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Reduction of Carbon Emissions in Kenya: Focus on Renewable Energy

Ann Mulea

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THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING PROGRAMME

Reduction of Carbon Emissions in Kenya: Focus on Renewable Energy

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Infrastructure and Economic Services Division

Kenya Institute for Public Policy
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Abstract

The country's development blueprint Kenya Vision 2030 identifies energy as a key driver of the economy. However, the sector remains a high contributor of carbon dioxide emissions. This study examines the effect of using renewable energy sources to reduce carbon dioxide emissions from the energy sector from 1971 to 2013. Elasticities of other factors such as energy efficiency, population and GDP which reduce carbon dioxide emissions were also estimated. Using data from the Kenya National Bureau of Statistics and the World Bank, this study uses the Instrumental Variable (IV) approach to estimate the elasticities. Gross Domestic Product and Energy Efficiency were found to be endogenous. After correcting for endogeneity, the results revealed that renewable energy usage and energy efficiency were significant factors for reducing carbon dioxide emissions from the energy sector both in the short and long run. The result also showed that GDP and population increase carbon dioxide emissions. In terms of policy, the study recommends measures towards increasing renewable energy production, as well as adopting energy efficient measures. Increased production from renewable energy sources can be achieved by reviewing the Feed-in-Tariffs to encourage private investors in the renewable energy sector. The government should increase investment in renewable energy sector particularly for wind, geothermal, solar projects and planting of energy crops such as miscanthus and jatropha. Energy efficiency can be achieved by use of upgraded technology in buildings, appliances, and industry as well as end-user applications, efficient lighting and heating, replacing old technologies with new ones in manufacturing, reusing waste heat and adoption of clean technology in its exploitation.

Abbreviations and Acronyms

2SLS	Two Stage Least Squares
APEC	Asia-Pacific Economic Cooperation
CERs	Certified Emission Reductions
CDM	Clean Development Mechanism
CO2	Carbon Dioxide
EAC	East African Community
EIA	Energy Information Administration
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOK	Government of Kenya
IV	Instrumental Variable
KenGen	Kenya Electricity Generating Company
NCCAP	National Climate Change Action Plan
Ksh	Kenya Shilling
Kt	Kilotonne
LTWP	Lake Turkana Wind Project
MENA	Middle East and North Africa
MDGs	Millennium Development Goals
MH4	Methane
Mt	Metric Tonnes
NO2	Nitrogen oxide
OECD	Organization for Economic Co-operation and Development
SDGs	Sustainable Development Goals
SO2	Sulphur dioxide
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WB	World Bank

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Chapter One: Introduction

1.1 Background

Global energy challenges have seen many countries adopt the use of resources that are not friendly to the environment in order to meet their energy needs. In generation of electricity, for instance, fossil fuels are the main source. Yet, burning of coal, oil and natural gas – the three main types of fossil fuels – produces and emits into the atmosphere carbon dioxide (CO_2) as well as other greenhouse gases (GHGs) among them nitrous oxide (N_2O), sulphur dioxide (SO_2) and methane (MH_4). These gases contribute to the rise in the earth's temperature since they are transparent to incoming (short-wave) radiation from the sun but block infrared (long-wave) radiation from leaving the earth's atmosphere. This phenomenon is what is referred to as the greenhouse effect. The rise in the earth's temperatures leads to global warming, whose outcome is what experts recently have come to refer to as climate change. The effects of climate change are manifested in severe weather patterns such as longer and hotter summers accompanied by droughts, and frequent extreme weather phenomena that includes hurricanes, monsoon rains, and rise in sea level.

Whether or not the recent abnormally warm weather is a manifestation of the increasing greenhouse gas effect is somewhat debatable, but as long as countries continue to use fossil fuels as the main source of electricity generation, it is believed that devastating consequences of greenhouse gas effect will soon force nations around the globe to individually and jointly give it high priority. On this, there is a strong consensus in both community of scientists and environmental experts. The same experts, not in the so distant past, had predicted the devastating effects that would befall nations on global scale if levels of GHGs emissions were not brought down to safe levels. A series of meetings and conferences by participating countries within the context of UNFCCC gave birth to the Kyoto Protocol. A total of 37 countries ratified the Protocol in 1997, thereby committing individually and severally to reduce emissions by at least 5 per cent below the 1990 levels during the first commitment period of 2008-2012. This took cognizance of the fact that these countries were principally responsible for the high levels of GHGs emissions in the atmosphere by then, as a result of more than 150 years of industrial activity. The Protocol thus placed a heavier burden on developed nations under the principle of "common but differentiated responsibilities." For the second commitment period (2013-2020), the countries agreed to reduce emissions by at least 18 per cent during the period 2013-2020.

Apart from the global front, African countries have come up with several joint initiatives to address the problems posed by climate change. These include the Africa Ministerial Conference on Environment, the Framework of Southern and Northern Africa Climate Change Programmes, and the East Africa Community Climate Change Policy. Evidence shows that the continent is most vulnerable to climate change due to weak adaptive capacity, high levels of poverty, and over-reliance on rain-fed agriculture. The East Africa Community Climate Change Policy was triggered by emerging issues and challenges due to impacts of climate change.

The key mitigation measures in the policy were promotion of energy efficiency, waste management, reforestation, efficient transport system, afforestation, and efficient livestock and crop production. The EAC partner states committed to increase investment to provide access to affordable and clean energy, improve energy efficiency, and promote clean technologies. The member states are also obligated to devise a precautionary method to their development of biofuels.

In the Kenyan case, a National Climate Change Action Plan covering the period 2013 to 2017 has been developed to address issues relating to climate change. To address the country's vulnerability, the plan encourages pursuance of sustainable development through low carbon climate resilient pathway. Among other things, the plan advocates for low carbon environment. The primary reason it puts emphasis on low carbon is due to realization that of all GHGs, CO_2 contributes to a large degree to climate change. In fact, experts predict that doubling the levels of CO_2 in the atmosphere will increase average temperature by 7°F. This, they say, is inevitable unless countries around the world act decisively. In terms of contribution to carbon emissions, the energy sector has been identified as the leader globally. Kenya is no different. Figure 1.1 shows the levels of emissions from different sectors in the economy.

From Figure 1.1, Kenya's energy sector is the highest source of emissions, with 51 per cent of the total carbon emissions. The other sectors account for the remaining 49 per cent.

Figure 1.2 shows the trend of carbon emissions from the energy sector. There was a sharp decrease in CO_2 levels in 2003, perhaps due to the high usage of renewable energy sources, which stood at 84 per cent of the total energy sources.

Figure 1.1: Carbon emissions per sector

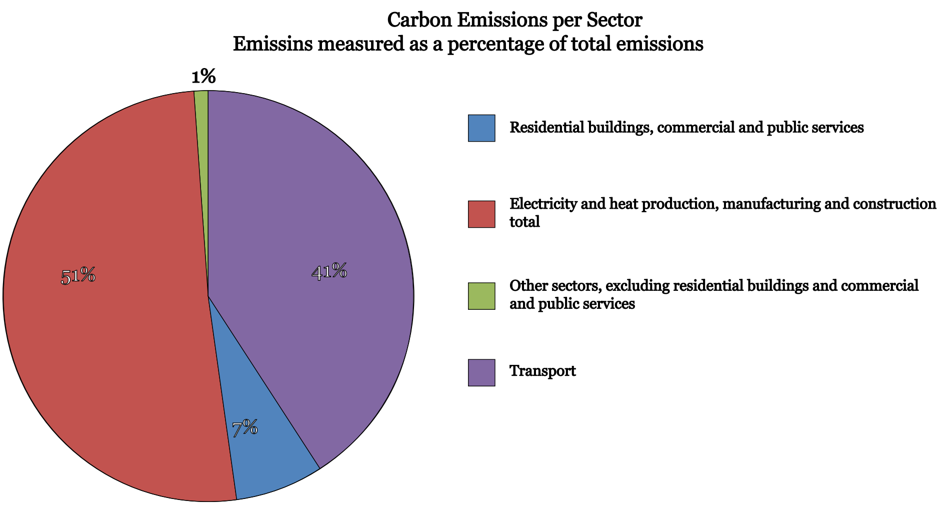
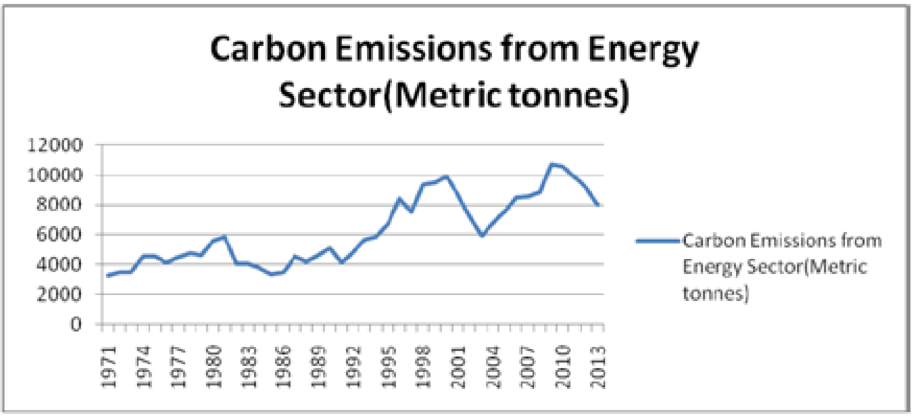


Figure 1.2: Trend of carbon emissions from the energy sector in Kenya, 1971-2013

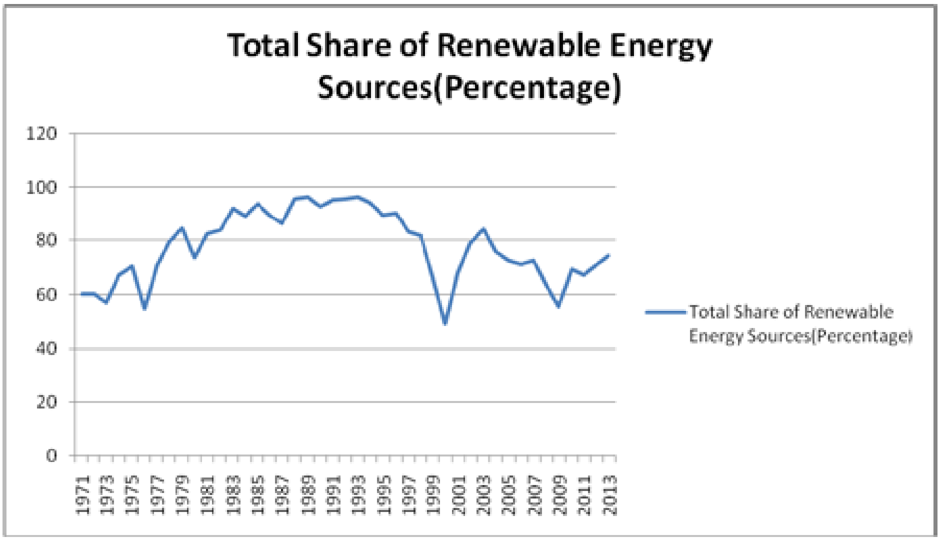


In an attempt to address the high levels of emissions generated by the energy sector, and in line with the Kyoto Protocol, which Kenya signed in 1997 and ratified in 2005, Kenya sought to engage in carbon trading through the Kenya Energy Generating Company (KenGen). The Protocol has identified carbon trading as the main target for reducing emission levels. By participating in implementation of 6 selected projects, KenGen expected to displace about 0.66 million tonnes of carbon dioxide annually. However, in 2008, carbon prices fell from Ksh 4,320 per tonne to less than a dollar (Ksh 86.40) in the European Union markets, leading to failure of carbon markets. Due to this, the future of carbon markets remains unpredictable. The demand/supply imbalance of compliance credits could also see prices remain low for a long period of time. External factors such as rules by the European Union to reject the Certified Emission Reductions (CERs) registered after 2012 will surely affect carbon trading in Kenya.

Apart from carbon trading, the National Energy and Petroleum Policy supports mitigation of climate change through energy efficiency and promotion of renewable energy sources. Also, the Feed-in Tariff policy of 2008 was revised in 2012 to encourage production of clean energy from renewable sources. The success attained from implementation of these and other policies is yet to be seen.

Figure 1.3 shows the pattern of renewable energy usage from 1971 to 2013. The renewable sources widely in use in the country include geothermal, hydro, biomass, biofuels and solar. Wind energy potential is huge due to wind speed of 6m/s in several parts of the country, including Marsabit, Uasin Gishu, Isiolo, Kajiado, Nyandarua, Laikipia, Meru, Kiambu, Kilifi, Turkana, Narok, Samburu, and Lamu counties. Also, the country has great ocean energy potential due to the long coastline of 536 kilometres.

Figure 1.3: Total share of renewable energy sources in Kenya from 1971-2013



1.2 Problem Statement

Energy is a key driver of the economy. Among other things, it facilitates technological and social advancements, therefore acting as a catalyst to economic growth. However, generation of electricity – a critical component of energy – leads to serious negative externalities, among them emission of large quantities of CO_2 as a result of using energy sources that are not clean (fossil fuels). Estimates indicate that a country that is burning three tonnes of coal annually produces 11 million tonnes of CO_2.

Statistics show that despite Kenya increasing the share of energy produced from renewable sources over the years, CO_2 levels from the sector have not gone down commensurate as it would be expected. In 1971, Kenya was using 60.43 per cent of renewable energy sources while by 2013 this had risen to 74.5 per cent. The amount of CO_2 has nonetheless been increasing gradually. In 1971, CO_2 from the energy sector was 3,290 metric tonnes and 8,018 metric tonnes in 2013. The recent discovery of two dirty fuels – coal and oil - is likely to complicate the matter even more as their use will render electricity generation cheaper, thus it will remain a very tempting option for energy sector players.

The economic costs associated with failure to adequately address the problem of greenhouse gas emissions are likely to have significant adverse impacts on poverty alleviation programmes and policies being implemented by the government. In short, the gains the country has made in its various development efforts, including the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) will be eroded. In the same breath, it will affect the country's ability to meet the objectives set out in Vision 2030, as well pursue the recently launched

Sustainable Development Goals (SDGs).

Use of renewable energy sources in electricity generation is one of the surest ways of reducing CO_2, as there is no combustion of fuels involved. It is therefore against this backdrop that the study seeks to establish the effect of factors such as energy efficiency, population and GDP on CO_2 reduction in the energy sector.

1.3 Objectives

The general objective of the study is to investigate and model the factors that reduce CO_2 in the energy sector. The specific objectives will be to:

(i) Determine the effect of renewable energy on carbon dioxide reduction in Kenya.

(ii) Estimate the elasticities of the factors that reduces CO_2 emissions in Kenya.

1.4 Research Questions

(i) What is the effect of renewable energy development on carbon reduction in Kenya?

(ii) What are the elasticities of the factors that reduce CO_2 emissions in Kenya?

1.5 Justification

Renewable energy sources are important as they ensure adequate supply of energy needs. They are also vital to ensuring low carbon dioxide emissions. Low emissions build more adaptive capacity, ensure sustainable development, improved livelihoods and reduces disaster risks. Energy efficiency measures are significant in the Kenyan economy. However, several challenges exist such as lack of knowledge of the benefits and methods of conservation, limited technical capacity, and insufficient data and apathy towards energy efficiency measures. One of the measures advanced to encourage clean energy is the use of renewable energy. The study set to determine the effect of renewable energy development on carbon emission reduction. This will be useful as Kenya is advocating for measures to move towards a green economy.

The Least Cost Power Development Plan 2008-2030 recognizes that several measures have been identified in the renewable energy sub-sector. These include promoting the consumption of renewable energy and energy conservation technologies for sustainable development, providing duty and tax incentives, and establishing an appropriate legal framework for renewable energies. Therefore, use of renewable energy sources should be promoted. The MDGs aim at ensuring environmental sustainability, and recommend investing in clean energy. The

SDGs advocate for access to sustainable energy by increasing renewable energy sources by 2030, and striving to double the global rate of improvement of energy efficiency by 2030 through upgrading of technology.

The Government of Kenya has also taken measures to reduce carbon dioxide. In the years 2005-2015, the Government of Kenya committed Ksh 37 billion and development partners Ksh 194 billion towards measures of reducing carbon dioxide emissions, according to the Kenya National Climate Change Action Plan 2013. Indeed, energy uses the largest share of climate financing, which stands at about 40 per cent (Government of Kenya, 2013). Finally, the Kenya Constitution 2010, under the Bill of Rights, also advocates for clean and healthy environment to all citizens.

Chapter Two: Literature Review

This section presents an overview of studies that have been done on renewable energy and its impact on reducing carbon dioxide emissions. The section outlines both theoretical and empirical literature. An overview of the literature is presented at the end of the chapter.

2.1 Theoretical Literature

Externalities/market failures

Studies by Brown (2001), Groba and Breitschopf (2013) show that government regulations are necessary to correct market failures and barriers in the renewable energy markets. Market failures are variations from perfectly operational markets. They include negative externalities, positive externalities, unpriced costs or benefits of externalities, information market failures, and market power. Market barriers include lack of awareness of energy issues, and distortionary fiscal and regulatory policies.

Negative externalities

In most cases, the prices of fossil fuels do not effectively match the related cost. Therefore, these fuels are consumed at a level above the optimum. This leads to a negative externality because the social costs of emission are above the private costs of emission (Brown, 2001). Therefore, substitutes for fossil fuels, such as renewable energies, are being under-utilized as the fossil fuels are cheaper. The government does not offer incentives on renewable energies.

Positive externalities

The technical know-how in energy generation could lead to spillover effect to those that did not have that kind of knowledge. There is no associated cost to those that benefit from this knowledge. Policy interventions are required to ensure the bearer of knowledge is allocated intellectual property rights.

Market power

Competition between energy sources could be highly unprofitable to small scale producers or those with lower technological know-how. There needs to be interventions that benefit all producers.

Information asymmetry

According to Brown (2001), information related costs are usually high when dealing with renewable energy investment and consumption. Information asymmetry leads to market failure. Information plays a key role in perfectly competitive markets.

Market Barriers

Some hindrances such as low awareness of policy makers, distortionary fiscal and regulatory policies, uncertainty in energy prices, and perceived risks lead to market failure, therefore reducing investment in the renewable energy market.

2.2 Empirical Literature

The various empirical evidence has proved that use of nergy is certainly a critical factor influencing the level of CO_2 emissions (Ang, 2008; Apergis and Payne, 2009). Jahl and Habibulah (2013) modelled CO_2 emissions as a function of economic growth, energy usage, foreign direct investment, industrial sector production, fossil fuel energy, and education levels. Their findings explained that use of energy was a significant factor, while fossil fuel energy consumption was insignificant in causing CO_2 emissions in the Asia-Pacific region. Akin (2014) modelled the determinants of CO_2 emission as economic growth, energy use, and trade openness in 85 countries and found a positive relationship between CO_2 emission and energy use.

Parikh et al (2013), in their study on low carbon development strategies, reported that mitigation of CO_2 emissions required more investments in renewable sources of energy. The recommendations from the study include provision of subsidized electricity to poor households, and targeting solar and wind-based power generation. They further noted that the high population in India of 340 million was causing rapid industrialization. High levels of poverty forced households to use cheap fossil fuels, which lead to high emission of CO_2.

A study by Leitao (2014) of Portugal evaluates the linkage between carbon dioxide emission, economic growth, renewable energy, and globalization. The results reveal that use of renewable energy was positively correlated to economic growth and negatively correlated to carbon dioxide emissions. Bozkurt and Akan (2014) study of Turkey used GDP per capita and energy consumption to model the relationship between economic growth, CO_2 emissions and energy consumption. The findings from the study indicate that CO_2 emissions had a negative effect on economic growth, while energy consumption had a positive effect on CO2. The study therefore recommended the use of renewable energy sources.

A study conducted by Fischer and Newell (2004) assessed different policy options for promoting renewable energy sources and their importance in reducing CO_2 emissions. Emission taxes were the most efficient in reducing pollution. Renewable energy producers therefore increased their production, leading to a cleaner and safer environment.

A Structural Vector Autoregressive Approach was used in the study by Silva et al (2012) on analysing the impact of renewable energy sources on carbon dioxide emissions. There was an evident decrease of CO_2 emissions per capita when renewable energy sources are used. The study used a sample of 4 countries. Taguchi (2012) used the Instrumental Variable approach in a study to estimate the relationship of environmental pollution and economic growth. The study used GDP lagged by one period as an instrument for GDP while estimating the effect on emissions on economic growth. This cured the endogeneity problem in the model used. However, Liu (2005) estimates on 24 OECD countries found that adding energy consumption implies a negative relation between income and CO_2 emissions. This outcome was supported by the study by Lee and Oh (2006) on 15 APEC countries that saw growth in energy intensity effect contribute negatively to CO_2 emissions in developed countries, but positively with developing countries except China. The findings by Zannawaziri et al (2012) reveal that renewable energy consumption by Nigeria's major gas and oil importers results to significant negative impact on its economy, and therefore was not a good measure towards reducing carbon dioxide emissions. Farhani and Rejeb (2012) reveal that in the short run, there was no causal link between CO_2 and energy consumption in a study for 15 countries in the MENA region.

2.3 Overview of the Literature

From the discussion of theoretical literature, CO_2 emission is a negative externality. To control these emissions, the question of who has the property rights to emit arises. A tax can also be levied to reduce the quantities of emission. Externalities can also be addressed through government regulations. Various empirical evidence has proved that use of energy is certainly a critical factor in affecting the level of CO_2 emissions. However, other studies show that use of energy has no effect on growth of CO_2 emissions. Various studies have used different methodologies, which include the SVAR, IV, Panel Data and Time Series approaches. This study adopted the 2SLS IV approach to estimate the elasticities, in order to cure the problem of endogeneity between variables. The study was carried out to establish the effect of renewable energy consumption and its effect on reduction of CO_2 emissions in Kenya. From the findings, the study was expected to recommend measures to increase the use of renewable energy for a sustainable environment.

Chapter Three: Methodology

This chapter outlines the analytical framework, conceptual framework, and the empirical model. It also outlines the definition of variables and data sources to be used for the study. The study uses time series data from 1971 to 2013. This is because significant energy production amounts were reported in the early 1970s following the construction and functioning of the first dam, Kamburu. It is also after the oil crisis of 1970s when the importance of energy became fully realized as a factor of production.

3.1 Analytical Framework

Recent studies on externalities have focused on water and air pollution. The two concepts are produced under joint distribution concept. This means that it is not possible to supply goods to one party without supplying to the others. Mohring and Boyd (1971) used an example of lake water and assuming an objective to maximize social utility given by the equation below:

$$Max\ U=\Sigma P_i Y^i(X_i, Z_i, Q_i)-\Sigma W_i X_i-\Sigma C(L)+\Sigma\lambda(Q_i-Q^i(Z_i....Z_n L) \qquad 1$$

Where C(L) is the yearly cost of changing lake characteristics.

Differentiating Equation 1 with respect to X_i, X_j, Q_i and L we get:

$$P_i- Y^i_{xi}-W_i=0(i=1....n) \qquad (a)$$

$$P_i Y^i_{zi}-\Sigma P_j Y^j Q_j Q^j_{zi}=0(i=1.....n) \qquad (b)$$

$$\Sigma P_j Y^j_{Qj} Q^j_L-C'-0 \qquad (c)$$

As is the common case with most externality problems, different people get different amounts of the externality good. This situation can be characterized by:

$$X^i=A^iX \qquad (2)$$

Where *A* is the quantity of a good received by individual *i* to the level of production.

From the above example, we can write the equation in a linear form as:

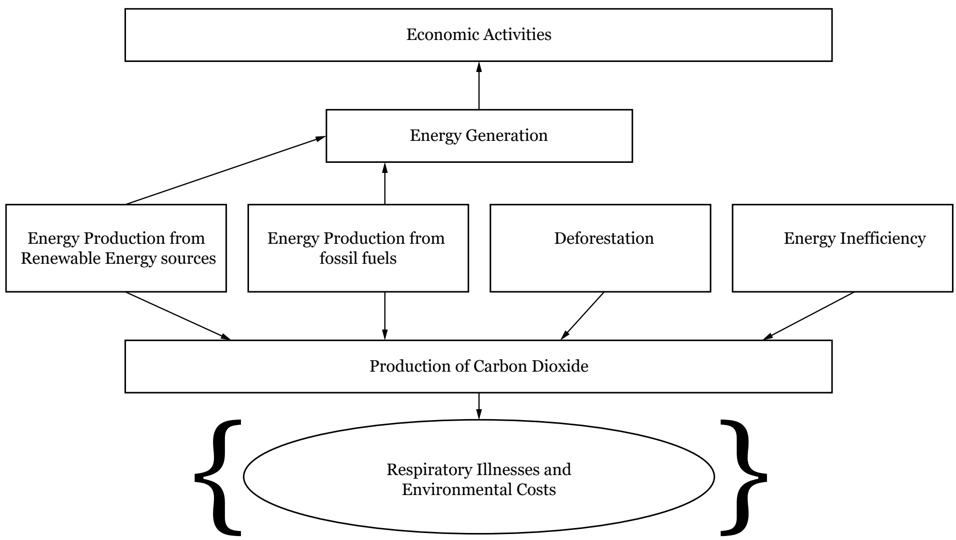
$$Y=X\alpha+Vi \qquad (3)$$

Where *X= (Xi......Xn)* and *Vi* is a random error term that represents unobserved effects and it is assumed to be uncorrelated with the *X* variables. α are the corresponding vectors of coefficients.

3.2 Conceptual Framework

It is conceptualized that carbon emissions are caused by unclean energy production, energy inefficiencies, deforestation, and methane emission. Energy production from fossil fuels increases the amount of carbon dioxide. Use of inefficient energy equipment or technologies also raises the levels of CO_2. Deforestation has adverse impacts on capture and storage of carbon dioxide. Methane emissions could be from natural and human sources. The main natural sources include wetlands and the oceans. Human sources of methane include landfills, transportation, livestock farming and its production, and use of fossil fuels. Use of clean energy and efficient technologies is expected to reduce the levels of carbon dioxide. Carbon emissions, on the other hand, cause global warming and environmental pollution.

Socio-economic Environment



Source: Author's illustration modified from Ebert (2011)

3.3 Empirical Model

The variables used in the study have been informed by past related studies as well as economic theory. Modifying Nyangena's (2004) model, this study expressed the CO_2 reduction as a function of renewable energy sources, GDP, population and energy efficiency. The model is appropriate as it was applied to Kenya. Borrowing from this model, the study estimated the model as shown below:

$CO_2 = f$ *(Share of Ren Energy Sources, Energy Efficiency, GDP, Popn*

In CO_2 *= SRES + EE + In GDP + In Popn*

Where: CO_2 = Carbon Dioxide; RES = Share of Electricity Produced from Renewable Energy Sources; GDP = Gross Domestic Product; EE = Energy Efficiency; and Popn = Population.

3.4 Definition of Variables

The table below gives a summary of the variables and their definitions, and the expected signs

Table 3.1: Definition of variables

Variable	**Definition**	**Expected Sign**
Carbon Dioxide Emissions	This is the Carbon Dioxide Emission generated by consumption of solid and liquid fuels, fossil fuels and manufacturing. The variable has been measured in metric tonnes.	Dependent Variable
Share of Renewable Energy Sources	This is the share of production of electricity from renewable sources to total power production. Literature shows there is effectiveness of renewable energy sources in climate change mitigation	-ve
Gross Domestic Product	This is the GDP measured in US$. Wide-ranging literature shows there is a relationship between energy consumption, economic growth and environmental pollution	+ve
Energy Efficiency	Energy Efficiency is given by energy intensity, which measures how efficiently a country uses energy. Energy efficiency captures the technological advances. Calculated as total energy per unit of output (IEA, 2011)	-ve
Population	This is the total country's population measured in millions. Population is expected to have a direct link with the quantities of energy demanded	+ve

3.5 Data Sources

The study used secondary data. Data was collected from government publications such as economic surveys, KenGen reports, and statistical abstracts. More data was obtained from the World Development Indicators.

Chapter Four: Estimation Results and Discussion

4.1 Introduction

The estimation results are classified into three: the descriptive statistics, long run results, and results from the dynamic error correction model after correcting for endogeneity using an instrumental variable approach. The descriptive, long-run and dynamic error correction results are presented in Tables 2, 5, and 7, respectively.

The summary statistics show that the average carbon emission from the energy sector was 8,822.851 metric tonnes per annum during the study period. The average usage of renewable energy sources across the period was 77.9 per cent. Most of the skewness and kurtosis values are near zero, implying a normal distribution.

Table 4.1: Descriptive statistics

Statistic	Variables					
	CO2	**Pop**	**Ee**	**Sres**	**Gdp**	**Gdp1**
Mean	8822.851	25.402	0.254	77.918	13700000000	1470000000
Median	7638.201	25	0.262	78.881	13100000000	13200000000
Maximum	16012.97	42.5	0.325	96.479	26900000000	47600000000
Minimum	4369.299	11.7	0.145	49.356	4940000000	5790000000
Std. Dev	3521.836	9.117	0.057	13.181	5860000000	7670000000
Skewness	0.0895	0.606	0.143	0.464	0.129	0.0009
Kurtosis	0.039	0.008	0.05	0.049	0.490	0.0002
JB Statistic	6.53	6.71	5.68	4.49	2.97	23.91
Probability	0.038	0.034	0.059	0.106	0.226	0.0009

Source: Author's estimates based on the data

Where:
CO_2 = Carbon Dioxide
Sres = Share of electricity produced from Renewable Energy Sources
Gdp = Gross Domestic Product
Ee = Energy Efficiency
Popn = Population

4.2 Cointegration

Table 4.2: Results from Johansen tests

Rank	eigenvalue	t-statistic	5% critical value
0	-	116.481	68.52
1	0.838	41.867*	47.21
2	0.493	13.996	29.68
3	0.233	3.117	15.41
4	0.073	0.000	3.76
5	0.000		

The results indicate that the rank (r=1) implying that there is one cointegrating equation and, therefore, a linear combination of all variables have a long term relationship. The trace statistic at r=0 is greater than the critical value. All the eigen values lie between 0 and 1; therefore, the series is cointegrated.

4.3 Unit Root Tests

Augmented Dickey Fuller test was used to test for unit root. Table 4.3 presents the p-values from the tests. All variables are integrated of order one.

Table 4.3: Results from Augmented Dickey Fuller unit root test

Variable	p-values at level	p-values at 1st difference
$InCO_2$	0.6563	0.0000
Inpopn	0.2457	0.0000
ee	0.1817	0.0000
sres	0.1845	0.0000
Ingdp	0.6621	0.0014
Ingdp1	0.9180	0.0054

Where:

$InCO_2$ = Natural logarithm of Carbon Dioxide
Sres = Share of electricity produced from renewable energy sources
Ingdp = Natural logarithm Gross Domestic Product
Ingdp1 = Natural logarithm Gross Domestic Product lagged by one period
Ee = Energy efficiency
Inpopn = Natural logarithm of population

4.4 Regression Results from the Long Run Model

Table 4.4: Regression results of the variables in the long run model

Variable	Coefficient	t-static	p-value
Constant	-18.007	-2.73	0.010
Inpopn	1.315	2.67	0.011
ee	-4.748	-2.94	0.006
sres	-1.1	-8.03	0.000
Ingdp	1.328	3.91	0.000

Source: Own Computation using STATA

Where:
Sres = Share of electricity produced from renewable energy sources
Ingdp = Natural logarithm Gross Domestic Product
Ee = Energy efficiency
Inpopn = Natural logarithm of population

The results indicate that a 1 per cent increase in population increases carbon emissions by 1.315 per cent in the long run. This explains why the higher the population, the higher the power demand, which increases the generation. A 1 per cent increase in GDP also increases CO_2 emissions by 1.328 per cent. Energy efficiency was also significant, and a 1 per cent increase in efficiency leads to a 4.748 per cent decrease in carbon emissions. A 1 per cent increase in production from renewable sources reduces carbon dioxide significantly by 1.1 per cent. This is because renewable sources are clean and environment friendly.

4.5 Selection of an Instrumental Variable

Endogeneity of variables can yield misleading results. The GDP variable moves directly with other independent variables and could also be correlated with the error term. Additionally, the energy efficiency variable is highly correlated with GDP variable with a correlation coefficient of 0.9664. This, therefore, results in correlation among the variables as shown in the Table 4.5.

Correlation matrix between explanatory variables

Table 4.5: Correlation coefficients

	Popn	**Gdp**	**Ee**	**Sres**
Popn	1.000			
Gdp	0.9933			
Ee	0.9778	0.9664	1.000	
Sres	0.0363	0.0254	0.1209	1.000

Where:

Sres = Share of electricity produced from renewable energy sources
Gdp = Gross Domestic Product
Ee = Energy efficiency
Popn = Population

GDP with one lagged period was used as an instrumental variable for GDP to cure the problem of endogeneity. The two variables are highly correlated with a correlation coefficient of 0.9835. Similarly, this variable was used in a study by Taguchi (2012) while estimating the relationship of environmental pollution and economic growth. The two-stage least squares procedure was used in the regression analysis.

4.6 Regression Results from the Dynamic Error Correction Model Using The OLS And IV-2sls Approaches

Table 4.6: Regression results from the Dynamic Error Correction model using the OLS and IV-2SLS approaches

Results	**OLS coefficients**			**IV-2SLS coefficients**		
	Coefficient	T value	p	Coefficient	Z value	p
Dependent Variable / Independent Variables	$DInCO_2$			$DInCO_2$		
Constant	-0.020	-0.49	0.627	-0.060	-1.20	0.229
$DInCO_2$(-1)	0.251	1.66	0.107	0.254	1.65	0.099
DInpopn(-3)	1.256	1.32	0.196	1.328	1.57	0.117
D1sres	-0.7	-3.64	0.001	-0.7	-3.78	0.000

Dee(-4)	-2.080	-1.49	0.146	-2.604	-1.87	0.062
DIngdp	0.261	0.37	0.713	1.576	1.26	0.206
ECT(-1)	-0.529	-3.73	0.01	-0.501	-3.75	0.000
R2			47.99%			42.12%

Source: Own computation from data

Where:
$InCO_2$ = Natural logarithm of Carbon Dioxide
Res = Share of electricity produced from renewable energy sources
Ingdp = Natural logarithm of Gross Domestic Product
Ee = Energy efficiency
Inpopn = Natural logarithm of population

Using instrumental variable improved the significance of energy efficiency. Further, the coefficients of all lagged CO_2 emissions and energy efficiency improved. Therefore, the regression results from the IV estimation were adopted.

All the variables had the expected signs. Power production from renewable sources and energy efficiency were significant factors for carbon emission reduction. A 1 per cent increase in each reduces CO_2 by 0.7 per cent and 2.604 per cent respectively. A study by KIPPRA (2010) shows the estimated national energy saving for all forms and sources of energy as Ksh 24.20 billion, translating to 7,604,374 giga joules following energy efficiency and conservation measures.

The error correction term had the expected sign and was significant, implying that the model was useful to correct past deviations. The coefficient indicates that 0.1 per cent of the deviations from the long run equilibrium were corrected.

4.7 Post-Estimation Tests

The Durbin statistic and the Wu-Hausman had probability values of 0.1868 and 0.2392, implying that the variables are exogenous.

Results from the first stage indicated values of 36.60 per cent, 24.33 per cent and 28.87 per cent for the R-squared, Adjusted R-squared and partial R-squared, respectively. The R-squared and adjusted R-squared explain the variations in the model from fitting the first stage regression. The partial R-squared measured the correlation between GDP and the additional instrument after ignoring the effect of other variables (Bound, Jaeger and Baker, 1995). The F-Statistic had a value of 12.583 with a probability value of 0.0013, implying that the instrument variable was significant. Its significance explained the power to control for the effects of other variables.

4.8 Limitation of the Study

Environmental taxes play a key role in reducing the levels of carbon emissions. However, there is limited data on environmental taxes or carbon taxes in Kenya.

Chapter Five: Conclusions and Policy Recommendations

5.1 Conclusion

Renewable energy has little or no carbon emissions. When low-emitting forms of renewable energy are used to replace fossil-fuel energy, reductions in air pollution occur, and cleaner air is the outcome. Evidence from this study reveals that use of renewable energy is a significant factor in carbon emission reduction. Using efficient equipment and technology was also a key factor of carbon emission reduction.

5.2 Policy Recommendations

Energy efficiency reduces overall resource use, cost and helps mitigate climate change by lowering GHG emissions. This can be achieved by use of upgraded technology in buildings, appliances, and industry as well as end-user applications. The following measures can also be used: efficient lighting and heating, replacing old technologies with new ones in industry and mining. The manufacturing sector can be efficient by reusing waste heat. The sector is the largest consumer of electricity in the country. Cogeneration will reduce the amount of energy used in manufacturing processes as heat and power production are done simultaneously. Kenya should also adopt clean coal technology in its exploitation.

The government should increase or encourage production of power from renewable energy sources as they lower GHGs and increase energy security. Geothermal sources have a potential of reducing CO_2 while wind and hydro have abatement potential of 2.5 metric tonnes of CO_2 by 2030 (Government of Kenya, 2013.). Increased production from renewable sources can also be achieved by reviewing the Feed-in-Tarrifs to encourage private investors in the renewable energy sector. The government needs to increase investment in the renewable energy sector, particularly for wind, geothermal, and solar projects. The government should also set aside land to plant energy crops such as miscanthus and jathropha, which adapt well with the climatic conditions in Kenya.

5.3 Area of further research

Further study is required to estimate the optimal level of carbon dioxide emissions that should be emitted to achieve maximum growth at the same time keeping the environment clean and safe.

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