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Green Energy and Its Impact on Employment and Economic Growth

Helen Hoka Osiolo

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Abstract

The main objective of this paper is to estimate the effects of renewable energy on employment and economic growth in Kenya. The paper shows how investment especially in renewable energy creates employment and meets the country's objective of generating cheap, sustainable and modern energy for all. The effects of renewable energy on employment and economic growth are analysed using econometric regression and Input-Output models. Applying the 4 vector error correction model, the results show that renewable energy is an important factor that positively influences growth. Also, through use of Jobs and Economic Development Impact model for geothermal power, the findings indicate that investments in renewable energy generation contribute to employment creation. Specifically, an estimate of 584 jobs is created through generating geothermal power from Olkaria IV plant and this amount to an estimated output of US$ 32, 000,000.

Key words: renewable energy, employment, growth, vector error correction model, JEDI model

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1.0 INTRODUCTION

According to the Organization for Economic Co-operation and Development 2012 report, green growth offers real opportunities for more inclusive growth in developing countries while protecting the environment. However, research on how green growth addresses unemployment are lacking.

The contribution of renewable energy (RE) in the energy mix is gaining attention globally, mainly because of its benefits to the environment and to the overall economy. According to OECD report, renewable energy has a lot to offer in the development of rural economies. First, it provides new revenue sources, which entails increasing the tax base for improving service provision in rural communities, and generating extra income for land owners and land based activities. Second, it provides new jobs and business opportunities – particularly when a large number of actors are involved and when the RE activity is embedded in the local economy. Direct jobs created include operating and maintaining equipment, while the indirect ones tend to be long-term which arise along the renewable energy supply-chain (manufacturing and specialized services), and by adapting existing expertise to the needs of the renewable energy industry. Third, rural areas host many renewable energy projects, where innovations in products, practices and policies take place. Fourth, through renewable energy, communities benefit from capacity building and empowerment. Fifth, renewable energy provides rural communities with the opportunities of generating their own energy which is considered affordable and can trigger economic development.

It is anticipated that through investing in renewable energy, green jobs would be created. It is however not clear whether green growth generates or rescinds jobs (Bowen and Karlygash, 2015). Borel-Saladin and Turok (2013) explains that one of the main benefits of green growth is that the jobs it creates tend to have higher local content than traditional fossil-fuel-based economic activities. This claim is also supported by UNEP (2011), which states that greening of economies is a net generator of decent jobs. Research studies from Michaels and Murphy (2009) and Alvarez et al. (2010) are some of the studies that are against the green growth jobs idea. There is little empirical evidence to conclude on the debate, largely because of data limitation (Bowen and Karlygash, 2015).

Kenya derives its energy from several sources including; hydro, wind, solar, geothermal, cogeneration, coal and petroleum products. In 2014, the total electricity generation stood at 9,138.7 GWh, which rose from 8,447.9 GWh in 2013. This was due to increased investment in renewable energy and a government policy to diversify electricity sources from hydro and thermal power to geothermal, wind, and cogeneration power. These initiatives aimed at reducing reliance on hydro power which greatly depends on weather conditions. It also aimed to reduce the costs and the unpredictability associated with fossil fuels.

According to the Least Cost Power Development Plan 2011-2030, renewable energy technologies are considered to have lower levelised cost hence investing in renewable energy implies lower electricity prices in the long run.

Table 1: Electricity generation by source, 2013-2014(GWh)

	2013	Percentage (%)	2014	Percentage (%)
Hydro	4,435.00	52.50	3569.00	39.05
Geothermal	1,780.90	21.08	2917.40	31.92
Cogeneration	55.60	0.66	50.00	0.54
Wind	14.70	0.17	17.00	0.18
Subtotal: Renewable energy	6,286.20	74.41	6553.40	71.71
Thermal	2,161.70	25.59	2585.20	28.29
Total	8,447.90	100.00	9138.70	100.00

Source: KNBS (2015)

The share of renewable energy generation from the total generation dropped from 74.4 percent in 2013 to 71.7 percent in 2014 as shown in Table 1. The Kenya Economic Report explains that the drop was due to a slight increase (1.6 %) in thermal generation in the same period. The report also explains that for financial year (FY) 2018/19, the largest share of total electricity will still be expected to come from renewable energy as government plans to inject 286 MW of geothermal power in the same period (KER, 2015).

The paper is based on the first thematic area of the programme, which focuses on green business in rural Africa. It seeks to answer the question: in what ways and through what measures could green business opportunities in infrastructure, livestock, fisheries, land and other natural resources sectors overcome the problem of growing unemployment in rural Africa. Specifically,

the paper focused on renewable energy strategies and how they address unemployment in Kenya.

The paper attempts to identify and quantify the impact of renewable energy investment in Kenya. It gives answers to: What are the economic impacts of renewable energy on overall economic growth? To what extent does renewable energy lead to creation of jobs? What is the estimated impact of geothermal power generation (as an investment in renewable energy) on employment? The paper contributes to knowledge by providing literature on the impact of renewable energy on economic growth, employment and the environment in Africa. It also assesses how green growth leads to job creation, using a Jobs and Economic Development Impact (JEDI) model.

2.0 LITERATURE REVIEW

2.1 Theoretical literature

The literature review is discussed according to the various approaches of analysing the impacts of renewable energy on economic growth. The theories underlying the relationship between renewable energy, employment and economic growth is explained by growth models, input-output models, social accounting matrix, computer general equilibrium models, real business cycle models, new Keynesian approaches, and econometric models.

The standard growth models also known as exogenous models borrow from the neoclassical school of thought where a representative household maximizes consumption or a firm maximizes the present value of profits (Ramsey, 1928; Cass 1965 and Koopmans 1965). According to the thought, an optimal growth path can be realized when specific technical conditions are achieved. It also assumes that technological change is exogenous and involuntary unemployment cannot occur. The Keynesian school of thought has a different view from the standard growth model. The Keynesian school of thought received a major contribution from Keynes (1936) and focuses on growth of aggregate output. In the short run or during recessions, economic output was strongly influenced by aggregate demand. Romer (1996) extended the discussion on Keynesian thought by including technological change. This came to be known as endogenous growth models where aspects on growth and unemployment, and growth and environment are addressed (Aghion and Howitt, 1994; and Greiner and Semmler, 2008). Generally, growth models can explain both employment and output, however they assume there is full

employment hence making it impossible to address whether there is presence of high or low employment.

Input-output (I-O) models are able to address both employment and growth only on broader dimension. I-O models provide analysis on individual industries in the economy where information on current production and consumption is available. I-O models are better suited for structural change analysis and provide more details on industry heterogeneity (Leontief, 1936). However, I-O models are considered linear and the coefficients produced do not vary over time. Also, technological change and behavioral responses to a change in relative prices are not considered. Since their analysis is partial, they are unable to explain changes in exogenous demand (ibid).

A Social Accounting Matrix (SAM) can be an alternative to the I-O model. SAM shows the relationship between variety of economic sectors and industries, and also provides information about employment, capital, households and other socioeconomic groups. However, they are not purely economic models that focus on economic structure or the production side of the economy but are more of accounting models that focus on both the economic and social structure of an economy and reconciles the production side of the economy with the rest of the economy. Computer General Equilibrium (CGE) models are based on I-O models (Johansen, 1960), the only difference is that CGE models incorporate behavioral assumptions and the availability of markets. CGE are multisector models that consist of both production and household sectors. They incorporate behavioral aspects hence they are able to explain aspects of growth and employment better than I-O models. However, CGE models are unclear on the existence of both growth and employment (Goulder, 1995; and Bye 2000).

The Real Business Cycle (RBC) models apply the technological error term that is missing in other discussed models (Taylor, 2004). However, they are not able to fully incorporate structural change and employment effects. They are suitable for short-term effects analysis and they focus on aggregate variables (Snowdon and Vane, 2005). The New Keynesian models are an improvement of RBC models, as they add market imperfections and sticky prices (Bridji & Charpe, 2011). When compared to the other models, the application of New Keynesian models on environmental issues is limited. Econometric models provide better analysis of employment and output effects than all the models discussed. However, their main disadvantage is statistical in nature and data related.

2.2 Empirical Literature

Different empirical studies have applied different methods of estimating the effects of renewable energy on economic growth. The econometric models have been applied by a number of authors (e.g. Jürgen, Braun, Edlerb, & Schill, 2011; Silva, Soares & Pinho, 2012; Inglesi-Lotz, 2013; Leitão, 2014). Inglesi-Lotz (2013) analyzed the impact of renewable energy consumption on economic welfare. A panel data model was used for thirty four member countries of the Organization for Economic Co-operation and Development (OECD), for the period 1990 to 2010. The findings show that there is a positive and statistically significant impact of renewable energy consumption and the share of renewable energy to the total energy mix on economic growth. A positive net effect on growth and employment was also reported by Jürgen et al. (2011). However, the size of the effects depend on labour market conditions and policies. The study used a Sectoral Energy-Economic Econometric Model

(SEEEM) to analyze the economic effects of renewable energy expansion. The results show that expansion of renewable energy can be achieved without compromising on growth or employment. Though Leitão (2014) also established a positive correlation with economic growth, the Granger causality tests show a unidirectional causality between renewable energy and economic growth. Using time series data from 1970 to 2010, the study aimed at investigating the correlation between economic growth, carbon dioxide (CO2) emissions, renewable energy and globalization. Silva (2012) found a contraversial result after estimating 3 variable structural vector autoregresive (SVAR) models for USA, Denmark, Portual and Spain, for the period between 1960 to 2004. Instead of positive net effects of renewable energy sources on economic growth and carbon dioxide emissions, the study observes that for all countries in the sample, except for the USA, the increasing renewable energy share had economic costs in terms of gross domestic product (GDP) per capita. However, the study indicates that the economic cost may disappear as these renewable energy sources become economically competitive.

The input-output approach was applied by Lehr & Lutz (2011), and also Edler (2012). Lehr & Lutz (2011) examined the labor market implication of large investments into renewable energy in German. An environmental macro econometric model PANTA RHEI approach was used where a set of possible scenarios are applied to assess the economic effects of increasing shares of renewable energy. The energy module was able to show the relationship between economic development, energy input, and CO2 emissions. Overall, the analysis shows possible impacts of the expansion of renewable energy. Similar results by Edler (2012) also showed a positive long term net economic impact of renewable expansion after carrying out several simulations. The study modelled economic impacts of renewable energy expansion in

Germany, using a Sectoral Energy-Economic Econometric Model (SEEEM) which is a form of static open input-output method.

Using macro-economic models, EmployRES (2009) estimated the gross effects (direct and indirect) and net effects (convectional replacement and budget effects) of renewable energy policies in Europe. The findings show that there is increased confidence in the economic impacts of renewable energy sources (RES). It highlights that the current high economic benefits of the RES sector can be increased in future if support policies are improved to stimulate appropriate innovative technologies. Furthermore, the benefits of RES in securing energy supply and mitigating climate change can go hand in hand with economic benefits.

Apart from the common methods discussed, the Life Cycle Assessment (LCA) is also one of the rare approaches used to analyze the effects of renewable energy on economic growth and employment. Gkatsou et al. (2014) examined the effects of green energy (renewable energy sources) on creation and loss of employment in Greece, for the period 2012 to 2050. The study concluded that though green energy is responsible for the creation of employment, it is also associated with loss of many others. The LCA approach was used to estimate the atmospheric emissions associated with each Renewable Energy Technology (RET) generation. In order to calculate the external cost, the impact pathway methodology was used.

A Meta-Analysis approach was applied by Meyer & Sommer (2014) to analyze the effects of renewable energy on employment and economic growth. The type of employment effects considered are direct, indirect, induced, gross or net. Though, the paper indicates that results from different studies were not comparable, there was a common finding of positive net employment effects.

The conclusion is that the positive link between renewable energy deployment and job creation is thus not straightforward, since different assumptions, system boundaries and modeled interactions such as the crowding out of alternative energy production or effects from prices, income and foreign trade influence the results.

An overview of the literature highlights that the econometric modelling approach is the dominant approach that is applied. Several studies such as EmployRES (2009); Lehr & Lutz (2011); Edler (2012); Gkatsou et al. (2014) and Meyer & Sommer (2014) are some of the studies that employed either the I-O, CGE, LCA or Meta-Analysis approaches. While there is lack of comparability among the studies due to the use of different approaches, the studies conclude that there is a positive effect in employment and economic growth. This paper adopted the econometric approach to anlayse the effects of renewable energy on economic growth. In addition, the Jobs and Economic Development Impact Model (JEDI) was used to estimate the contribution of renewable energy to employment, using geothermal power as a case study.

3.0 METHODOLOGY

3.1 Theoretical model

The economics of production provides the basis for analyzing the effects of renewable energy in the Kenyan economy. The approach is adopted from Fang (2011) and Inglesi-Lotz (2013). The relationship between inputs and outputs is presented using a Cobb-Douglas functional form as shown:

$$Q = A\, L^{\propto} K^{\beta} \qquad (1)$$

Where:

- Q is the monetary value of production,
- L is the labour input,
- K is the capital input,
- A is the technological change, and
- $\propto$ and β are the elasticities of labour and capital respectively.

According to Fang (2011), the technological change is captured by renewable energy consumption to economic growth, total consumption of renewable energy and share of renewable consumption to the energy mix. Fang estimated the following Cobb-Douglas function:

$$gdp\ (gdppc) = \propto_0 + \propto_1 trc(or\ src) + \propto_2 cap + \propto_3 empl + \propto_4 \mathrm{r\_d} + \mu \qquad (2)$$

Where:

- gdp is the Gross Domestic Product,
- $gdppc$ is the Gross Domestic Product per capita,
- trc is the total renewable energy consumption,
- src is the share of renewable energy consumption to total energy consumption,

- cap is the gross capital formation,
- $empl$ is the number of employees,
- r_d is the R&D expenditure of the each country,
- $\propto_0 \ldots \propto_4$ are the unknown parameters to be estimated, and
- μ is an error term.

3.2 Empirical model

In order to address the effects of renewable energy to the economy, equation (2) has been modified following Silva et al. (2012) and Leitão (2014) using the Cobb-Douglas production function:

$$\text{GDP} = \propto_0 + \beta_1 \text{RE} + \beta_2 \text{CO}_2 + \beta_3 \text{EC} + \beta_3 \text{EP} + \mu \quad (3)$$

Where:

- GDP captures growth[1],
- RE is share of renewable energy from electricity generation,
- CO_2 is carbon dioxide emissions,
- EC is electricity consumption and
- EP is electricity sector employment.
- α_o is the constant term,
- β is the coefficient for each variable, and
- μ is the error term.

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[1] Macroeconomic variables that affect GDP such as investment, exchange rate, and inflation were not included in the model.

The effects of renewable energy on employment are analysed using the I-O approach applying the JEDI model. The approach is adopted because it is more appropriate for structural change analysis and offers more details on industry heterogeneity (Leontief, 1936). More information about the JEDI model can be accessed at: http://www.nrel.gov/analysis/jedi/.

3.3 Data

The regression analysis covers the period 1985 – 2014. Data on GDP, Electricity consumption (GWh), share of renewable energy from electricity generation (%), employment from electricity sector, and carbon dioxide emissions are proxied by the area covered by forest in hectares. Most of the variables were sourced from the Kenya Economic Survey. A positive relationship is expected between share of renewable energy from electricity generation and carbon dioxide emissions with GDP. Electricity consumption is expected to have either a positive or negative relationship.

Various time series tests were done. These include: the unit root test that checks for stationarity, cointegration test that establishes whether there is a long run relationship among variables, and the test for distribution of error terms. For the JEDI model, project specific data was used, in this case the data was derived from the geothermal plant (Olkaria IV power plant). The data includes: project descriptive data, model inputs (project costs i.e. initial investment cost and operating and maintenance costs) and investment costs i.e. debt and equity financing, tax etc.

4.0 EMPIRICAL RESULTS AND DISCUSSIONS

4.1 Econometric Model Results

4.1.1 Descriptive statistics

The descriptive statistics of the variables used in the analysis are presented in Table 2. The mean for GDP growth was 3.8 percent while the mean for renewable energy share was about 80 percent. The variable with the highest dispersion from the mean was electricity consumption, and it was also the only variable with a positive skewness.

Table 2 Descriptive statistics

Variables	N	Mean	Standard deviation	Min	Max	Variance	Skewness	Kurtosis
GDP (%)	30	3.767	2.211	0.2	8.4	4.889	-0.072	2.061
Carbon dioxide (000)	30	141.3	20.71	110.5	169	0.0192	-0.341	2.075
Electricity consumption (000)	29	4.106	1.475	2.158	7.769	2174687	0.825	2.799
Renewable energy share (%)	30	79.727	13.845	51.7	100	191.699	-0.342	2.077
Electricity sector employment (000)	30	19.89	3.394	11.4	23.4	11.521	-1.168	3.449

The Ordinary Least Squares (OLS) regression assumes that there is homogeneity of variance of the residuals. This implies that the variance of the

residuals is constant, if it is non-constant then the residual variance is considered heteroscedastic. In order to test for heteroscedasticity, the Breusch-Pagan test was used. The null hypothesis assumes that the residuals are homogenous. The test result was not significant; therefore, the null hypothesis of constant variance was not rejected. This means that the variance of the residuals was constant (see Appendix I, test for heteroskedasticity).

Muliticollinearity occurs when variables are highly correlated with each other. When there is presence of multicollinearity, estimates of the regression model become unstable and the standard errors will be inflated. Both the variance inflation factor (VIF) and the tolerance (1/VIF) were used to determine the level of collinearity. A VIF of 10 or a tolerance value lower than 0.1 implies that there is high correlation. Multicollinearity may be addressed by omitting the variable that causes collinearity. The test for multicollienearity (as shown in the Appendix 1) shows that all variables have a VIF of less than 4. This implies that there is no multicollinearity.

Linearity assumes that the relationship between the dependent and independent variables is linear. The test for linearity (as shown in the Appendix I) shows that most variables deviated from linearity or were skewed. This therefore suggests the need to transform the variables.

Model specification test (as shown in the Appendix I) was carried out to ascertain whether they are relevant variables omitted or whether they are irrelevant variables included in the model. The results show that the model specification is correct and there are no omitted variables.

4.1.2 Ordinary Least Squares (OLS) estimation

The ordinary least squares (OLS) method was used to determine the factors influencing economic growth (GDP), with the independent variables being: renewable energy share, electricity consumption, carbon dioxide emissions and employment in the electricity sector. Figure 1 reports the results of the OLS regression.

Table 3 OLS Regression

Independent Variables :	Coefficient	Std. Errors
Log of Renewable energy share	3.123*	-1.412
Log of Electricity consumption	-0.043	-0.949
Log of Carbon dioxide	-2.284	-2.234
Log of Employment in electricity sector	-2.641*	-1.148
_cons	21.267	-18.289
N	29	
F(4, 24)	3.27	
Prob> F	0.028	
R-squared	35	

Significance level = $p<0.10$, * $p<0.05$, ** $p<0.01$

Renewable energy share is positive and significant at 10 percent while employment in electricity sector is negative and significant at 5 percent. A similar study by Leitão (2014) also found a positive and a significant relationship for renewable energy share on economic growth. Moreover,

Leitão found a negative relationship between electricity consumption and economic growth; this was attributed to the efficient use of energy and reduced levels of energy dependence for the countries studied.

Unit root tests

Unit root is a term used to refer to variables that are not stationary. Variables that are not stationary cannot therefore validly be used to make hypothesis. In order to test for existence of unit roots among the variables the Augmented Dickey Fuller (ADF) and Philips-Perron (PP) tests were applied. The null hypothesis for both tests assumes the series have a unit root while the alternative assumes that the series are stationary. Before carrying out the unit root tests, it is important to determine the number of lags to be used. The most basic methods applied are the Akaike Information Criterion (AIC) and the Schwarz' Bayesian Information Criterion (SBIC). The results for selecting the number of lags are presented in Table 4.

Table 4 Selecting number of lags test

Variable	Lags	P	AIC	SBIC
growth	1	0.001	2.75328*	2.85006*
renewable energy share	1	0.000	-1.29334*	-1.19656*
electricity consumption	1	0.000	-3.44762*	-3.35011*
carbon dioxide emissions	1	0.000	-2.94469*	-2.84791*
Employment in electricity sector	1	0.000	-1.40273*	-1.30596*
Observation	26			

In addition to AIC and SBIC, all the selection order methods indicate significant values at lag 1 for all variables. The maximum number of lags (in this case lag was 1) was applied to the ADF and PP tests. The results for unit root tests are presented in table 5. All the variables have unit roots and become stationary after the first difference as reported by both tests.

Table 5 Unit root tests

Trend and Intercept	Level		First difference	
Variables	Augmented Dickey fuller	Phillips-Perron	Augmented Dickey fuller	Phillips-Perron
GDP	-3.253(1)	-2.825 (1)	-4.005*** (1)	-5.935 ***(1)
Renewable energy share	-2.572(1)	-2.605 (1)	-4.051*** (1)	-5.624***(1)
Electricity consumption	0.8365 (3)	1.438 (1)	-3.370*(1)	-4.121***(1)
Carbon dioxide	-1.610(4)	-1.740 (1)	-4.264*(1)	-4.905 ***(1)
Employment in electricity sector	-2.562(1)	-2.337 (1)	-4.925*** (1)	-4.926 ***(1)
Observations	27	27	27	27

* p<0.1, ** p<0.05, *** p<0.001
The parenthesis represents the lag order

Cointegration test

To establish whether there is a long run relationship among the variables, the cointegration test was performed using the Johansen test proposed by Johansen (1995). The null hypothesis indicates that there is no cointegration. The results for cointegration test are presented in Table 6.

Table 6 Johansen tests for cointegration

Maximum rank	Eigenvalue	Trace Static	5 % Critical value
0	.	71.2582	68.52
1	0.6721	41.1549*	47.21
2	0. 5126	21.7517	29.68
3	0. 4809	0.0478	15.41
4	0. 1383	4.0492	
5	0.0011	0.0298	3.76
Observations	27		

The trace static is significant at rank 1. This implies that there is one cointegrating equation. Therefore, the null hypothesis of no cointegration is rejected. When the rank is maximum (r=5), it implies that all variables in the model are stationary.

To check if the number of cointergrating equations is correctly specified, the stability test is performed. The stability test for the cointegration relationship in the model is shown in Table 7.

Table 7 Eigenvalue stability condition

Eigenvalue	Modulus
1	1
1	1
1	1
1	1
0.492941 + 0.4621264i	0.675686
0.492941 - 0.4621264i	0.675686
-0.360013 + 0.2938379i	0.464704
-0.360013 + 0.2938379i	0.464704
0.0800728 + 0.1751038i	0.192544
0.0800728 + 0.1751038i	0.192544

The VECM specification imposes 4 unit moduli.

There is only one eigenvalue approaching 1. This confirms that there is one cointegrating equation. The presence of unit root and cointegrated series make the use of VAR in the long run impossible; instead the vector error-correction model (VECM) is applied to correct these issues. The VECM model is able to estimate both the short run and long run estimates. The short run effects are presented in Table 8.

Table 8: VEC model – short run estimates

VARIABLES	D_lngdp	D_lnrenshare	D_lneleccons	D_lnco2	D_lnempelec
L._ce1	-0.349**	-0.0586***	-0.00169	-0.00247	-0.00726
	(0.160)	(0.0164)	(0.00700)	(0.00745)	(0.0192)
LD.lngdp	0.119	0.0520**	0.00916	0.0181*	-0.0211
	(0.228)	(0.0233)	(0.00996)	(0.0106)	(0.0273)
LD.lnrenshare	-0.849	-0.168	0.0346	0.142	0.215
	(1.899)	(0.194)	(0.0828)	(0.0883)	(0.227)
LD.lneleccons	2.889	1.348*	0.109	0.335	0.837
	(6.789)	(0.694)	(0.296)	(0.315)	(0.813)
LD.lnco2	5.836	-0.294	0.0252	0.0477	-0.0192
	(3.989)	(0.408)	(0.174)	(0.185)	(0.478)
LD.lnempelec	1.545	0.355*	0.00267	0.0886	0.0983
	(1.882)	(0.192)	(0.0821)	(0.0875)	(0.225)
Constant	0.0100	-0.0548	0.0401***	-0.0208	-0.0407
	(0.343)	(0.0351)	(0.0150)	(0.0160)	(0.0411)
Observations	27	27	27	27	27

Standard errors in parentheses. Significance level = *** $p<0.01$, ** $p<0.05$, * $p<0.1$

We conclude from the VECM that the equation for log of renewable energy share and that for log of GDP, log of electricity consumption and log of employment in the electricity sector were significant. In addition, the equation

for log of carbon dioxide had only log of GDP as the only significant variable. The long run estimates are presented in Table 9.

Table 9 VEC Model – long run estimates

Variables	Coefficients	Standard Error
GDP	1	(.)
Renewable energy share	6.5613 **	(2.7270)
Electricity consumption	4.7685 *	(1.5621)
Carbon dioxide emissions	-1.16921	(3.7375)
Employment in electricity sector	5.79340	(1.8539)
_cons	-49.99195	(.)
Observations	27	
Cointegrating equations	4	
Chi2 (p> chi2)	29.382	(0.0000)

Standard errors in parentheses. Significance level = *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results indicate that both the coefficients for renewable energy share and electricity consumption have a positive relationship and are significant at 5 and 1 percent level.

The matrix estimates from the VECM is shown below:

$$\hat{\alpha} = (-0.3874 \quad -0.0586 \quad -0.0017 \quad -0.0025 \quad -0.073\,)$$

$$\hat{\beta} = (1 \quad 6.5614 \quad 4.7685 \quad -1.1692 \quad 5.7934\,)$$

$$\hat{V} = (0.0100 \quad -0.0351 \quad 0.0401 \quad -0.0208 \quad 0.0407)$$

$$\hat{\tau} = \begin{pmatrix} 0.1187 & -0.8487 & 2.8894 & 5.8355 & 1.5445 \\ 0.0520 & -0.1677 & 1.3479 & -0.2940 & 0.3546 \\ 0.0092 & 0.0346 & 0.1092 & 0.0252 & 0.0027 \\ 0.0182 & 0.1424 & 0.3348 & 0.0477 & 0.0886 \\ -0.0212 & 0.2148 & 0.8368 & 0.0192 & 0.0983 \end{pmatrix}$$

To be able to derive the likelihood function, it is important to establish whether the errors are independently, identically and normally distributed with zero mean and finite variance that ensure consistent and efficient parameter estimates. The test for the distribution of the error term in the model is critical. The results for the Jarque-Bera, skewness and kurtosis tests are reported in Table 10, Table 11, and Table 12.

Table 10 Jarque-Bera Test

Equation	chi2	Df	Prob > Chi2
D_lngdp	0.111	2	0.94621
D_lnrenshare	5.422	2	0.06648
D_lneleccons	0.214	2	0.89873
D_lnco2	8.023	2	0.01811
D_lnempelec	12.537	2	0.00189
ALL	26.306	10	0.00335

Table 11 Skewness Test

Equation	skewness	chi2	Df	Prob > Chi2
D_lngdp	0.14823	0.099	1	0.75318
D_lnrenshare	-0.93123	3.902	1	0.04822
D_lneleccons	0.20686	0.193	1	0.66080
D_lnco2	-1.008	4.572	1	0.03250
D_lnempelec	-0.84638	3.224	1	0.07258
ALL		11.989	5	0.03493

Table 12: Kurtosis Test

Equation	Kurtosis	chi2	Df	Prob > Chi2
D_lngdp	3.102	0.012	1	0.91388
D_lnrenshare	4.1621	1.519	1	0.21772
D_lneleccons	2.8634	0.021	1	0.88483
D_lnco2	4.7514	3.451	1	0.06321
D_lnempelec	5.8773	9	1	0.00227
ALL		14.317	5	0.01372

The Jarque-Bera test results indicate that the errors are normally distributed and there is no evidence of skewness and kurtosis. When compared to GDP, renewable energy share, and carbon dioxide, the electricity consumption had a higher adjustment parameter of -0.0017. This means a fast correction to equilibrium. When there is a high growth in the economy, the electricity consumption adjusts upwards to match the growth of the economy, while the

growth of the economy and carbon dioxide emissions adjust upwards, the renewable energy share adjusts downwards.

The long run equation is given as:

GDP = -49.99195 + 6.5613 (renewable energy share) + 4.7685 (electricity consumption) - 1.16921 (carbon dioxide emissions) + 5.79340 (employment in electricity sector)

A one percent rise in electricity consumption will leads to a 4.7685 percent increase in GDP. In addition, the results also signify that growth is also not only attributed to electricity consumption and carbon dioxide emissions, but to other macroeconomic indicators such as interest rate.

4.2 JEDI Results

As outlined in the methodology section, the Olkaria IV geothermal plant, which has a capacity of 140 MW was used as an example to assess the effects of renewable energy on the employment. The JEDI model was used to analyze these effects. The model uses a spread sheet that incorporates the input-output framework. It requires input data from various components; some of the input data is presented in the appendix II. In summary the main data includes:

- Project descriptive data,
- Model inputs (project costs i.e. initial investment cost and operating and maintenance costs) and
- Investment costs i.e. debt and equity financing, tax etc.

The results of JEDI model analysis are presented in Table 13.

Table 13: Local employment effects

	Jobs (FTE)	Earnings (Millions of $2010)	Output (Millions of $2010)
During construction period			
Project Development and Onsite Labor Impacts	578	$18.62	$2.06
Construction Labor	578	$18.62	
Construction Related Services	0	$0.00	
Turbine and Supply Chain Impacts	6	$1.97	$23.88
Induced Impacts	0	$0.00	$5.82
Total Impacts	584	$20.58	$31.76
During operating years (annual)			
Onsite Labor Impacts	16	$1.29	$0.06
Local Revenue and Supply Chain Impacts	0	$0.01	$0.09
Induced Impacts	0	$0.00	$0.04
Total Impacts	16	$1.29	$0.20

Notes: Earnings and Output values are millions of dollars in year dollars. Construction and operating jobs are full-time equivalent (FTE) for a period of one year (1 FTE = 2,080 hours). Plant workers include operators, field technicians, administration and management. Economic impacts "During operating years" represent impacts that occur from plant and wellfield operations/expenditures. The analysis does not include impacts associated with spending of plant "profits" and assumes no tax abatement unless noted.

About 584 and 16 full-time equivalent (FTE) jobs are created during construction and operating period annually with an estimated output of US$ 32 000 000. The construction and operation phase only takes into account the employment generated during this phase just before the geothermal plant begins to generate electricity. If the total effective capacity (1798 MW) in the country was generated by geothermal power, then an estimate of 7, 514 and 207 FTE jobs will be created during construction and operating time respectively. In addition, an average of US$ 413 000 000 value of output will be generated.

5.0 CONCLUSION

The paper analyzed the effects of green energy on both employment and economic growth in Kenya, using the Olkaria IV geothermal plant as a case study. Econometric regression model and Input-Output models were used to estimate the effects of renewable energy on employment and economic growth. The paper has established that renewable electricity share has a positive impact on economic growth. In terms of employment impacts, the JEDI model established that investments in renewable energy generation contribute to employment creation. For instance, in the Olkaria IV geothermal plant case study, about 584 jobs are created from the generation of geothermal power and an estimated value of output amounting to US$ 32 000 000.

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7.0 APPENDICES

7.1 Appendix I

Figure 1: Test of Heteroskedasticity

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of gdp

         chi2(1)      =     0.04
         Prob > chi2  =   0.8499
```

Figure 2: Test for Multicollinearity

Variable	VIF	1/VIF
co2	3.93	0.254607
energycons	3.74	0.267307
renshare	2.80	0.357631
empelec	2.30	0.434768
Mean VIF	3.19	

Figure 3: Carbon Dioxide Test for linearity

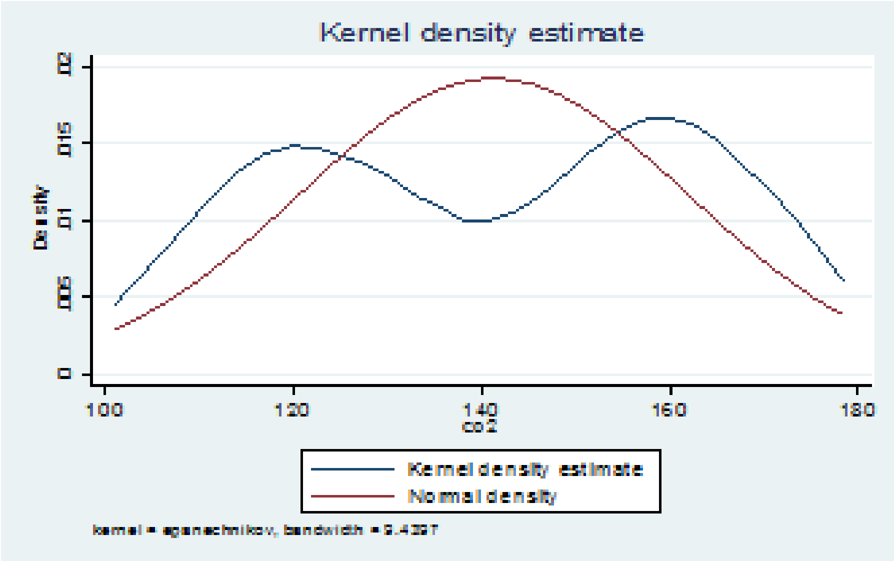

Figure 4: Renewable Energy Share Test for linearity

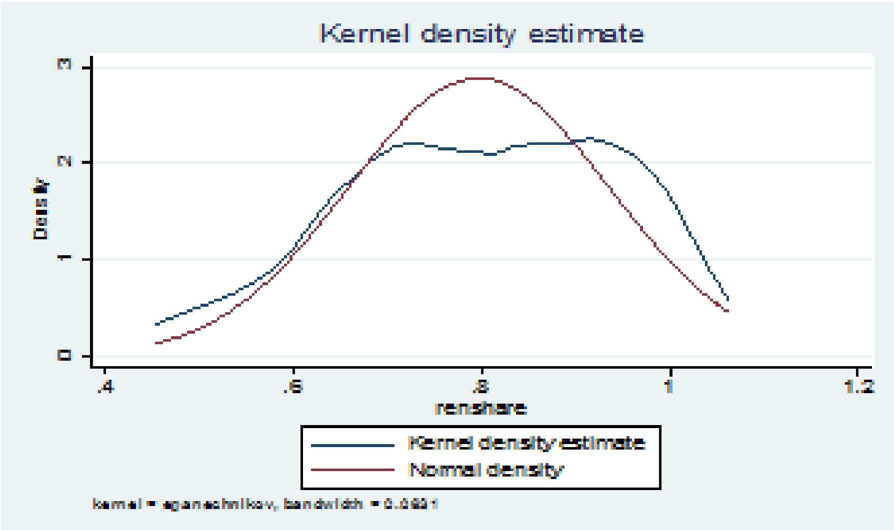

Figure 5: Employment in Electricity Sector Test for linearity

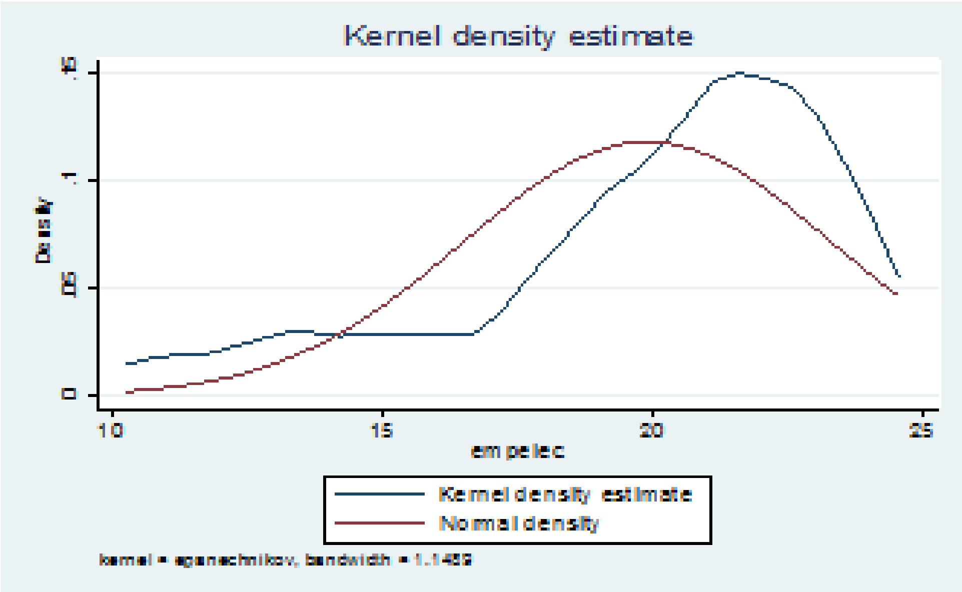

Figure 6: Electricity Consumption Test for linearity

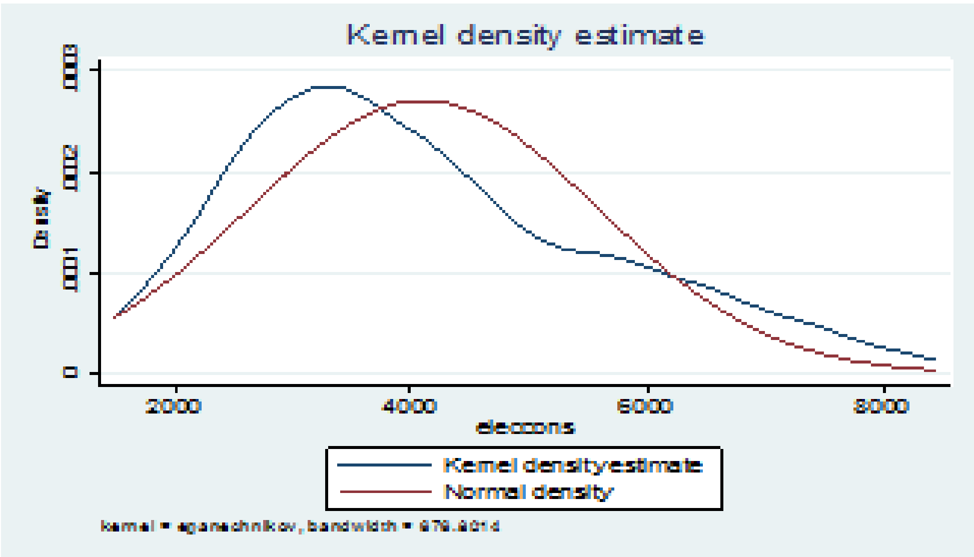

Figure 7: GDP Test for linearity

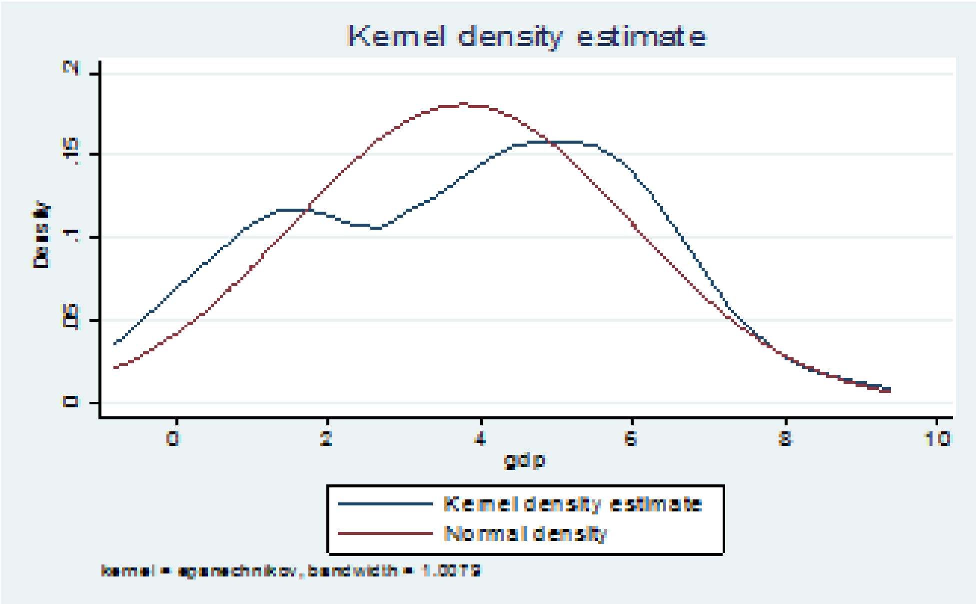

Figure 8: Model Specification Test

Source	SS	df	MS		
Model	69.5330641	2	34.766532	Number of obs =	29
Residual	72.1386356	26	2.77456291	F(2, 26) =	12.53
Total	141.67172	28	5.05970427	Prob > F =	0.0002
				R-squared =	0.4908
				Adj R-squared =	0.4516
				Root MSE =	1.6657

gdp	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
_hat	1.034587	.7482477	1.38	0.179	-.505514	2.574687
_hatsq	-.0042659	.0886481	-0.05	0.962	-.1864046	.1778728
_cons	-.0598273	1.488533	-0.04	0.968	-3.121607	3.001952

Figure 9: An alternative test for Model Specification test

Ramsey RESET test using powers of the fitted values of gdp
Ho: model has no omitted variables
F(3, 21) = 0.05
Prob > F = 0.9841

7.2 Appendix 11

Table A1 Project descriptive data

Project Size - Nameplate Capacity (MW)	140.1
Project Installed Cost	$418,977,509
Plant Capital Cost	$152,104,373
Flash Installed Plant Cost ($/kW)	$1,641
Annual Direct O&M Cost ($/kW)	$56
Installed Project Cost ($/kW)	$4,520
Number of Production Wells	39
Number of Injection Wells	19

Table A2 Project Investment cost and Operating & Maintenance costs

Installed Project Cost ($/kW)	$4,520
Annual O&M Cost ($/kW)	$56
Money Value (Dollar Year)	2010
Installed Project Cost	$418,977,509
Total Annual Operational Expenses	$114,965,966

Table A3 Financial Parameters

Debt Financing	
Percentage financed	70%

Years financed (term)	14
Interest rate	4%
Equity Financing	
Percentage equity	30%
Repayment term (years)	10

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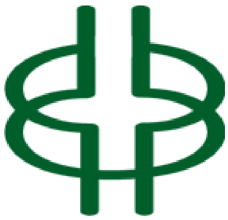
MATE MASIE

"What I hear, I keep"-Symbol of wisdom, knowledge

NEA ONNIMNO SUA A, OHU

"He who does not know can know from learning, -Symbol of life-long



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