumption. This paper will also increase the understanding on the need to integrate energy markets with in the region for greater benefits.

*Keywords: (Nuclear energy, clean energy, drivers, barriers, Uganda)*



## 1. INTRODUCTION

### 1.1 Preamble

Energy is vital determinant of economic growth. It stimulates investment, income and employment through the multiplier effect[1]. Following a steady rise in the global consumption of crude oil and rising emission of greenhouse gases (GHGs) with its attendant challenges, there is an unprecedented effort to step up the consumption of renewable energy and promote sustainable growth and development [2]. Although studies on renewable energy consumption and economic growth have been done [3]Tugcu and Topcu 2018, [4]Vo et al., 2019, [5] Zafar et al. 2019, [6] Adjarwati et al., 2020, [7] Halkos and Gkampoura (2021), none of those was carried out on Uganda. Related studies carried out for the case of Uganda are associated with Electricity consumption and Economic growth in Uganda [8], [9],[10],[11],[12]. The renewable energy question was still left unanswered, this study therefore seeks to unveil the peculiar relationship between renewable energy consumption and economic growth for the case of Uganda and how this interplay promotes decision making regarding sustainable growth and development.

This enquiry seeks to investigate the direction of causality of renewable energy on economic growth in Uganda; with a view of informing policy. With Uganda's renewable energy (RE) arising from traditional biomass and renewable electricity, it is not clear how this consumption mix impacts on economic growth. Traditional biomass refers to inefficient use

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of fuel wood, charcoal, tree leaves, and agricultural residues for cooking, lighting and space heating [13]. This perpetrates indoor air pollution (IAP) leading to adverse health p concerns such as respiratory tract diseases, and other chronic pulmonary diseases [14], [15]. Biomass has the potential of providing clean and efficient energy in the future in Uganda as it is in developed countries [16], [17].

Large foreign investments into renewable energy infrastructure, generation and consumption has been done with a view that this will promote rapid economic growth [18]. The large foreign investments into renewable energy leads to increased public debt, so its impact on economic growth in Uganda is not clearly known. The complexity of the energy system in Uganda and how renewable energy resources are extracted and developed warrants this study [19]. Therefore, the increased interest of Multinational corporations to invest in Uganda's renewable energy sector and how this interplays with economic growth is a subject of investigation of this paper.

This study is motivated by the possibility of 100% RE mix, the need to achieve sustained growth and development that heavily relies on clean energy [20]. The need to transition from traditional biomass to cleaner energy sources while maximising growth dividends. This should rely on quality decision making that puts into account the dynamic causal relationship between RE and economic growth for which this paper investigates.



## 1.2 Aims/ Objective

The main aim of this study is to investigate the relationship between renewable and non-renewable energy and economic growth, while specific objectives include to:

(i) Analyse the trend of RE consumption and economic growth in Uganda
(ii) Investigate the relationship between RE consumption and economic growth in Uganda
(iii) To investigate how existing RE policy influences economic growth in Uganda.

## 1.3 Research Questions

(i) What is the trend of RE and economic growth in Uganda
(ii) What is the relationship between RE consumption and economic growth in Uganda
(iii) How does RE policy influence economic growth in Uganda

## 1.4 Renewable energy consumption in Uganda

Uganda's current energy matrix is 89% from renewable sources. From all electricity sources, 92% is from renewable energy sources. 68% is from large hydro, 12 from small hydro power projects, 8% from bagasse co-generational while 4% is from solar PV [20]. Efforts to increase hydro power include the 600MW Karuma dam construction, which is 97% complete. Relying of hydro power with over 80% of the electricity mix presents a risk in case of fluctuations in the water levels of L. Victoria and consequently R. Nile as was the case in 2006. There is therefore need to diversify to other renewable energy sources for sustained economic growth. The renewable energy policy of 2007 was crafted to increase electricity access from 4 in 2006 to 42 % by 2020 using renewable energy resources. The biomass dominates this mix with 87% of overall energy mix. Most of the residential cooking energy is got from fuel wood and charcoal.

Uganda's renewable energy potential is mainly Hydro (4500MW), biomass (2500MW), solar (5000MW), wind and geothermal (1500 MW) constitute 33% of the overall energy mix. Yet the consumption mix is 87% this shows a fair consideration of renewable energy. But little information exists on how RE drives growth amidst plenty of energy resources yet nuclear and thermal energy constitute 57% and 10% respectively. It is important that rational decisions are made based on existing information to yield the greatest outcome for sustainable growth and development.

### 1.5 Contribution

The contribution of this paper is to use a multivariate framework of analysis with labour and capital as controls to avoid an omitted variables bias, that many bivariate models are riddled with [21].

Secondly, we used a more robust methodology of auto regressive distributed lag (ARDL), were a long run relationship existed among variables with Phillips Perron cointegration, and Granger causality procedure to analyse a dynamic causal relation among variables and with an intention to make a contribution to the theory of methodology [22].

Thirdly is contribution to empirical literature on the dynamic relationship between RE and economic growth as a developing country perspective. No country study has been undertaken to the best of our knowledge. It is this knowledge gap that this study seeks to fill.

Finally, the practical contribution to policy makers in appreciating and implementing an appropriate policy for REC, which will remove the country from a lacuna such that it improves rather than worsen the pre-existing situation. If it is energy portfolio diversification against efficiency goals then it must follow a rigorous and well-argued debate.

The remainder of this papers composed of empirical framework in section 2 with research hypothesis, literature on Renewable energy consumption and economic growth, methods in section three, findings and discussion in section 4, conclusions and policy implications in section 5.

## 2. Empirical framework

Literature to appreciate the role of energy consumption on economic growth exists [23], [24],[25], while others demonstrate that overutilization environmental resources reduces the role of energy consumption on economic growth [27]. When the economy is growing energy consumption will shift to less energy intensive activities like from industry to service where energy consumption lowers economic growth [3]. The more the debate is analysed, the more controversial it gets; what seems to be emerging with consensus is that renewable energy sources generally emit less GHGs than non-renewable energy resources therefore causing les environmental degradation. The debate on REC and Economic growth is a highly contested debate. With conflicting results, a need to make more and deeper inquiries at country and cross country studies is timely in order to come up with unified views and logical explanations on causality between these two variables of study. The debate is far from over and with increased adoration of REC as a futuristic energy option then this debate needs to be treated as both important and urgent. With important lessons not only for Uganda, but many countries of Sub Saharan Africa (SSA).

### 2.1 Research hypothesis

There exist four hypotheses that are associated to the relationship between REC and economic growth namely: the growth, conservation, the feedback and neutral hypothesis [27], [28].

(i) Growth hypothesis supports the argument that consuming renewable energy complemented with some non-renewable energy will promote economic growth. So the dynamic relationship runs from Energy to economic growth as supported by; [22],[29],[30][31],[32],[33]. The growth hypothesis alludes to the fact that, it is energy consumption that causes economic growth, thus, energy has both a direct and indirect effect on economic growth [28],[34],[35][36],[37],[38]. For instance, renewable energy development like solar, wind, hydropower and biomass is a prerequisite for green and sustainable growth. The development of renewable energy facilities create employment opportunity in both the public and private sectors, ultimately increasing incomes to people hence augmenting economic growth. The direct channel is through investment in human and physical capital as it augments these inputs, there is an overall increase in output hence economic growth while indirectly through employment a key macroeconomic variable that is a precursor to economic growth [9].

(ii) Feedback hypothesis has a two way causal relationship between energy (Renewable and non-renewable energy and economic growth[39],[40], [41]. The bidirectional hypothesis suggests complementarity between renewable energy consumption and economic growth. In other, renewable energy drives economic growth just as economic growth can drive renewable energy consumption. And policies to increase renewable energy consumption should be consciously done to avoid any feedback loops that are injurious to the overall economy.

(iii) Conservation hypothesis has a unidirectional relationship running from economic growth to either renewable or non-renewable energy [42],[43],[44],[45]. And policies to increase renewable energy consumption may be undertaken to promote sustainable development.

(iv) Neutral hypothesis shows that neither of the variables cause each other. The relationship between Energy consumption and economic growth has such a tiny association with each other that in fact no causality exists [46], [47]. And policies to increase renewable energy consumption may have no direct causal link to this transmission mechanism as growth is majorly from other causes other than energy.

## 2.2 Literature on Renewable energy and Economic growth

To foster greener economic growth for sustainable developmental goals, investigating the link between renewable energy and economic growth to becomes crucial in contemporary literature. Despite the interest in this area, empirical evidence has produced conflicting results, the debate is still inconclusive [48]. Furthermore, country studies [49] [50], [51], [54] that employs the time series methods of analysis. [53] found a bidirectional hypothesis. [22] investigated a causality relationship between renewable energy and economic growth for china using ARDL and Johansen cointegration, they found a bidirectional relationship. [55], found a unidirectional relationship running from energy consumption to GDP, [56] found no causality, [30], investigated renewable, non-renewable energy and economic in Iran using data of 1979-2014 and found a unidirectional relationship running from renewable energy to Economic growth. [57] found a bidirectional relationship. [58] found a relationship running from renewable energy consumption to GDP. [59], found a relationship running from RE consumption to GDP. [60] found a unidirectional relationship running from RE consumption to GDP, while study of [61] found no relationship between the variables.[62] found the relationship running from energy consumption to GDP. [63] found no relationship between electricity and GDP of Denmark. [64] studied Nepal and found no relationship, earlier [66] had studied the same and found a unidirectional relationship running from electricity to economic growth. [65] studied 28 EU countries using data of 1995-2015, ARDL methodology and Dumistrescu- Hurlin confirmed a growth relationship between renewable energy and economic growth. [67] found a bidirectional relationship. [69] found a unidirectional relationship running from renewable energy consumption to GDP. [70] found a unidirectional relationship running form RE consumption to economic growth, which is in agreement with earlier work of [71]Agee and Butt (2015). [68] found a relationship running from GDP to RE, while Junsheg et al. (2018) using Toda Yamamoto and Granger found the relationship running from RE consumption to GDP. The findings are contentious and this debate is not yet concluded, no country studies of this kind have been carried out in Uganda, this study therefore, seeks to establish the relationship of REC on economic growth to be able to guide decision making.

## 3.0 Data and Methods

### 3.1 Research Design

The study will use expost facto research design, with a quantitative approach [72]. It uses logical positivistic, antirealist instrumentalism (Friedman1953, Mirowsky1984) to advance the debate. Tokens of the observable world are captured in the time series data that is availed to this study for analysis. This will enable the use of time series secondary data to investigate the relationship between dependent (Economic growth) and independent variables (RE, labour and capital. This covered a period of 26 years from 1990-2015. All the data from the selected variables are continuous in nature. This is supported by (Davis, 2006) who highlighted that time series research is frequently quantitative in nature. Time series analysis is used to describe patterns of change in individuals or other units of measurement over time; establish the direction and magnitude of relationships among conditions, events, treatments, and later outcomes as measured by parameters of independent variables (Raskind et al., 1998). In this study the dependent variable is GDP, while the independent variables are renewable, labour force (LF), Gross fixed capital formation (GCF), real electricity trade (ELT), foreign direct investment (FDI), trade openness (TO).

### 3.2 Data and variable selection

Annual data of Uganda's GDP, REC, Labour force (LF) and Gross fixed capital formation (GCF) from1990 to 2015 was obtained World Bank Development indicators. The variables selected included; Gross domestic Product, Gross Capital formation both at a constant. US$ 2010, Labour force, proportion of Renewable and non-renewable energy consumption of Total energy consumption.

Table 1: Variable description and expected signs

| Variables | Symbol | Measure | Expected Sign | Data source |
|---|---|---|---|---|
| Gross Domestic Product | $GDP_t$ | GDP constant 2010 US$ | + | World Bank: World development indicators(WDI) |
| Gross capital formation | $GCF_t$ | GDP constant 2010 US$ | + | World Bank: World development indicators (WDI) |

| | | | | |
|---|---|---|---|---|
| Gross labour force | $LBR_t$ | Labour | + | World Bank: World development indicators (WDI). |
| Trade Openness | $OPN_t$ | $\frac{(Export + Import)}{GDP}$ | + | World Bank: World development indicators (WDI). |
| Real Electricity trade | $ELT_t$ | (Electricity Exports +Imports) | + | World Bank: World development indicators(WDI) |
| Renewable energy | $REC_t$ | Percentage composition | + | International Energy Agency (IEA) |

Constant GDP is used and is robust for taking care of inflationary tendencies over time, while gross capital and labour are controls in the conventional Solow model. Trade openness is a ratio of the sum of exports and imports to GDP. Real electricity trade (ELT) is constructed as the sum of net electricity imports and exports as a proxy for energy trade in the region.

### 3.3 Model specifications

To analyse the relationship between REC and economic growth, the study uses a multivariate framework, this is preferred because it overcomes the omitted variables bias (Lütkepohl,1982), based on the neoclassical production model where gross capital formation (GCF), labour force (LF) and energy are taken as separate inputs. This helps avoid the omitted variables bias. The model specification is given as

$Y_t$= f ($K_t$, $L_t$, $REC_{t,}$ )……………………………………………. (1)

Where Y is real GDP, K is capital stock, L is labour, REC is percentage of renewable energy over total energy consumption.

#### 3.3.1 Theoretical model- The neo classical aggregate production framework

The Neo classical aggregate production model was used to analyse the relationship for REC and economic growth. The standard aggregate production follows a growth model advanced by Solow growth (1956, 1987), was adapted. We take the translog as shown below:

$LGDP_t = \beta_0 + \beta_1 LGCF_t + \beta_2 LLF_t + \beta_3 LREC_t$ ……..(2)

Where LGDP, LGCF, LLF, LREC, represent natural logs of Real GDP. Capital formation, Labour, Renewable and Non-renewable energy consumption.

#### 3.3.2 Econometric model

The generalized $ARDL(p,q)$ model is specified as follows;

$$LGDP_t = \gamma_{0j} + \sum_{t=1}^{p} \delta_j LGDP_{t-i} + \sum_{i}^{q} \beta_j' X_{t-i} + \varepsilon_{jt} \ldots\ldots\ldots\ldots 3$$

Where $Y_t$ and $X_t$ are vectors and the variables are allowed to be purely $I(0)$ or $I(1)$ or jointly cointegrated; $\beta$ and $\delta$ are coefficients, $\gamma$ is the constant; $j = 1,..K;$ $p,q$ are the optimal length orders $\varepsilon_{jt}$ is a vector of errors- unobservable zero mean white noise vector process (serially uncorrelated or independent). The dependent variable is a function of its lag values, the current lag and the lag values of the exogenous variables in the model. The lag length of p and q may not necessarily be the same. P lags are used for the dependent variables while q lags are for the explanatory variables. To perform a bound test for cointegration, the conditional $ARDL(p, q_{1,} q_2)$ model with three variables is specified as follows:

$$\Delta \ln GDP_t = a_{o1} + b_{11} \ln GDP_{t-i} + b_{21} \ln RE_{t-i} + b_{31} \ln NRE_{t-i} + b_{41} \ln GCF_{t-i} + b_{51} \ln LBR_{t-i} + b_{61} \ln ELT_{t-i} + b_{71} \ln OPN_{t-i} + b_{71} \ln FDI_{t-i} + \sum_{i=1}^{p} a_{1j} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q1} a_{2j} \Delta \ln RE_{t-1} + \sum_{i=1}^{q2} a_{3j} \Delta \ln NRE_{t-1} + e_{1t} \text{.......... ....4}$$

$$\Delta \ln RE_t = a_{02} + b_{12} \log \ln RE_{t-i} + b_{22} \ln GDP_{t-i} + b_{32} \ln NRE_{t-i} + b_{42} \ln GCF_{t-i} + b_{52} \ln LBR_{t-i} + b_{62} \ln ELT_{t-i} + b_{72} \ln OPN_{t-i} + b_{82} \ln FDI_{t-i} \sum_{i=1}^{p} a_{1j} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q1} a_{2j} \Delta \ln RE_{t-1} + \sum_{i=1}^{q2} a_{3j} \Delta \ln NRE_{t-1} + e_{2t} \text{.......... .......... 5}$$

$$\Delta \ln NRE_t = a_{03} + b_{13} \ln NRE_{t-i} + b_{22} \ln GDP_{t-i} + b_{32} \ln RE_{t-i} + b_{42} \ln GCF_{t-i} + b_{52} \ln LBR_{t-i} + b_{62} \ln ELT_{t-i} + b_{72} \ln OPN_{t-i} + b_{82} \ln FDI_{t-i} + \sum_{i=1}^{p} a_{1j} \Delta \ln GDP_{t-i} + \sum_{i=1}^{q1} a_{2j} \Delta \ln RE_{t-1} + \sum_{i=1}^{q2} a_{3j} \Delta \ln NRE_{t-1} + e_{3t} \text{.......... ...6}$$

All the variables were used as independent variables and bound test for co-integration was conducted.

### 3.4.1 Test for Stationarity and Unit Root

According to the Phillips- Perron (PP) and Augmented Dickey Fuller (ADF) are used to test for stationarity. To test for unit roots in our variables, we use the Augmented Dickey Fuller (ADF) test. Using the results of Dickey and Fuller (1979) and PP, the null hypothesis that the variable shows that all variables.

### 3.4.2 Test for Serial Correlation

According to Samson, 2015, autocorrelation is the correlation of a time series with its own past and future values. We used the Breusch-Godfrey LM test because (Damodar, 2004) for both AR(p) and MA (q) error structures as well as for the presence of lagged regressand and explanatory variables. The null hypothesis (Ho) is that there is no serial correlation of any order. If the sample size is large enough, Breusch and Godfrey have shown that:

$$(n-p)R^2 \sim X_p^2 \text{………………………………………………………. (7)}$$

Implying that asymptotically, n-p times the $R^2$ follows the chi-square distribution with PDF. If in an application, (n-p) $R^2$ exceeds the critical chi-square value at a chosen level of significance, we reject the null hypothesis. Thus, the null hypothesis is rejected if p-value is less than 5%, in our case it is 0.00 so we reject the null hypothesis.

### 3.4.3 Determining the appropriate Lag Length for Auto regressive distributed lag (ARDL), model

The need for the lags arises because values in the past affect today's values for a given variable. This is to say the variable in question is persistent. There are various methods to determine how many lags to use. The AIC was used to determine the appropriate lag length given the large sample size of 234 observations in the 26 series. The appropriate lag length is 4.

### 3.4.4 Co-integration test

This test is useful in establishing if there exists a long-run relationship between the study variables. Generally, a set of variables is said to be co-integrated if a linear combination of the individual series, which are I(d), is stationary. Intuitively, if xt ∼ I(d) and yt ∼ I(d), a regression is run, If the residuals, εt, are I(0), then Et and yt are co-integrated. We use Johansen's (1988) approach, which allows us to estimate and test for the presence of multiple co-integration relationships. The choice of lag length is made according to the AIC criterion. In conclusion there is one co-integration rank (long-run relationship). When determining lag structures of the data-generating processes (DGP), we use the Phillips Perron (PP) procedure to test the existence of long-run equilibrium relations using the trace statistic test for co-integration, because our data are based on rather small samples, the t statistics suggest the existence of co-integrating relationships between GDP and all other independent variables except labour force. Hence. The Dickey Fuller test is used to determine whether the remainder is stationary Dickey Fuller, and the Augmented Dickey Fuller test is applied on the least square residual to implement the Engel and Granger procedure.

3.4.5 Test for functional form

We may have a model that is correctly specified, in terms of including the appropriate explanatory variables, yet commit functional form misspecification. In this case, the model does not properly account for the form of the relationship between dependent and observed explanatory variables. In this study, a general test for functional form misspecification is Ramsey's RESET (regression specification error test) which was applied.

3.4.6 Test for heteroscedasticity

The error term is found to homoscedastic using the Breush Pagan test this shows the stability of the parameters using residual diagnostics to minimize errors (or residuals). The error term is be independently and identically distributed (i.i.d). Using the correlogram, the error term of the estimated model. This procedure of log transformation is important because it stabilises the means, however the means are also non stationary.

3.4.7 Test for normality

The Jacque Bera normality test was used to test for normality, which variable is relevant to express as linear combination among other variables, using the maximum likelihood- auto regressive conditional heteroskedasticity (ML ARCH) the residuals were normally distributed.

3.4.8 Test for causality

The Granger Wald causality test was used, a negative causal relationship exists between RE and GDP.

## 4.0 Findings and discussion

### 4.1 Findings of descriptive statistics

In order to identify the model and reduce on false regressions all variables in levels were transformed and the table 2

Table 2: Descriptive statistics

| Variable | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| lnGDP | 26 | 2.75 | 0.51 | 1.94 | 3.54 |
| lnGCF | 26 | 1.28 | 0.62 | 0.35 | 2.18 |
| lnFDI | 25 | -1.40 | 1.35 | -4.96 | 0.19 |
| lnLBR | 26 | 2.22 | 0.24 | 1.84 | 2.64 |
| lnELC | 26 | 0.14 | 0.41 | -0.51 | 0.94 |
| lnELT | 26 | -1.99 | 0.28 | -2.41 | -1.31 |

| | | | | | |
|---|---|---|---|---|---|
| lnOPN | 26 | -1.20 | 0.24 | -1.66 | -0.84 |
| lnRE | 26 | 4.54 | 0.02 | 4.49 | 4.57 |

From the statistics, mean FDI, trade openness and real electricity trade are negative mainly due to the high cash outflows in the foreign trade balance ad high imports. Even though the net electricity trade is positive for Uganda, overall average real electricity trade (ELT) is still negative. Other variables, on average are positive.

### 4.1.1 Unit root analysis

In order to examine the impact of renewable and non-renewable energy consumption on economic growth, unit root tests are tests conducted to establish the stationarity of the variables. Augmented Dickey Fuller and Phillips Perron tests are some of the tests performed. The results are tabulated below

Table 3: Unit root test

| VARIABLE | AUGMENTED DICKEY FULLER (ADF) | | | | PHILLIPS PERRON | | | |
|---|---|---|---|---|---|---|---|---|
| | LEVELS | | FIRST DIFFERENCE | | LEVELS | | FIRST DIFFERENCE | |
| | t-stat | prob | t-stat | Prob | t-stat | Prob | t-stat | prob |
| lnGDP | -0.597133 | 0.8543 | -4.081961 | 0.0045 | -0.597133 | 0.8543 | -4.081961 | 0.0045 |
| InGCF | -0.512474 | 0.8729 | -3.952871 | 0.0061 | -0.519966 | 0.8713 | -3.850184 | 0.0077 |
| InFDI | -1.530926 | 0.5019 | -9.037965 | 0.0000 | -1.541094 | 0.4968 | -8.636226 | 0.0000 |
| lnLBR | 2.457150 | 0.9999 | -0.000305 | 0.9496 | 6.389976 | 1.0000 | -0.025502 | 0.9471 |
| lnELC | -0.259239 | 0.9175 | -7.261968 | 0.0000 | -0.452016 | 0.8850 | -7.891911 | 0.0000 |
| lnELT | -2.157046 | 0.2258 | -4.967172 | 0.0006 | -2.157046 | 0.2258 | -4.973708 | 0.0006 |
| lnOPN | -1.087501 | 0.7043 | -4.329281 | 0.0026 | -1.109130 | 0.6958 | -4.538636 | 0.0016 |
| lnRE | 0.673215 | 0.9889 | -5.103610 | 0.0004 | 0.673215 | 0.9889 | -5.103610 | 0.0004 |

None of the variables given is stationary in levels both using Augmented Dickey-Fuller (ADF) and Phillips- Peron tests. Only lnLBR is not stationary at first difference using both tests ADF and Phillips-Peron, while the remaining variables are stationary at first difference since they are statistically significant at 1% including FDI which is statistically significant at 5% level of significance.

The inverse causal relationship between RE and economic growth implies that traditional; biomass which is the dominant source of RE mix is not effective in driving growth. The option is to switch to modern RE options that are abundant in Uganda's energy mix.

## 4.2 Discussion

From the results renewable energy consumption has an inverse relationship with economic growth implying the conservation hypothesis. This means that Uganda can safely pursue its clean energy goals to achieve sustainable development. It can also improve its energy efficiency as it diversifies its renewable energy mix.

Greater investment must be undertaken in clean energy generation and consumption as has positive multiplier effects and can drive industrial and commercial output hence economic growth (Chingoiro & Mbulawa, 2017). .

However, GDP is positively associated with gross capital formation, FDI, Electricity trade as well as trade openness. This can therefore promote greater integration of energy markets within the East African Market. FDI can still be enhanced but carefully avoiding those corporations that may be heavy polluters and are running away from strict pollution rules and regulations in their home countries

## 5.0 Conclusions and policy implications

## 5.1 Conclusions

The study examined a quantitative analysis of REC and GDP, GCF and LF for Uganda. Using the unit root, co-integration, Granger causality an Auto regressive distributed lag (ARDL), empirical results were analysed. Estimation results shows co-integration exists among all variables, therefore a long run equilibrium exists. REC is negatively affecting GDP per capita. This means Uganda should invest more in modern RE as the dominating traditional biomass is inversely related to economic growth, it is not sustainable to continue along that paradigm. It is possible to invest in modern bioenergy technologies that are friendly to the environment and would avoid carbon dioxide emission. This conservation mechanism has been supported by other studies (Uzokwe and Onyinje 2020, Al- Tal et al 2021, Titalessy2021).

Uganda should diverse its clean energy goals mainly by stepping up the production of more Solar, biomass, geothermal hydroelectricity as well as nuclear energy potential. This will help increase output in both the industrial and commercial sector (Sekantsi and Motlokoa, 2016). As with a diverse power base electricity efficiently serves industry and commercial sector as other intermittent power source feed the residential and transport sector.

Increased marketization of electricity into the East African Community, because Uganda has an excess electricity supply capacity. With a reserve capacity of 40 % yet elsewhere in the region remarkable electricity shortages occur.

Uganda ought to systematically reorganise its energy sector by keeping up to date information (EIB Report 2018). An electrification master plan ought to be developed informed by research and sound policy. The clean energy policy must be crafted clearly giving a clear road map on how these energy sources are to be developed.

There should be increased marketization of electricity with the region so that there is increased supply capacity for Uganda can be traded to neighbouring countries with acute electricity shortages at the ongoing market prices. This will foster greater cooperation within the East African Community (Mayyas et al., 2019).

## 5.2 Policy implications

The renewable energy policy is in dire need of a review to carefully capture clear and meaningful guidelines on a diversified energy portfolio in the renewable energy systems and sustainability. There is need for independent policies on geothermal, solar, wind, which would ensure investor confidence and proper exploration and development of these energy sources. Renewable energy consumption should be deepened from the low grade and low intensity tradition biomass is dominant and cannot drive industrial growth so a need to promote modern bioenergy and energy saving mechanism as a way to promote sustainable growth and development.

For further interrogation FDI and economic growth should be interrogated further with carbon emissions to establish whether their investment is helping save carbon emissions. It is possible that these multinationals are targeting Uganda for having less strict regulations on pollution and environmental standards control (Zhang and Zhang 2018).

The other area for further inquiry is to try and understand how regional energy markets work and this may include studying a panel of East African countries to establish whether with increased regionalisation energy markets have an increasing volume of trade (Cramer et al., 2021).



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