EXPLORING THE USE AND IMPACTS OF RENEWABLE ENERGY SOURCES IN COMBATING CLIMATE CHANGE IN THE RURAL COMMUNITIES OF KENYA: A CASE STUDY OF BUNGOMA COUNTY

BY

IMBUGWA INYAMBURA DIANA

MASTER OF SCIENCE THESIS

SUBMITTED TO PAN-AFRICAN UNIVERSITY
INSTITUTE OF WATER AND ENERGY SCIENCES
(Including CLIMATE CHANGE)

DEPARTMENT: ENERGY POLICY

DEFENDED ON 18TH DECEMBER 2021

<u>JURY MEMBERS:</u>

Prof. (Eng). James M Raude – (JKUAT, Kenya)
Prof. Sidi-Mohamed Chebane -Sari – (Tlemcen Univ. Algeria)
Prof. Dr. Christian Von Hirschhausen – (TU Berlin, Germany)
Prof. Mohamed Benbouziane – (Tlemcen Univ, Algeria)

2021

DECLARATION

This thesis is my original work and has not been submitted for award of a degree in any other University.

SIGNATURE:.....................DATE: 21st December 2021

Reg. No: PAUWES/2019/MEP05

Imbugwa Inyambura Diana

This thesis has been submitted for examination with our approval as Supervisors.

SIGNATURE: .... DATE: 21st December 2021

Prof. (Eng). James M. Raude, PhD

Jomo Kenyatta University of Agriculture and Technology, Kenya

SIGNATURE: .... DATE: 21st December 2021

Dr. Sylvia I. Murunga, PhD

Jomo Kenyatta University of Agriculture and Technology, Kenya

Acknowledgements

I am grateful to my family for the support they have given me and all participants who took time off their busy schedules to contribute their perspectives on the research. I thank my thesis advisors Prof. (Eng). James M. Raude, PhD (Jomo Kenya University of Science and Technology) and Dr. Sylvia I. Murunga, PhD (Jomo Kenyatta University of Science and Technology) for consistently guiding, reviewing, commenting and motivating me throughout the development of this research.

I as well want to express my gratitude to the African Union Commission for granting me the scholarship and the opportunity to pursue my master studies and for funding this research. I sincerely thank Pan African University for Water and Energy Sciences (including climate change) for hosting and supporting me throughout my time of the studies.

Diana Imbugwa

Abstract

Climate change is an emerging global issue that can longer be ignored and requires immediate actions. This can clearly be seen from the unpredictable weather patterns which have made it difficult to maintain crops in the regions that depend on normal weather conditions because of the variation in weather patten. Global warming and climate change relate to one another with the increase in average global temperature believed to be naturally caused by anthropogenic activities. Climate Change and Renewable Energy (RE) are connected to a very significant level in the fact that renewable energy serves as a tool for coping with climate change, as a mitigation strategy and also as an adaptation strategy. This is attributed to RE resources being naturally clean during energy production as compared to the electricity generation from conventional resources. This study assessed the uses and impacts of renewable energy resources in combating climate change in the rural communities of Bungoma County in Kenya. This was achieved through critical review of the literature on the current climate policy projections of Kenya, and a critical review of the link between Renewable energy and Climate Change. The methodology further involved data collection through admission of questionnaires, key informant interviews and direct observation. The research utilized both Qualitative and quantitative data analysis with the Low Emissions Analysis Platform tool being used for the modeling of the energy scenarios with the Implementation of new energy efficiency policies. The findings showed that despite the significant increase in the adoption of renewable energy technologies in Kenya, rural households practice fuel staking in both cooking and lighting. Most households in the rural areas are not connected to the national electrical grid due to the high cost of connectivity. Wood is the dominant source of fuel in 95% of the households, followed by charcoal and LPG at 67% and 22% respectively. Most households use open air (three stone) cook stoves for cooking and collect their energy from the environment. There has been an increase of 86% in built up area and 37% of baren land with a decrease of 59% in vegetation cover from 1990 to 2020 impacting the environment. High initial cost, finance, lack of information and institutional barriers were some of the barriers and challenges identified in the adoption of RE technologies. Business As Usual (BAU) scenario projected an increase in energy demand and emissions by 36% and 6% respectively by 2040. Implementation of energy efficient policies projected a reduction in energy demand and emissions by 26% and 21% respectively in 2040. The finding shows that adoption of renewable energy resources and implementation of energy efficient policies is the key to reduction of GHG emissions a mitigation factor to global warming and climate change.

Diana Imbugwa

Table of Contents

DECLARATION ii

Abstract iv

List of Acronyms and Abbreviations xi

CHAPTER ONE 1

INTRODUCTION 1

1.1 Background Information 1

1.1 Statement of the Problem 4

1.3 Objectives 5

1.3.1 Main Objective of the Study 5

1.3.2 Specific Objectives 5

1.4 Research Questions 5

1.5 Justification of the Study 5

1.6 Significance of the Study 6

1.7 Delimitation and Limitation 7

1.8 Assumption 7

1.9 Conceptual Framework 7

CHAPTER TWO 10

LITERATURE REVIEW 10

2.1 Overview of Kenya's Social, Economic and Energy Sector 10

2.1.2 Economic Growth 11

2.1.3 Energy Access 12

2.1.4 Energy Resources in Kenya 13

2.1.4.1 Non-Renewable energy Resources 14

2.1.4.2 Renewable Energy Resources 18

2.1.5. Kenya Current Climate Policy Projections 29

2.1.6 Climate Change Policies in Kenya 30

2.1.7 Existing Renewable Energy Policies in Kenya 31

2.1.7.1 The Energy Act (MoE, 2019) 31

2.1.7.2 The Geothermal Resource Act 1982 Revise (2012) 33

2.1.7.3 The Energy (Solar Photovoltaic Systems) Regulations 2012 33

2.1.7.4 The Bio Energy strategy (MoE, 2020) 33

2.1.7.5 Kenya National Energy Efficiency and Conservation Strategy (NEECS, 2020)..................... 33
2.2 Renewable Energy and Climate Change.. 34
2.2.1 Climate Change Definition.. 34
2.2.2 Renewable Energy Definition... 35
2.2.3 Renewable Energy and Climate Change Interrelation 35
2.3 Socio-Economic Impacts of Climate Change 37
2.4 Stakeholder Theory 39
2.4.1 Stakeholder Engagement on Climate Adaption.. 40
2.5 Barriers to Adoption of Renewable Energy Sources 41
2.6 Energy Models... 42
2.6.1 Long Range Energy Alternatives Planning (LEAP) Model 46
2.7 Research Gap 49
CHAPTER THREE... 50
MATERIALS AND METHODS 50
3.1 Study area.. 50
3.2 Research Design 50
3.3. Sample Size... 51
3.5 Data collection Instruments 52
3.6. Data Analysis and Presentation Methods.. 53
3.6.1. Statistical Analysis 53
3.7 Land Use/Cover Data Acquisition and Processing. 54
3.7.1 Land Use/Cover Classification 54
3.8 Long-range Energy Alternatives Planning System (LEAP) model 55
3.8.1 LEAP Input Data Requirements.. 55
3.8.2 Scenario Simulation Steps 56
CHAPTER FOUR.. 57
RESULTS AND DISCUSIONS 57
4.1 General Knowledge of the Respondents... 57
4.1.2 Household Energy Use and Consumption.. 60
4.1.3 Household Cooking Energy... 63
4.1.4 Challenges Facing Bungoma Households while Using the Energy Resources.......................... 66
4.2 Climate Change Effects in Bungoma County. 70
4.2.1 Effects on Socio-Economic Activities in Bungoma County....................................... 74
4.2.4 Barriers to Renewable Energy Adoption in Rural Areas 76
4.3 Land Use and Land Cover Change in Bungoma County Since 1990- 2020................................. 77

4.4 LEAP Model Scenarios and Forecasting Results 82
4.4.1 Business as Usual (BAU) Scenario Analysis 83
4.4.1.1 BAU Household Cooking Energy Demand Scenario Projection 84
4.4.1.2: BAU Carbon Emissions Scenario Projection 84
4.4.2 Energy Efficient Scenario Projections 85
4.4.2.1 Energy Efficient Scenario Implications on Emissions 86
CHAPTER FIVE 89
CONCLUSION AND RECOMMENDATIONS 89
5.1 Conclusion 89
5.2 Recommendations 89
References 91
Appendix 99
1 Questionnaire 99
2 LEAP Data Input Interface 107
3 LEAP Results Interface 108

List of Tables

TABLE 2.1: CHARACTERISTICS OF TOP-DOWN MODELS AND BOTTOM-UP MODELS……………………...43
TABLE 2.2: STRENGTHS AND WEAKNESS OF ENERGY MODELS…………...………………………………44
TABLE 3.1: LAND USE/LAND COVER CLASSIFICATION SCHEME…………...………………………………54
TABLE 3.2: LULC IMAGE DATA PROCESSING SUMMARY…………………...……………………………55
TABLE 4.1: LAND USE/ LAND COVER CHANGES 1990-2020…………...……………………………………...79

List of Figures

FIGURE 1.1:THE THREE SPHERES OF SUSTAINABILITY 3
FIGURE 1.3: CONCEPTUAL FRAMEWORK 9
FIGURE 2.1:HISTORIC POPULATION GROWTH OF BUNGOMA COUNTY 10
FIGURE 2.1:THE MAP OF KENYA. 12
FIGURE 2.2:CARBON EMISSION TRENDS IN KENYA OVER THE PAST 20 YEARS 13
FIGURE 2.3:GEOTHERMAL INSTALLED CAPACITY IN KENYA 21
FIGURE 2.4: WIND DISTRIBUTION AREA MAP 25
FIGURE 2.5: SOLAR ELECTRIFIED SCHOOLS BY REREC 31
FIGURE 2.6:THE SYSTEMATIC PROCESS OF THE LOW EMISSION ANALYSIS MODELLING (LEAP) TOOL 46
FIGURE 3.1:STUDY LOCATION MAP 50
FIGURE 4.1: RESPONDENTS GENDER REPRESENTATION 57
FIGURE 4.2: EDUCATION LEVEL OF RESPONDENTS 57
FIGURE 4.3: INCOME LEVEL 58
FIGURE 4.4:CROPS CULTIVATED IN THE STUDY AREA 59
FIGURE 4.5:ANIMALS REARED IN THE STUDY AREA 59
FIGURE 4.6:ENERGY SOURCES 60
FIGURE 4.7: GRID CONNECTION LEVEL 61
FIGURE 4.8:LIGHTING BULBS USED 61
FIGURE 4.9: BACK UP LIGHTING SOURCES 62
FIGURE 4.10: ELECTRIC APPLIANCES IN THE HOUSEHOLDS 63
FIGURE 4.11: HOUSEHOLD COOKING ENERGY 63
FIGURE 4.12: HOUSEHOLD COOKSTOVES 64
FIGURE 4.13: ENERGY SOURCE COLLECTION CENTRE 65
FIGURE 4.14:REASON FOR USING THE COOKING SOURCE 66
FIGURE 4.15: RAINFALL PATTERN FOR 30 YEARS 70
FIGURE 4.16: TEMPERATURE RANGE FOR 20 YEARS 70
FIGURE 4.18:LULC MAP FOR 1990 76
FIGURE 4.19:LULC MAP FOR 2000 77
FIGURE 4.20:LULC MAP FOR 2010 78
FIGURE 4.21:LULC MAP FOR 2020 79
FIGURE 4.22: BAU ENERGY DEMAND GRAPH 2019-2040 81
FIGURE 4.23:BAU HOUSEHOLD COOKING ENERGY DEMAND 2019-2040 82
FIGURE 4.24: BAU GHG EMISSIONS SCENARIO 2019-2040 83
FIGURE 4.25: ENERGY EFFICIENT SCENARIO ENERGY DEMAND 2019-2040 84
FIGURE 4.26: ENERGY EFFICIENT SCENARIO ON EMISSIONS 2019-2040 84

List of Plates

PLATE 1.1: SWAM OF LOCUSTS THAT HAD INVADED SOME PARTS OF THE COUNTRY………...……8
PLATE 2.1: GARISSA SOLAR POWER PLANT…………...………………………………………………………25
PLATE 2.2: LAKE TURKANA WIND POWER STATION………...………………………………………………26
PLATE 4.1: SMOKE EFFECTS FROM OPEN AIR COOKING ON POTS………...…………………………………...67
PLATE 4.2: SMOKE EFFECTS FROM OPEN AIR COOKING ON WALL AND IRON SHEETS ………...……….67
PLATE 4.1: KEROSENE LAMP USED FOR LIGHTING IS SOME HOUSEHOLDS ………...…………………….68
PLATE 4.1: ARMY WORM PET AFFECTING MAIZE CROP……………………...……………………………...73

List of Acronyms and Abbreviations

CAT	Climate Action Tracker
CEEPA	Centre for Environmental Economics and Policy in Africa
CO_2	Carbon (iv) Oxide
CSA	Climate Smart Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organization
EA	Energy Agency
EIA	Environmental Impact Assessment
EMCA	Environment management and coordination Act
ERC	Energy Regulatory Commission
FAO	Food and Agriculture Organization
GDP	Gros Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoK	Government of Kenya
GW	Gigawatts
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IT	Information Technology
KenGen	Kenya Electricity Generating Company
KENOL	Kenya Oil company
Ketraco	Kenya Electricity Transmission Company
KNBS	Kenya National Bureau of Statistics (KNBS
KNES	Kenya National Electrification Strategy
KPLC	Kenya Petroleum Refineries Limited
KT	Kilotons
LEAP	Low Emissions Analysis Platform
LPG	Liquified Petroleum Gas
LTS	Long Term Support

LTWP	Lake Turkana Wind Power Project
MoA	Ministry of Agriculture
MoE	Ministry of Energy
MOE&NR	Ministry of Energy & Natural Resources
MW	Megawatts
NAP	National Adaptation Plan
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NDC	National Determined Contributions
NEMA	National Environment Management Authority
NGO	Non-Governmental Organizations
NOCK	National oil Corporation of Kenya
RE	Renewable Energy
REREC	Rural Electrification and Renewable Energy Corporation
SD	Sustainable Development
SDG	Sustainable Development Goal
SEI	Stockholm Environment Institute
SGR	Standard Gauge Railway
SHS	Solar Home Systems
TARDA	Tana and Athi River Development Authority
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Climate change is no longer a far of problem it is happening here and it is happening now all over the globe. This can be clearly seen through the unpredictable weather patterns which has made it difficult to grow and maintain crops in the regions that depend on natural weather pattern. Agriculture is an economic activity which is highly reliant on climate and weather in order to produce the food and fiber necessary to sustain human life (Zayan, 2019). The author also adds that climate change influences the occurrence and prevalence of crop diseases as it affects the interaction between pathogens and crops. This affects agricultural production as the crops are not able to cope with new pests and diseases thriving as a result of the new climatic conditions favoring their manifestation. The recent changes in temperature have caused prolonged droughts in areas that used to have rain and heavy downpours leading to flooding, destruction of property and infrastructure. This is a clear indication of the variation in climatic conditions which requires urgent need for mitigation measures aimed at addressing the effects of climate change.

Global warming and climate change relate to one another with the increase in average global temperature believed to be naturally caused by human activities (Onkar, 2012). Many countries Kenya being one of them depend on fossil fuels that is coal and oil as sources of energy for cooking, lighting, heating, transport etc, in their quest to achieve development. The over dependence on the conventional sources of energy has led to the increase in Carbon Dioxide (CO_2) emission a greenhouse gas that is among the contributors of global warming.

The recent Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming (2018) underlined the urgent need of taking decisive steps to lower global temperatures and reducing carbon emission to 1.5°C by 2030. It is important to globally transition to the use of renewable energy and the adoption of energy efficient practices in order to tackle climate change considering that two thirds of greenhouse gas (GHG) emissions originate from the energy sector (IPCC, 2018).

The International Renewable Energy Agency's (IRENA) report on Global Energy Transformation: A Roadmap to 2050 (IRENA, 2019a), estimates that in order to meet the objectives of the Paris Agreement on limiting global warming to 2°C or less by 2030 Global energy demand has to be reduced. The report suggests that countries have to increase the electrification pathway for all end-use sectors, energy efficiency and increase the use of renewable sources in the energy mix. A global approach has to be adopted by engaging all stakeholders from government, local communities, regions, private and public sectors in order for the energy transformation and transition to be impactful.

Renewable Energy (RE) sources play a role in providing energy services in a sustainable way and in mitigating climate change as these sources are free from CO_2 emissions and friendly to the environment. Kenya is endowed with diverse RE sources among them Hydropower, Geothermal, wind and solar Energy. However, the energy sector is highly dominated by the use of fossil fuels that is mainly petroleum accounting for 80% of the commercial sector while biomass contributes to 70% of the energy demand. This accounts for 90% of the energy use in the rural communities and the informal sector (Energypedia, 2020).

The development and use of renewable energy will improve the energy security, economy, help to create new jobs and assist in promoting environmental protection. The use of renewable energy sources not only helps in climate change mitigation but also in the achievement of sustainable development (SD). This is possible by the use of sustainable energy and by ensuring access to affordable, reliable, sustainable, and modern energy for the citizens (Majid, 2020). Sustainable economies must be supported by the use of renewable resources such as solar, wind, geothermal and biomass with the equal interaction of the three spheres of sustainability. Figure 1.1 (ConocoPhillips, 2006) illustrates the harmonious sustainability interaction of these spheres ensuring that one sector does not thrive at the expense of the other.

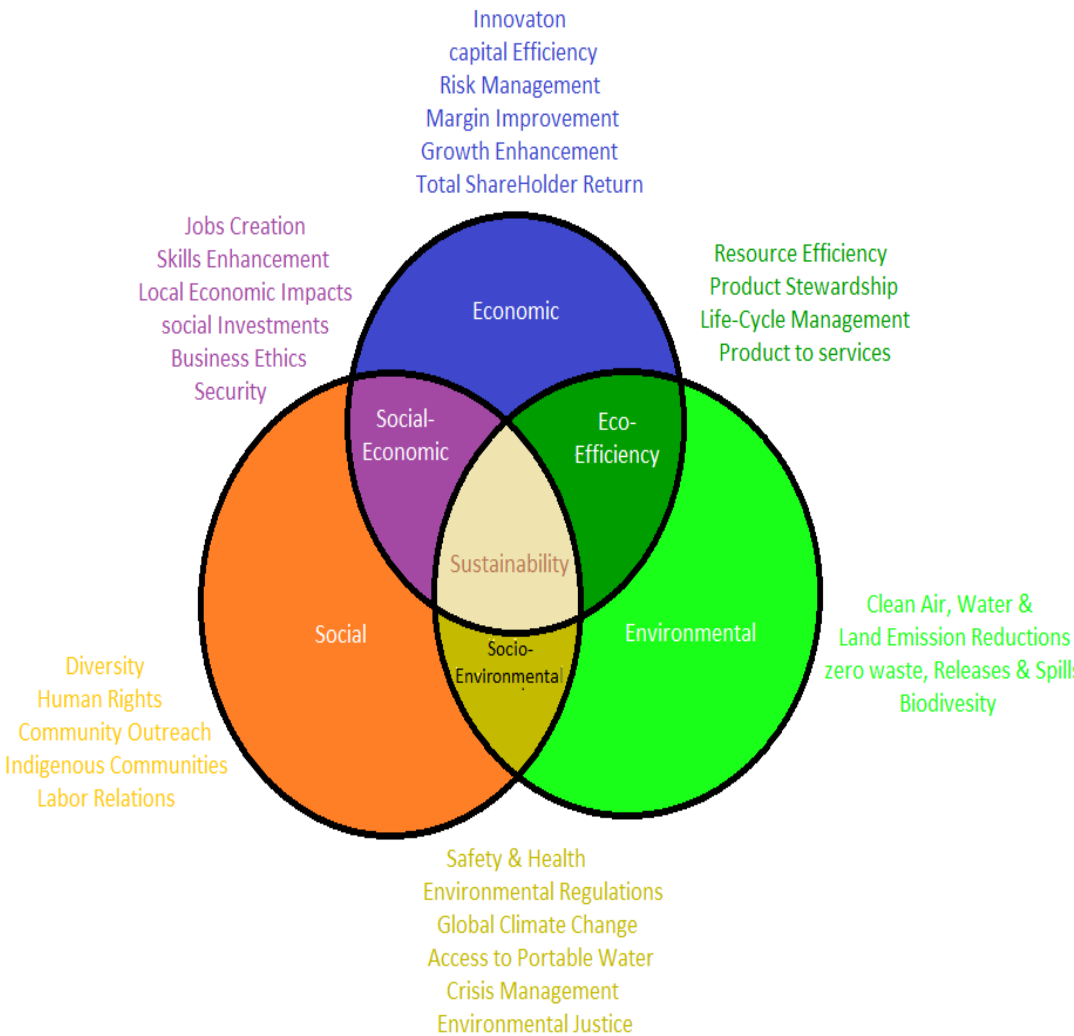


Figure 1.1:The Three Spheres of Sustainability

The adoption of RE technologies requires a wholistic approach with the involvement of all stakeholders. Kenya has come up with several policy documents in order to meet the Intended Nationally Determined Contribution (INDC) adopted at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). The documents include;

the National Climate Change Response Strategy (NCCRS 2010), National Climate Change Action Plan (NCCAP 2013), and a National Adaptation Plan (NAP) under preparation which provides a vision for low carbon and climate resilient development pathway (MOE&NR, 2015). The implementation of the policies and programs outlined in the documents and the adoption of renewable sources of energy will help significantly in climate change mitigation, economic development, social improvement and creation of green jobs to the unemployed youths.

1.1 Statement of the Problem

Over the past decades; there has been rising concerns globally over the increased rate of greenhouse gas emission mainly Carbon (iv) oxide (CO_2) caused by over dependence on non-renewable sources of energy. Many countries depend on coal and oil as sources of energy for cooking, lighting, heating, transport just to mention a few in their quest to achieve development. This is causing great impact on the environment in terms of carbon emission which is a major contributor to global warming which in turn leads to climate change.

The impacts of climate change can be clearly seen globally with rising of sea level, changes in the weather patterns where countries are experiencing long droughts affecting the agricultural activities of the rural communities. There is increased spread of pests and diseases affecting crops in farms. Additionally, climate change influences the occurrence and prevalence of plant diseases (Zayan, 2019). The recent occurrence of a swarm of locusts in many countries especially in the eastern part of Africa attacking peoples crops in acres of land in a short period of time is a clear indication of the changes in climate that is providing a conducive place for the insects and the crop diseases to thrive (Kean & Fowler, 2015)

There is therefore a need to move from the use of fossil fuels to the use of cleaner sources of energy for the production of electricity. The use of renewable energy resources is the definite solutions to the problem of emissions because they are considered to be environmentally friendly. Renewable energy sources have no or little emissions of greenhouse gases like carbon (iv) oxide, sulfur dioxide, carbon monoxide just to mention a few of the greenhouse gases that causes global warming that influences climate change (IPCC, 2013). The use of renewable resources for power generation is very important as can be used again and again to produce energy for a long time as compared to the non-renewable sources that get depleted.

1.3 Objectives

1.3.1 Main Objective of the Study.

The main objective of this study was to assess the uses and impacts of renewable energy resources in combating climate change in the rural communities of Bungoma County in Kenya.

1.3.2 Specific Objectives.

The specific objectives of this study were to:

a) Analyze the potential challenges and the barriers hindering the adoption of renewable energy technologies a case study of Bungoma County in Kenya.

b) Assess the effects of climate change on the socio-economic sector of the rural communities for the case of Bungoma County.

c) Analyze the land use/cover and population changes in Bungoma County over the last 30 years.

d) Model the business as usual (BAU) against the renewable energy efficient scenario to mitigate climate change.

1.4 Research Questions

a) What are the potential challenges and barriers hindering effective implementation of renewable energy technologies in combating climate change for the case of Bungoma County in Kenya?

b) What are the effects of renewable energy sources on the socio-economic sector of the rural communities?

c) How does land use /cover and population changes in Bungoma County influence climate Change?

d) What is the implication of Implementing renewable energy efficient policies and influence on climate change mitigation?

1.5 Justification of the Study

Climate change is happening all over the globe and immediate action need to be taken in order to combat it before the impacts become irreversible. This can only be achieved through intense research and the adoption of environmentally friendly innovations and technologies. Renewable energy sources are one such great step towards reducing carbon emissions one of the Green House Gasses (GHGs) contributing to global warming (Desonie, 2008).

A lot of research on the uses of Renewable Energy Sources to combat climate change has been carried out in other countries with less research in Kenya most especially in the rural areas. Conducting this research is therefore helpful not only in my county but also other rural areas in Kenya and the country as a whole that is facing climate change effects. The research provides the best way possible to adopt the energy efficient practices and in embracing renewable energy technologies to the rural areas that are facing great impacts. The agricultural sector is the backbone of economic growth and directly contributes to 26% of the Gros Domestic Product (GDP) and 27% indirectly through linkage with other sectors is affected most with the impacts. The sector also employs more than 40% of the total population with 70% coming from the rural areas (FAO, 2020).

1.6 Significance of the Study

Kenya is also facing climate change impacts and the associated socio-economic losses. The situation is being worsened by the use of fossil fuels in the running of the important sectors in the country which has led to the development of a National Climate Change Response Strategy (NCCRS 2010), National Climate Change Action Plan (NCCAP 2013), and a National Adaptation Plan (NAP) which provides a vision for low carbon and climate resilient development pathway. The research results will therefore be useful to the country on the uses of renewable energy sources available in the country and most especially in the rural areas to combat climate change.

Climate change and renewable energy technologies require continuous research and innovation in order to deal with the emerging challenges and barriers in the adoption of the technologies and the fight against climate change. The research finding will be used to inform policy makers and decision makers on the best practices possible that lead to low carbon emissions while meeting Sustainable Development Goal (SDG) 7 of ensuring access to affordable, reliable, sustainable and modern energy for all.

1.7 Delimitation and Limitation

The study was carried out in Bungoma county with a focus on the type of energy resources being used in the households. The study area was selected because of the expected impacts of climate change most especially the area being in a rural set up and most people depend on agriculture for survival. The availability of several renewable energy sources in this area made it a good research area. The study was limited to the uses of solar energy and hydropower as the Renewable energy resources being the only ones commonly used in the study area.

1.8 Assumption

The study was based on the assumption that all the households in the study area are connected or use one of the renewable energy sources available to them. The research findings nullified the researchers' assumptions as some of the households were not connected to any of the renewable energy sources and depending on traditional sources of energy for cooking and lighting.

1.9 Conceptual Framework

Climate change effects are being felt globally and Kenya is not left out including the rural community that the research targeted. The impacts of climate change are being felt in terms of Prolonged droughts due to the increased temperatures in places that are arid and semi-arid and long rains that exceed the expected amount. There is also the prevalence of plant diseases and insect outbreak the recent one being the swam of locust that has been experienced in the east African countries Kenya being among the affected countries (Jason Beaubien, 2021). These impacts have led to decline in water supply due to the high temperatures, flooding and rise in the water levels of the lakes causing destruction of infrastructure, land and crops, food insecurity due to destructed agricultural activities and increased levels of poverty. plate 1.1 (Deutsche Welle, 2021) shows a picture of the swam of locusts that had invaded some parts of the country creating a lot havoc and destruction of anything green that was in the way.

Plate 1.1:Swam of Locusts that had Invaded some Parts of the Country

The use of Renewable Energy Sources including Hydropower, Solar, Wind, Geothermal and Biomass with use of Improved cook stoves plays a role in the energy transition. Figure 1.2 illustrates how climate change an independent variable impacts the environment and the people and how transition to renewable energy resources and energy efficiency mitigates the impacts. Land use and cover management with increased afforestation mitigates the impacts as the trees are natural carbon sinks. The use of improved cookstoves leads to energy efficiency and reduces indoor air pollution which leads to improved health. The mitigation factors lead to positive outcomes including; food security, improved livelihoods, improved education and creation of green jobs to the people while at the same time fighting climate change.

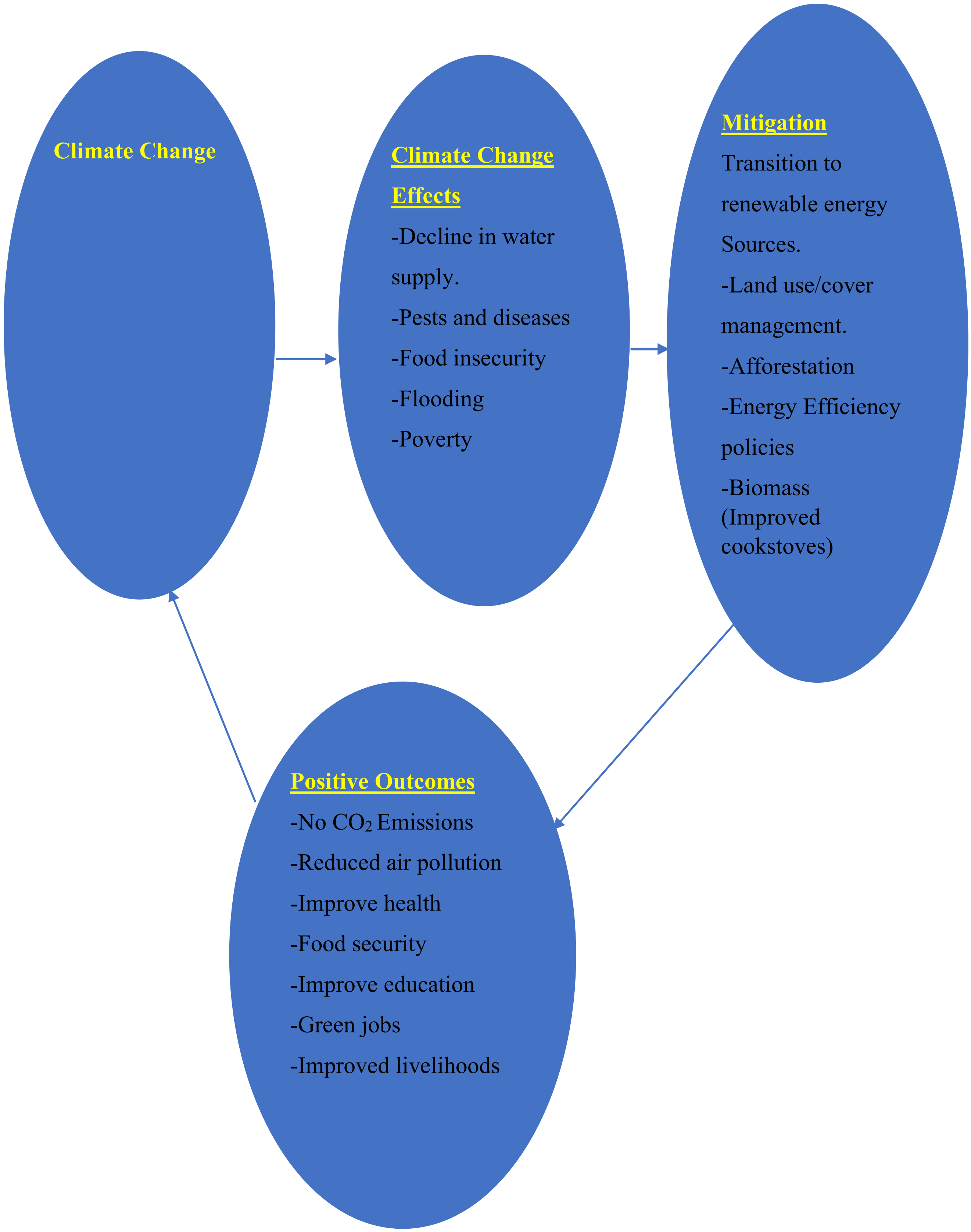


Figure 1.2: Conceptual Framework

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Kenya's Social, Economic and Energy Sector

2.1.1 Population Growth

Kenya is an African developing country found on the Eastern part of the continent bordered by the Indian Ocean, Somalia to the east, Ethiopia to the north, South Sudan and Uganda to the west, and Tanzania to the south as shown in Figure 2.1 (Geology, 2021).

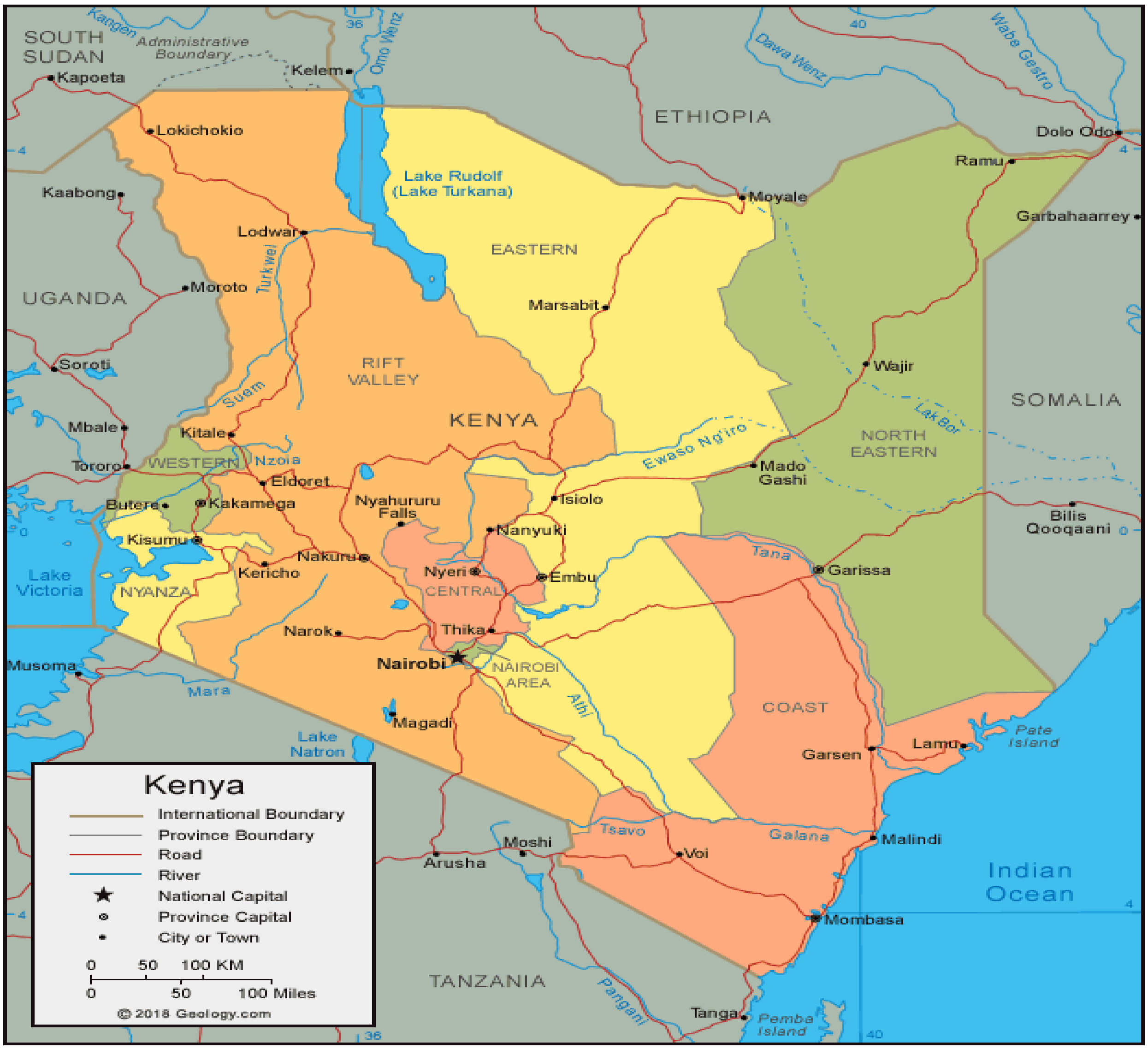


Figure 2.1: The Map of Kenya.

Kenyas population according to (KNBS, 2019) stands at 47.6 million with 23.5 million being men and 24 million being women an increase of 9 million from the last census carried in 2010. The population has been growing tremendously at the rate of 2.5% which can clearly be seen from the past years and has a life expectancy of 66.7 years (World Bank, 2019). Bungoma county has a population of 1.66 million, 358,796 number of households with an average household of 4.6 persons. It has a population density of 753.95 person/sq.km and out of the total population 812,146 persons are male, 858,389 and 35 are intersex. Figure 2.2 shows the historic population growth of Bungoma county (KNBS, 2019).

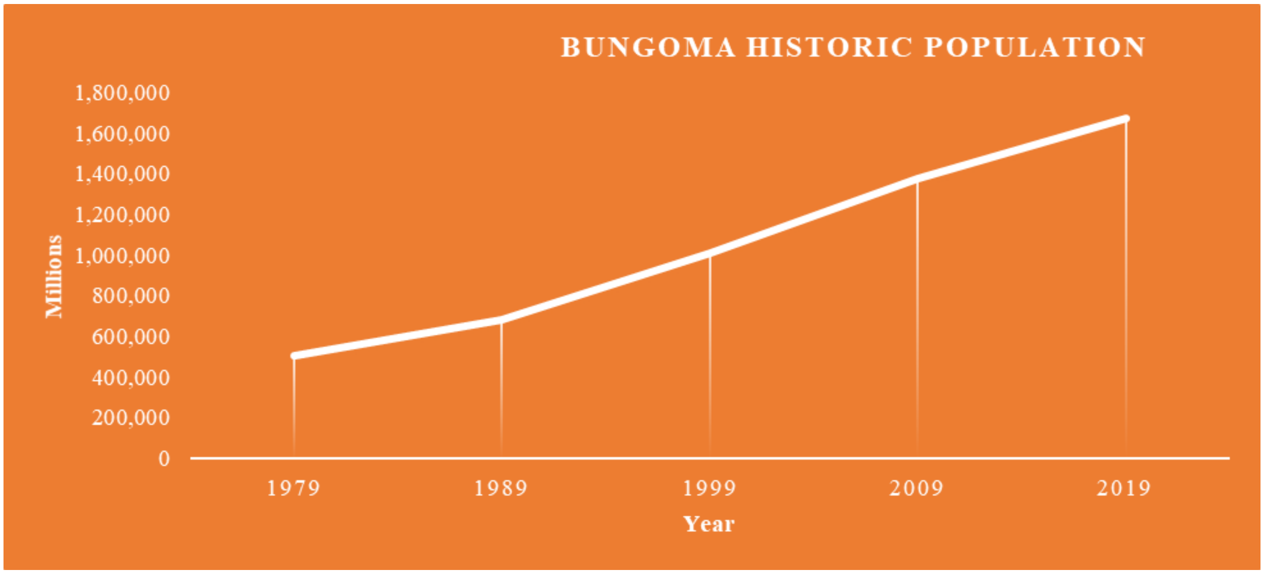


Figure 2.2: Historic Population Growth of Bungoma County

2.1.2 Economic Growth

Kenya's economic growth for the year 2019 averaged at 5.7% making it to be among one of the fast-growing economies in sub-Saharan Africa. However, the COVID-19 (coronavirus) pandemic, the locust attack which started early 2020 and affected many parts of Kenya especially the North East has had a negative impact on the food security and growth of the agricultural sector in the country. Real gross domestic product (GDP) growth is projected to decrease from an annual average of 5.7% by 2019 to 1.5% in 2020. According to (World Bank, 2020), Kenya's Gross Domestic Product is 98.84 Billion USD with the agricultural sector directly contributing to 26% of the GDP and 27% indirectly through linkage with other sectors. The sector employs more than 40% of the total population with 70% percent coming from the rural area (FAO, 2020). Most of the sectors such as agriculture, manufacturing, and transportation have slowed down with agriculture, electricity, and water supply being greatly affected by the change in weather patterns.

The main economic activity in Bungoma county is agriculture and most families rely on crop production and animal rearing. The main crops planted include maize, beans, finger millet, sweet potatoes, bananas, Irish potatoes, assorted vegetables and sugarcane with the livestock being kept including cattle, sheep, goats, pigs and poultry. Agriculture is practiced both for subsistence and in large scale with the farmers selling excess crops being harvested to meet other family needs and
also producing milk and poultry products for commercial use. This therefore shows that Bungoma county plays an important role in the overall GDP growth of the country.

2.1.3 Energy Access

Kenya crossed the 1,800 MW energy demand in 2018 and efforts from the government and private investors have boosted electricity access in the country intending to achieve universal energy access in 2022 (MoE, 2019). The total energy access is estimated to be 75% from both the grid and non-grid being supplied largely with hydropower that currently contributes to 57% of the energy mix. However, the recent changes in weather patterns and prolonged drought affected the hydro-electric power production leading to increased electricity prices and frequent blackouts across the country.

Kenya’s Energy sector is highly dominated by the use of fossil fuels that is petroleum with wood fuel being the basic energy consumption of the rural communities and the informal sector (EnergyPedia, 2020). An analysis of the national energy shows heavy dependency on wood fuel and other biomass that account for 68% of the total energy consumption with Petroleum covering 22%, Electricity 9% and other sources accounting for 1% (Knoema, 2019). Electricity access to the people of Kenya is still low despite the government’s ambitious target to increase electricity connectivity through rural electrification from the current 15% to 65% by the year 2022 (Energypedia, 2020). Bungoma county consumes most of the electricity generated for lighting with most of the population highly relying on biomass such as wood fuel and charcoal for cooking and heating which has a high impact on the environment and the human health.

The Primary energy consumption of kenya stood at 0.01 quadrillion BTU by the year 2019. The energy consumption increased by 0.15 quadrillion BTU from the the year 1998 to 2017 growing at an average annual rate of 4.36% (Knoema, 2019). The increase in energy consumption especially from the fossil fuels has led to increased CO_2 emmission produced annually into the atmosphere. The CO_2 emmission per capita for kenya has been changing yearly hitting 0.38 tons per capita and an overal 19.8 Millions tonnes of emission (Knoema, 2019). Figure 2.3 (Knoema, 2019) illustrastes the change in CO_2 emisions from 1999 to 2019 a period of 20 years.

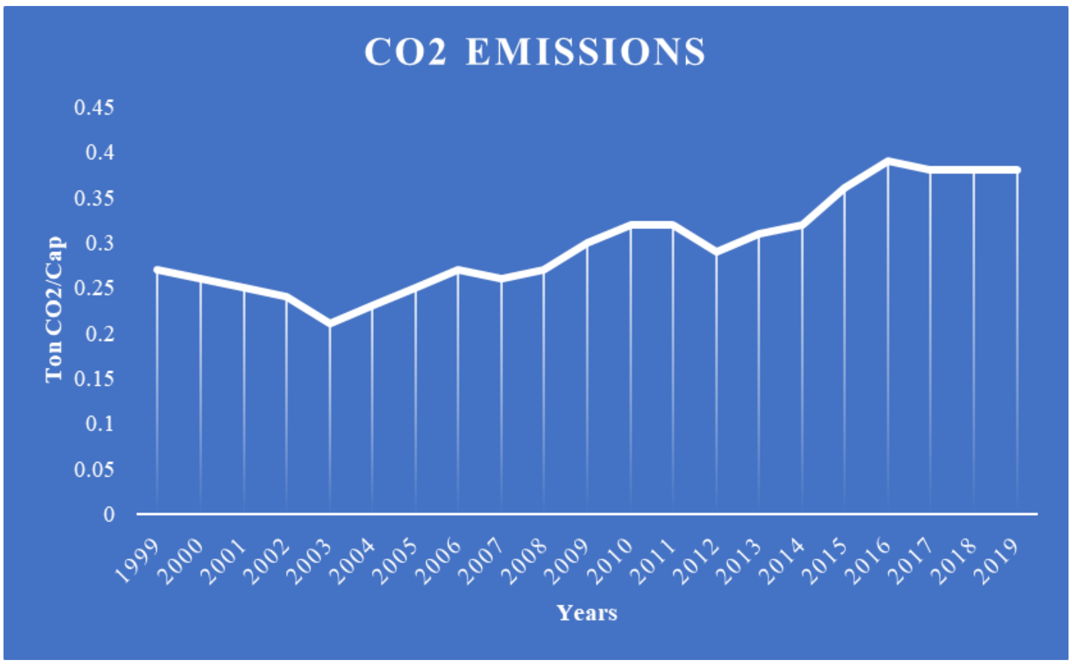


Figure 2.3: Carbon Emission Trends in Kenya over the past 20 Years

Figure 2.3 clearly shows the tremendous increase in CO_2 emissions which is highly attributed to the growing population and increased demand of energy from fossil fuels a dominant source of energy in the country and the greatest contributor to emissions that leads to global warming.

2.1.4 Energy Resources in Kenya

Kenya is well endowed with a lot of energy resources including the non-renewable resources (Petroleum, LPG and Coal) and renewable resources (Hydropower, Geothermal, Solar, Wind and Biomass) as discussed in the study.

2.1.4.1 Non-Renewable energy Resources

a. Petroleum

Petroleum is Kenya's major source of energy which accounts for over 80% of Kenya's commercial requirements. As of 2007, the country spent about 40% of its foreign exchange earnings in the importation of crude oil and other petroleum products (EnergyPedia, 2020). This cost increase yearly with the tremendous growth in population and the increased per capita energy consumption. Kenya consumed 114 barrels per day of oil by the year 2016 and it is ranked 75th in the world for oil consumption. Kenya currently imports most of its petroleum products from Saudi Arabia as shown by data from The Kenya National Bureau of Statistics (KNBS) the importation of petroleum products from Saudi Arabia rose by 61% an increase from 32% in 2018. The leading oil marketing company in the country being Shell with 30% of the market share. Other marketing companies involved include; Kobil, Oil Libya, Total, Caltex, Engen, Kenya Oil company (KENOL) and National oil Corporation of Kenya (NOCK) which is owned by the government (EnergyPedia, 2020).

Kenya has several storage facilities for crude oil and finished Petroleum products across the country. Most of the refinery companies are based at the coast with the main one being Kenya Petroleum Refineries Limited (KPRL) based in Mombasa and owned and managed by the government of Kenya as it holds 100% of the shares. The refinery has a capacity of 90,000 barrels per day. The oil distribution infrastructure is mainly by road, rail and pipeline system. Currently Kenya pipeline company is the only one that manages the pipeline system across the whole country (EnergyPedia, 2020).

The National oil corporation of Kenya (NOCK) made17 blocks available for petroleum negotiations and has since confirmed 4 prospective petroleum basins namely; The Mandera Basin, the Anza Graben and the Lamu Embayment. All the blocks are mainly offshore with only the southern Lamu Embayment offering both offshore and onshore blocks. Kenya has drilled about 30 wells for exploration but none has encountered commercial activities to date. It would take Kenya close to 4 -7 years before the country could benefit from the insulation effect from surge in global oil prices if oil was discovered. The increasing dependency of importation of petroleum oil products makes the country vulnerable to energy terrorism (EnergyPedia, 2020).

In 2012 the Ministry of Energy (MoE) announced that they had discovered vast oil resources in Turkana County and a private company named Tullow oil was looking into exploration of the oil. The company has estimated that the Country's Turkana fields hold 560 million barrels of oil and the company expects to produce up to 100,000 barrels per day from the year 2022. In 2019 the first shipment of 250,000 barrels of crude oil was exported from Turkana mines through tracks as there is no rail connecting from Turkana to the port of Mombasa. Plans are underway to construct a pipeline for easier transportation of the crude oil (MoE, 2019).

b. Liquified Petroleum Gas (LPG)

Kenya's LPG production per annum in 2019 was approximately 170 Kilotons (KT) as compared to a demand of 300 KT per annum (EnergyPedia, 2020). The LPG consumption in Kenya stood at 2 Kilos per capita in 2019 which is below Africa's average per capita consumption of 3 Kilos. This is mainly because of lack of sufficient storage facilities and distribution channels making it impossible for the uptake of the energy source to most Kenyan households. Also, the commodity is very much costly as compared to other sources of energy as a kilo goes for about 2 dollars as compared to the global average of 0.6 dollars per kilo. The total LPG storage infrastructure in the country stands at 6,000 metric tonnes against a consumption demand projected at 300,000 metric tonnes per year (Energypedia, 2020).

According to (Energypedia, 2021), the Kenya Petroleum Refinery Limited makes about 30,000 metric tonnes of LPG which is not enough for the demand thus making the country rely mostly on the importation of the product which in turn makes the commodity very expensive for most of the people who live under a dollar a day to afford. The government has plans of increasing the production of LPG to about 115, 000 metric tonnes to reduce on the importation of the commodity. In 2016 the government removed import taxes from LPG cylinders through the finance act to make it cheaper for the consumers to acquire the cylinders however, in 2021 The Kenya Revenue Authority imposed the 16% VAT on LPG in line with the Finance Act that reinstated the 2016 Value added tax (VAT) Exemption on LPG (Business Daily, 2021). The increase in the prices of cooking gas has affected many households who are already struggling with the reduced income due to economic hard times and the Covid-19 pandemic making many of them shift back to the use of unclean sources of energy. Currently Total Energies is the leading distributor of LPG for domestic and commercial use in the country.

The government needs to increase the storage facilities and distribution channels of LPG in the country and increase the amount produced at its refinery in order to reduce the cost of buying the commodity in order for it to be accessible to everyone. The 16% VAT on LPG should be exempted to reduce the cost as the imposed VAT increases the price of a 13kg cylinder from Sh. 2,250 to Sh. 2.610 an increase by Sh.350 (Business Daily, 2021) which is not affordable to many people especially those in rural areas. This will not only increase the LPG consumption per capita but also reduce the dependence on other fossil fuels that produces a lot of carbon emissions that are a threat to global warming leading to climate change.

c. Coal

Kenya is yet to exploit Coal as a source of energy even after The Ministry of Energy identifying two sites in Kenya for the exploration of Coal. These sites are Mui basin of Kitui county and Taru basin of Kwale county which showed existence of a good amount of coal for commercial use. The samples from the two basins compare very well with the sub-bituminous used in south Africa for generation of power. The construction and setting up of the two sites have since faced a lot of controversies from the issue of climate change and the cost that would be used to finish the project. This will make Kenyans to pay a lot of taxes even before they could start benefiting from the intended low-cost energy from the mining of coal (EnergyPedia, 2020).

The Lamu coal Power station was estimated to produce around 1,050 MW coal fired thermal power station in the country (EnergyPedia, 2020). The proposed plant was to be put on 865 acres of land with a 210-meter-tall smoke stack making it the tallest structure in East Africa. In June 2019, Kenyan judges revoked the Environmental Impact Assessment License (EIA) issued to the Chinese based construction firm (Amu Power) that was to construct the coal power station. The environmental campaigners took the firm and the National Environment Management Authority (NEMA) to court for failing to undertake rigorous environmental impact assessment of the coal plant and also failing to include community concerns in the report as they did not consult them. The construction has been put on halt over climate change issues and also until a new EIA is done and the community views included (BBC, 2019).

The Mui basin in Kituyi has also suffered almost the same fate as the Lamu Project. The coal mine was estimated to have a value of 3.4 trillion whose exploration would make Kenya an industrial hub like other European power houses. The coal power plant was to contribute about

1,000 MW of electricity that was to be connected to the National grid. The mining license was awarded to a Chinese based firm called Fenxi Industry Mining company in 2013. The community around the proposed area formed Community Based Organizations (CBOs) and went to court with petitions opposing the construction and mining of coal on their lands because of the various negative impacts of coal mining to the environment and that it would affect their livelihoods.

It would be almost impossible to fully construct a coal plant in the country due to the increasing awareness, environmental activism and the high cost that would be put into the construction. Many donors have since backed out of sponsoring such projects due to; the increased public outcry on Climate Change as coal is a fossil fuel that is a great contributor to carbon emission a greenhouse gas causing global warming (IPCC, 2018).

Large amounts of carbon dioxide, a greenhouse gas is released into the air when fossil fuels are burned. This greenhouse gas trap heat in the atmosphere causing global warming (ClientEarth, 2020). Already the average global temperature has increased by 1°C and warming of above 1.5°C risks further extreme weather conditions, biodiversity loss, sea level rise and species extinction affecting food security, worsening health and poverty for millions of people worldwide (IPCC, 2018).

Fossil fuel usage results in the imposition of other large externality costs on the global economy aside from climate change. They include; environmental costs due to multiple pollutants and waste products produced during combustion (primarily coal), including particulate matter, nitrogen oxides, carbon monoxide, sulfur oxides and unburned hydrocarbons. Human Health is another cost incurred due to a variety of negative health effects associated with the environmental impacts such as air pollution and fine particulate that cause respiratory diseases and smog. Fossil fuels wastes also leads to pollution and contamination of water bodies leading to loss of aquatic animals (IEA-RETD, 2011)

Fossil fuels contributes to the highest emissions in the world with Coal being the dirtiest of the fossil fuels and responsible for over 0.3°C of the 1°C increase in global average temperatures and the single largest source of global temperature rise (ClientEarth, 2020). The report further highlights that oil releases approximately a third of the world's total carbon emissions when burned and the impacts on the environment are catastrophic when spills occur in the ocean ecosystem. Natural gas is often referred to as a cleaner energy source for cooking However, it accounts for a large amount of carbon emission during its production and is ranked fifth in carbon emissions in the world (ClientEarth, 2020).

2.1.4.2 Renewable Energy Resources

The renewable energy sector in Kenya is one of the active sectors in Africa. Investments related to renewable energy tremendously grew from almost 0 in 2009 to 1.3 billion US Dollars in 2010 with technologies ranging from wind, geothermal, small scale-hydro and biofuels. Kenya is currently Africa's number one producer of geothermal energy with the Rift Valley having a potential of 2000 MW and also leads Africa in the number of solar power systems installed per capita.

a. Hydropower

Hydropower is the largest generation of electricity to the Kenya's national grid with an estimated national potential of between 7,000 to 10,000 MW. The Kenya Electricity Generating Company (KenGen) is the leading power generating company in East Africa with an installed capacity of 825.69 MW contributing to the 49% of Hydropower connected to the national grid (KENGEN, 2021). The government is strongly pushing away from the use of hydropower to other sources of energy so that the water bodies can be used for other activities like irrigation for agriculture and fishing. Kenya's Vision 2030 blue print estimates that hydropower will only account for 5% of the total energy capacity at the end of the 2030.

The hydroelectric generating power station in Kenya are the seven forks scheme which generates 530 MW of power covering almost all of the country's hydroelectric power (Energypedia, 2021). There is also Sondu Miriu Hydroelectric Power station and the Turkwel Hydroelectric power station. The seven forks scheme includes the following series of dams:

i. Gitaru Power Station

The Gitaru Hydroelectric Power also called Gitaru Dam is a rock and earth-filled embankment dam constructed on river Tana with a primary purpose of generating Hydroelectric power. The 30 m (98ft) tall dam has a volume capacity of 16,000,000m^3 (13,000a acre ft) reservoir supports 225 MW power station. Gitaru power station is the biggest among the seven forks schemes because of its high installed capacity mentioned previously and is operated by the Kenya Electricity Generating Company (KenGen)

ii. Masinga Power Station

Masinga Hydroelectric power station also called Masinga Dam is an embankment on the longest river in Kenya the Tana. The dam is 60m tall with a volume of 4,950,000m^3 and generation capacity 40MW owned by Tana and Athi River Development Authority (TARDA) but it is operated by KenGen.

iii. Kamburu Power Station

The Kamburu Hydroelectric power station also called Kamburu Dam is rock-filled embankment dam on the Tana-river constructed purposely for generation of hydropower. The 52m (171ft) tall dam has a reservoir with a volume of 123,000,000m^3 (100, 000-acre ft) being operated By KenGen and supports 93 MW power station.

iv. Kindaruma Power Station

The Kindaruma Hydroelectric Power station also called Kindaruma Dam is an embankment dam with two gravity dam sections on river tana of Kenya with a primary purpose of generating hydroelectric power. The 24m (79 ft) tall dam has a volume of 18,300,000m^3 with a capacity of 72MW and is being operated by the KenGen.

v. Kiambere Power Station

The Kiambere Hydroelectric power is an earth-filled embankment dam on the Tana River constructed purposely for generating hydroelectric power. The 110m (360 ft) tall dams holds a volume of 585,000,000m^3 (474,000-acre. ft) reservoir. It has a capacity of 165 MW and is being operated by KenGen.

vi. Sondu Miriu and Sang'oro Hydroelectric Power Station

Despite the seven forks scheme contributing the highest amount of electricity to the National Grid there is also the Sondu Miriu Hydroelectric Power Station on Sondu river in Kisumu County that generates electricity capacity of 60 MW. There is another Hydroelectric power plant connecting with Sondu Miriu on River Sondu called Sang'oro Hydroelectric Power Station producing about 20.2 MW of hydroelectric power.

vii. The Turkwel Hydroelectric Power Station

The Turkwel Hydroelectric power station on river Turkwel which also provides other services aside from generating power including irrigation and fisheries to the local community. It is the third largest hydroelectric power generating plant with an installed electric capacity of 106 MW. It is also the tallest dam in Kenya with 153m (502 ft) with a water retention capacity of 1,641 million M^3(1,330,000-acre ft).

Hydroelectric power is Kenya's most exploited renewable source of energy with some small hydroelectric power station of capacities less than 20 MW not connected to the national grid. The only disadvantage in the dependence of hydroelectric energy is the increased power shortage due to the reduced levels of water in the dams as the effects of climate change are being experienced with prolonged periods of drought with little or no rainfall.

a. Geothermal Energy Resource

Kenya has discovered the potential of Geothermal power in its overall development plans. This can be clearly seen in Kenya's Vision 2030 where the country hopes to extend geothermal generation capacity to 5,000 MW. Kenya is the first African country to tap geothermal power and the largest producer of geothermal energy having 20% installed capacity of electricity into the national grid accounting. Figure 2.4 (IRENA, 2019) shows that Kenya's Geothermal installation capacity has been on a gradual increase yearly and by the year 2019 the installation capacity had reached 823.8MW with possibilities of having more installations.

Most of the country's geothermal energy is harnessed from Olkaria located in the Hell's Gate National Park in Nakuru County. Olkaria power plant consists of six plants. Olkaria I, Olkaria II, Olkaria III, Olkaria IV which are currently operational while Olkaria V is under construction and Olkaria VI planned for year 2021.

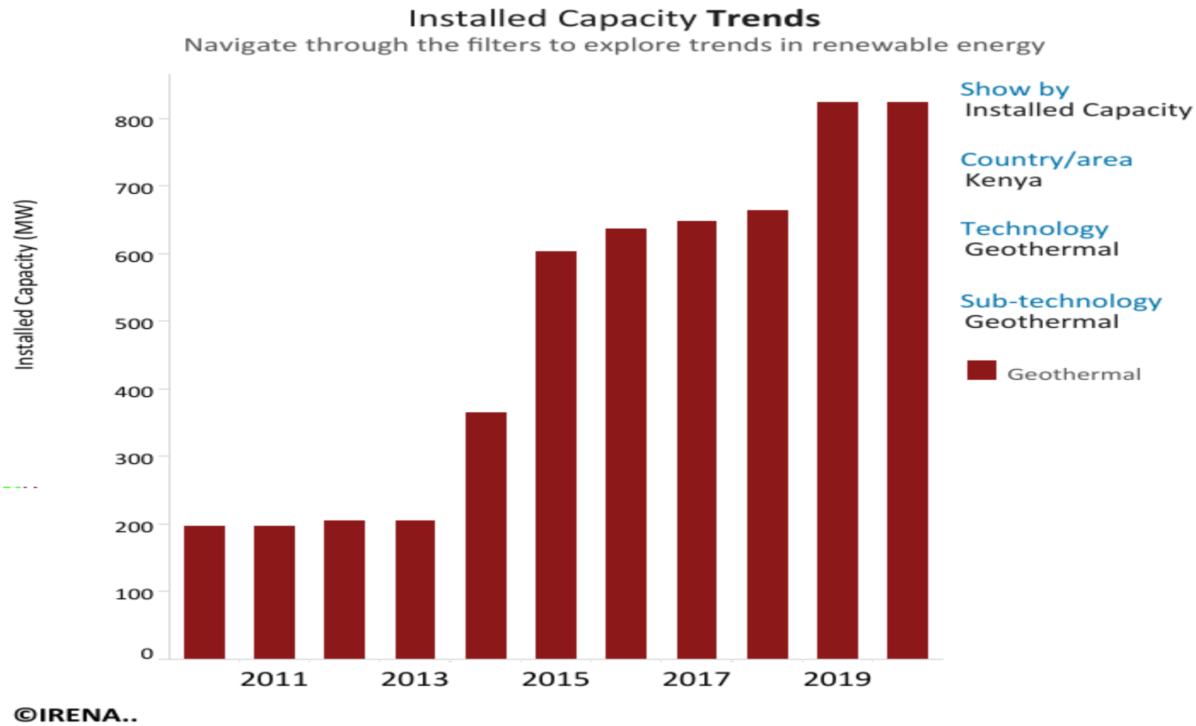


Figure 2.4: Geothermal Installed Capacity in Kenya

i. Olkaria I Geothermal Power Plant

It is the first geothermal power plant in the country that started operating in the year 1981. It is one of the six clustered geothermal power stations in Olkaria area of Nakuru County. The facility started with an installed capacity of 15 MW but KenGen the company that operated the facility has been increasing the number of turbines and currently the facility has generation capacity of 185 MW of electricity. The construction of another unit at the facility with an expected completion of 2021 entered its final construction face in June 2021 and will increase the generation capacity to 273.7 MW (KENGEN, 2021).

ii. Olkaria II Geothermal Power Plant

Olkaria II geothermal power station is one of the six clustered geothermal power stations in Olkaria area of Nakuru County that started operating in 2003 and is being managed by KenGen. The facility started operating with a generation capacity of 35 MW but currently has a generation capacity of 105 MW after KenGen constructed other additional units in the plant.

iii. Olkaria III Geothermal Power Plant

Olkaria III geothermal Power station also called 'OrPower4' is the sister station to the other six power station in the Olkaria area of Nakuru County. It was first operational in 2000 with a generation capacity of 13 MW but the generation capacity has been increasing with the installation of more units in the facility. It is a large Geothermal power plant in Kenya with a generation capacity of 139 MW.

iv. Olkaria IV Geothermal Power Plant

The power plant is owned by KenGen and is one of the six clustered geothermal power stations either operational, under construction or planned and has an electricity generating capacity of 140 MW.

v. Olkaria V Geothermal Power Station

The power plant is still under construction and is also one of the six Olkaria power stations. It has a generation capacity of 158 MW if it's completely finished and is fully operational. Its construction started in the year 2017 and its first unit was connected to the National grid in the year 2019 with a generating capacity of 79 MW bringing the total geothermal electricity connected to the grid to around 700 MW to 850 MW.

vi. Planned Geothermal Power Plants

The country still has plans of constructing other geothermal power stations among them the Olkaria VI with a generation capacity of 140 MW, Akiira One Geothermal Power Station with a capacity of 70 MW, Menengai I, II, and III Geothermal Power Station Each with a generation capacity of 35 MW.

The National Climate Change Action Plan and the 5000 + MW in 40 months initiative recognizes geothermal power to be a reliable source of energy at a low cost and also cuts the carbon emission reducing the vulnerability of the environment to the adverse effects of Climate Change. The country has a lot of commitment it needs to play to achieve these ambitious targets including getting the required technology, finance and also high political will which are all challenges the country is facing currently in energy access and distribution.

b. Solar Energy

Kenya has a high insolation rate receiving sunshine for about 5-7 peak hours in a day with only 10% - 14% of this energy that can be converted into electricity due to the low efficiency of photovoltaic (PV) modules. Kenyans are world leader in the connection of solar energy per capita as most of the households have solar power systems installed in their houses for domestic electrical use. Most of this solar power is not connected to the national grid due to the high cost of connectivity and also because of the abundance of solar energy countrywide thus, they don't require the government to help them in the access of this energy.

i. Solar Home Systems (SHS)

Kenya has over 200,000 households having connected to the solar home systems largely because of the help of some private sector being involved actively in bringing this service closer to the rural community and at an affordable price. Some of the private companies actively pushing for solar energy use include M-kopa, Solar Mtaani, One-Acre Fund among others. Over 20% to 40 % of household in Western and Central regions have been connected to the solar home systems with energy capacity of 10-20Wp. Some of the uses of solar energy in the house holds includes lighting the houses, connecting to radios and television, pumping of water and also charging mobile phones. This therefore shows that more households in the rural areas need to be connected to the solar home systems in order to reduce emissions from Kerosene an energy source that the remaining percentage use for lighting.

ii. Solar Hybrid Mini-grids

In the new Energy Act of 2019, the Rural Electrification and Renewable Energy Corporation (REREC) has been established as the successor of the Rural Electrification Authority (REA). Under the new dispensation, REREC has an expanded mandate of spearheading Kenya's renewable energy drive, in addition to implementing rural electrification projects. Under section 44(1) of the Energy Act 2019, REREC is mandated to run the following functions:

- Oversee the implementation of the Rural Electrification Programme.
- Manage the Rural Electrification Programme Fund.
- Source additional funds for the Rural Electrification Programme and renewable energy.
- Develop and update the rural electrification master plans in consultation with County Governments.

- Develop and update the renewable energy master plan taking into account county specific needs and the principle of equity in the development of renewable energy resources.
- Support the establishment of energy centers in the counties.
- Establish framework for collaboration with County Governments in the discharge of its mandate.
- Undertake on-farm and on station demonstration of wood-fuel species, seedling production and management.
- Undertake feasibility studies and maintain data with a view to availing the same to developers of renewable energy resources.

The corporation has mobilized countrywide rural electrification projects among them solar mini-grids both stand alone and hybrid projects for benefitting the schools and communities that are situated 5 Kilometers away from the main national grid. This offers a boost to the renewable energy sectors most especially to the marginalized rural communities of the Kenyan population.

The solar hybrid mini-grids are not only being spearheaded by the government but also the private sector. The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) is a private entity promoting rural and remote electrification with an aim of enhancing electricity access to the rural communities. Their vision is to increase the levels of effectiveness, affordability and sustainability through private sector leadership. Talek Power mini-grid was set up as a pilot project in collaboration with the county government of Narok and the German Agro Action. It consists of 50 kW solar generation power plant combining PV modules, battery packs and a diesel generator currently providing energy to the local community and also acting as a learning center to different stakeholders in the country.

iii.Garissa Solar Power Project

The **50 MW Garissa Solar Power Plant** is located in Garissa County located on 85 hectares (210 acre) piece of land consisting of 200,200 solar panels. It is the largest grid connected Solar Power Plant in East and Central Africa owned and operated by Kenya Rural Electrification Company which is a government agency. Plate 2.1 (Gitogo, 2019) shows the power plant that is to provide energy for 70,000 households in Garissa County or about 350,000 people a step towards achieving Sustainable Development Goal (SDG) number 7 on affordable and Clean Energy for all.

Plate 2.1: Garissa Solar Power Plant

c. Wind Energy

The topographic effect and the presence of the Rift Valley and various mountains and highlands have made some parts of the country viable for harnessing of wind energy. The North-West parts of the country specifically Marsabit and Turkana and the edges of the rift valley are the large windiest areas with an average wind speed of 9 m/s at 50 m high as shown in Figure 2.4 (GBA, 2017).

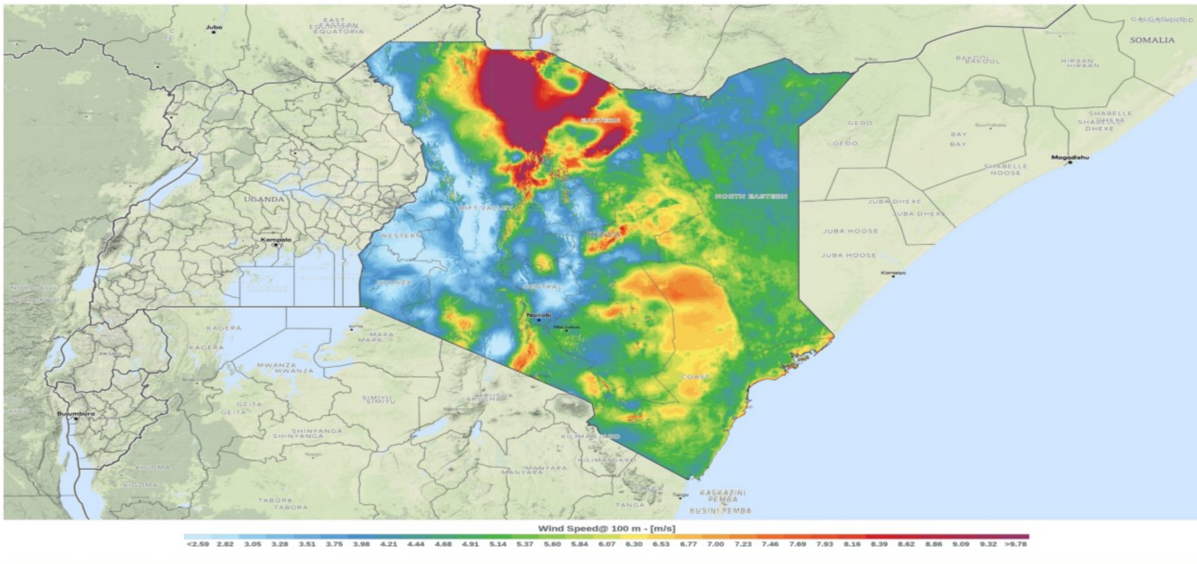


Figure 2.4: Wind Distribution Area Map

i. Turkana Wind Power Station

Lake Turkana Wind Power Project (LTWP) is Kenya's largest private owned wind power project and the largest wind power plant in Africa. The power plant has 365 wind turbines that covers 40,000 acres of land with a generation capacity of 310 MW able to provide reliable and low-cost energy to one million homes and contribute 17% of installed capacity to the national grid (Norfund, 2021). The wind is strongest in the morning in October and weakest in the month of February afternoon contrasting with Ngong Hills Wind Power Station. Having this power project operational in the country not only provides green jobs like in the Lake Turkana Project where 75% of the local communities were employed but also a step towards embracing renewable energy and a move away from the use of fossil fuels. Plate 2.2 (Norfund, 2021) shows the lake Turkana Wind turbine power farm image

Plate 1.2: Lake Turkana Wind Power Station

ii. Ngong Hills Wind Power Station

The wind power station is located in the Northern foothills of Ngong hills in Kajiado County. The wind in this area is strongest in the evening and in the month of March and weakest in the morning and the month July contrasting with the Lake Turkan Wind Power Station. The power plant is owned and operated by KenGen and has a generation capacity of 25.5 MW.

iii. Proposed Wind Power Plants

Kenya has a vision of developing more wind power stations in the country in the areas that have viable wind. Among the proposed stations Include: The Kajiado Wind Power Station in Kajiado with a generation capacity of 100 MW, Meru Wind Power Station which is currently under construction in Meru County with a generation capacity of 400 MW and the Lamu Wind Power Station that will be located in Lamu county with a generation capacity of 90 MW.

The country has a compatibility of 25% wind technology but the only problem hindering the exploitation of the wind is the limited knowledge on the Country’s wind resources with unreliable meteorological data due to the scarce meteorological stations distributed in the country. If the required technology is put in place to get reliable and accurate information on the country's wind resources it would be easy to herness wind energy which is renewable and cleaner to use.

d. Biomass Resource

Bio-energy is the energy derived from varied sources of solid, Liquid and gaseous biomass including wood fuel, charcoal, bio-gas and bio-fuel. Biomass contributes to 70% of Kenya's energy demand and provides 90% of the energy use in the rural households (Energypedia, 2021). Kenya depends mostly on firewood, charcoal and agricultural waste as the main sources of biomass. At the national level 68% of household use firewood as the main source of energy for cooking while 90% of the rural population depend on firewood for cooking and heating leaving approximately 10% of the urban population using firewood (Energypedia, 2021). Charcoal is mainly used by the urban population as a source of energy accounting for 82% as compared to the 34% of the rural households that use charcoal. About 90% Educational Institutions in Kenya use firewood as a source of energy for preparing school meals this is mainly because of the high rise in petroleum prices and high cost of other sources of energy like LPG and Electricity.

Kenya has the potential of generating electricity from biomass sources generated from agricultural waste among them sugarcane. Mumias Sugar Company used to generate 35 MW from sugarcane bagasse with 26 MW having been dispatched to the National grid until the sugar company faced problems due to management and could not run accordingly. Other sugar companies have been estimated to produce around 300 MW if they were to explore this opportunity.

Biogas generation in Kenya is mainly practiced by learning institutions as they produce a lot of waste mainly from the kitchen and also some keep animals for instance cows thus use cow dung in their biodigesters. One of successful biogas plant in the Kenya is the Sisal Cum Cattle Farm in Kilifi which converts sisal waste and cow manure into biogas and produces electricity amounting to 90 Kw. The country has a thousand biodigesters installed but many of them operate below the capacity needed or others are currently not in operation due to technological loop and the high cost of maintenance.

2.1.5. Kenya Current Climate Policy Projections

Kenya has been on track to meet and even overachieve its NDC target of 30% decrease greenhouse emissions by 2030 even before the COVID-19 pandemic. The Climate Action Tracker (CAT, 2020) estimates that Kenya's emissions may decrease further towards 2030 by around 3% to 6% below the pre-COVID-19 projection However, it is challenging to project the eventual impact of the ongoing COVID-19 pandemic on future emissions of the country. The decrease in emissions could be sustained if the government would consider climate mitigation policies in its COVID-19 recovery plans. (MyGov, 2020) stipulates the countries actions plans linked to manufacturing, affordable housing, universal health coverage and food security Known us the four pillars of the President's Big Four Agenda and Climate change-related aspects are not explicitly covered in the country's recovery plans.

Although climate mitigation is not prioritized in the Big Four Agenda nor in the country's Vision 2030, the Kenyan Government has already adopted the Climate Change Act (2016), which provides a framework for the promotion of climate-resilient low-carbon economic development (Republic of Kenya, 2016b). The Act mandates the government to develop a National Climate Change Action Plan (NCCAP) and update it every five years (Republic of Kenya, 2016b). The second and most recent NCCAP covers the period between 2018-2022 with the main objective of guiding climate action during this time and supporting the implementation of Kenya's NDC. Under the NCCAP, sector representatives define priority mitigation actions that are designed to ensure that sectors achieve their sectoral NDC targets (Ministry of Environment and Forestry, 2018).

A brief chapter on implications of the different scenarios on emissions is explained in the Ministry of Energy's latest electricity supply plan (2017-2037 LCPDP) but there is no reference to the sectoral NDC target (Republic of Kenya, 2018). According to the Least Cost Power Development Plans (LCPDP), emissions are projected to be reduced to almost zero in 2030 compared to an increase to 44.7 $MtCO_2e$ in 2030, as indicated in the NDC baseline.

The transport sector is the first and only sector to publish an annual report on performance and progress of climate action, as requested by Climate Change Act (Government of Kenya, 2019). In line with the NCCAP 2018-2022, the report includes mitigation actions the transport sector is undertaking to reduce GHG emissions to achieve the sectoral mitigation target of 3.7 $MtCO_2e$ against the NDC baseline in 2030 (Government of Kenya, 2019). Achieving the sector target is equivalent to an emissions level of 18.9 $MtCO_2e$ in 2030 compared to 22.6 $MtCO_2e$ under the NDC baseline scenario (MENR, 2017).

The Ministry of Agriculture's Climate Smart Agriculture (CSA) Strategy for 2017-2026 is considered as a tool to implement mitigation actions in the agricultural sector in the bid to contribute to Kenya's NDC and projects that absolute emissions will decrease to 31.6 $MtCO_2e$ in 2030, a decrease of 10 $MtCO_2e$ in 2030 below the NDC baseline. This will enable the sector to meet its 2030 NDC emissions reductions target (MoA, 2018). A lot is happening in other sectors with regards to meeting the country's NDC target However, priority mitigation actions proposed for the energy demand and the industrial processes sectors are insufficient. The research is significant in shading light on the use of renewable energy sources to combat climate change and also will help the sectors comply with their respective NDC targets by 2030.

2.1.6 Climate Change Policies in Kenya

In an effort for Kenya to deal with climate change effects both at national level and government, it has come up with different national climate policies and became signatories to international climate policies. Some of the policies guiding the country and the county governments include:

1. The Constitution of Kenya 2010 that makes it a right for every Kenyan to reside in a clean and healthy environment. It puts emphasis on sustainable development which forms the basis of climate change policy framework and legal instruments.
2. The Environmental Management and Coordination (EMCA) Act1999; EMCA (Amendment) Act 2015 that is the basis of all National legislations with environmental conservation for posterity being the main goal.
3. The National Climate Change Act, 2016 that provides a regulatory framework for an enhanced response to climate change and promotes mainstreaming climate change actions into County Government functions.
4. The National Climate Change Response Strategy (NCCRS) launched in 2010 and the National Climate Change Action Plan 2018 - 2022 both policy documents aim to strengthen and focus nationwide actions towards climate change adaptation and greenhouse gas (GHG) emission mitigation.

5. The Green Economy Strategy and Implementation Plan (GESIP) 2016 -2030 which is the country's blueprint in advancing towards a low-carbon, resource efficient, equitable and inclusive socio-economic transformation.
6. In 2005 Kenya ratified the Kyoto Protocol which seeks to reduce the emission levels that contribute to climate change and thereafter submitted the Nationally Determined Contribution (NDC) at the Paris Conference of Parties to the Kyoto Protocol in 2015.

2.1.7 Existing Renewable Energy Policies in Kenya

As the country works towards achieving 100% electrification and in ensuring access to clean and affordable energy, it has come up with policies and regulations to guide the implementation of the energy projects.

2.1.7.1 The Energy Act (MoE, 2019)

The energy act came into law in march 2019 with the aim of:

a. Consolidating the laws relating to energy.
b. Properly delineate the functions of the national and devolved levels of government in relation to energy.
c. Provide for the exploitation of renewable energy sources.
d. Regulate midstream and downstream petroleum and coal activity and for the supply and use of electricity and other forms of electricity.

The new Act has established several new energy sector entities and expanded mandates for the ones that were existing to strengthen capabilities and to properly discharge their functions. These institutions include:

a. Energy and Petroleum Regulatory Authority (EPRA)

The EPRA is the successor to the Energy Regulatory Commission (ERC), which exercised regulatory control over the energy sector. The functions specified for EPRA is to be the regulatory control over the energy sector as a whole and in charge of standardization and regulation of the energy efficient equipments.

b. Rural Electrification and Renewable Energy (REREC)

REREC is the successor to the Rural Electrification Authority (REA). The corporation has been given the mandate of spearheading Kenya's renewable energy drive, in addition to implementing rural electrification projects policy formulation, international cooperation, research and development.

The corporation has so far installed solar panels in 4,596 schools in 39 Counties in Kenya as illustrated in Figure 2.5.

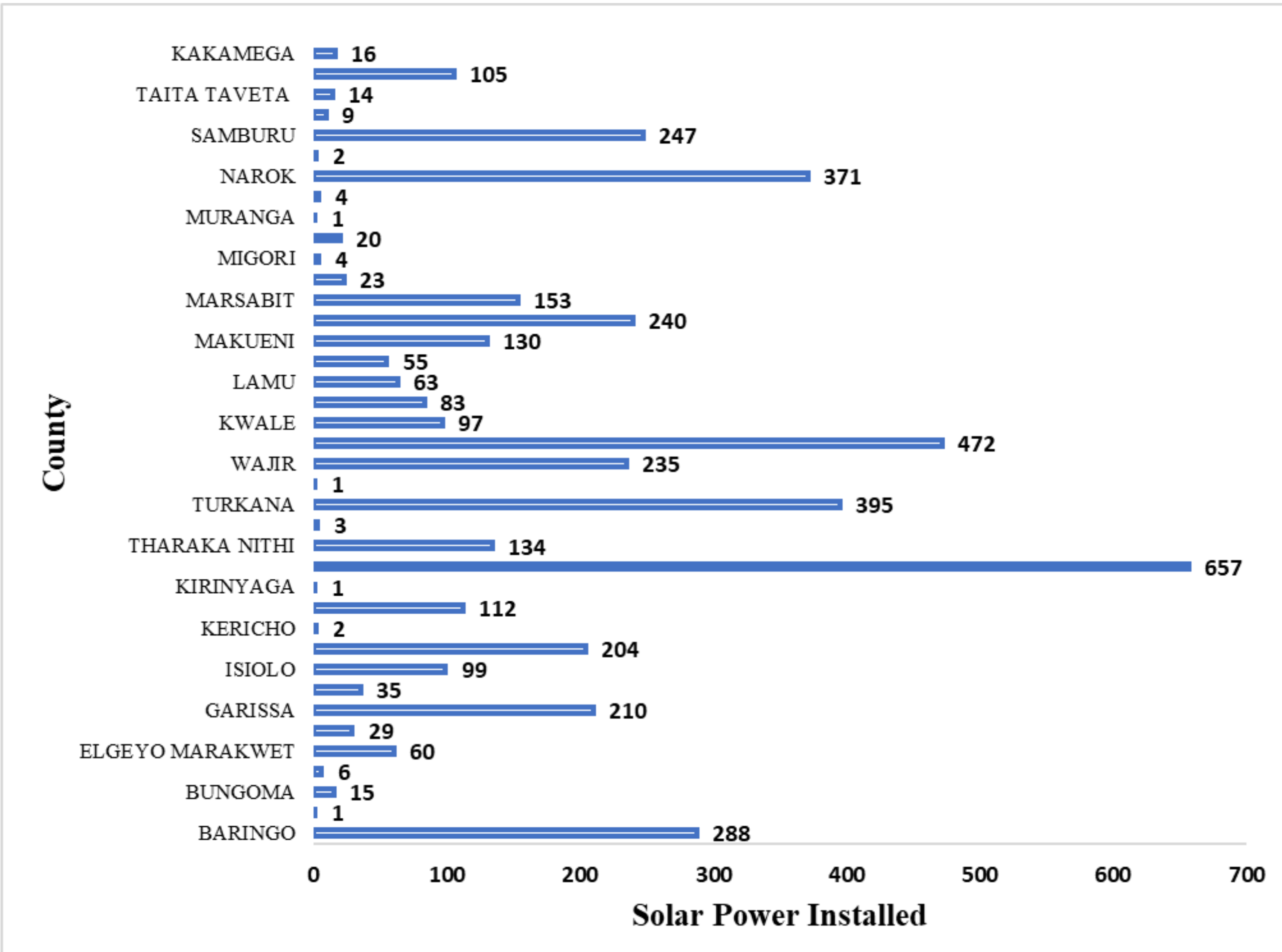


Figure 2.5: Solar Electrified Schools By REREC

c. Nuclear Power and Energy Agency (NUPEA)

The NUPEA is the successor to the Kenya Nuclear Electricity Board a state corporation that was established pursuant to the Kenya Nuclear Electricity Board Order No. 131 of 2012. Its mandate is to develop and implement Kenya's nuclear energy Programme.

2.1.7.2 The Geothermal Resource Act 1982 Revise (2012)

This is an Act of Parliament used to control the exploitation and use of geothermal resources in the country. The act stipulates that all un-extracted geothermal resources under or in any land shall be vested in the Government and Unauthorized use of geothermal resource is prohibited and requires licensing.

2.1.7.3 The Energy (Solar Photovoltaic Systems) Regulations 2012

These regulations apply to a solar PV system manufacturer, importer, vendor, technician, contractor, system owner, a solar PV system installation and consumer devices. The regulation provides the guidelines on the licensing of Solar PV manufactures and technicians and prohibits manufacturing or installation of solar PV system without a license from the government.

2.1.7.4 The Bio Energy strategy (MoE, 2020)

The strategy came into place after extensive and elaborate expert consultation and multi-stakeholder dialogue processes that commenced in 2018. The strategy highlights that biomass is the most common source of energy in the country and the world therefore requires proper management and handling in order to avoid carbon emissions. The goal of this Strategy is sustainable bioenergy for all by 2028 and has the following Specific objectives:

- To promote sustainable production and consumption of bioenergy.
- To accelerate transition to clean cooking technologies and fuels.
- To provide potential investors with requisite information on viable opportunities for bioenergy development in Kenya.
- To serve as a framework for regional and international cooperation and trade in bioenergy and related feedstocks.

2.1.7.5 Kenya National Energy Efficiency and Conservation Strategy (NEECS, 2020)

One of the key pillars of sustainable development in Kenya and the world is Energy Efficiency and Conservation. The government of Kenya has placed energy efficiency as one of the priority areas of improvement in the effort to enhance the quality of life of the citizens. Several initiatives aimed at improving energy efficiency and conservation are drawn from policies such as Sessional Paper No. 4 of 2004 on Energy, Energy Act 2019, Vision 2030, the Energy (Energy Management) Regulations 2012, Sustainable Energy for All (SE4ALL) Initiative, and the Energy (Appliances' Energy Performance and Labelling) Regulations 2016.

The initiatives have helped improve energy efficiency and conservation in commercial, domestic, industrial and institutional sectors of energy consumption. These initiatives however adopt a disparate approach with lack of central coordination and do not cover all the essential areas outlined in the Big Four Agenda (Food, security, affordable housing, manufacturing, and affordable healthcare. Therefore, the (NEECS) was developed to enhance the ongoing efforts by providing a roadmap towards setting and achieving energy efficiency goals.

2.2 Renewable Energy and Climate Change

All societies require energy services to meet basic human needs like lighting, cooking, space comfort and relaxation, mobility and communication and to serve productive processes. Delivery of energy services need to be secure and have low environmental impacts for development to be sustainable. This Sustainable social and economic development requires assured and affordable access to the energy resources necessary to provide essential and sustainable energy services.

2.2.1 Climate Change Definition

Climate change in IPCC is referred to as a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer (IPCC- Edenhofer, et al., 2011). The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time period (UNFCCC, 2011). UNFCC further states that Climate change is largely caused by the continuous greenhouse gas emissions and over accumulation that have led to global warming.

Changes in climatic conditions are visible through regional and ocean basin scales, including changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, Floods, heat waves, fires and the intensity of tropical cyclones (IPCC, 2013). Global efforts to cope with climate change and its accompanying effects should primarily be driven by mitigation-oriented solutions.

Various methods are being used as mitigation strategies in an attempt to reduce the physical effects of climate change reduction in GHG emissions being the most popular (IPCC- Edenhofer, et al., 2011). This is being done through reducing factories' pollution, advancing sustainable agriculture systems, the use of cleaner means of transportation and other mechanisms. Mitigation efforts are practiced and applied in many sectors globally with a focus on enabling systems, institutions and human to adapt to potential harm from climate therefore; reducing the global greenhouse gas emissions proven to cause global warming and climate change is pertinent (Bojana Bajželj, 2013).

2.2.2 Renewable Energy Definition

Renewable is generally referred to as the energy resources and technologies that are non-depletable or naturally replenished or any source of energy that is not based on fossil fuels and include solar, wind, hydroelectric, biomass and other technologies (Eitan, 2021). Renewable energy resources and technologies are a key component of sustainable development because; they generally cause less environmental impact than any other energy sources and provides a flexible array of options for their use. They cannot be depleted. If used carefully in appropriate applications, renewable energy resources can provide a reliable and sustainable supply of energy almost indefinitely. In contrast, fossil fuel and uranium resources are diminished by extraction and consumption (Ibrahim Dincer, 2013).

2.2.3 Renewable Energy and Climate Change Interrelation

Climate change and renewable energy are connected to a very significant level in the fact that renewable energy serves as a tool for coping with climate change Bevan, (2012) mostly as a mitigation strategy but also as an adaptation strategy because of being naturally clean during energy production as compared to the electricity generation from conventional resources (Weisser, 2007). The Reduction of anthropogenic greenhouse gas (GHG) emissions in material quantities, globally, is an important element in limiting the impacts of global warming (Douglas J.Arent, 2011). GHG emissions associated with energy extraction and use are a major component of any strategy addressing climate change mitigation and RE can be used to address the emissions.

IPCCC suggests that RE sources play a role in providing energy services in a sustainable manner and in mitigating climate change GHG emissions associated with the provision of energy services a major cause of climate change. The IPCC Fourth Assessment Report (AR4) concluded that "Most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." Which have continued to grow and by the end of 2010 had reached 39% above preindustrial levels (IPCC-Moomaw, 2011).

The report advices that there are multiple means for lowering GHG emissions from the energy system, while still providing desired energy services and recommends the use of RE technologies which are diverse and can serve the full range of energy service needs. On a global basis, it is estimated that RE accounted for 12.9% of the total 492 EJ of primary energy supply in 2008. The largest RE contributor was biomass (10.2%), with the majority (roughly 60%) of the biomass fuel used in traditional cooking and heating applications in developing countries but with rapidly increasing use of modern biomass as well.

According to the analysis done by IRENA, a combination of renewable energy, energy efficiency and electrification represent a safe, reliable, affordable and already deployable pathway capable of achieving over 90% of the energy-related CO_2 emission reductions that is needed to meet the agreed-on climate goals (IRENA, 2019a). Reduction GHG emissions is achievable at relatively low costs, if the right policies are put in place and better integration of climate change objectives in relevant policy areas such as energy, transport, building, agriculture or forestry, and other measures to speed technological innovation and diffusion. The combination of energy and information technology (IT) innovations and renewable energy's growing competitiveness are transforming the landscape of energy services (IRENA, 2019). Local communities, non-governmental organizations (NGOs) and the private sector can as well combine their knowledge, expertise in the decision-making processes to take immediate action being supported by the government on matters climate change.

The intergovernmental Panel on Climate Change (IPCC-Moomaw, 2011) states that, energy services must be provided with low environmental impacts and low greenhouse gas (GHG) emissions. However, 85% of current primary energy driving global economies comes from the combustion of fossil fuels and consumption of fossil fuels accounts for 56.6% of all anthropogenic GHG emissions. The Report explores the current contribution and potential of renewable energy (RE) sources to provide energy services for a sustainable social and economic development path. It includes assessments of available RE resources and technologies, costs and co-benefits, barriers to up-scaling and integration requirements, future scenarios and policy options.

The report further indicates that in the absence of any climate policy, the overwhelming majority of the baseline scenarios exhibit considerably higher emissions in future leading to rising CO_2 concentrations and, in turn, enhanced global warming. According to the report, to avoid adverse impacts of such climate change on water resources, ecosystems, food security, human health and coastal settlements with potentially irreversible abrupt changes in the climate system, there is need for limiting global average temperature rises to not more than 2°C above preindustrial values and agreed to consider limiting this rise to 1.5°C.

The report however adds that increasing the share of RE in the energy mix requires policies that stimulate changes in the energy system. They include government policies, the declining cost of many RE technologies, changes in the prices of fossil fuels and other factors supports the continuing increase in the use of RE. These developments suggest the possibility that RE could play a much more prominent role in both developed and developing countries over the coming decades. RE may provide a number of opportunities and can not only address climate change mitigation but also address sustainable and equitable economic development, energy access, secure energy supply and local environmental and health impacts.

2.3 Socio-Economic Impacts of Climate Change

Climate change is arguably one of the most important challenges facing African countries, largely due to their geographic exposure, low income, greater reliance on climate-sensitive sectors such as agriculture, and weak capacity to adapt to the changing climate. Agriculture contributes greatly to the Kenyan economy making it an important contributor to employment and food security of rural households. Climate change has significantly affected global agriculture in the 21st century presenting a threat to food security in Kenya with the effects on rainfall, soil moisture and production. Empirical results show that climate variability causes significant economic costs as a result of periodic floods and droughts that leads to major macro-economic costs and reductions in economic growth (SEI, 2009). Climatic variability and change directly affects agricultural production and food security as most of the population in Kenya lives in the rural areas and relies on agriculture for its livelihoods with agriculture being rain-fed dependent.

According to (Pankaj Lal, 2011), the impacts of climate change can be grouped into three aspects: ecological, social and economic. The ecological impacts of climate change include: change in forest density and agricultural production, expansion of arid land, decline in water quality and quantity, shifts of vegetation types and associated impacts on biodiversity and stresses from pests, diseases, and wildfire. The social impacts may include changes in employment, equity and risk distribution of resources, human health and relocations of populations. Lastly the Economic impacts include: alteration in productivity for crops and forest products, increased cost of utilities and services, reduction in supply of ecosystem goods and services, altered energy needs and increased risk and uncertainty of forest or agricultural production. These impacts affect the daily activities of the people and the vulnerability is high to the rural population who are already disadvantaged in the distribution of the national resources.

The economic sector plays a very important role in the growth and development of any country. The sector also has subsectors that are affected by climate change making it impossible for the economy to grow as anticipated. The subsectors to be affected by climate change if action is not taken now is: Fishery, tourism, agriculture, health, coastal infrastructure and urban planning (PRCM, 2021). The report suggests that the rise in sea temperatures will cause fish species to move to colder waters which in turn will lead to a loss of revenue for tropical countries, with the changes in climatic conditions; there will be a reduction in the available beach areas due to the erosion and sea-level rise, thus causing significant damages to the fishing industry and fishery-dependent local economies.

Agriculture for African farmers is 98% rain-fed and with the increase in droughts and floods due to climate change, producing food in the expected quantity and quality will become problematic for many farmers. These risks add to difficulties that the subsectors are already facing including overfishing, marine pollution, political unrest and epidemic risks (Covid-19) all of them impacting the economic sector. The people that are already considered vulnerable in terms of development requirements are the ones most affected by climate change (PRCM, 2021) and the rural population is one among them.

Research conducted in Zimbabwe by (Mano, 2007) funded by the World bank and coordinated by the Centre for Environmental Economics and Policy in Africa (CEEPA) shows that climatic variables (temperature and precipitation) had significant effects on net farm revenues in Zimbabwe. The study analyzed the effects on dryland farms and irrigation farms and the analysis indicated that net farm revenues were affected negatively by increases in temperature and positively by increases in precipitation. The sensitivity analysis results suggested that agricultural production in Zimbabwe's smallholder farming system is significantly constrained by climatic factors (high temperature and low rainfall) therefore; variation in any of the variables led to significant impacts on the agricultural production of the smallholder farming therefore impacting negatively their economic development.

A study conducted by (Kabubo, 2007) on climate change in 38 former districts of Kenya analyzed the economic impact of climate on crop agriculture. The authors based their analysis on different types of data: long-term mean seasonal temperature and precipitation data, long-term mean monthly hydrological data, main classes of soil types and cross-sectional household level data. The results showed that climate affects crop revenue increased precipitation was positively correlated with increased crop yield. The results also showed that there was a non-linear relationship between revenue and the temperature and precipitation variables.

Climatic variability and change have always presented a threat to food security in Kenya through their effect on rainfall, soil moisture and production this leads to reduced economic activities especially from the rural communities who largely practice farming in order to sustain their livelihoods. Other impacts include increased hunger and poverty levels that effect the health of the rural people especially children who do not get enough food supplements for their growth and development. This therefore calls for more research and adoption of renewable energy sources in a bid to combat climate change and reduce the impact on the socio-economic development of the rural communities.

2.4 Stakeholder Theory

The term stakeholder was first coined and defined as “any group or individual who is affected by the achievement of an organization’s objective (Freeman, 1984). The CSIRO framework for stakeholder engagement on climate adaptation report (Gardner, 2009) describes a stakeholder as anyone with an interest in a particular decision and can act as an individual or as a representative of a larger group. The framework highlights that the stakeholder interest can influence the decision or be influenced by the decision.

The framework further describes stakeholder engagement as any process that involves stakeholders in a form of collaborative effort directed towards a decision that might involve future planning or behaviour change. The extent of this collaboration can vary from brief and simple information provision, to more extensive and long-term relationships amongst participants. The nature of stakeholder engagement required depends on the goals that are being pursued, issues that are contentious, involve risk, and those in which values may differ strongly between different stakeholder groups require more interactive and deliberative processes.

2.4.1 Stakeholder Engagement on Climate Adaption

Stakeholder engagement is important in the implementation and achievement of any objective therefore it is better to understand the engagement and information preferences of key stakeholders in relation to adaptation to climate change and climate variability (Gardner, 2009). The stakeholders may include regional, industry and community groups for which climate adaptation is important. Climate change is complex with many explanations to its occurrence and the challenge is to help various stakeholders plan for the future while acknowledging the uncertainty inherent in the current climate models. Research conducted by CSIRO found that stakeholders become alarmed, fearful, and concerned about their future before moving onto identifying possible solutions when they are engaged in discussions about climate change. The findings highlight the importance of engaging stakeholders in an appropriate manner to ensure that interactions are positive and enabling rather than the opposite.

Multiple benefits derived from involving stakeholders in decision-making with proper consultations and discussion highlighted by (Gardner, 2009) include:

- Facilitation of clear communication and exchange of information with all parties involved developing a more thorough understanding of issues, potential solutions and alternative perspectives to choose from the best solution.
- Improvement of the effectiveness of decision-making processes through gaining better insight into potential equitable outcomes, solutions to conflicts and effective planning.

- Strengthening the resources of involved groups by increasing awareness, confidence, skills and co-operation among stakeholders.
- Improvement in the sustainability of any initiative by increasing the quality of decisions and their acceptance amongst stakeholders.

When introducing new electricity generation technologies in a country or a region, stakeholders influence significantly the decision-making process and therefore their views and perceptions on large-scale renewables are very crucial (Ahmed, 2018).

Stakeholder engagement is therefore an important aspect of any outcome in a company, industry or community as they directly or indirectly influence the processes involved in the decision making. Its early adoption enables the parties to both solve problems before they escalate into complains and provide valuable information to improve the overall standards of customer service. The use of renewable energy sources in combating climate change in the rural areas requires objective involvement of the stakeholders.

2.5 Barriers to Adoption of Renewable Energy Sources

Understanding the challenges in RE technology value chain is essential for key actors in order to disseminate these technologies for rural electrification in Kenya and it is important to understand how these challenges can be overcome once they have been identified. Some of the barriers to adoption of RE sources include: market failures, up-front costs, financial risk, lack of data as well as capacities and public institutional awareness (Amakobe, 2014). The author further identifies perceived social norms, value structures, present infrastructure, current energy market regulation, inappropriate intellectual property laws, trade regulations, land use conflicts, lack of amenable policies and programs amongst existing barriers and issues to expanding the use of RE. The solar energy stakeholder workshop held at the Desmond Tutu Conference Centre in Nairobi on 11th June 2014 identified some of the barriers to the adoption of solar Photovoltaic (PV) systems to the rural communities. PVs are the dominantly used renewable energy in the country due to the readily available solar light in most parts However, the workshop identifies some of the barriers to adoption as follows:

- The capacity of solar energy technologies is limited by the power demand Stabilization by means of batteries or solar controller is required to increase renewable energy penetration.
- Policies such as the reintroduction of VAT on solar energy technologies are an inhibitor of the solar energy market in the country.
- Lack of adequate knowledge and information available for private investors and the Kenyan general public.
- Lack of technical capacity and business models that support the implementation and sustenance of the PVs.
- The high cost of technologies, accessories and installation are unaffordable for many people living in rural Kenya.

Despite RE sources being readily available with recent technological enhancements, the process of getting people to switch from the use of non-renewable energy sources has been quite slow and uncertain especially in the developing nations. The study is thus aimed at identifying the barriers to adoption of RE sources in combating climate change in the rural settlement and propose recommendations for future policy formulation.

2.6 Energy Models

Energy models contribute to various system operations, engineering design and energy policy development and can be international, regional, national, municipal or stand-alone in scope. Energy models often employ scenario analysis in investigating different assumptions on the technical and economic conditions on the grounds with the Outputs including; greenhouse gas emissions, cumulative financial costs, the system feasibility, natural resource use and energy efficiency of the systems being investigated.

The IPCC reports that energy sector is the largest contributor to global greenhouse gas emissions and that climate change mitigation and other environmental impacts related to energy use requires a fundamental transformation of the energy supply system. Energy models characterize the energy system, its evolution, and its interactions with the broader economy (Timothy, 2010). There is need to understand the role that energy plays and requires a lot of awareness of how energy is produced and consumed. The energy models commonly used are dynamic, built around a mathematical optimization framework and incorporate either classical economic theory or systems engineering principles. Outcomes for the analysis includes technology choices, energy consumption, pollutant emissions and marginal costs for energy resources over time and by region.

Policy making in the energy sector is strongly influenced by models designed to forecast the effects of policies on energy demand, economic output and energy-related pollution. This has spurred the creation of many different energy-economy models which can be classified in two major categories as follows (Rivers & Jaccard, 2005):

Top-down models are characterized by the use of aggregated data to examine interactions between the energy sector and other sectors of the economy as well as examine the overall macro-economic performance of the economy (Van Beeck, 1999). The process is done by internalizing behavioral relationships as much as possible thus Past behavior can then be extrapolated into the future. This makes top-down models suitable for short-term predictive purposes contrast to bottom-up models that usually focus on the energy sector exclusively and use highly disaggregated data to describe in detail the energy end-uses and technological options (Van Beeck, 1999). An important modeling distinction captures differences in the representation of economic feedbacks and technology detail with top-down models adopting a macroeconomic perspective and balances the demand for and supply of resources, including energy across sectors of the economy. (Timothy, 2010)

Bottom-Up models are characterized by the use of highly disaggregated data on specific technologies such as estimated cost of energy technologies and determine the financially optimized (cheapest) way based on available technologies and processes. They are therefore well utilized to produce detailed and fair energy use projections by type and sectors, typically to identify least-cost configurations and are categorized as: simulation Models, accounting Frameworks and optimization models (Van Beeck, 1999). Bottom-up models in contrast to top-down downplay key economic feedbacks such as the responsiveness of demand to changes in energy prices, in favor of a detailed representation of individual technologies (Timothy, 2010).

The difference between top-down and bottom-up can generally be illustrated as the distinction between aggregated and disaggregated models respectively, or as the difference between models with a maximum degree of internalized behavior and models with a minimum degree. Table 2.1

(Van Beeck, 1999) shows the different aspects, associated with top-down and bottom-up models besides them only being used for prediction and exploring purposes respectively.

Table 2.1: Characteristics of Top-Down Models and Bottom-Up Models

Top-down	Bottom-up
Based on observed market behavior	Independent of observed market behavior
Cannot explicitly represents technologies	Describes technologies in detail
Endogenize behavioral relationships	Assess costs of technological options directly
Most efficient technologies are given by the production frontier set by market behaviour.	Efficient technologies can lie beyond the economic production frontier suggested by market behavior
Disregard the technically most efficient technologies available, thus underestimate potential for efficiency improvements	Disregard market thresholds (hidden costs and other constraints), thus overestimate the potential for efficiency improvements
Assumes there are no discontinuities in historical trends.	Assumes interactions between energy sector and other sectors is negligible.
Reflect available technologies adopted by the market.	Reflect technical potential.
Give pessimistic estimates on "best" performance	Give optimistic estimates on "best" performance
Use aggregated data for the predicting purposes	Use disaggregated data for exploring purposes
Use an economic approach	Use an engineering approach

Energy models both bottom-up and top-down have advantages and limitations that researchers and policy makers need to be well aware of and take into consideration before employing them. Table 2.2 shows the different models their strengths and weaknesses (Herbst, 2012).

Table 2.2: Strengths and Weakness of Energy Models

Model		Strengths	Weakness	Examples
Top-down	**Simple extrapolation**	Requires small data needs and is easy to	Lacks technological	Spreadsheet models

		use.	detail.	
	Computable general equilibrium	Feed-back effects on macroeconomic variables		ENV-Linkages (OECD), SGM and CETA
Bottom-Up	**Accounting**	Requires small data needs and is easy to use.	The link with the broader macroeconomic developments is missing.	LEAP, MEDE & MAED
	Optimization	Technological detail and least cost projections		MARKAL/ TIMES, POLES MESSAGE and EFOM
Hybrid		Consistent with economic projections and technologically detailed.	It is very resource-intensive	WEM (IEA), NEMS, MARKAL-MACRO and IPAC

Multi-Agent Models

Multi-agent modelling is a simulation approach that considers market imperfections such as asymmetric information, strategic behaviour and other non-economic influences. Their concept and architecture are derived from the distributed artificial intelligence concept whose application has been greatly extended across several research areas. One major obstacle of developing and using multi-agent models is the enormous demand on additional empirical data in order to simulate the behaviour of the different agents and their limitation to applications of the energy converting technologies and a few applications on final energy sectors (Herbst, 2012).

Simulation Energy Models

Simulation energy models allow users to simulate behavior of consumers and producers under various signals like policies, incomes, populations, and prices which are corelated with the general economic and demographic development as well as energy and climate change. It allows the users to explore different scenarios and investigate technologically oriented measures. Accounting frameworks are considered to be a simple form of simulation models which aims to account for the physical and economic flows of the energy system over a period of time (Herbst, 2012). The iterative approach is used to find the market clearing demand, supply equilibrium and enable the modeler to explicitly specify outcomes. The model accounts for the outcomes of the assumed development an approach commonly applied to project future energy demand of final energy sectors and the related emissions. They are not commonly applied to simulate common decision process due to their simple structure and accounting frameworks as the sectors have been restructured and liberalized.

2.6.1 Long Range Energy Alternatives Planning (LEAP) Model

LEAP is a modelling software tool for energy policy analysis and climate change mitigation assessment (SEI, 2012). It was developed at the Stockholm Environment Institute's (SEI) US Center and can be used to examine city, statewide, national, and regional energy systems. LEAP is normally used to forecast energy scenarios of between 20–50 years with most of its calculations occurring at yearly intervals. LEAP allows policy analysts to create and evaluate alternative scenarios and to compare their energy requirements, social costs, benefits, and environmental impacts making it an important energy model that was used in the research to model the BAU against efficient and clean energy technologies as a driver to combating climate change.

LEAP is a scenario-based modeling software tool used for energy policy analysis, climate change and GHG mitigation assessment. The software can be used to track energy generation, consumption and how resources are extracted from the economy. The software gives account for both greenhouse gas emission sources, their sinks and tracking them in the environment following the systematic process in Figure 2.6 (Heaps, 2011).

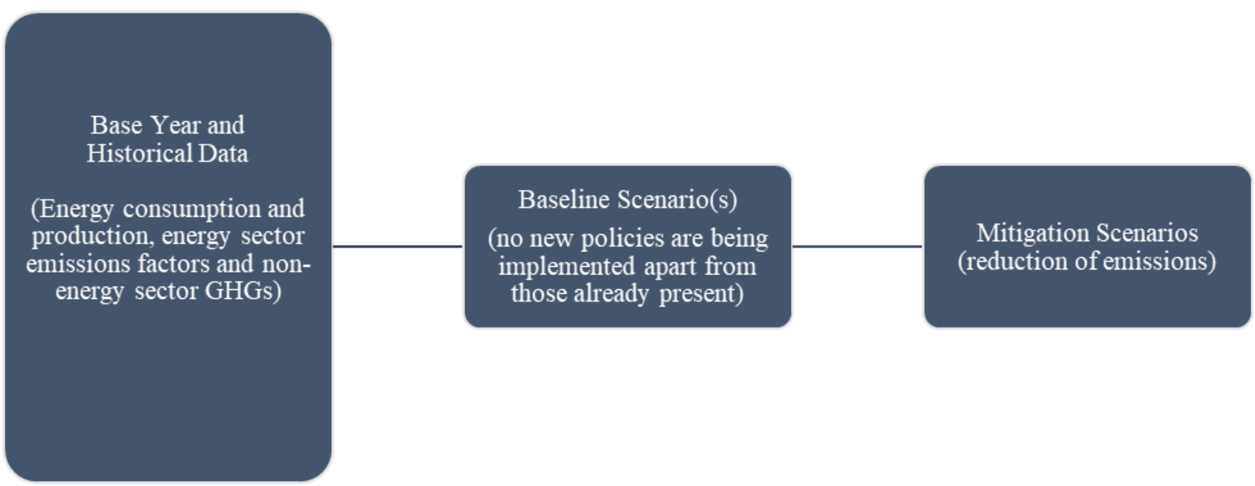


Figure 2.6: The Systematic Process of the Low Emission Analysis Modelling (LEAP) Tool

The LEAP software key benefit is its low initial data requirements which depends on the type of energy modeling being carried out during the research. The data demand inputs required for this software according to (SEI, 2012) include:

- **Demographic data** usually the general data of a country or study are that includes; national population data, rates of urbanization, average household sizes, household growth rate, population growth rate, and urbanization growth rates that are entered into the software for simulations.
- **Economic data** this includes GDP/GNP data, value added by sector or subsector, interest rates and average income levels. It also includes data on the production of energy-intensive materials (output in tons or US$ per steel), transport needs (passenger-km, tonne-km, vehicle-km) and income distribution.
- **General energy data** this data is already present and usually found in the National statistical bodies, agencies and corporations in charge of energy generation and distribution. It providing data on energy consumption and production by sector/sub-sector in an economy.

Demand modelling methodologies used in the LEAP tool include:

- **Final Energy analysis**

Equation 2.1: Energy Analysis Calculation Method

$$e = a \ x \ i \qquad (2.1)$$

Where:

e = Energy Demand.

a = Activity level (type of energy used) and

I = Final energy intensity (energy consumed per household annually).

This study uses this equation in the calculation and projection of energy demand and carbon emissions from 2019 to 2040. The energy which is consumed in the household and used in the LEAP modelling include Electricity, Wood, Charcoal, LPG, Kerosene and Solar energy.

- **Useful energy analysis:**

Equation 2.2: Useful Energy Calculation Method

$$e = a \ x \ \left(\frac{u}{n}\right) \qquad (2.2)$$

Where:

u = useful energy intensity and

n = efficiency.

LEAP supports a wide range of different modeling methodologies in that on the demand side it supports bottom up, top down, and hybrid modelling methodologies while providing flexible and transparent accounting, simulation, and optimization methodologies to model power generation and capacity expansion planning on the supply side. LEAP provides two conceptual levels the first level comprising of LEAP's built-in expressions while the second level allowing modelers to specify multi-variable models or enter spreadsheets and expressions for during calculations. (Heaps, 2011)

LEAP has been used in the past worldwide in journal papers including the modelling sustainable long-term electricity supply-demand in Africa (Ouedraogo, 2017), Energy efficiency and CO_2 mitigation potential of the Turkish iron and steel industry using the LEAP (long-range energy alternatives planning) system (Ates, 2015), Future Scenarios and Trends of Energy Demand in Colombia using Long-range Energy Alternative Planning (Paez, Maldonado, & Castro, 2017) Hydrologic impacts of climate change on the Nile River Basin: implications of the 2007 IPCC scenarios (Beyene T, 2009) and is currently being used by the government of Kenya to come up with a Long-term Support (LTS) for carbon emission for the year 2050 for the country ahead of the Conference of Parties (COP_{26}) to be held in Glasgow United Kingdom.

Modeling tools that rely on optimization tend to have high initial data requirements because they require that all technologies be fully defined both in terms of their operating characteristics and their costs. The LEAP model's key benefit of requiring low initial data requirements makes it a good option to be used to track energy consumption, production and resource extraction in all sectors of an economy. Other advantages of the software when used in modelling as compared to the other software previously discussed include:

- Uses tree data structure to organize thoughts with an interface that is user-friendly, rich in technical specifications and end-use details.
- Uses both top-down and bottom-up approach allowing the modeler to use the data available to carry out simulations.
- Capability of integrating the approaches by sector and sub-sector.
- Links related sectors assumption e.g., Population growth as driver for residential energy. consumption and waste management.

These advantages of the LEAP software and its ability to model carbon emissions for different sectors and simulate the demand side management scenarios for future energy projections makes it suitable to be used for residential household demand modelling.

2.7 Research Gap

More research has been done on RE technologies and how they can be used to combat climate change in other countries. Kenya is endowed with diverse natural resources renewable energy being amongst. Since the adoption of renewable energy technologies in Kenya no research has been carried out on the uses of Renewable energy in combating climate change in the rural communities of Kenya. There is little research on the level of RE technology adoption in the rural communities in the country.

There have been numerous studies on the land use and cover changes and its impacts on hydrological and soil formation. There is a gap on the impacts of land use and land cover management on climate change and how they can be used as a mitigation factor in reducing emissions and combating climate change. There is no research that has been done in Kenya projecting the household energy consumption and carbon emissions at the county level and in the rural set up. Therefore, this research is addressing this gap by assessing the land use and cover changes and using LEAP to project the household energy demand and emissions when new policies are implemented.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study area

This research was conducted in Bungoma County located in western Kenya along the border with Uganda and is divided into 9 sub-counties namely Bumula, Cheptais, Kimilili, Mt. Elgon, Webuye East, Webuye West, Kanduyi, Sirisia, Kabuchai and Tongaren as shown in Figure 3.1.

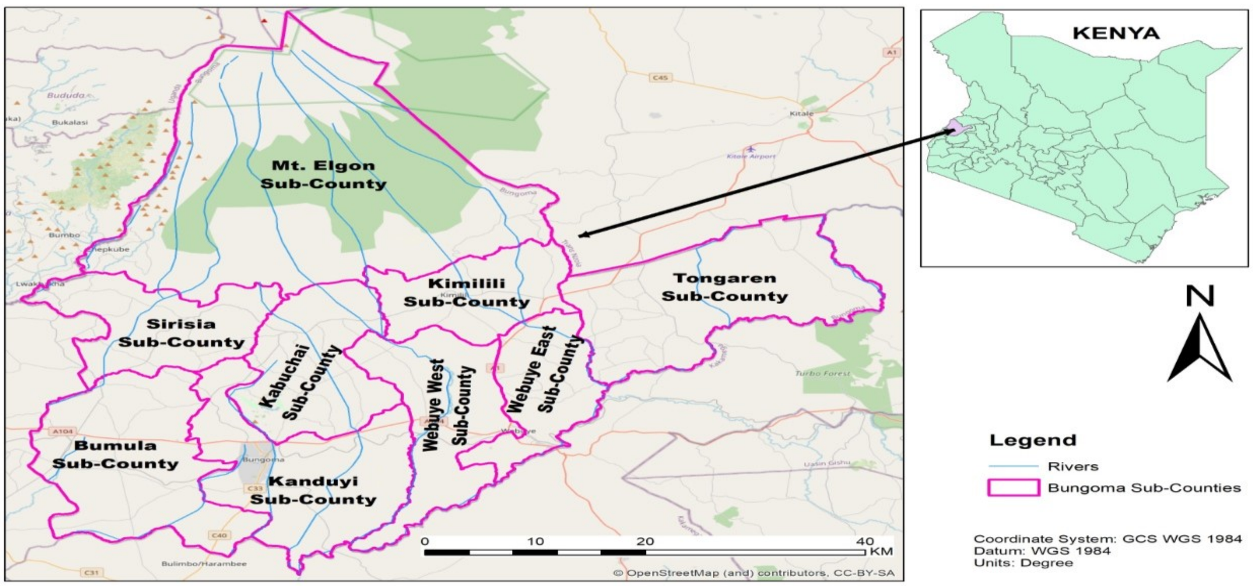


Figure 3.1: Study location Map

Temperatures range from a minimum of between 15-20^{0}c to a maximum of between 22-30^{0}c and has two rainy seasons with an average rainfall of 1200mm to 1800mm per annum. The rains are mostly experienced in the months of April, May and July-August and the coldest months being July and September. Bungoma County has brown fiable sandy clay loam soils that makes it suitable for farming therefore any changes in weather patterns would affect the agricultural activities of the community.

3.2 Research Design

The research involved a mixture of both quantitative and qualitative methods since it aimed at analyzing the relationship between different variables on renewable energy and climate change. The design was ideal for the research as it seeks to empirically establish the relationship of different variables that contribute to renewable energy adoption and the impact of the outcome in combating climate change.

3.3. Sample Size

To assess the energy consumption level and the sources of energy present in the different households; a representative sample size in which questionnaires were distributed randomly was calculated as per the formula given in Equation 3.1.

Equation 3.1: Sample Size Calculation Method

$$\boldsymbol{n} = \frac{\left(\boldsymbol{Z^2} * \frac{\mathbf{P(1-P)}}{\boldsymbol{e^2}}\right)}{\mathbf{1} + \left(\boldsymbol{Z^2} * \frac{\boldsymbol{P(1-P)}}{\boldsymbol{e^2 N}}\right)}$$

Where:

n= sample size

Z= z-score,

e= Margin of error,

p= standard of deviation and

N=number of households in Bungoma.

The sample number of households (N) used in the study was 358,796 the households present in Bungoma County as per the 2019 census. A confidence level of 85%, a z score of >1.44, a standard deviation (P) of 0.5 and a margin of error of 0.05 was used by the researcher to calculate the sample size.

Thus:

Equation 3.2: Sample Calculation with Values

$$\boldsymbol{n} = \frac{\left(1.44^2 * \frac{0.5(1-0.5)}{0.05^2}\right)}{1 + \left(1.44^2 * \frac{0.5(1-0.5)}{0.05^2 * 358{,}796}\right)}$$

n= 207 households

3.5 Data collection Instruments

The research used different data collection methods in order to meet the objectives including questionnaires, key informant interviews, direct observation and literature of the different books, programs related to energy efficiency and future planning documents for the county government of Bungoma.

a. Questionnaires

A total number of 207 questionnaires were distributed to the households randomly selected through which many respondents were reached. The questionnaires were used to enable the respondents to provide information about the different energy sources used in the households for lighting, cooking and any other activity that requires energy giving them freedom to write their own opinions, views, perceptions and feelings based on their experiences living in Bungoma County. To avoid bias during data collection the original questionnaire was pre-tested in Trans-Nzoia county to validate its legibility and clarity and fit all the respondents in the rural area set up. This helped the dwellers to understand well the content and the researcher was present to give an explanation on technical terms that the respondents could not understand. A copy of the questionnaire is appended in appendix 1.

b. Key Informant Interview

Structured and Unstructured interview schedules for government officers and stakeholders were also used to collect information from key informant respondents that were considered to have relevant information about Renewable energy and their technologies, Climate Change and weather. The key informants in charge of renewable energy and climate change departments were selected from the National Environmental Management Authority (NEMA) Climate Change Department, Rural Electrification and Renewable Energy Cooperation (REREC), The ministry of Environment and Energy in Bungoma County and the Meteorological department.

c. Direct observation

The research also involved direct observation a very important tool that was used for collection of current and actual information on the ground and increased the range of relevance and reliability of data. Through this tool is how the research managed to take photographs of the different cooking stoves and their effects on the respondents houses when using firewood as a source of fuel for cooking.

3.6. Data Analysis and Presentation Methods

Descriptive statistics that involved providing simple summaries about the sample size and the selected key informants was used. Both qualitative and quantitative data analysis method were used with excel being used to analyze the data collected through the questionnaires and key informant interviews.

Quantitative analysis - all the correspondents using firewood, charcoal, electricity solar and other sources of energy were examined, counted, and categorized depending on why they preferred the type of energy over the other. The main advantage of this method is its ability to reflect in a relatively broad statistical manner the amount and variety of discourse on the role of renewable energies in coping with climate change making it to be widely used in literature to examine various policy deliberations and decisions.

Qualitative analysis was carried out in order to conduct a comprehensive examination on all statements from the correspondents that expressed the disadvantages of using the various types of energy sources for cooking to cleaner sources also how they have been affected with the recent changes in climate change when it comes to farming their main economic activity. The main advantage of qualitative method is its ability to capture and evaluate the context of the various statements from different correspondents and stakeholders.

Thus, the role of both the quantitative and qualitative methods in this study was to provide a comprehensive examination of the volume and the context of statements expressed by the correspondents and key informants on the effects of climate change and how renewable energy resources can be used as a tool for coping with climate change in Bungoma County.

3.6.1. Statistical Analysis

Microsoft excel office suite was used to carry out statistical analysis with the mean value analysis and frequency analysis being used to analyze the raw data collected from the answered questionnaires issued to the households. Data has been presented using percentages, tables, figures, graphs and plates to ensure clarity in discussion of the research finding.

3.7 Land Use/Cover Data Acquisition and Processing.

Landsat satellite images for the study area were downloaded from USGS website and produced four images for 1990, 2000, 2010 and 2020. ArcGIS 10.5 was used for layer stacking, image classification, recording of features and accuracy assessments, re-projection and analysis. Digital elevation map was extracted from USGS EROS Archive - Digital Elevation - Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global (30 meters resolution). The map was processed using ArcGIS 10.5 and image output saved in form of a map in the GeoTIFF format.

Land use/cover maps were based on Landsat Collection 1 Level-1 for the year 1990, Landsat 7 for the years 2000 and 2010 and Landsat 8 for the year 2020. A land use/land cover layer for 1990 was obtained from Landsat 1-5 Multispectral Scanner (MSS) Level-1, 2000 and 2010 from Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1 and 2020 from Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor). Three dominant types of land use and land cover patterns as shown on table 3.1 were identified in the entire study area. Land use/ land cover output map was generated and saved in raster format

Table 3.1: Land Use/Land Cover Classification Scheme

LULC	Description
Open Water	Areas covered with water such as lakes and rivers.
Vegetation	Trees, shrubs other plants growing close to each other.
Barren Land	Areas of bare soil and exposed rocks.
Built-up Area	Human settlement with high population density of infrastructure of built environment.

3.7.1 Land Use/Cover Classification

The study integrated GIS methodology and Remote sensing techniques to carry out accuracy assessment and change detection. Two criteria were followed in choosing the satellites images to be used for LULC classification. They included: the satellite images having less than 10% of cloud coverage (if possible, cloud free) and secondly, the images satellite series availability for a long time series. Before the image classification process, pre- processing steps for satellite images was done. The image processing chain was performed using ArcGIS 10.5. as per the summary table 3.2; 1990 (bands 1,2,3,4,5,6,), 2000 (bands 1,2,3,4,5,7,8) and 2010 and 2020 (bands 1,2,3,4,5,6,7,8,9,10,11) datasets for path 59 and 60 were layer stacked considering all the bands. The stacked layers were then clipped so as to extract area of interest (AOI). Red Green Blue (RGB) and Near-infrared (NIR) bands of the datasets are common and thus these four bands were considered for classification and unsupervised classification approach was used to prepare Land use inventory.

Table 3.2: LULC Image Data Processing Summary

Year	Satellite	Bands
1990	Landsat Level-1	1,2,3,4,5,6
2000	Landsat 7	1,2,3,4,5,6,7,8
2010	Landsat 7	1,2,3,4,5,6,7,8
2020	Landsat 8	1,2,3,4,5,6,7,8,9,10,11

3.8 Long-range Energy Alternatives Planning System (LEAP) model

This is a scenario-based modeling software tool used for energy policy analysis, climate change and GHG mitigation assessment. This model was used to generate different scenarios towards renewable energy transition which included Business as Usual (BAU) case scenario and Low Carbon emission scenario. In a BAU case, the study evaluated how maintaining the status quo from fossil fuel energy sources impacted the economy and climate change. In a Low Carbon Economy scenario, the study focused on how the increase in the use of cleaner energy sources and integrating renewable energy resources in rural households would impact the growth of the country and GHG emissions.

3.8.1 LEAP Input Data Requirements

LEAP requires low initial data for modelling and supports a wide range of modelling methodologies as it supports bottom up, top down and hybrid modelling methodologies on the demand side. The data set that was used for this research included:

- **Demographic data** generated from the country and county studies and included; county population data, rates of urbanization, average household sizes, household growth rate, population growth rate, and urbanization growth rates that were entered into the software for simulations.

- **Energy data** collected during the research from the questionnaires specifically on energy consumption and the different energy sources in the households. Data on energy generation in the county was outsourced from the Kenya Bureau of Statistics (KNBS), Bungoma County agenda 2040 document and other relevant energy bodies.
- **Economic data** including Gross Domestic Product (GDP) data, the average income levels of the households and economic growth of the county.

3.8.2 Scenario Simulation Steps

In order to come up with the desired simulation in the LEAP model the following steps were used:

Step 1: Identification of key variables: It was important to identify the variables to be used to build the scenario. The aim of the research was to assess the uses and impacts of renewable enrgy sources in combating clinate change Thus, the main variables used were Electricity, Solar power, Firewood, charcoal, Kerosene and LPG with the majority being the main souces of energy currently being used in the rural areas of Bungoma county appended in (Appendix 2).

Step 2: Assessing current energy consumption pattern: This stage involved inputting the data into the software and this included collected data from the questionnaires on energy demand and consumption and the data already available in Bungoma County development documents.

Step 3: Developing scenarios: this involved developing business as usual (BAU) scenarios based on the energy demands and consumption of the study area as per (Equation 2.1). This scenarios were run to see how the energy demand in Bungoma County will develop in the future in the absence of new and explicit energy efficiency policies and mitigation measures against the adoption of new policies and adaptation measure of clean cooking energy and Renewables will influence reduction in residential carbon emissions thus combating climate change.

Step 4: Results and Discussion: This step involved the generation and presentation of results after the simulation have been run in the LEAP model software. The diagrams, graphs and chats of the different simulation were retrieved at this stage and have been discussed in the next chapter a representation is appended in (Appendix 3).

CHAPTER FOUR
RESULTS AND DISCUSIONS

4.1 General Knowledge of the Respondents

The questionnaires were distributed to 207 households randomly selected in the nine sub-counties of Bungoma county in order to ascertain the energy sources and consumptions in the different households. The gender distribution of the respondents as shown in Figure 4.1 was 54% female as compared to 46% male. The difference is attributed to the fact that male have in most cases to go out to look for jobs and run other family activities while the role of energy provision in the households is mostly carried out by the female members of the household.

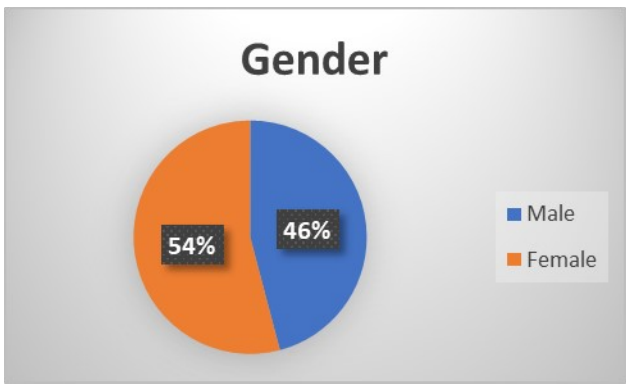


Figure 4.1: Respondents Gender Representation

Based on the sample size as shown in Figure 4.2; 52% had attained primary level of education with only 24%, 19% and 5% attaining secondary school, tertiary institutions and no education respectively.

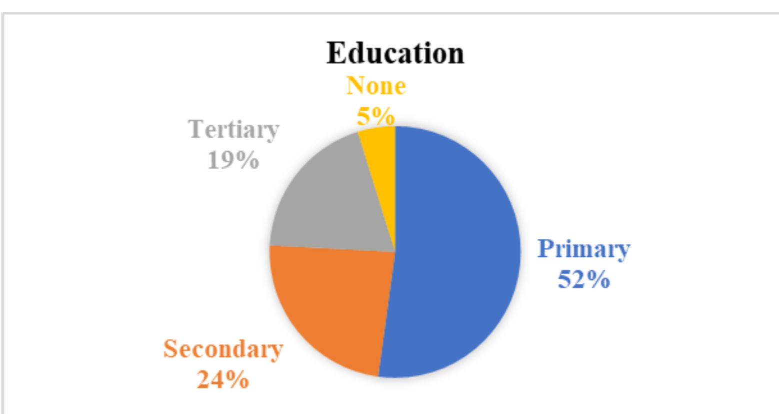


Figure 4.2: Education Level of Respondents

The study found out that on average 81% of the sample population were farmers, 7% employed while 4% were self-employed, casual Laboure's and business persons as shown in Figure 4.3. This can be linked to the low level of education in the households and also the average age as 36% of the correspondent were above 45 years.

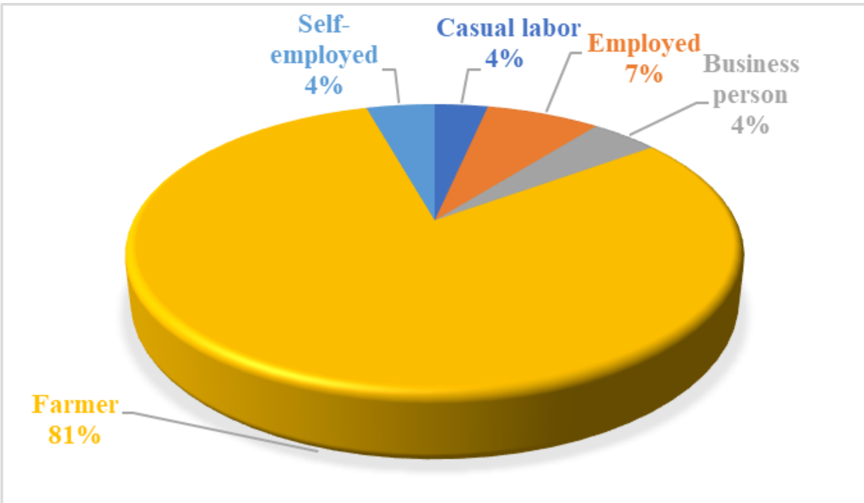


Figure 4.3: Income Level

Bungoma county population depends on agricultural activity for both domestic and commercial production the researcher sought to understand the types of crops the farmers cultivated and also the type of animals reared in their farm lands. The study found out that most of the farmers practice mixed farming and cultivate more than one crop depending on the season and time of the year. 100% of the households cultivated maize in their farms because it is the staple food in the region. Other crops cultivated included: Wheat 10%, cassava 32%, Sugarcane 64%, Sweet potatoes 74%, Beans 38% and Bananas 1% as shown in Figure 4.4.

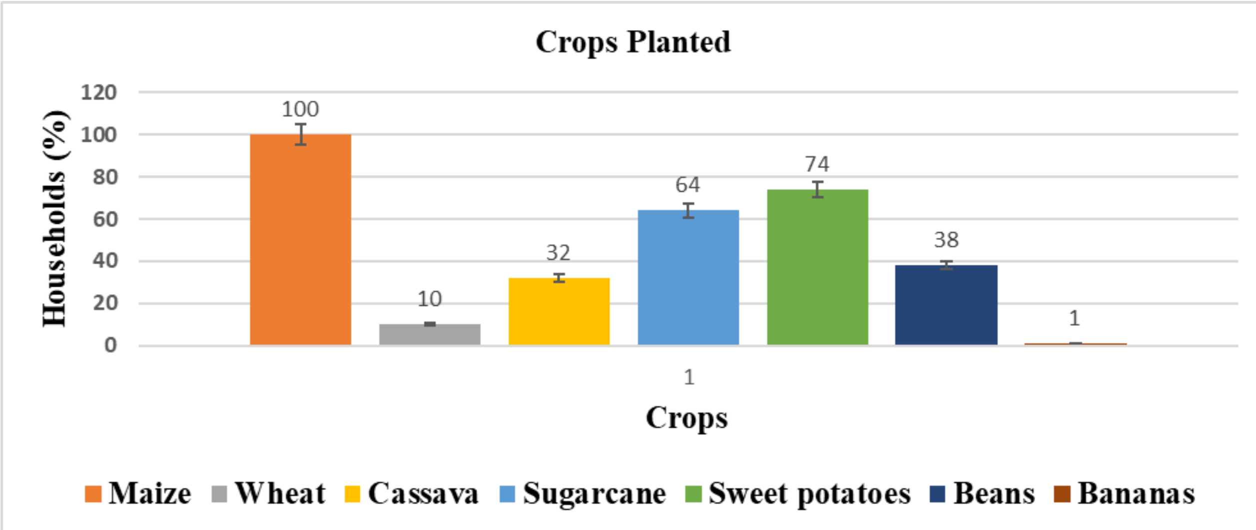


Figure 4.4:Crops Cultivated in the Study Area

On the other hand, on average among the animals reared included chicken taking up a huge share of the households, Cattle, Sheep, Pigs and Goats as shown in Figure 4.5.

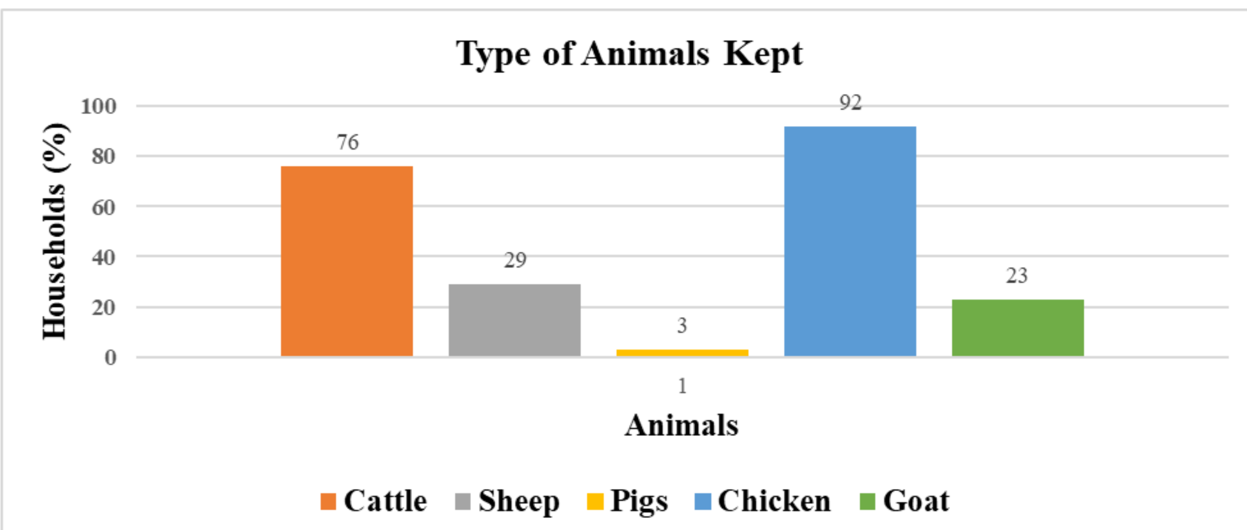


Figure 4.5:Animals Reared in the Study Area

Based on the data collected, it was evident that most people in Bungoma county are farmers and therefore vulnerable to climate change and its effects. Undertaking the research in this study area was key to come up with solutions and recommendations on how the communities can mitigate and cope with Climate change effects.

4.1.2 Household Energy Use and Consumption

Based on the sample size of 207 households in Bungoma County, fuel stacking is commonly practiced with 7 sources of energy being used in the household to run their daily activities. Firewood was dominant accounting to 94%, Charcoal 70%, solar power 68%, kerosene 54% and electricity 43% as per the presentation in Figure 4.6**.**

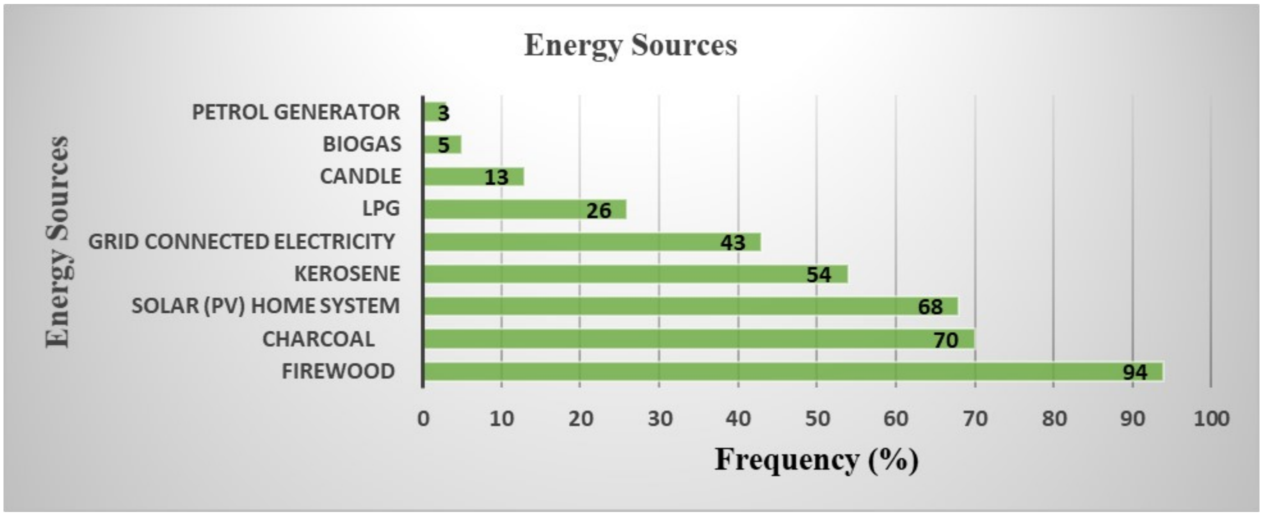


Figure 4.6: Energy Usage Sources at Household Level

The findings compare well with the results by IEA, (2010) that shows that 40% of the world's population, currently rely directly on burning biomass for their primary cooking fuel with the vast majority facing energy poverty living in the rural areas of the developing world especially in South Asia and Sub-Saharan Africa. Similar findings show that, an increase in wood energy use in Germany households was directly proportional to the rural areas (Glasenappa, Francisco, Holger, & Udo, 2019). Further findings shows that a high percentage of household in India depend on solid biomass for cooking (Ravindra, Maninder, Suman, & Siby, 2018). which is consistent with the results from the households in the rural areas of Bungoma County.

Despite Kenya as a country having a vision of 100% electrification by 2022 the study found that only 43% of the households were connected to the national electricity Grid while 57% are not connected (Figure 4.7). Most of the households that are not connected to the national electricity grid stated that the reason why they were not connected to the grid was because of the high cost of connection and the fact that the users have to pay a monthly charge to KPLC which most of them could not afford.

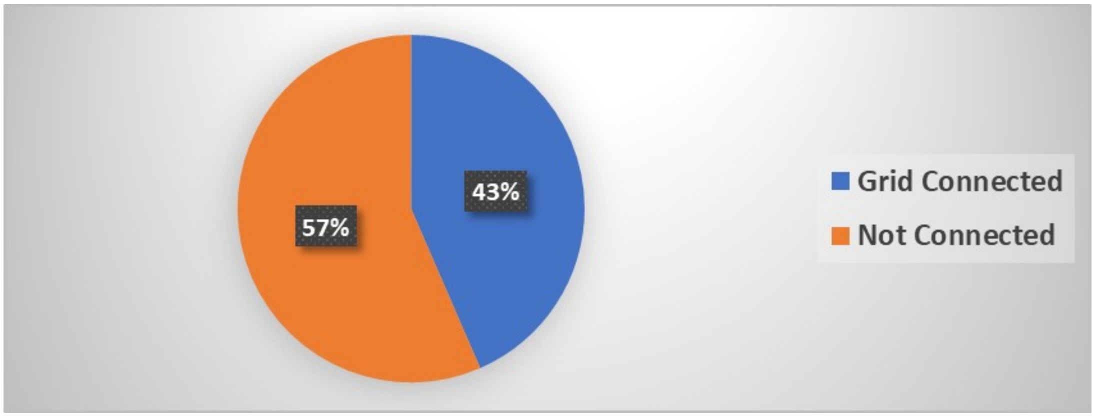


Figure 4.7: Grid Connection Level

The study found out that the households that were connected to the grid preferred to use incandescent bulbs for lighting accounting to 50% of the electrified households with LED being second most preferred bulbs at 39% and lastly the florescent bulbs at 11%. Figure 4.8 illustrates the bulb preferences.

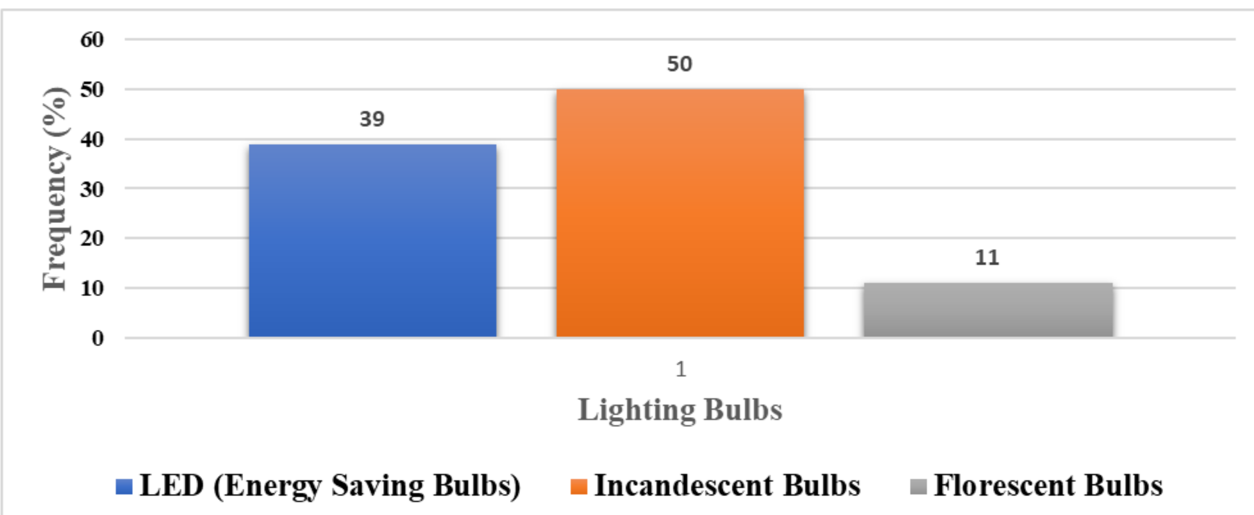


Figure 4.8: Lighting Bulbs Used

The results showed that 50% of grid connected households preferred using the incandescent bulbs as compared to LED because they are readily available and cheap costing $0.5 each as compared to the LED whose cost is approximately $1.5 each. The 39% of households using LED bulbs reported that their bulbs were energy saving and had a longer life time as compared to the incandescent bulbs that could blow up in less than a month of use**.** One of the biggest challenge the grid connected households are facing is the rate at which they experience blackouts sometimes lasting for one week or more especially if there is a problem with the transformer distributing power to their respective households.

The households expressed their concerns on the issue of blackouts and added that they always have to rely on other back up sources of energy as they wait for the power distributor to come and sort the connection issue. Solar lamps were the most preferred back up source in 89% of the households, Kerosene 69% which produces a lot of smoke leading to air pollution and emits CO_2 to the environment, candle 37%, generator 2% and dry cell battery 11%. Figure 4.9 illustrates the household backup power distribution.

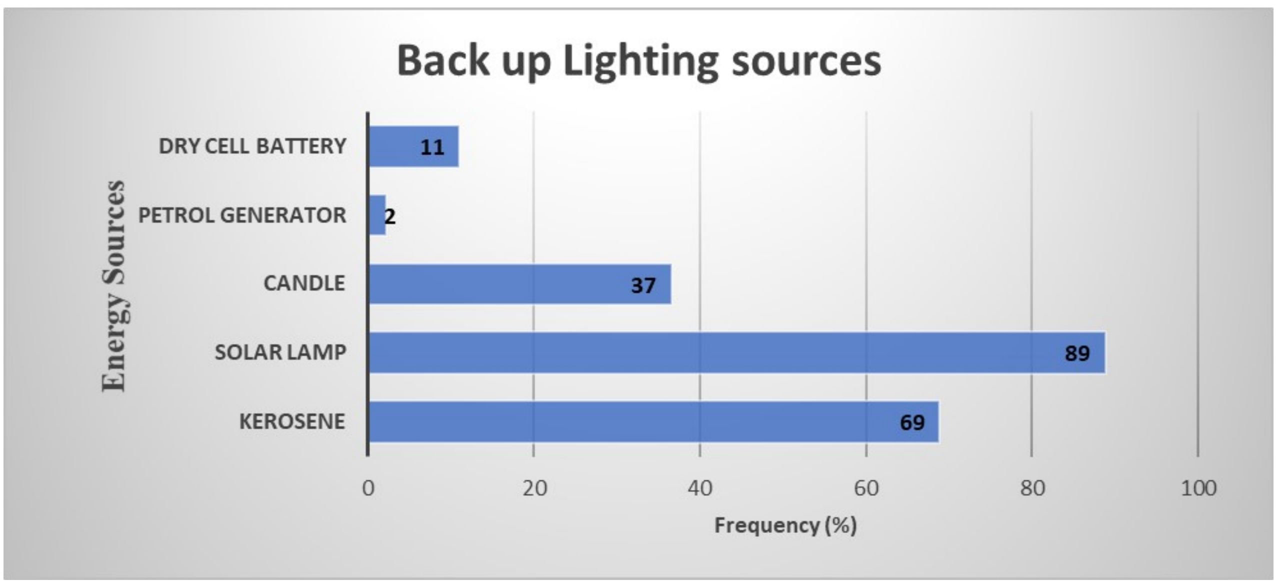


Figure 4.9: Back Up Lighting Sources

Based on the 207-sample size, 92% of the households own mobile phones, 70% radios 13% refrigerators, with only 3% and 2% of the households owning electric stove and water pumps respectively. The study found out that many people had access to phones as compared to other appliances because of the existence of private owned companies like M-Kopa and One Acre fund that provide the solar panels, phones, solar lamps and television to the households. The households pay as they use the products either daily or weekly depending on the agreement with the provider and get full ownership of the appliances after completion. An illustration of the share of electrical appliances is shown in Figure 4.10.

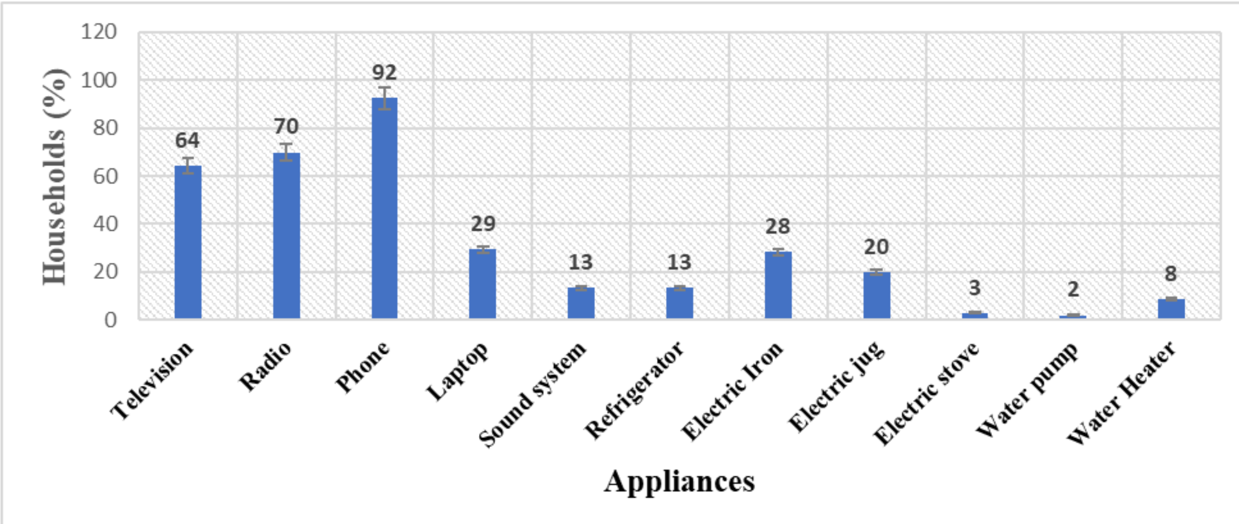


Figure 4.10: Electric Appliances in the Households

The results showed that 68% of the households use solar power in the running of their appliances, 27% use grid connected, 4% use battery specifically for Radios and lastly only 1% use generators which is attributed to the high cost of petroleum per liter that many households cannot afford.

4.1.3 Household Cooking Energy

The household in Bungoma county use more than one source of energy for cooking depending on the one available at that time. Firewood dominates as the most preferred source of cooking with 94% of the sample size using it for cooking all their meals**.** Figure 4.11 shows the household cooking source distribution in Bungoma County.

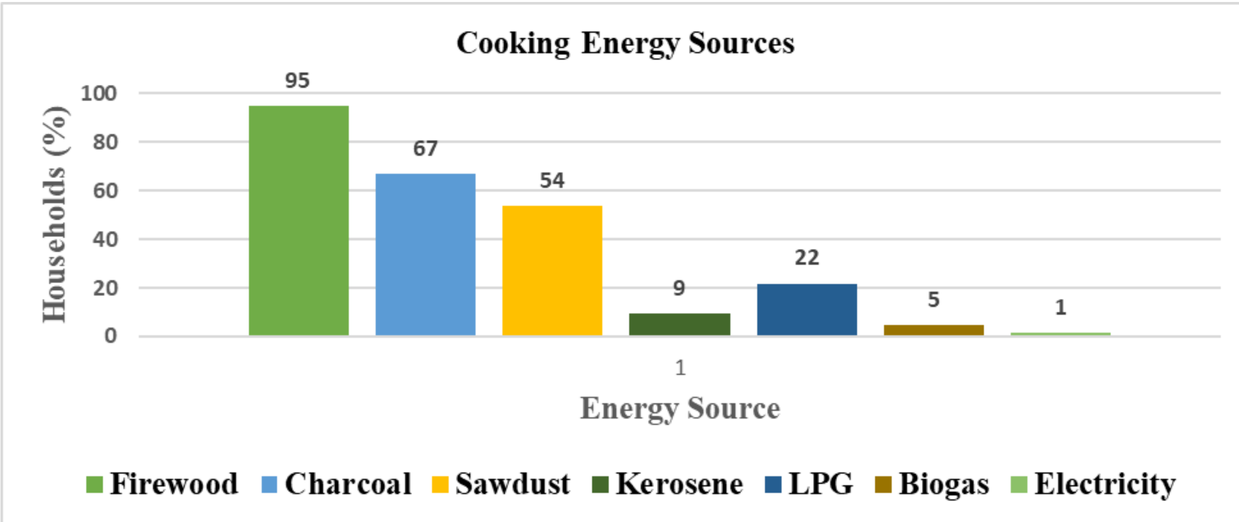


Figure 4.11: Household Cooking Energy

The households use different types of cookstoves to prepare their meals with Open air (three stones) dominating at 66%, traditional stoves without chimney at 10%, LPG cylinder stoves at 7%, improved cooked stoves at 5%, Kerosene at 5%, traditional stove with chimney at 4% and biogas stoves at 2%. Electric cooker stoves users are only 1% because it is very expensive to cook using the grid connected electricity. Figure 4.12 shows the percentage distribution of household cook stoves in Bungoma County.

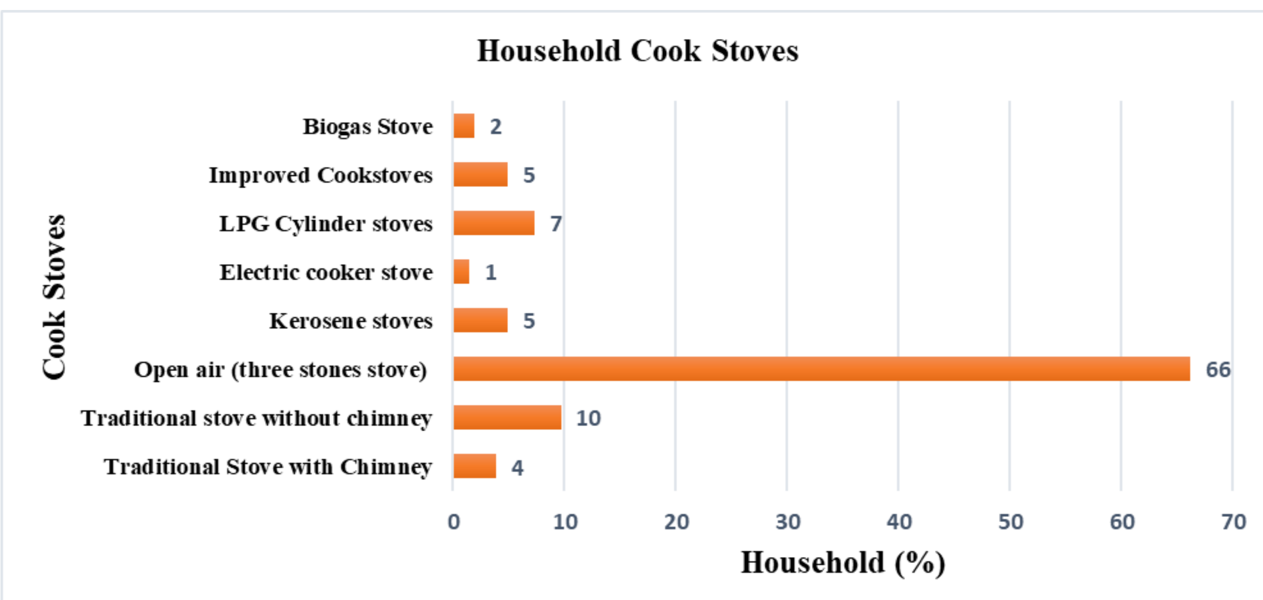


Figure 4.12: Household Cookstoves

The results on cook stove compares well with findings by Ochieng, et al., (2016) who reported that household cookstove stacking was common in rural areas of Siaya County with open air cooking stove being the dominant stoves for wood fuel. Similarly, the findings by Jewitta, Peter, & Mike, (2020) indicates that, cooking system choices in selected rural households of Nigeria were constrained by economic and access considerations linked to variations in fuel cost, availability and service quality coupled with socio-cultural and utilitarian influences on cooking practices. In another study by Twumasia, et al., (2021) the household choice of cooking energy in Ghana was positively and significantly influenced by householder education, off-farm work and source of income. This factors therefore contributes highly to most rural households practicing energy stacking and the use of wood as the main source of cooking fuel.

A very high percentage of the households get their source of energy from the Environment which leads to deforestation in search of firewood and charcoal for cooking. Figure 4.13 illustrates the percentage distribution of where the households get their sources of energy for cooking.

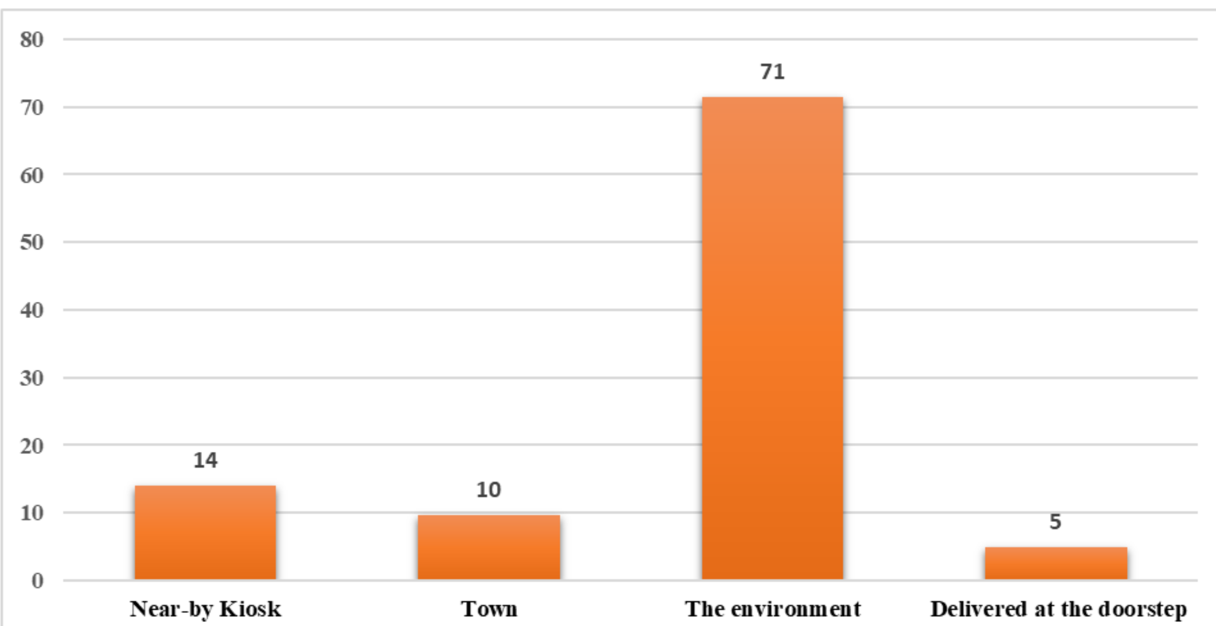


Figure 4.13: Energy Source Collection Centre

Based on the data collected, 61% of the correspondents reported that the women were the ones responsible for provision of energy in their households with only 32% reporting that the role was for both women and men.

The data collected showed that 41% of the households preferred to use the preferred type of fuel because of it being cheap and readily available while for efficiency13% and giving clean energy at 5% (Figure 4.14). Not prioritizing efficiency and cleaner sources of cooking is not a good indication to combating climate change as efficiency and clean sources of energy is a great mitigation that needs to be adopted in order to reduce carbon emissions.

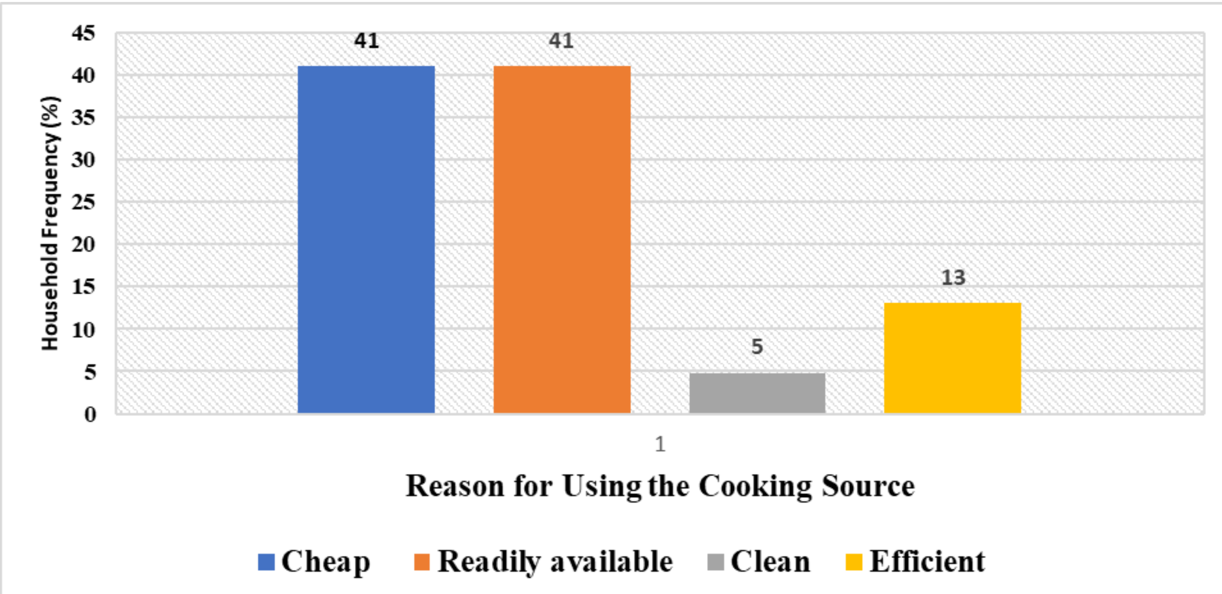


Figure 4.14: Reason for Using the Cooking Source

These findings are consistent with the research by Dominik, et al., (2013) that shows that there is a significant difference in per capita energy consumptions requirements for rural households in Australia. The Mitigation strategies requires transition to high efficiency standards and RE that is expected to reduce greenhouse gas emissions. Research by Foell, et al., (2011) suggests that promoting more efficient and sustainable use of traditional biomass and encouraging people to switch to modern cooking fuels and technologies is the solution to clean cooking and indoor air pollution.

4.1.4 Challenges Facing Bungoma Households while Using the Energy Resources

From this study it can be observed that the households in Bungoma county were facing several challenges in the quest to fulfil their energy demands. Every energy resource had its own challenges as discussed below:

- Most of the household using firewood and charcoal for cooking admitted to the source being unclean as it produces smoke. The households added that the smoke makes their pots turn black and leads to breathing and eye problems to the children and the members of the households. The researcher observed and took pictures of how their houses were covered in soot from the smoke leading to the corrosion of the iron sheets. Plate 4.1 and Plate 4.2 illustrates the effects of smoke on the pots, walls and the iron sheets of the household using firewood for cooking respectively.

Plate 4.1: Smoke Effects from Open Air Cooking on Pots

Plate 4.2: Smoke Effects from Open Air Cooking on Walls and Iron Sheets

- The households also reported that the cooking sources are expensive especially LPG which is now more expensive after the government introduced a 16% VAT on the product in July 2021. The household reported that this has made them resort to the use of firewood and other crop residues for cooking.
- The households further reported that frequent blackouts experienced from the grid connected electricity has led to many of them using kerosene for lighting as illustrated in Plate 4.3 which is not a clean source of energy.

Plate 4.3: Kerosene Lighting Lamp Used in Some Households

- The women and girls who have the responsibility of providing energy to the household noted that they have to walk for long distances in search of firewood. This is attributed to the forest being far and sometimes they cross to other counties in such of wood.
- The households also complained that because of the recent increase in rainfall in Bungoma county, the household are finding it hard to get dry firewood from the environment for cooking forcing them to buy from the nearby kiosks which expensive for them to afford.
- The inefficiency of the energy sources was also another challenge that the households complained. Using open air (three stone stove) and inefficient charcoal stoves consumes a lot of firewood and charcoal respectively. The inefficiency of the stoves leads to increased consumption of firewood and charcoal the increases the deforestation and reduces the carbon sinks.
- The use of inefficient sources of energy is slow and tiresome especially if the firwood is wet some respondents noted. Someone has to be present at cooking place all throughout to make sure that the fire does not go off which leads to wasting of time that could be used to do other things while cooking.

Similar findings show that, the use of biomass for cooking and when resources are harvested in unsustainable manner with inefficient and dirty technologies there are serious adverse consequences for health, the environment, social and economic development (Foell, Shonali, Daniel, & Hisham, 2011). Similarly, residential biomass burning is responsible for an estimated 18% of global black carbon emissions (Bond & Sun, 2005).

It is clear that women generally play the major role in energy provision in countries where traditional fuels dominate household energy use (Foell, Shonali, Daniel, & Hisham, 2011). The women and children suffer the greatest share of the health burden, time-losses and physical impacts of fuel collection, processing and transportation.

Household air pollution is known to contribute to lower respiratory infections, cardiovascular disease, chronic respiratory disease, cancer, and is a leading risk factor for childhood pneumonia and low birthweight (Sana, Somda, Meda, & Bouland, 2018). Another study further highlights that; Health effects associated with household air pollution include increased blood pressure (BP), lung cancer, childhood pneumonia, dyspnea, low birthweight and cardiovascular diseases (Pratiti, David, Zirk, & Parul, 2020). This therefore calls for urgent need for the use of improved cook stoves and cleaner sources of energy in the rural households.

4.2 Climate Change Effects in Bungoma County.

Data received from Bungoma meteorological department shows that the weather patterns in the county has been fluctuating over the years see Figure 4.15**.**

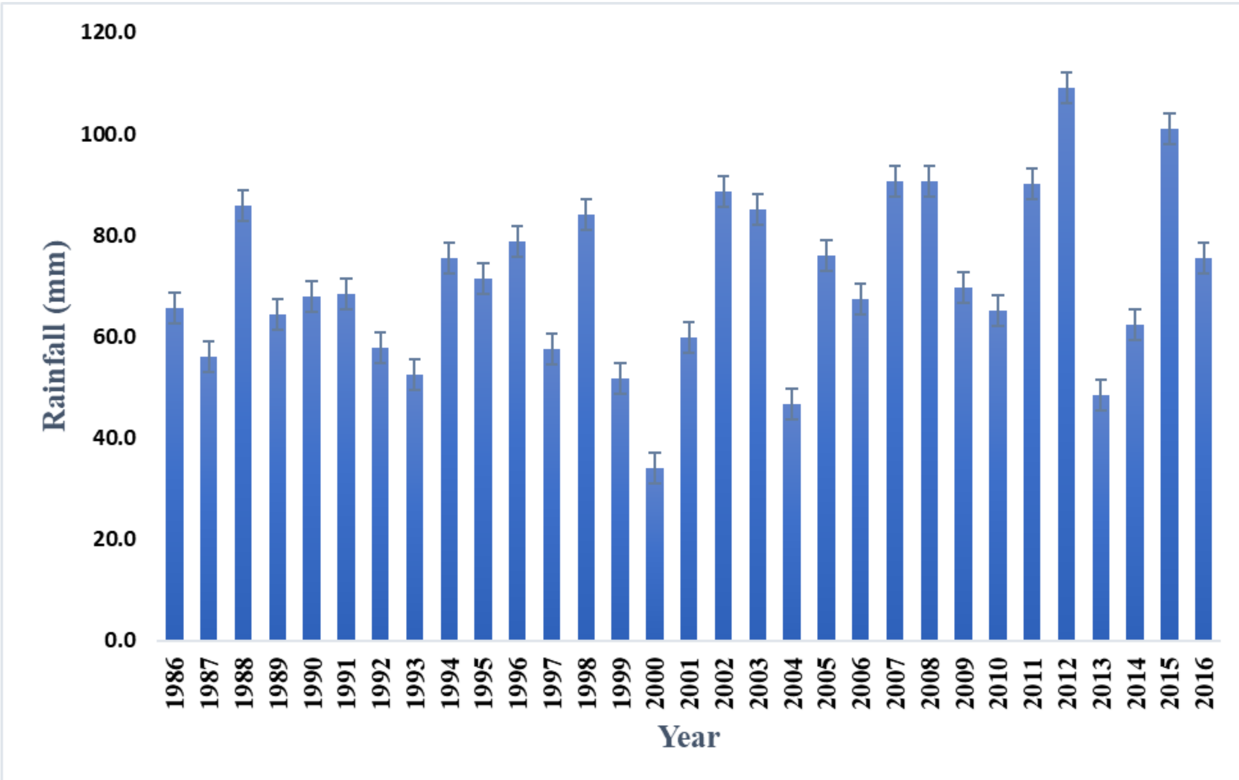


Figure 4.15: Rainfall Pattern for 30 Years

The county has been experiencing increased rainfall which can be attributed to the change in climate. 100% of the respondents and the key informants agreed that there is climate change in the county adding that recently low temperatures and increased rainfall is being experienced.

Figure 4.16 shows the temperatures changes over a period of 20 years with the average ranging from 27 – 28 °C while the minimum ranging from 14 -15 °C.

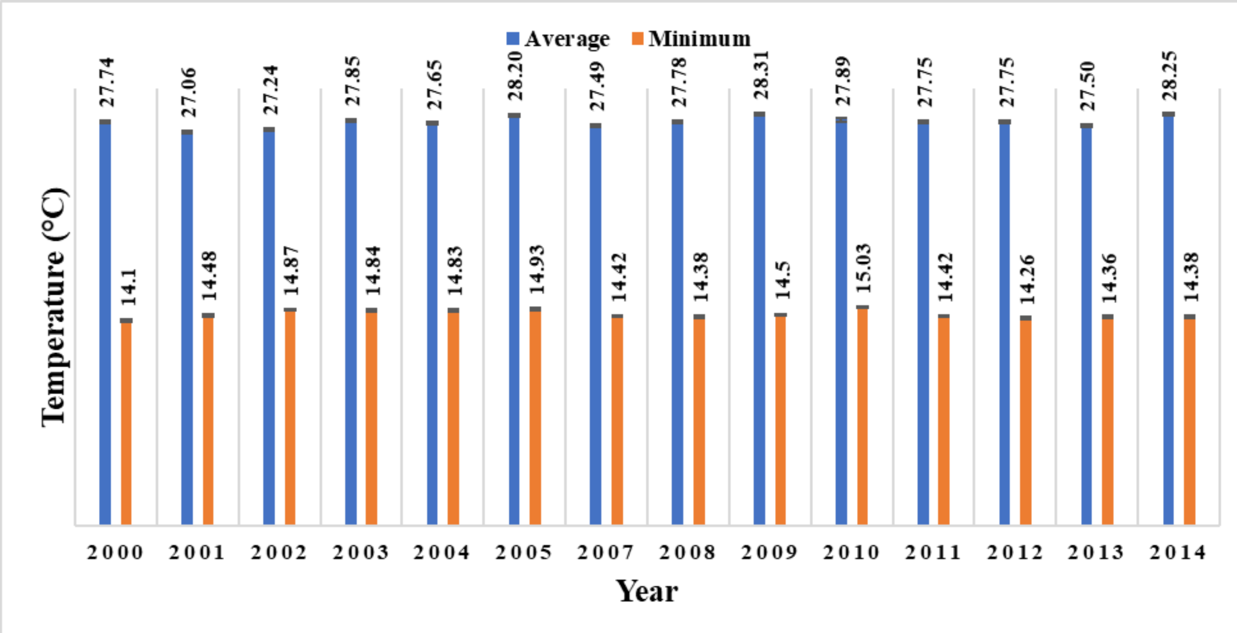


Figure 4.16: Temperature Range for 20 Years

The county government of Bungoma developed and rolled out the Climate Change Policy 2020 in the bid to come up with ways of combating climate change in the county. The policy document highlights that the county has been affected by climate change and is evident through:

- Decreased quality and quantities of ground and surface water and decreased agricultural yields due to unreliable climatic conditions.
- Increasing occurrence of climate-associated disasters such as floods, prolonged drought and landslides.
- Increased cultivation of hilltops, wetlands and riparian land that has resulted in soil erosion, sedimentation of rivers and streams contributing to increased and intense flooding in the lower regions of the County and the neighboring Counties of Busia, Siaya and Kisumu.
- Unpredictable weather conditions such as increased temperatures and rainfall leading to reduced agricultural yield.
- Increased cases of destructive invasive species and pests such as the dodder plant and fall army worms.
- Outbreak and prevalence of climate-related diseases.

- Increased conflicts over natural resources between communities residing in the upper regions of Mt. Elgon and those on the lower regions due to the reduced forest cover and streams supporting their livelihoods.

The policy document highlights that the key drivers of environmental degradation within the County causing climate change include:

a. Uncontrolled and illegal logging.
b. Household and institutional (including public schools) demand for wood fuel.
c. Charcoal burning
d. Increased encroachment on riparian and gazetted areas due population growth and demand for agricultural land.
e. Extensive clear felling of trees without re-afforestation in Mt. Elgon Forest Reserve and water tower in certain areas such as Kaberwa and Kaboywo has reduced the forest cover which naturally act as natural carbon sinks.

Bungoma county government acknowledges the urgent need for combating climate change before the effects becomes irreversible. In order to mainstream climate change into all sectors of the county, achieve sustainable development and build a climate resilient county; The Bungoma County Climate Change Policy 2020 is being guided by the following objectives:

a. To promote conservation of natural resources for posterity.
b. To integrate climate change into all County development projects and Programmes.
c. To appropriately address County climate change challenges for sustainable development.
d. To strengthen County inter-departmental mechanisms on climate change.
e. To enable effective and proper resource mobilization available at both International National and County level to combat climate change.
f. To ensure effective stakeholder and community participation is enhanced in climate change adaptation and mitigation initiatives.
g. To contribute towards Kenya`s role in addressing climate change challenges.

In order to meet the above objectives, the county government has to work in partnership with all sectors, be accountable and cost effectively handle all the Programs that are in line with promoting a climate resilience.

4.2.1 Effects on Socio-Economic Activities in Bungoma County

Rainfall variability caused by climate change most heavily impacts those least able to cope with the effects mainly the farmers on marginal land who dependent upon on rain-fed agriculture. 100% of the correspondents stated that climate change had really impacted their livelihoods because most of them depend on agriculture that is rain-fed. Some of the effects of climate change stated by the respondents include:

- Unpredictable and fluctuating weather patterns making it hard for them to know when to plant their crops leading to changes in the cultivation period and reduced crop yields.
- Reduced harvest due to the fluctuating weather patterns as increased rainfall and low temperatures destroys crops in the farm.
- Prevalence of crop diseases and pest like the army worm shown in Plate 4.4 which destroys maize in the farms leading to reduced harvest.

Plate 4.4: Army Worm Pest Affecting Maize Crop

- Farming has become expensive as the farmers have to buy pesticides in order to control the pests and diseases and end up not harvesting enough to cover for the cost of farming and generate profits.

- The heavy rains have led to destruction of infrastructure especially the roads making it hard for the farmers to transport their harvest to the markets.
- Reduced milk production from the cattle as there is no enough water and grass to feed the cattle.
- The farmers are not able to educate their children as most of them depend on selling the excess harvest for school fees.
- Increased hunger and poverty due to dry seasons and reduced crop harvest negatively affecting the livelihoods of the community.

Unreliable and low harvest levels affect household livelihoods and results in poverty and hunger in the community. Further encroachment on the County`s marginal lands including riparian areas, hilltops and forests is inevitable undermining the ecosystems leading to soil erosion and environmental degradation. Poverty pushes people to illegally cut trees or sell on-farm trees to either pay school fees or meet other cash needs which negatively impacts the environment.

Reliance on solid bio-based energy resources is often linked to poverty, lack of modern energy alternatives and other economic factors. Capacity building through training and education, population growth management and households' adoption of modern technologies plays a vital role in alleviating rural energy crisis and improving livelihoods (Guta, 2014). Technological changes such as the substitution of biomass by renewable resources can be a sustainable strategy for reconciling the climate mitigation actions and an upgrade to the middle-income country category (Baniya, Damien, & Scott, 2020).

One of the major implications of widespread use of solid fuels is its significant impacts on human health through indoor air pollution (Wesley, 2011). Health Statics from WHO on women and children impacted by indoor air pollution is high ''Globally, pneumonia remains the single most important child killer and is responsible for 2 million deaths every year and indoor smoke is one of the underlying causes (WHO, 2006). WHO states that these deaths occur due to the continuous exposure to smoke which deposits soot in their lungs and is responsible for 511,000 of the 1.3 million deaths due to chronic obstructive pulmonary disease (COPD).

The need for the use of improved energy efficient and clean cook stoves is evident worldwide to avoid this health implications especially to the rural population. Aside from the direct impacts on human welfare arising from the unsustainable use of fuelwood; pressures on the local and regional environment can be created including deforestation, soil degradation and erosion. Emissions of black carbon emitted from inefficient biomass burning are now known to play a large role in influencing climate change (Foell, Shonali, Daniel, & Hisham, 2011).

4.2.4 Barriers to Renewable Energy Adoption in Rural Areas

Data collected form the key informants showed that there were several barriers that the RE sector was facing. The barriers mentioned included the following:

a. High initial cost of installing renewable energy projects is the greatest barrier to the adoption of the technologies.
b. Institutional barriers from unclear policies governing the renewable energy sector and lengthy procedures in order to set up a decentralized system is a great challenge that need to be addressed. Investors shy away from investing in RE projects due to unclear permitting process involved.
c. Lack of qualified technical local personnel in the installation implementation of the RE projects is a big barrier making the country to outsources services which is costly.
d. The market entry of renewable energy technology is very low due to the lack of awareness on the importance of using RE in the households and the competition from the traditional sources of energy.
e. Renewable energy has to compete with the fossil fuels that are subsidized as compared to the RE technologies that have high taxes imposed on them.
f. Misconceptions on reliability of the RE because of some of them like sun only being available during the day. Making the people to prefer using the readily available sources of energy.
g. Land use Conflict among the communities makes it hard to decide a better site or location for installation and transmission of the RE technologies.
h. Financial risk associated with RE technologies makes it hard for investors to invest in such projects as many want to put their money where they can get returns as quickly as possible.
i. Little faith in RE sources being used to power factory and institutional needs thus being used only for lighting and charging phones in the rural areas.

j. Rigid energy transmission infrastructure makes it hard to bring in renewable energy resources for use in the household as requires upgrade that are expensive.

It is therefore important to identify these barriers and provide proper data related to RE resources and enhance capacity and public institutional awareness on the importance of RE. The current energy market regulations should also be flexible to include easier RE adoption. Competitive markets, liberalization and privatization have to be fostered to keep energy affordable and ensure fare competitiveness (Thavasi & Ramakrishna, 2009).

The uncertainty on the government's commitment towards large-scale solar power is the most dominant institutional barrier towards large-scale solar power projects in Tanzania (Ahmed, 2018). The findings from this report also sites stakeholder engagement, technological, financial and qualified technical personnel as other barriers in the implementation of RE resources. There is need for a flexibility in Policy as its complexity and overall governance in countries impact the perceived risk of investments especially for long term infrastructure like clean energy projects (Jones, 2015).

The constraints that unfairly discriminate against RE are as a result of lack of commercial skills and information, the high initial capital costs coupled with lack of fuel-price risk assessment and the absence of relative legal and policy framework (Mezher, Gihan, & Zeina, 2011). The over dependence on fossil fuels makes the market for renewable energy technologies young leading to higher volatility and greater risk of investing RE projects (Pegels, 2010).

4.3 Land Use and Land Cover Change in Bungoma County Since 1990- 2020

In order to obtain reliable and latest information on the temporal and spatial change, variations of changes in the study area were conducted using four land use classes. The dominant four land uses (open water, vegetation, barren land and built-up) were identified for change analysis so as to have a connection between before and the current development on land cover/land use. Land use data for year 1990, 2000, 2010 and 2020 were used in assessing Land Use Land Cover changes in the area of study. The data was used in the form of separate GIS- layer (either vector or raster) then reclassified as illustrated in Figure 4.17, 4.18, 4.19 and 4.20.

For 1990 LULC classification, Landsat MSS 1-5 C1 Level-1 was generated from USGS and the RGB bands were used to layer stack. According to Figure 4.17 the area is majorly covered with vegetation with a bit of bared land and built- up areas.

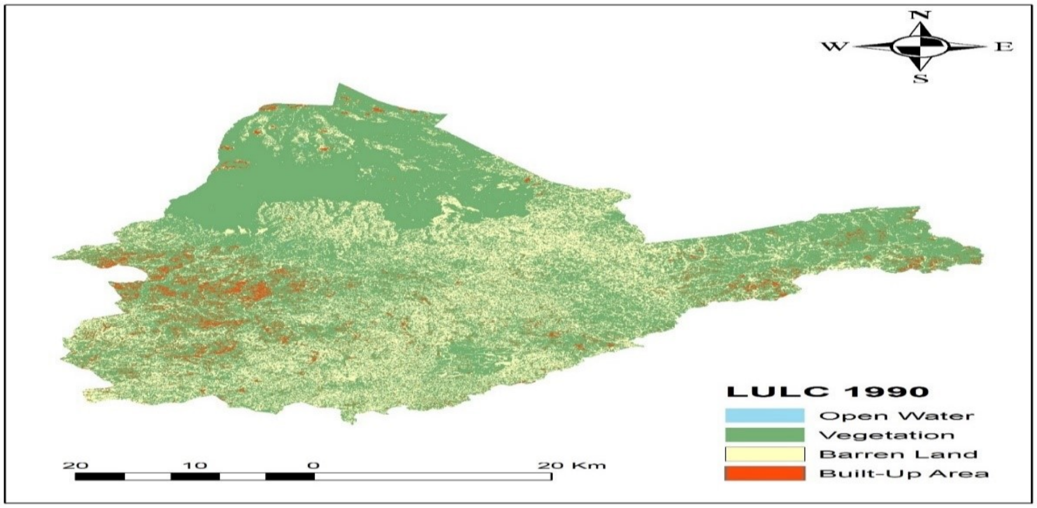


Figure 4.17: LULC Map for 1990

As compared to 1990 LULC map, it is evident that in 2000 green vegetation and forest cover reduced by 19% while built up area increased by 70%. Furthermore, bare land areas had increased by 5% which is attributed to the rapid population increase leading to clearance of the forest to pave way for settlement. Figure 4.18 shows the changes in the land use and cover for the year 2000.

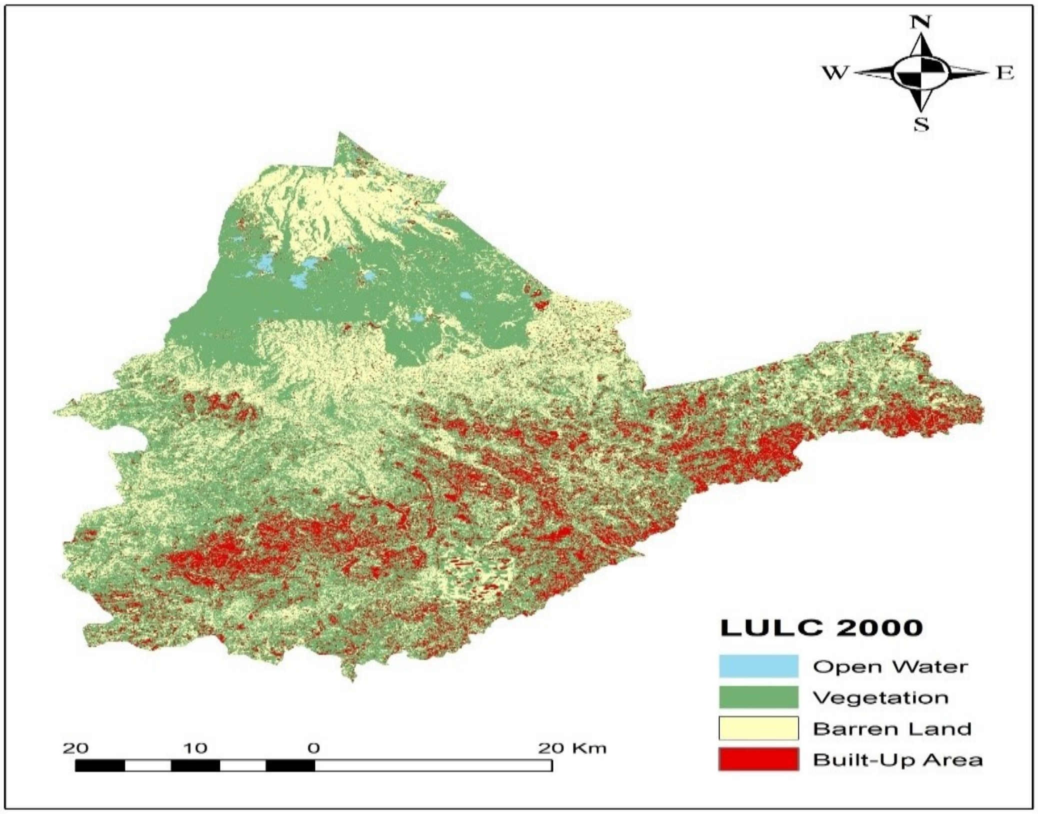


Figure 4.18: LULC Map for 2000

For the year 2010 as illustrated in Figure 4.19 there was increased bare land by 8% and built-up areas by 25% especially in the Northern part of the map which was majorly covered with vegetation in the year 1990. However, the Southern part of the study area has a mixture of both built up and vegetation which is highly attributed to increased activities of The Green Belt Movement (GBM) that had resulted into more that 50 million newly planted trees countrywide (Rechlin, 2010). The mission of GBM is to mobilize community consciousness for self-determination, justice, equity, reduction of poverty and environmental conservation through tree planting (Green Belt Movement, 2003).

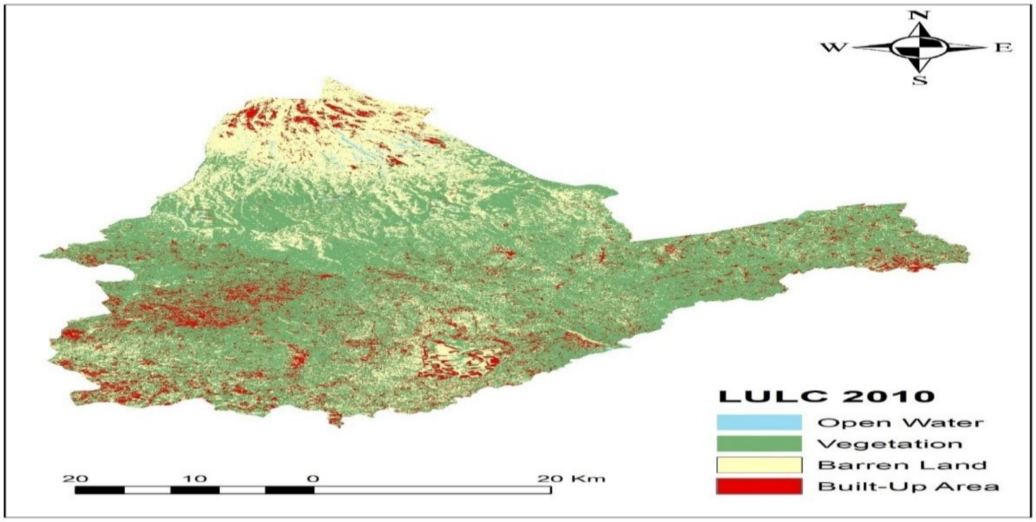


Figure 4.19: LULC Map for 2010

The year 2020 shows that Bungoma county lost a large area of the vegetation cover by 55% with an increase in the built-up areas by 62% and barren land by 65%. The tremendous changes are highly attributed the rapid population and household growth and the increased demand for farming and firewood for cooking. Figure 4.20 shows the LULC for the year 2020.

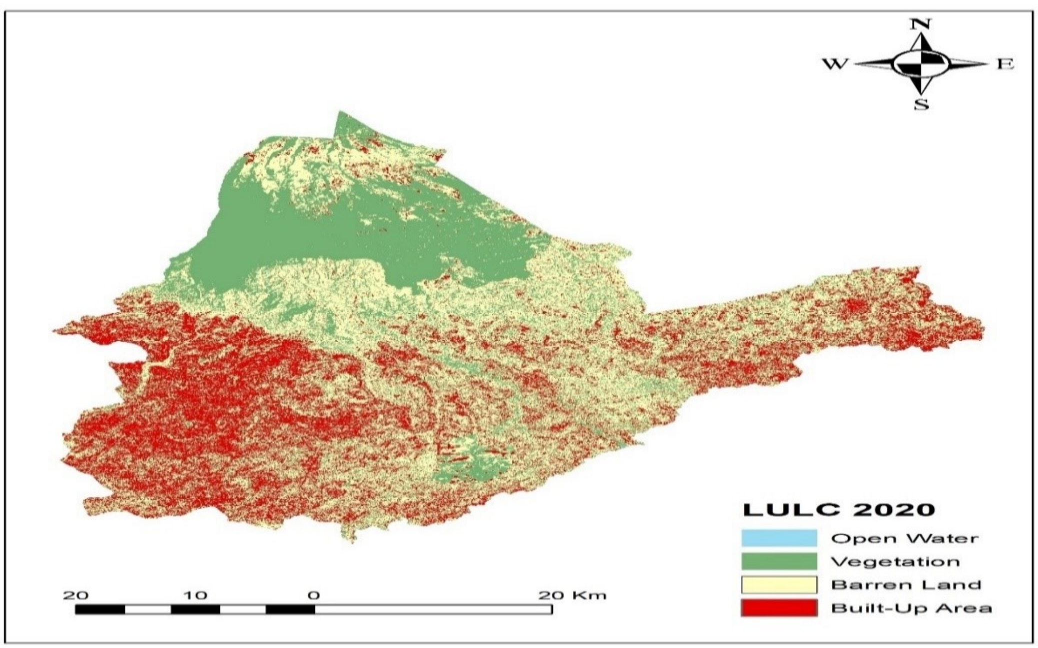


Figure 4.20: LULC Map for 2020

The changes in LULC have been represent in Table 4.1.

Table 4.1: Land Use/Cover Change 1990-2020

LULC	1990	2000	2010	2020	% Change 1990-2020
Open Water	888	13,937	20,093	456	-49
Vegetation	2,273,175	1,903,211	2,074,919	935,855	-59
Barren Land	948,651	996,696	913,062	1,507,567	37
Built-Up Area	129,254	438,124	343,894	908,090	86

It is evident as illustrated in Figure 4.21 that the LULC has tremendously changed over the 30-year period. The key informant from the county government explained that there has been a combination of encroachment and clearing of vegetation, Illegal logging and charcoal burning that has witnessed loss of forest cover affecting ecosystem services in Bungoma.

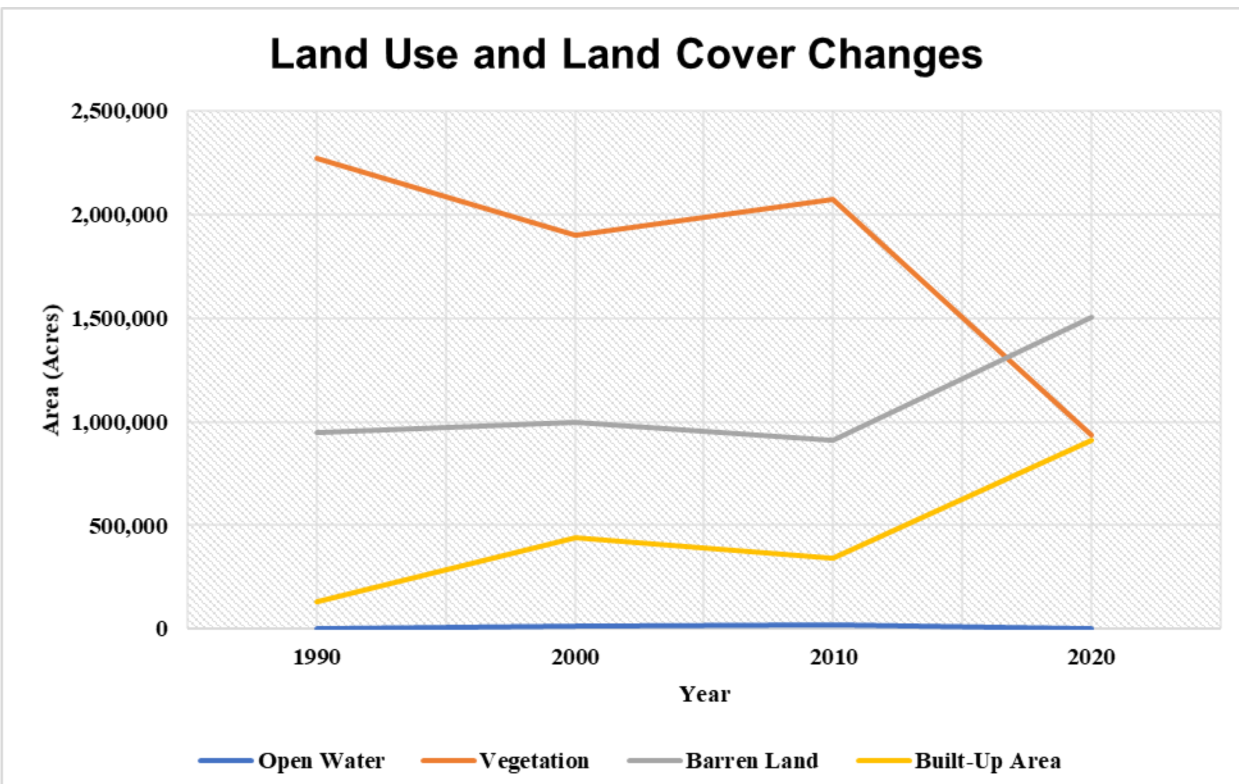


Figure 4.21: LULC Trend 1990-2020

The findings showed that there has been a rapid increase in barren land by 37% and built-up area by 86% with a major decrease in forest cover and vegetation land by 59% from 1990 to 2020. There is also a decrease in open water by 49% which is highly attributed to the rapid population growth in Bungoma county that directly translates to deforestation and conversion of land to agriculture and settlement. This therefore means that, if the trend continues and with the increased emissions from the use of firewood for cooking and reduced carbon sinks, climate change will continue to be a problem that will last longer than we expect.

The findings compare with studies carried out by other researchers suggesting that Land-use changes can significantly impact the dynamics of terrestrial ecosystems and influence the biodiversity globally. Implementation of alternatives like land use change, forest management through afforestation could lead to the reduction in GHG emission in Europe through forest carbon sequestration (Ovando & Alejandro, 2008).

A study conducted by Mbungu, (2016) found out that changes in land use and land cover from 1991 to 2015 in the Upper Ruvu Watershed had a huge impact on soil erosion. This was mainly attributed to forest clearing primarily for agricultural activities, timber and building poles, charcoal and firewood production which increases the surface runoff specifically in the rainy season. It is therefore important to practice land use management as it plays a great role in the generation and transport of runoff and sediments from landscapes which has implications on smallholder farmers and different water users from various sectors (Mbungu, 2016).

The forest ecosystem act as carbon sinks as it plays a significant role in the carbon cycling process by capturing, storing and using CO_2 as a building block for organic molecules (Thavasi & Ramakrishna, 2009). Escalated population growth is associated with increased consumption of forest resources threatening forests which are major carbon sinks (Brandt, 2017). Therefore; In order to reduce on emissions and combat climate change, proper management of land use and cover with afforestation practises need to be adopted for the benefit of the future generations.

4.4 LEAP Model Scenarios and Forecasting Results

The base year used to carry out the different scenarios was 2019 and the scenario projection for first and last year was 2020 and 2040 respectively. The population of the country during the base year was 47.5 million with approximately 12.2 million as the number of households in the country and an average household size of 3.9. Bungoma county had a population of 1.66 million with 358,796 number of households averaging to 4.6 persons per household. The households are projected to grow at the rate of 3.8% annually leading to an increase in energy demand.

The data collected showed that 43% of the households are connected to the national grid while the remaining 57% of the households are not connected to the national grid and are using other sources of energy for lighting including solar and kerosene. The households practice fuel stacking for cooking with firewood being the most preferred source of energy at 95% followed by Charcoal 67%, LPG 22% and kerosene 9% depending on the availability of the fuel.

4.4.1 Business as Usual (BAU) Scenario Analysis

The LEAP software was used to project the energy demand and the environmental effects of the household energy consumption in the study area by 2040 with no new implementation of energy efficient policies. The energy demand is directly proportional to the population and household growth in the county as illustrated in Figure 4.22. The projected household energy demand will increase by 55% from 4,782.1 thousand gigajoules in 2019 to 7,432.3 thousand gigajoules in 2040 .

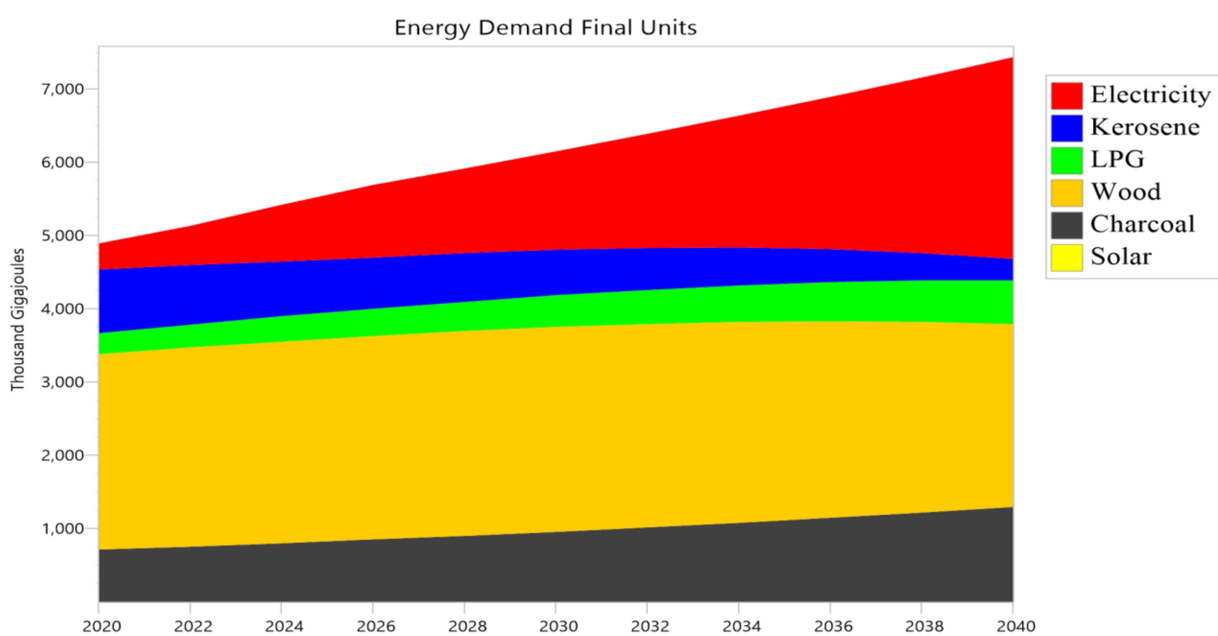


Figure 4.22: BAU Energy Demand Graph 2019-2040

4.4.1.1 BAU Household Cooking Energy Demand Scenario Projection

The BAU scenerio for household cooking demand in 2040 as illustrated in Figure 4.23 shows that the most preferred energy for cooking remains to be wood fuel at 53.1%, charcoal at 24.2%, LPG at 20.3% and kerosene at 2.2%. The final cooking energy demand has increased by 64% from 1,643.3 thousand gigajoules in 2019 to 4,681.7 in 2040.

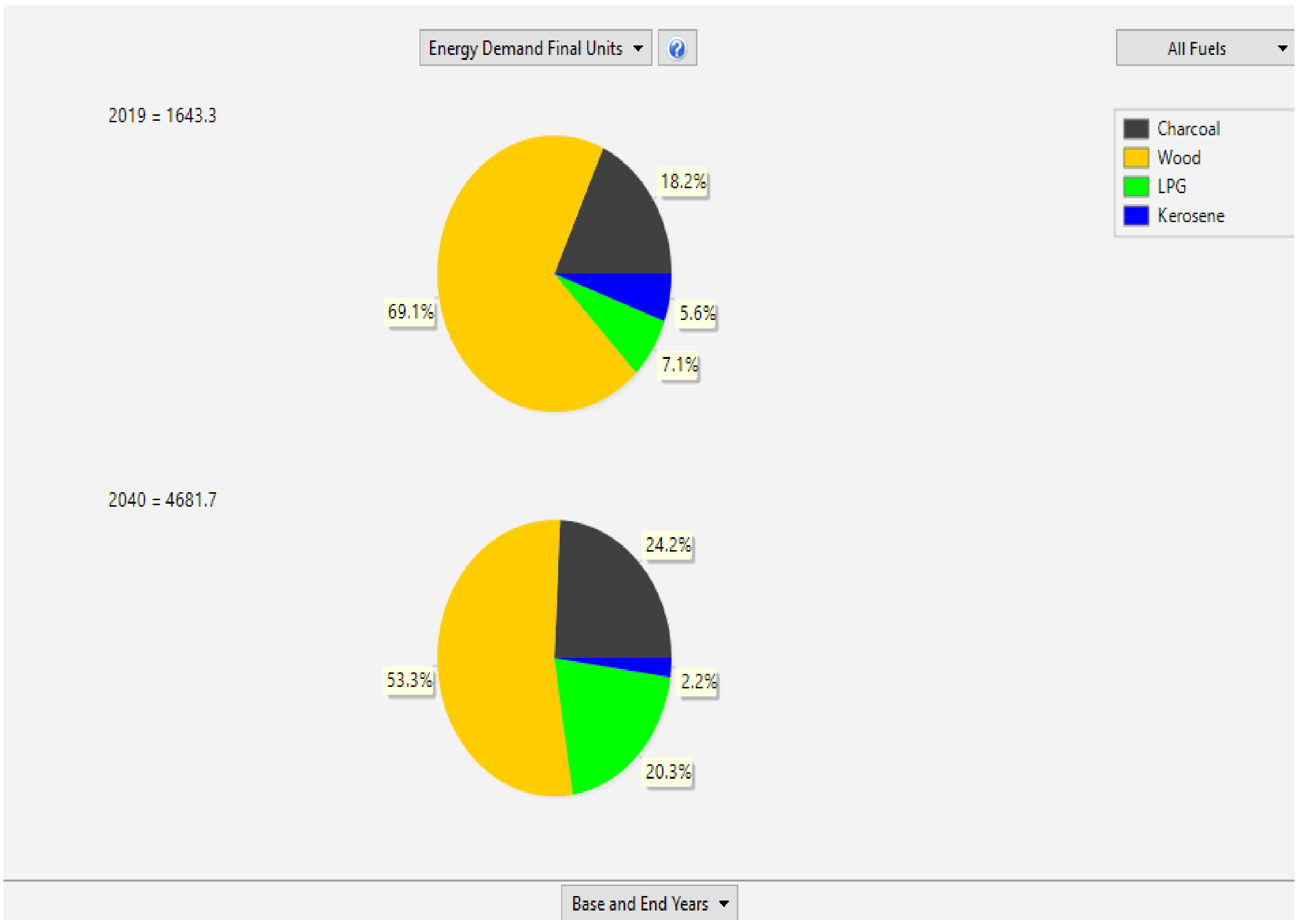


Figure 4.23: BAU Household cooking energy demand 2019 - 2040

4.4.1.2: BAU Carbon Emissions Scenario Projection

The increase in the household energy demand for both cooking and lighting will lead to emission of GHGs that negatively impacts the environment. There is a 6% increase of carbon emissions in the baseline scenario with no implementation and enforcement of new energy efficiency policies in the county. The scenario forecasts that 123.4 thousand metric tons of CO_2 equivalent will be emitted in 2040 an increment from 116 thousand metric tons of CO_2 equivalent emitted in 2019 as illustrated in Figure 4.24.

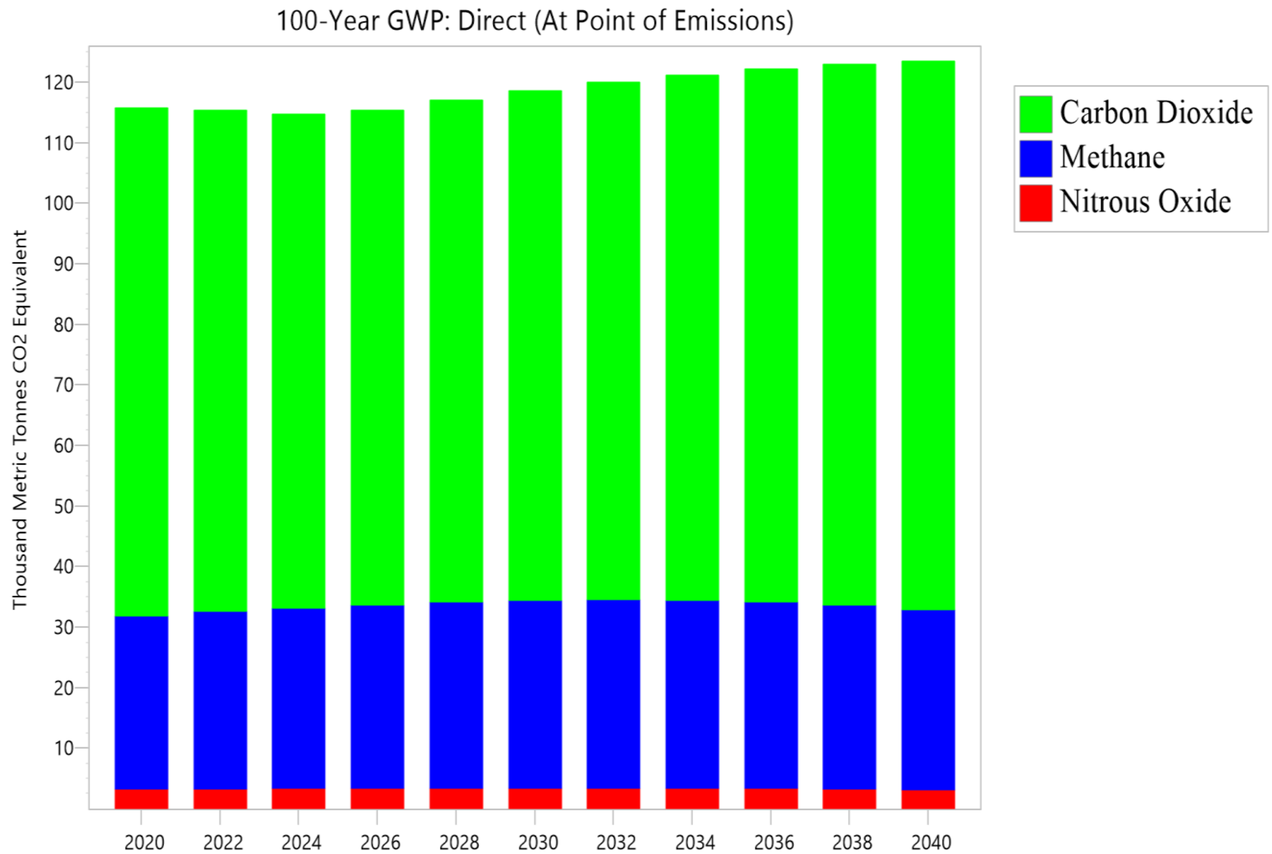


Figure 4.24: BAU GHG Emissions Scenario 2019-2040

4.4.2 Energy Efficient Scenario Projections

The county government is implementing the Climate change policy 2020 with the aim of mitigating climate change that is affecting the rain-fed agricultural sector. Among the policies to be implemented include; distribution of clean cooking cook stoves, the use of solar power LED bulbs for lighting and 18% increase of forest cover from the current 14% by 2030 (The Standard, 2020). In the demand side management scenario; the energy demand is expected to reduce by 26% from 4,892 thousand Gigajoules in 2019 to 3,531 thousand Gigajoules in 2040. Figure 4.25 illustrates this is positive outcome that will be achieved if the new policies are fully implemented.

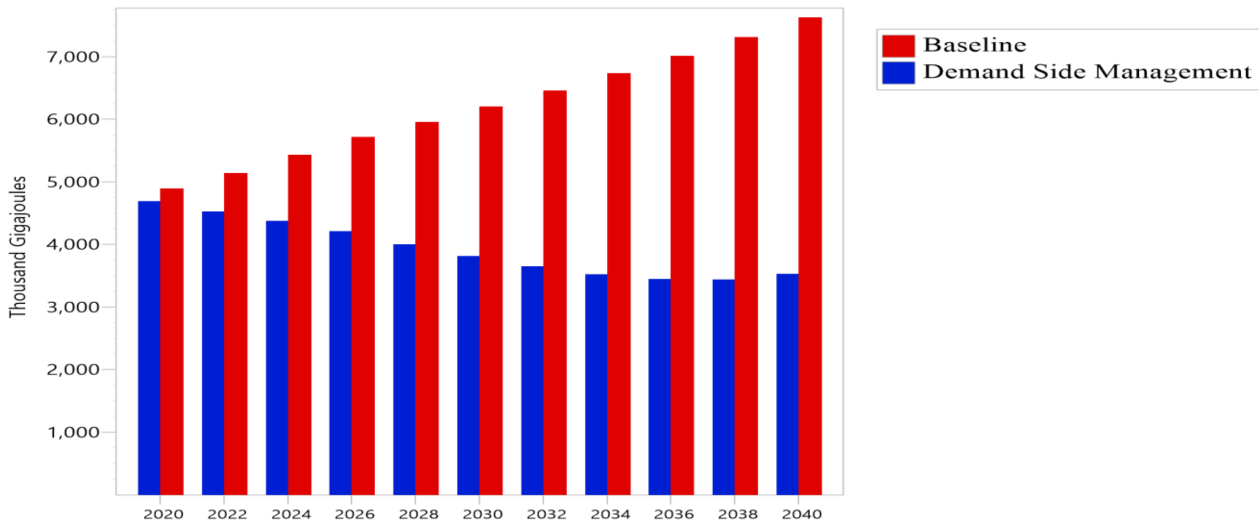


Figure 4.25: Energy Efficient Scenario Energy Demand 2019-2040

4.4.2.1 Energy Efficient Scenario Implications on Emissions

The implementation of energy efficient policies has a positive impact on the greenhouse gas emissions to the environment in Bungoma county. It is expected that the GHG emissions will reduce by 21% from 116 thousand metric tons CO_2 equivalent in 2019 to 91.3 thousand metric tons CO_2 equivalent in 2040. Figure 4.26 illustrates the baseline and demand side management GHG emissions reduction with presence of energy efficient policies which is a great mitigation factor to climate change.

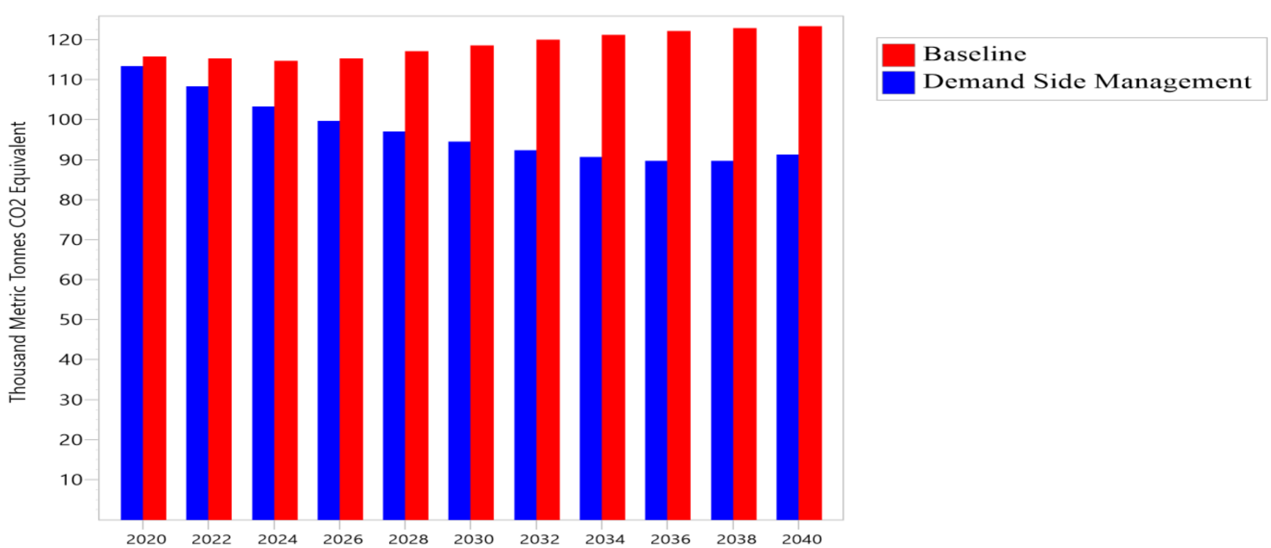


Figure 4.26: Energy Efficient Scenario on Emissions 2019-2040

The reduction of household energy demand through the use of improved cook stoves and LED bulbs in lighting plays an integral role in mitigating climate change through the reduction of GHGs produced during the utilization of the energy resources. Therefore, implementation of new policies in the development process of the county activities and in the household energy demands has a positive impact in GHG emissions. Energy efficiency not only improves a nation's energy security but also increase the competitiveness of private entities and reduction of energy demand and GHG emissions (Thavasi & Ramakrishna, 2009).

Similar findings in Australia shows that; energy demand is likely to increase under business-as-usual scenario while a higher renewable energy integration results in lower wholesale electricity prices (Emodia, Taha, & Rabiul, 2019). The scenario analysis with introduction of a combined policy option involving modal shift and penetration of RE leads to decreased energy demand and low emissions. A combination of renewable energy sources and energy efficiency policies could provide the safer and cost-effective way to combat climate change (Thavasi & Ramakrishna, 2009).

Climate change and fossil fuel depletion are the main drivers for the recent focus on finding alternative energy resources with RE being an obvious choice to reduce carbon dioxide and other pollutants contributing to global warming (Mezher, Gihan, & Zeina, 2011). End-use energy efficiency is expected to play a large role in the future energy system. Provision of concrete energy conservation measures, information and activities for the end-users and development of new innovative business models need to be adopted (Apajalahti, Raim, & Eva, 2015).

Government policy is important in regulating and reducing residential energy consumption. Finding by Aydin & Dick, (2017) reveals that there is a reduction in residential electricity use after the government introduced a mandatory disclosure of energy labels for an electric appliance group that represent ten percent of households' electricity use in EU. Effective energy policy implementation in RE and energy efficiency directly impacts energy consumptions in different sectors. A study undertaken in EU member states shows that Energy policies have an impact in reducing energy consumption. In the absence of energy policies, energy consumption in EU 29 countries would have been approximately 11% higher in 2013 (Bertoldi & Rocco, 2015). The governments should invest and implement climate policies considering the long-term effects rather than the short-term system costs. It is clear that adoption of improved cookstoves reduces the carbon emissions and improves energy efficiency in the households (Pratiti, David, Zirk, & Parul, 2020).

It is evident that climate change threatens the agricultural system and extreme events like floods, pests and diseases are common. Overall, it is clear that the climate change mitigation required will be possible with implementation of energy efficient policies, partnership and collaboration within stakeholders and increased budget allocation towards climate policies and RE technologies.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study sought to explore the uses and impacts of renewable energy sources in combating climate change in the rural communities of Bungoma county. The study also analyzed the land use and land cover changes over a 30-year period and identified different renewable energy policies present and the barriers to their adoption.

1. Fuel stacking was common in the households with 7 sources of energy being used and Firewood being the dominant source of energy for cooking. Open air (three stone) cooking stoves were the most commonly used which consumes a lot of energy and contributes to indoor air pollution a negative implication to the people's health, economy and the environment as a whole.
2. High initial cost of installing renewable energy resources, low market entry of renewable energy technology, unfair competition with fossil fuels, Rigid energy transmission infrastructure and high financial risk are some of the barriers to adoption of renewable energy resources in combating climate change.
3. There has been a rapid increase in barren land and built-up area with a major decrease in forest cover and vegetation land. These tremendous changes are highly attributed to the rapid population and household growth and the increased demand for farming and firewood for cooking.
4. Energy demand is directly proportional to the population and household growth in the county as BAU projection shows household energy demand increased with an increase in emissions. Therefore the implementation of energy efficient policies leads to a positive impact on energy demand and the greenhouse gas emissions to the environment in Bungoma county.

5.2 Recommendations

Climate Change is a global issue that requires stringent measures and collaboration with different stakeholders in order to come up with adaptation and mitigation measures to combat climate change. It is evident that the use of renewable energy resources in all the sectors of development is a great step towards the reduction of emissions mitigation measure to combating climate change. There is a need for public sensitization and awareness on matters of renewable energy technologies and long-term importance of energy efficiency as the households only look at the initial costs. However; More research should be carried out on:

- The measurement of Indoor household air pollution and the implications on the environment and the health of the rural population in Kenya.
- Cost benefit analysis modelling on energy demand, externalities from emissions and the environmental external costs of using traditional sources of energy in the rural communities of Kenya.

References

1. Ahmed, a. A.-G. (2018). Barriers to Large-scale Solar Power in Tanzania. Elsevier, 52.
2. Amakobe, G. W. (2014). Dissemination of Solar Energy Technologies in Kenya for Rural Electrification: Challenges & Opportunities.
3. Apajalahti, E. L., R. o., & E. H. (2015). From demand side management (DSM) to energy efficiency services : A Finnish case study. 86.
4. Ates, S. A. (2015). Energy efficiency and CO2 mitigation potential of the Turkish iron and steel industry using the LEAP (long-range energy alternatives planning) system. https://doi.org/10.1016/j.energy.2015.07.059
5. Aydin, E., & D. B. (2017). The impact of policy on residential energy consumption. Elsevier, 115 -129.
6. Baniya, B., D. G., & S. K. (2020). Green growth in Nepal and Bangladesh: Empirical analysis and future prospects. Elservier.
7. Bank, W. (2019). World Bank Group.
8. Barthlett, J.E, II, Kotrlik, J, W, and Higgins, C. (2001). Organizational research: determining appropriate sample size for survey research. Information technology, learning and performance journal, 19(1) 43-50.
9. BBC. (2019, June 26). Kenya halts Lamu coal power project at World Heritage Site. Retrieved from BBC News: https://www.bbc.com/news/world-africa-48771519 accessed on 15/10/2021
10. Bertoldi, P., & R. M. (2015). The impact of energy efficiency policies on energy consumption in the EU Member States: a new approach based on Energy Policy indicators. European Commision, 5-89.
11. Bevan, G. (2012). Royal Statistical Society. Retrieved from Renewable energy and climate change: https://doi.org/10.1111/j.1740-9713.2012.00614.x accessed on 15/9/2021
12. Beyene T, L. D. (2009). Hydrologic impacts of climate change on the Nile River Basin: implications of the 2007 IPCC scenarios. Retrieved from Springer: https://link.springer.com/article/10.1007%2Fs10584-009-9693-0

13. Bojana Bajželj, J. M. (2013). Designing Climate Change Mitigation Plans That Add Up. Environ. Sci. Technol. 2013, 47, 14, 8062–8069. Retrieved from https://pubs.acs.org/doi/10.1021/es400399h accessed on 14/9/2021
14. Bond, T., & S. H. (2005). Can reducing black carbon emissions counteract global warming? 39(16),5921–5926.: Environmental Science and Technology.
15. Brandt, M. R. (2017). Human Population Growth Offsets Climate-driven Increase in Woody Vegetation in Sub-Saharan Africa. Elsevier, http://refhub.elsevier.com/S0973-0826(20)30321-5/rf0045.
16. Business Daily. (2021, 8 17). Cooking Gas Price Rise. Retrieved from https://www.businessdailyafrica.com/bd/economy/cooking-gas-prices-rise-sh350-on-new-tax-3373296
17. CAT. (2020). Kenyan Policy projections-https://climateactiontracker.org/countries/kenya/.
18. ClientEarth. (2020, November 11). ClientEarth Communications. Retrieved from https://www.clientearth.org/latest/latest-updates/stories/fossil-fuels-and-climate-change-the-facts/ accessed 15/10/2019
19. ConocoPhillips. (2006). Sustainable Development Report.
20. Desonie, D. (2008). Climate: Causes and Effcets of Climate Change. New York City: Infobase Publishing 132 West 31st Street.
21. Deutsche Welle. (2021). Retrieved from East Africa braces for a return of the locusts: https://www.dw.com/en/east-africa-braces-for-a-return-of-the-locusts/a-56133496 Accessed on 13/9/2021
22. Dominik, W., M. L., & J. K. (2013). Energy requirements of consumption: Urban form,climatic and socio-economic factors,rebounds and their policy implications. Elservier, 2-12.
23. Douglas J.Arent, A. W. (2011). The status and prospects of renewable energy for combating global warming. Retrieved from Elsevier: https://doi.org/10.1016/j.eneco.2010.11.003
24. Eitan, A. (2021). Promoting Renewable Energy to Cope with Climate Change—Policy Discourse in Israel: Sustainability. Retrieved from https://doi.org/10.3390/su13063170

25. Emodia, N. V., T. C., & R. A. (2019). A techno-economic and environmental assessment of long-term energy policies and climate variability impact on the energy system. Elsevier, 329-344.
26. EnergyPedia. (2020). Retrieved from Fossil fuel Resorces in Kenya: https://energypedia.info/wiki/Fossil_Fuel_Resources_in_Kenya #coal accessed on 20/08/2021
27. Energypedia. (2020). Kenya Energy Situation. Retrieved from Biomass: https://energypedia.info/wiki/Kenya_Energy_Situation#toc accessed on 16/9/2021
28. Energypedia. (2021, 8 13). Retrieved from Hydropower Stations in Kenya: https://energypedia.info/wiki/Hydropower_Stations_in_Kenya
29. Energypedia. (2021, 8 12). Kenya Energy Situation. Retrieved from https://energypedia.info/wiki/Kenya_Energy_Situation#LPG
30. FAO. (2020). Kenya at a Glance_http://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en.
31. Foell, W., S. P., D. S., & H. Z. (2011). Household cooking fuels and technologies in developing economies. USA: Elsevier.
32. Freeman, R. E. (1984). Stratigic Management: A Stakeholder Approach .
33. Gardner, J. D.-M. (2009). A framework for stakeholder engagement on climate adaptation. CSIRO Climate Adaptation Flagship Working paper No.3. http://www.csiro.au/resources/CAF-working-papers.html.
34. GBA. (2017). Global Wind Atlas. Retrieved from https://en.wikipedia.org/wiki/Wind_power_in_Kenya#/media/File:Mean-wind-speed-map-kenya-global-wind-atlas.png Accessed on 23/9/2021
35. Geology. (2021). Geology.com;Geosicence News and Information. Retrieved from Kenya Map and Satellite Image: https://geology.com/world/kenya-satellite-image.shtml accessed on 17/9/2021
36. Gitogo, W. (2019, 12 15). The Kenyan Mall Street. Retrieved from https://kenyanwallstreet.com/garissa-50-mw-solar-plant-connected-to-national-grid/ accessd on 31st Aug 2021
37. Glasenappa, S., F. X., H. W., & U. M. (2019). Assessment of residential wood energy consumption using German household-level data. Elsevier, 117 - 129.

38. Green Belt Movement. (2003). Annual Report . Lantern Books, 6.
39. Guta, D. D. (2014). Effect offuelwoodscarcityandsocio-economicfactorsonhousehold bio-based energyuseandenergysubstitutioninruralEthiopia. Elsevier, 217 - 226.
40. Heaps, C. G. (2011). Long-range Energy Alternatives Planning (LEAP) system. Stockholm Environmental Institute. Retrieved from http://www.energycommunity.org/WebHelpPro/LEAP.htm#t=Concepts%2FIntroduction.htm
41. Herbst, A. F. (2012). Introduction to Energy Systems Modelling. Swiss Society of Economics and Statistics, Vol. 148 (2).
42. Ibrahim Dincer, M. A. (2013). Exergy, Environment And Sustainable Development: The Role of Renewables in Sustainable Development. Retrieved from https://www.sciencedirect.com/topics/engineering/renewable-energy-resources accessed on 15/9/2021
43. IEA. (2010). International Energy Agency. Paris: World Energy Outlook.
44. IEA-RETD. (2011, July 15). Climate Change Adaptation, Damages and Fossil Fuel Dependence; Final Report. 77 South Bedford Street, Suite 400, Burlington, MA 01803: Navigant Consulting, Inc. Retrieved from Renewable Energy Technology Deployment.
45. IPCC. (2013). Climate Change The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Chang. Retrieved from http://www.climatechange2013.org/ accessed 13/9/2012
46. IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from http://www.climatechange2013.org/ accesed on 14/9/2021
47. IPCC. (2018). Special Report on Global Warming .
48. IPCC- Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Kadner, S., Zwickel, T., . . . von. (2011). Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate. Cambridge, UK: Cambridge University Press.

49. IPCC-Moomaw, W. F. (2011). Introduction. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, United Kingdom and New York, NY, USA.: Cambridge University Press,.
50. IRENA. (2019). Retrieved from International Renewable Energy Agency: Renewable Energy Insights Technologies: https://www.irena.org/geothermal acccesed on 17/08/2021
51. IRENA. (2019). Climate Change and Renewable Energy National policies and the role of communities, cities and regions (Report to the G20 Climate Sustainability Working Group (CSWG)), International Renewable Energy Agency, Abu Dhabi.
52. IRENA. (2019a). A Report on Global Energy Transformation: A Roadmap to 2050.
53. Jason Beaubien. (2021, January). Locust Swarms Threaten Parts Of East Africa: Kenya. Retrieved from https://www.npr.org/2021/01/19/958543535/locust-swarms-threaten-parts-of-east-africa
54. Jewitta, S., P. A., & M. C. (2020). We cannot stop cooking": Stove stacking, seasonality and the risky practices of household cookstove transitions in Nigeria. Elsevier, 1-10.
55. Jones, A. W. (2015). Perceived barriers and policy solutions in clean energy infrastructure investment. Elsevier, 300.
56. Kabubo, J. M. (2007). The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach, Glob. Planet. Change 57 (3) 319–330,. Retrieved from http://dx.doi.org/10.1016/j.gloplacha.2007.01.002
57. Kean, J. M., & Fowler, &. S. (2015). The Effects of Climate Change on Current and Potential Biosecurity Pests and Diseases in New Zealand.
58. KENGEN. (2021, 8 13). Retrieved from The Kenya Electricity Genarating Company: https://www.kengen.co.ke/index.php/business/power-generation/hydro.html
59. KENGEN. (2021). Kenya Electricity Genrating Company Ltd. Retrieved from https://www.kengen.co.ke/index.php/information-center/news-and-events/kengen-enters-final-construction-phase-of-olkaria-i-additional-unit-6-geothermal-power-plant.html accesed on 23/9/2021
60. KNBS. (2019). Kenya National Bureau of Statistics, Kenya Population and Housing Census: Population Distribution by Administration units. .
61. Knoema. (2019). Retrieved from World data atlas on Energy consumtion: https://knoema.com/atlas/Kenya/Primary-energy-consumption accessed on 20/08/2021

62. Knoema. (2019). Knoema Word Data Tool. Retrieved from https://knoema.com/atlas/Kenya/CO2-emissions-per-capita accessed on 20/08/2021
63. Majid, C. R. (2020). Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities.
64. Mano, C. N. (2007). Assessment of the Economic Impacts of Climate Change on Agriculture in Zimbabwe: A Ricardian Approach. Policy Research Working Paper; No. 4292. World Bank, Washington, DC. © World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/7484/Wps4292.pdf?sequence=1&isAllowed=y
65. Mbungu, W. B. (2016). Impacts of Land Use and Land Cover Changes, and Climate Variability on Hydrology and Soil Erosion in the Upper Ruvu Watershed, Tanzania. 30-134.
66. Mezher, T. n., G. D., & Z. A. (2011). RenewableenergypolicyoptionsforAbuDhabi:Driversandbarriers. Elsevier, 315 - 326.
67. MoA. (2018). Ministry of Agriculture, Republic of Kenya.
68. MoE. (2019). Ministry of Energy. Nairobi: The Government of Kenya.
69. MoE. (2020). The Bioenergy Strategy. Nairobi: Government of Kenya.
70. MOE&NR. (2015). Kenya's Intended Nationally Determined Contribution (INDC).
71. NEECS. (2020). Kenya National Energy Efficiency and Conservation Strategy. Nairobi: Government of Kenya.
72. Norfund. (2021). The Lake Turkana Wind Project. Retrieved from https://www.norfund.no/lake-turkana/ accessed on 31st Aug 2021
73. Ochieng, A. C., Y. Z., J. K., N. D., I. O., & C. S. (2016). Household perspectives on cookstove and fuel stacking: A qualitative study in urban and rural Kenya. Elsevier, 154-159.
74. Onkar, B. R. (2012). Study of Impacts of Global Warming on Climate Change: Rise in Sea Level and Disaster Frequency.
75. Ouedraogo, S. N. (2017). Modeling sustainable long-term electricity supply-demand in Africa. Retrieved from Applied Energy: https://doi.org/10.1016/j.apenergy.2016.12.162
76. Ovando, P., & A. C. (2008). Land useandcarbonmitigationinEurope:Asurveyofthepotentialsof. Elsevier, 992-1002.

77. Paez, A. F., M. Y., & Castro, A. O. (2017). Future Scenarios and Trends of Energy Demand in Colombia using Long-range Energy Alternative Planning. Retrieved from International journal of Energy Economics and Policy: https://www.econjournals.com/index.php/ijeep/article/download/5390/3324
78. Pankaj Lal, J. A. (2011). Socioeconomic impacts of climate change on rural communities in the United States. In Effects of Climate Change on Natural Resources and Communities (p. 73). portland: United States Department of Agriculture.
79. Pegels, A. (2010). RenewableenergyinSouthAfrica:Potentials,barriersand options forsupport. Elsevier, 4948.
80. Piel, M. (1982). Social Science Research Method, African handbook. Hodder and Straughten London.
81. Pratiti, R., D. V., Z. a., & P. S. (2020). Health effects of household air pollution related to biomass cook stoves in resource limited countries and its mitigation by improved cookstoves. Elsevier.
82. PRCM. (2021). Partenariat Régional pour la Conservation de la zone côtière et Marine en Afrique de l'Ouest. Retrieved from Socio-economic impact of climate change: a possible worst-case scenario if appropriate measures are not taken now: http://www.prcmarine.org/en/socio-economic-impact-climate-change-possible-worst-case-scenario-if-appropriate-measures-are-not accessed on 16/9/2021.
83. Ravindra, K., M. K.-S., S. M., & S. J. (2018). Trend in household energy consumption pattern in India: A case study on the influence of socio-cultural factors for the choice of clean fuel use. Elsevier.
84. Rechlin, B. B. (2010). Women in Forestry: A study of Kenyas Green Belt Movement and Nepa'ls Community Forestry Program. Forest Research , 69-72.
85. Rivers, N., & J. M. (2005). Combining Top-Down and Bottom-Up Approaches to Energy-Economy Modeling Using Discrete Choice Methods. The Energy Journal, 83-106.
86. Sana, A., S. S., M. N., & Bouland, C. (2018). . Chronic obstructive pulmonary disease associated with biomass fuel use in women: a systematic review and meta-analysis. Retrieved from https://bmjopenrespres.bmj.com/content/5/1/e000246.

87. SEI. (2009). (Stockholm Environment Institute), Economics of Climate Change Kenya,Project Report.
88. SEI. (2012). LEAP: Long range Energy Alternatives Planning System: a tool for energy policy analysis and climate change mitigation assessment.
89. Thavasi, V., & R. S. (2009). Asia energymixesfromsocio-economicandenvironmentalperspectives. Elsevier, 4246.
90. The Standard. (2020, October 18). The Standard News Paper by Counties. Retrieved from https://www.standardmedia.co.ke/kenya/article/2001390567/bungoma-residents-challenged-to-plant-trees-on-private-farms.
91. Timothy, J. L. (2010, October 15). Energy Models.. 2010. SAGE Publications. 15 Oct. 2010. <http://www.sage-ereference.com/geography/Article_n347.html>. Encyclopedia of Geography.
92. Twumasia, M. A., Y. J., B. A., D. A., D. L., & Z. D. (2021). Determinants of household choice of cooking energy and the effect of clean cooking energy onsumption on household members' health status: The case of rural Ghana. Elsevier.
93. UNFCCC. (2011). United Nations Framework Convention on Climate Change. Retrieved from https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_science.pdf.
94. Van Beeck, N. M. (1999). Classification of Energy Models. (FEW Research Memorandum; Vol. 777) Operations Research.
95. Weisser, D. (2007). A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies. Retrieved from Elsevier: https://doi.org/10.1016/j.energy.2007.01.008.
96. Wesley, F. S. (2011). Household cooking fuels and technologies in developing economies. Elsevier, 7488.
97. WHO. (2006). World Health Organization, fuel for Life: Household Energy and Health .
98. World Bank. (2019). The World Bank Group. Retrieved from https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=KE accessed on 8/12/2021.

99. World Bank. (2020). The world Bank Group. Retrieved from Gross Domestic Product of Kenya: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KE accessed on 8/12/2021

100. Zayan, S. A. (2019). Impact of Climate Change on Plant Diseases and IPM Strategies.

Appendix

1 Questionnaire

Developed by
D.I

INDIVIDUAL Interviews TOOL

Dear respondent,

My name is ***Diana Imbugwa*** *a master's student at the Pan African University of Water and Energy Sciences including Climate Change in Tlemcen Algeria studying Energy Policy. I am undertaking research on* ***Exploring the Uses and Impacts of Renewable Energy Resources in Combating Climate Change to the rural communities of Bungoma.*** *The information you will provide will be useful in this research project. Your responses will be COMPLETELY CONFIDENTIAL and will be strictly used for academic purposes. If you choose to participate you may decline to respond to certain questions or may stop participating at any time.* I will appreciate any additional information that you consider relevant for my research.

Do you agree to participate? (*If yes, start the interview. If no, terminate the interview and thank the respondent*)

1. Yes ☐
2. No ☐

Section A: Demographic Information

A1. Date (day/month/year) ☐

A2. Gender of the respondent (**tick where appropriate**)

1. Male ☐
2. Female ☐

A3. Age of respondent in years (**tick where appropriate**)

1. 18-24 ☐
2. 25-30 ☐
3. 31-35 ☐
4. 36-40 ☐
5. 41-45 ☐
6. 46-50 ☐
7. Over 50 ☐

A4. What is your highest education level (**tick where appropriate**)

1. Primary ☐
2. Secondary ☐
3. Tertiary ☐
4. None ☐
5. Other places specify…………………………………………………………….

A5. Occupation/ income status? (**Tick where appropriate**)

1. Casual labor ☐
2. Employed ☐
3. Business person ☐
4. Farmer ☐
5. Self-employed ☐
6. Other (Please specify) ……………………………………………………………

A6. What is your position in your household? (**Tick where appropriate**)

1. Head ☐
2. Spouse ☐
3. Son ☐
4. Daughter ☐
5. Relative ☐
6. Others (*Specify*) ☐

A7. What is your marital status?

1. Single ☐
2. Married ☐

☐

3. Divorced
4. Widowed
5. Separated

A8. How many are you in the household? (**Tick where appropriate**)

1. 1-4
2. 5-10
3. 11-15
4. Over 15

A9. How many years have you lived in Bungoma County? (**Tick where appropriate**)

1. 1-5
2. 6-10
3. 11-15
4. 16-20
5. Above 20

A10. What type of animals do you keep? (**Tick all applicable**)

1. Cattle
2. Sheep
3. Pigs
4. Chicken
5. Goat
6. Others specify…………………………………………………………………....

A11. Which type of food do you grow? (**Tick all applicable**)

1. Maize
2. Wheat
3. Cassava
4. Sugarcane
5. Sweet potatoes
6. Beans
7. Others specify………………………………………………………

A12. For how many years have you been farming? (**Tick where appropriate)**

1. 1-5
2. 6-10

3. 11-15 ☐
4. 16-20 ☐
5. Above 20 (Specify)……………………………………………….

SECTION B: Energy Resources and Uses in the Households.

B1. Which of the following is the energy source currently used in your home? (**Tick all applicable**)

a. Firewood ☐
b. Charcoal ☐
c. LPG ☐
d. Kerosene ☐
e. Biogas ☐
f. Candle ☐
g. Generator ☐
h. Solar ☐
i. Grid Connected Electricity ☐
j. Others Specify………………………………………………………………….

B2. Which of the following sources of energy are used for lighting in your household? (**Tick all applicable**)

a. Grid Connected Electricity ☐
b. Kerosene ☐
c. Generator ☐
d. Solar Lamps ☐
e. Electricity charged lamps ☐
f. Solar Home Systems ☐
g. Other (Specify)……………………………………………………

B3. Are you connected to the electrical grid system (i.e, have electricity in your household)

1. Yes ☐
2. No ☐

B4. If yes, what is the monthly cost of the Electricity used in the household (Kshs)…………………

……………………………………………………………………………………………

B5. Which of the following lighting bulbs do you use in your household?

Bulbs	Number of bulbs	How many hrs per day are the bulbs on
LED (Energy Saving Bulbs)		
Incandescent Bulbs		

Florescent Bulbs		
None		

B6. Why do you prefer using the types of bulbs you have in your household**? (Tick all applicable)**

1. Energy saving ☐
2. Efficient ☐
3. Cheap ☐
4. Lasts Longer ☐
5. Readily available ☐
6. Other (Specify)…………………………………………………………………….

B7. In case of power failure which of the following sources of energy do you use as backup? (**Tick all applicable**).

a. Kerosene ☐
b. Solar Lamp ☐
c. Candle ☐
d. Generator ☐
e. Dry cell Battery ☐
f. Others (Specify)…………………………………………………………………...

B8. Which of the following electric appliances does your household use? (**Tick all applicable)**

Appliance	**Power Source**	**How many of each in the house**	**Number of hrs in use per day**
Television			
Radio			
Phone			
Laptop			
Sound system			
Refrigerator			
Electric Iron			
Electric jug			
Electric stove			
Water pump			
Water Heater			
Other (Specify)			

B9. Which of the following do you use for cooking meals in the household? (**Tick all applicable**)

1. Firewood ☐
2. Charcoal ☐

☐

3. Sawdust
4. Kerosene ☐
5. LPG ☐
6. Biogas ☐
7. Electricity ☐

B10. Which stoves do use with the energy sources mentioned above for cooking? (**Tick all applicable)**

1. Traditional Stove with Chimney ☐
2. Traditional stove without chimney ☐
3. Open air (three stones stove) ☐
4. Kerosene stoves ☐
5. Electric cooker stove ☐
6. LPG Cylinder stoves ☐
7. Improved cook stoves ☐
8. Biogas stove ☐

B11. Why do you prefer to use the fuels that you currently use in your households for cooking?

a) Cheap ☐
b) Readily available ☐
c) Clean ☐
d) Efficient ☐
e) Other specify………………………………………………………………………………..

B12. Where do you get these fuels from?

1. Near-by Kiosk ☐
2. Town ☐
3. The environment ☐
4. Delivered at the doorstep ☐
5. Other (Specify)……………………………………………………………………….

B13. Who is in charge of ensuring that the energy used is available?

1. Women ☐
2. Men ☐
3. Both ☐

B14. Do you encounter any challenges with the energy source you use for cooking?

1. Yes ☐
2. No ☐

B15. If yes, which ones ……………………………………………….…………………………….

……

……

……………………………………………………………………………………

B16. What is the amount and cost of the energy sources used for cooking in the household?

Fuel	How much Kgs/Ltrs (Monthly)	Cost (Ksh) (Monthly)
Firewood		
Charcoal		
Sawdust		
Kerosene		
LPG		
Biogas		
Electricity		

Section C: Impacts of Climate change on the socio-economic sector

C1. For the years you have stayed here have you experienced changes in weather pattern?

1. Yes
2. No

C2. If yes which one?

1. Low rainfall
2. Increased/High rainfall
3. Increased Temperature
4. Low temperatures
5. Other (Specify)…………………………………………………………………...

C3. Have you experienced change in the time you used to start planting your crops due to delayed rainfall?

1. Yes
2. No

C4. Have you experienced reduced harvest of your produce?

1. Yes
2. No

C5. If yes Explain Why………………………………………………………………………

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

C6. Have you been experiencing the spread of crop pests and diseases that you never used to have before?

1. Yes

2. No

C7. If yes Which ones……………………………………………………………………………

………………………………………………………………………………………………..

………………………………………………………………………………………………..

C8. How has the changes in weather pattern affected your daily economic activity?

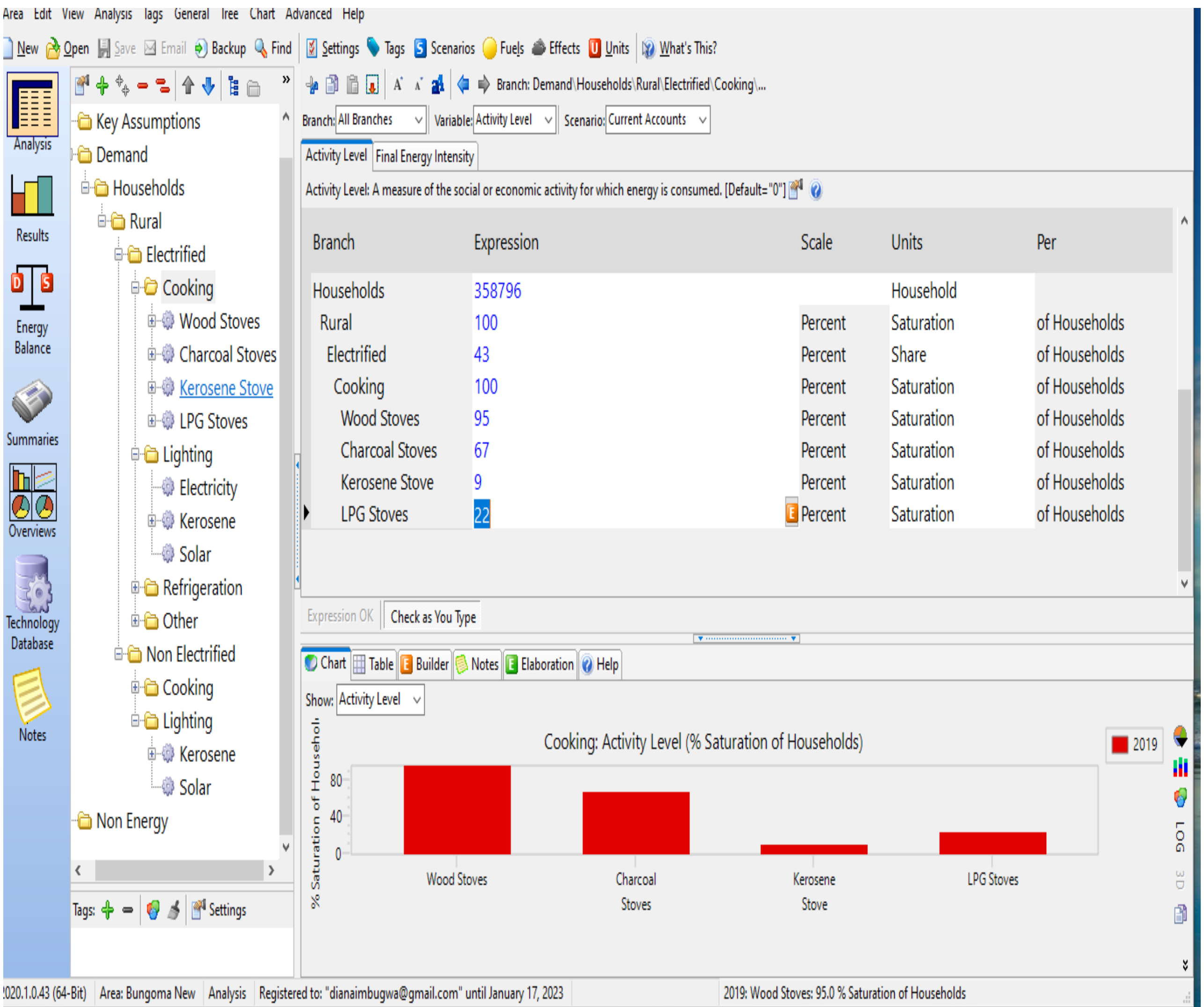
……………………………………………………………………………………………………

……………………………………………………………………………………………………

Guide to key informant Interview

1. What is your take on the adoption of Renewable Energy Technologies in the rural communities in the country? (Especially Solar technology)
2. Which policies, regulations and standards do you think have been put in place to enhance the adoption / market growth of RET?
3. Are there gaps in policies, regulations and standards that you know of; if yes which ones?
4. Explain to me the major challenges you face, especially when working in field while implementing RE projects to help in combating climate change?
5. What recommendations regarding the RE sector; Markets and Adoption that will see to a transition in the use of RET's as a remedy to climate change in the rural communities?

2 LEAP Data Input Interface



3 LEAP Results Interface