SOLAR PHOTOVOLTAIC TECHNOLOGY UPTAKE IN CLIMATE CHANGE MITIGATION BY HOUSEHOLDS IN EMBU COUNTY, KENYA

By

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DECLARATION

I affirm that this work is entirely my own creation and, to the best of my knowledge, has not been submitted for any academic program at any other university.

Signature: ……………………………… **DATE: ………………………**

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This project has been submitted for examination with my approval as the University supervisor.

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DEDICATION

To express my gratitude to all those who contributed to the success and completion of this study and ensured I gained an unforgettable experience. To God Almighty who gave me the strength, and guidance to face the everyday challenges and made me resilient throughout the master's program, I'm forever grateful. To my dear parents: Erick Njeru Nthiga and Margaret Maitha Nyaga and my brothers Evas Macharia Njeru and Estine Mugendi Njeru, words can never express how grateful I am for seeing me through this journey. You were always present and offered support, guidance, and advice throughout this journey. May God bless and favor you forever. I would like to sincerely thank my supervisor, Professor Ezekiel Ndunda for your guidance, support, and patience throughout this study. Your brilliant comments and advice have been a key pillar to the completion of this study. Thank you and may God bless you.To all my diligent lecturers, and instructors, I also dedicate this to all of you, for sharing knowledge and effective teachings.

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LIST OF ACRONYMS AND ABBREVIATIONS

EPRA	Energy and Petroleaum Regulatory Authority
GHS	Greenhouse Gas Emissions
GIS	Geographical Information Systems
GW	Gigawatts
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IPCC	Intergovernmental Convention on Climate Change
KMD	Kenya Meteorological Department
LSS	Living Standard Survey
MW	Megawatts
MAM	March, April, May
NDCs	Nationally Determined Contributions
NGO	Non-governmental Organizations
OND	October, November, December
PV	Photovoltaic
SDGs	Sustainable Development Goals
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

DEFINITON OF TERMS

Climate change- in this study climate change refers to the changes in climate that are identifiable for example through statistical tests by changes in variability of its properties and/or the mean, and the changes persist for a prolonged period, usually decades or longer. Therefore, climatic changes occur over an extended period, and it occurs due to unstainable human activities or natural variability (IPCC, AR6 Synthesis Report: Climate Change, 2022).

Climate mitigation- in the study refers to the efforts undertaken by the community to stop or reduce emissions of greenhouse gases. In this study mitigation refers to the use of renewable energies and new technologies, changing consumer behavior or management practices or making older equipment the already in use more energy efficient (United Nations Environmental Programme , 2022)

Feed-In Tariff (FIT)- is a policy designed to support the development of renewable energy sources by providing a guaranteed, above-market price for producers (Investopedia, 2024).

Nationally Determined Contributions- national climate pledges that each Party is required to develop that articulate how they will contribute to reducing greenhouse gas (GHG) emissions and adapting to impacts (United Nations Development Programme, 2023).

Renewable energy- in this study refers to the energy directly generated from various natural processes and are replenished continuously in the environment, and they include different types of biomasses, water, wind, sunlight, tides and geothermal heat. Renewable energy can never be exhausted as it is constantly renewed (Ciolkosz, 2009)

Solar photovoltaic- as the bifacial solar photovoltaic (PV) technology: a mature technology that promotes the increase of electricity production per PV module square meter through the utilization of absorbed light from the albedo (Guerrero-Lemus, 2016)

ABSTRACT

Globally, adoption and diffusion of solar energy technology is being promoted as a source of sustainable energy for climate change mitigation. However, the take-up of solar photovoltaic technology in Embu County remains low. The study sought to assess the uptake of solar photovoltaic technology by households for climate change mitigation and identify the determinants of uptake of the solar Photovoltaic technology. Cross sectional data was collected from households in Mbeere- North Sub County in Embu County to carry out this study. A sample size of 395 respondents was employed, and purposive and simple random sampling was employed to choose the respondents for inclusion of the study. For data collection, some of the tools that were used include questionnaires, interviews, and observations. After data collection qualitative and quantitative data analysis methods were used to analyze the data including SPSS (Statistical Package for the Social Sciences). The results indicate an overall increasing temperature and overall decreasing rainfall in Embu County. Income demonstrated a greater influence compared to other factors in determining the decision to adopt solar appliances at P =0.397. A significant proportion of respondents (36.9%) reported having limited awareness of climate change and its impact and social and mass media were main sources of climate information. There was a positive significant correlation between respondents who displayed awareness of climate change and its impacts and the adoption of solar energy and awareness on solar energy adoption as a solution to climate change at P values of 0.348 and 0.140. The study recommends for first the Kenyan government through its relevant ministries including the Ministry of Energy and the Ministry of Environment needs to provide targeted capacity building initiatives to increase the level of knowledge and awareness on climate change and the use of solar energy. Secondly, a portion of the respondents indicated that climate variability had no influence in their uptake of solar energy, to gain a deeper understanding of these findings, further analysis is necessary. Finally, the respondents indicated utilizing other sources of energy, mainly biomass based. The county needs to get involved to provide energy solutions regardless of the availability of alternative/substitute of other sources of energy. Solar power will eventually help the county achieve better forest cover as individuals will turn to solar and depend less on wood-based fuel. The community should be encouraged to harness solar energy as it is cheaper and more easily accessible than the other sources of energy given that the community comes from an area where the sun is abundant. The results helped in assessing the uptake of solar photovoltaic in climate change mitigation in Embu County and show the determinants driving households on the uptake of solar photovoltaic technology.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

According to International Energy Agency (IEA) and different scholars the utilization of clean renewable energy is now recognized as a great mechanism of driving towards sustainable development and achievement of the world set (SDGs) Sustainable Development Goals (Yasmina , *et al.,* 2022). The access of energy services needs to be highly affordable and convenient to effectively meet all the required and basic energy requirements mostly in the world's developing countries and most importantly in low-income households globally. This particular condition is critical as it helps in generating income activities and opportunities in the business field for households in poverty, additionally it promotes improved social equity, communication, health, drinking water and education and in particular promotes green economic development (Mirzabaev, *et al.,* 2015).

In consonance with the World Bank the metric of persons who did not have access to electricity by the year 2019 were approximately 759 million and it is estimated that by 2030 and estimated 660 million people would still not be connected to electricity (The World Bank Group, 2021). Therefore, many households continue to rely on kerosene for cooking and lighting purposes. Moreover, usage of fossil fuels is linked to health and environmental problems resulting from indoor air pollution. The WHO estimated that over 3.8 million persons a year die prematurely from different illness that are directly attributed to the household air pollution resulting from the inefficient utilization of solid fuels and kerosene for cooking (World Health Organization, 2021). This conclusion implies that globally indoor air pollution is a great health threat.

In the same way, dependence on traditional sources of energy like dung cake, charcoal, fuelwood, and crop residue in rural households has seriously threatened the loss of agricultural productivity, forest cover, and ecological disruptions. Therefore, the general consensus promotes the shift from the utilization and over dependence on traditional energy sources and now focus on the modern sources of energy (renewable clean energies) to help relieve the induced pressure on our ecosystems, improve the existing living standards in the society which includes households and help expedite green sustainable development which is a goal/target that most countries in the world today are now striving to achieve.

Altogether, the argument remains that the accessibility to all the different types of renewable clean energy sources and available services is greatly required to with the issues revolving around extreme poverty and strive towards attaining the set SDGs in the low-income countries and households (Bhide & Monroy, 2011).

This case applies to many countries located in the Sub-Saharan Africa which includes Kenya. While most of the countries have a high potential of renewable energy, approximately 700 million people in Africa have no access to basic electricity connections ((Kiendnoma, *et al.*,, 2022). Most of these population resides in the rural areas and electricity in these areas is a huge problem and hence are greatly impacted by the efficient accessibility of renewable and clean energies. Most countries within the region have resulted in investing in developing and using renewable clean energy technologies to address this issue (Szeberényi, 2021).

Kenya is home to an estimated 53.77 million people and the biggest proportion of the population (World , 2020) resides mainly in the rural areas (International Fund for Agricultural Development, 2022) with low electrical grid connectivity, therefore making Kenya, Embu County a good case study on assessing the uptake of solar photovoltaic technology by households. According to (Energy and Petroleum Regulatory Authority, 2022). The existing interconnected installed capacity in Kenya is of 2.925 megawatts (MW). While approximately 57% of the installed capacity is hydro power, approximately 32% of the installed capacity is in thermal and the remaining is comprised of geothermal and emergency thermal power. Solar photovoltaic and wind power plays an inconsiderable part contributing only 2%. Nonetheless, hydropower continues to range from 38-76% of the entire generation mix due to cases of poor rainfall amounts received. To make up for all the existing energy shortfalls, thermal energy is utilized which varies between 16-33%.

In Kenya, currently the installed (grid connected) electricity that is effective capacity is estimated to 2,990 MW. Even as electricity remains vital in our society today, most of it is still dominantly sourced from different hydro and fossil fuel (thermal) sources. The existing generation energy mix comprises of hydro power at 838 MW, geothermal power at 863 MW, 2% from cogeneration of biogas, wind power at 437 MW and solar power at 173 MW. According to (Energypedia, 2022), an estimated 8.6 million households in Kenya have been connected to the grid at the end of 2021, i.e., which is over 75% of the total population.

Households in Kenya result to using the following source for their lighting needs: Electricity - at 15% of the total population. Source of lighting (electricity) in the urbanized areas at - 42%; however, kerosene lamps remain at 55% as the main source of lighting in these households, and in rural households' kerosene is used for lighting purposes at - 87% (Energypedia, 2022).

Kenya has a great untapped potential of different sources of clean energy like geothermal, hydropower, bioenergy, solar, and wind (Daniel *et al.,* 2021). There are major benefits accrued from households' efficient access to clean and renewable energy including increased security, improved household welfare and contributes towards a sustainable environment. In the world, there is increased awareness on the importance green economic development and Kenya has not been left behind and the government and other entities are giving emphasis on the different sources of renewable energy applicable in the rural communities.

Kenya has an estimated solar potential of 1500MW with an installed capacity of 100mw and in addition the country receives 5kWh/m2 of daily solar insolation, ((EPRA, 2022). Therefore, approximately 1% of the solar energy has been tapped. Households in the rural areas who are off-grid, solar photovoltaic becomes the suitable clean energy option. Initial purchase and installation of solar photovoltaic attracts high capital investments, therefore, households who have limited or lack the financial muscle/capacity to purchase the solar PV technology end up not accessing the technology. Apart from poverty there are other institutional, sociological, demographic, and economic factors hindering the uptake of solar photovoltaic technologies by society and households. Taking all these into consideration, there is an importance of assessing the behavior of households when it comes to decision making regarding solar photovoltaic uptake for climate change mitigation.

1.2: Research Problem

Several studies have shown the barriers hindering similar adoption and the catalyst of world transition to low-carbon emission sources of energy. Many studies have greatly focused on determinants of renewable energy adoption focusing mainly on the first-world regions (countries) due to data availability. Very few studies have explored on the assessment of the uptake solar photovoltaic technology for climate change mitigation in Kenya and the factors impacting household adoption of solar photovoltaic decision in Kenya; most of the studies focus on biogas, its impacts on livelihoods, challenges, and history (Wanjohi *et al.,* 2022).

Other studies based in Kenya have focused on renewable energy adoption and perceptions by the public (Oluoch *et al.*, 2021). Additionally, a cross-country study has been carried out in three countries i.e., Uganda, Ethiopia and Kenya examining the household determinants of adoption of the solar photovoltaic using the LSS (Rahut ., *et al.,* 2017). Among other studies carried out they have had a key focus on mainly the various technical aspects like physical availability and cost of renewable energy technologies. The main hurdle was and still remains to be the scarcity of data on PV solar energy technologies adoption and diffusion in rural Kenya in recent phenomena.

To the researcher's knowledge the existing carried out quantitative empirical studies in the rural Kenya focusing on household solar photovoltaic uptake in climate change mitigation mechanism are limited. The bigger proportion on studies carried out based on energy issues in the country mainly have focused on cook stove choices and energy mix and only very few studies conducted have wholly considered the household and societal energy demand in rural areas however, they also greatly focus on fossil fuel, biomass and green energy technologies (Jabeen *et al.,2020*), (Lumadede , *et al.*, 2021).

In this regard, this study seeks to fill the identified gaps building upon the already existing studies. This was done using both qualitative and quantitative data analysis to investigate uptake of solar photovoltaic by households, following the study was the analysis of the underlying determinants of the uptake of solar photovoltaic by households and offer great inputs on informed policy formulation and implementation; this will consequently speed up the transition of households' adoption of clean and renewable energy. To effectively achieve the study objectives, raw data was collected from households located in the rural communities in Embu County to directly examine the institutional, economic, and socio-demographic factors on uptake of solar photovoltaic by households.

1.3 Research Questions

1) What are the temperature and precipitation trends in Embu County?
2) What are the sources of energy utilized by households in Embu County?

3) How is solar energy being utilized by households in Embu County?
4) How is the awareness about solar photovoltaic energy in climate change mitigation and adaptation in Embu County?
5) What are the socioeconomic determinants of households on solar photovoltaic energy uptake as a climate change mitigation measure in Embu County?

1.4 Research Objectives

1) To determine the trends in temperature and precipitation for the last 40 years in Embu County
2) To identify the sources of energy utilized by households in Embu County
3) To classify solar energy uses at household level in Embu County
4) To analyze the awareness about solar photovoltaic energy for climate change mitigation in Embu County
5) To evaluate the socioeconomic determinants of solar energy adoption by households in Embu County

1.5 Research Hypotheses

The null hypothesis will guide this study.

1) There are no significant trends for temperature and precipitation in Embu County.
2) Socioeconomic factors have no significant effect on the adoption of photovoltaic energy in Embu County.

1.6 Justification of the Study

There are studies carried out focusing on factors influencing decision making of households uptake of solar photovoltaic, peer influence among households, uptake of renewable energy and the economic determinants of households on uptake of solar photovoltaic (Komatsu, *et al.*, 2013) (Davidson, *et al.*, 2014) (Rahut, *et al.*, 2018). However, micro household analysis of the uptake of solar photovoltaic technology for climate change mitigation in Embu County, Mbeere North Sub County is still under researched and this study seeks to fill that gap.

1.7 Conceptual Framework

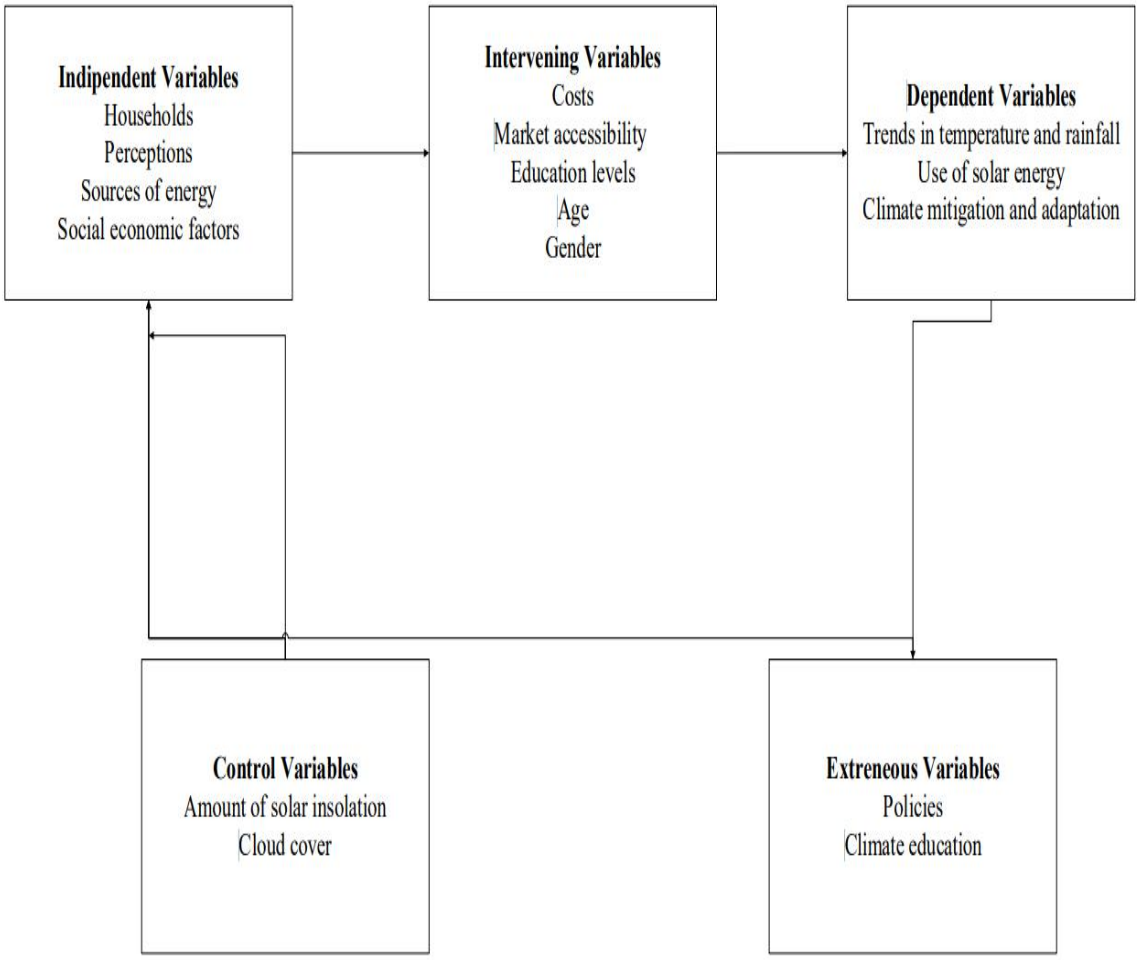

Figure 1.1: Conceptual Framework indicating solar photovoltaic uptake for climate change mitigation in Embu County, Kenya.

Figure 1.1 shows the conceptual framework which describes the proposed study "Assessing the solar photovoltaic technology uptake for climate change mitigation by households in Embu County, Mbeere North Sub County, Kenya". The study identifies key variables influencing household decisions. Independent variables include household characteristics, perceptions of energy sources, types of energy used, and socioeconomic factors, all of which directly affect the use of solar energy and climate adaptation efforts. Intervening variables such as costs, market accessibility, education levels, age, and gender mediate the relationships between these independent variables and the dependent outcomes.

In the study dependent variables including trends in temperature and rainfall, the use of solar energy, and climate mitigation actions. To account for potential confounding influences, extraneous variables like government policies and climate education initiatives are considered, while control variables such as the amount of solar insolation and cloud cover are managed to isolate the primary effects of the independent variables. By integrating these factors, the research aims to provide a comprehensive understanding of the determinants and barriers to solar energy uptake for climate mitigation among households.

CHAPTER TWO: LITERATURE REVIEW

In this chapter, related literature review was outlined in support of the research. The literature review gives the definitions of various concepts like renewable energy, meaning of climate change impacts, trends, and concepts in climate change mitigation. This chapter will also discuss rural households' demand for photovoltaic technology and the involved determining factors, possible aspects influencing the nature of mitigation measures adopted and directly applied by the society (community).

2.1 Green Renewable Energy Sources

Renewable energy, which is commonly referred to clean energies, originates from different natural sources or processes that replenish constantly in the environment (Wróblewski & Mariusz , 2022). For instance, the sun rays keep shining and wind blowing, however, the availability of wind and sun rays are wholly dependent on time and prevailing weather. There are various micro-hydro projects, improved cooking jikos, biogas technologies, wind energy, solar power and improved water mills all used for adaptation and mitigation towards climate change. Increased use of renewable energies helps in reduced emissions of greenhouse gas and promotes carbon sequestration (Favero, *et al.,* 2020).

Furthermore, a considerable rise in the use of renewable energies is a vital strategy toward mitigating climate change in economic, sociological and health sectors leading to alternative sources of income, better education status, improved health, time savings, promotion of social capital and local job opportunities (Khurshid, *et al.,* 2022). The benefits accrued from climate change adaptation and mitigation from production of carbon dioxide emissions through renewable energies are significant at international, national, and local levels.

Renewable energy has a high potential of providing and covering domestic energy requirements without polluting the environment as it is environmentally friendly (Assi, *et al.,* 2021). Due to the high energy demand globally, there is a need to adopt renewable energy and replace conventional fuels as they contribute to different environmental challenges like greenhouse gas emissions, energy security and climate change (Suman, 2021). Many households especially in the rural areas have minimal knowledge on the importance of renewable energy to the environment even when most of these households have adopted different renewable sources of energy like solar panels, solar lighting, and solar lambs (Saim & Khan, 2021). Increased public awareness enlarges the market for renewable energy, purchase, and installation (Li, *et al.*,, 2020). Interaction will with the public will increase understanding on energy challenges people face making it easy to make better future plans (Cappa, , *et al.*, 2020).

2.2 Climate Change and Related Impacts

Climate change effects continue occurring and are now felt globally. Ice on lakes and rivers is now breaking apart earlier due to the high temperatures leading to melting of the ice, glaciers are shrinking, reduced biodiversity and flowering trees and plants are flowering earlier (Palakodeti, 2022). The scientists' earlier predictions are being observed including loss of sea ice, more intense heat waves, and increased sea level rise (Serdeczny, *et al.*, 2017). Mostly greenhouse gases result from unsustainable human activities contributing to the climatic changes being felt in the world today.

The extent to which climate change affects any region varies over a long period and the potential of different ecosystems and social systems to adapt or mitigate to climate changes. If climate change is not acted upon by the bigger population in the world, then we will continue to experience more and more climate change impacts like higher temperatures, longer frost-free season, shift in prediction patterns, increased heat waves and prolonged droughts, more intense and stronger hurricanes, sea level rise, flooding, melting ice and glaciers, reduced agricultural productivity, insect outbreaks, increased wildfires, negative health impacts and additional concerns.

According to (IPCC, Summary for Policymakers In Global warming of 1.5°C, 2018) the special report on the 1.5-degree earth warming indicates that climate change actions are needed urgently as the global emissions will be at a peak by 2030 and reduce rapidly by 2050 to net-zero if we stay within the Paris Agreement established safe limits. Climate change affects all economic and natural systems, therefore, there is a need to monitor how we interact with the environment like deforestation, waste management, greenhouse gas emissions, wetlands, and use of non-renewable sources of energy. The world has come together to work towards a common climate goal including setting up policies, environmental bodies and agreements which focus on reducing climate change. For example, the adaption of the Paris Agreements, UNFCCC, UNEP, Kyoto protocol, among others. There are suggestions which have proven to work well to manage climate change including protection of the biodiversity, marine environments, afforestation, and reforestation, using renewable sources of energy and soil carbon sequestration.

2.3 The Concept of Solar Photovoltaic

Solar photovoltaic technologies work through creation of electricity that is then used for different needs in households and enterprises whereas solar thermal technology are directly used to heat water or air. Solar photovoltaic technology products are usually purchased from retail shops or financed by financial institutions depending on the cost of the chosen technology. Some of the examples of the technologies include solar lamps, solar inverter, solar powered flashlights, solar powered radio, solar panels, solar streetlights, and solar traffic lights among others. Solar technologies are important in the national and international efforts to reduce greenhouse gas emissions and achieve the ambitious climate goals. Solar energy contributes to reliability and resilience of the electric grid making the county and country energy secure in the era of increased natural disasters which are now more evident and frequent resulting from climate change.

Among the solar technologies include solar panels that are great at offsetting the carbon dioxide emissions through displacing and replacing the current and future fossil fueled electricity sources as solar panels have a technical potential of 1,500–50,000 EJ per year (Muradov & Veziroğlu, 2008). The solar panels are easily mounted on the already existing structures for example on the rooftop to offer decentralized power. The offered storage battery increases the reliability of the solar panels as it powers through the dark days and at night. The estimated lifespan of solar panels ranges between fifteen to thirty years and has minimal maintenance costs after proper installation has been conducted. Among the maintenance works includes minimal cleaning. The photovoltaic cells directly convert sunlight into electricity. Installation of bigger solar panels help in heating hot water, running turbines to produce electricity, running machinery in industries, among others.

2.4 Policy Incentives

According to a study done by Chernyakhovskiy, (2015), on the state policy effectives that had been applied in the United States to increase solar photovoltaic capacity by households. From the carried-out study there was an undeniable positive relationship between solar photovoltaic demand and financial incentives that resulted into a reduction of the up-front cost of solar photovoltaic uptake, solar-specific mandates, and pro-environmental preferences. However, the context is entirely different in the least developing or the developing countries as the provided financial incentives aimed at reducing the actual costs of solar photovoltaic is assumed to have a crucial mandate in determining the household and societal behavior. The reason is due to the fact that the costs directly associated to solar photovoltaic remains a crucial factor that hinders the larger diffusion and uptake of the solar photovoltaic technology (Jabeen, *et al.*,, 2021).

2.5 Factors Affecting Mitigation Measures towards Climate Change

Mitigation actions at both the household and societal and community level are crucial as they have a significant contribution to greenhouse gases emission and are greatly impacted by the occurring climate changes (International Panel on Climate Change, 2013). There are several measures affecting the mitigation actions against climate change. The level of knowledge and financial status influences the extent to which the community takes climate actions. The educational level and age also affect the level of response.

People with higher environmental and climate change awareness influence people to make better decisions affecting climate change. They are willing to purchase green products and adaptive measures that reduce emissions and promote sustainable growth and agriculture. Also, people who understand the perceived risk of climate change are more willing to address issues of climate change and support all the implemented policies (Wong & Rubin, 2022).

Knowledge impacts people in various ways like affecting individual concerns and the will to take action or accept climate policies. Understanding and information about climate change is important to enhance action (McDonald , *et al.*, 2015). Financial self-efficacy in any households increases their confidence to execute the different measures put in place relating to climate change, despite their objective level of financial resources.

Social capital increases households and individual social networks that comprises of different relationships between family members, neighbors, friends, and others (Intergovernmental Panel on Climate Change, 2007). Social capital continues to gain importance in climate change as all the formed relationships offer knowledge, security, collective and support action among the different households fostering better climate actions. Socio-demographic characteristics are also important in climate related matters.

2.6 Solar Photovoltaic Energy in Climate Change Mitigation and Adaptation

Renewable energy is crucial in climate change mitigation and adaptation in the different parts of the world. Renewable energy has a huge potential in households, especially solar photovoltaic to help adapt and mitigate against climate change. Gradual use of solar photovoltaic will help in curbing greenhouse gas emissions and further increase carbon sequestration. Significant uptake of solar photovoltaic is a key strategy in adapting and mitigating climate changes in households and helps promote economic, health and social sectors resulting in job creation, improved health, time saving, better education status and promoting social capital. The accrued benefits of climate mitigation and adaptation from solar photovoltaic through reduced carbon emissions cuts across international, national, and local levels.

2.7 Current Status of Solar Photovoltaic Technology in Kenya

Kenya has signed and ratified the Paris Agreement and to align with its goals, through her Nationally Determined Contributions (NDCs) commits to pursue low emission climate resilient pathways to realize the 2030 vision, spilling over to global environmental goals. To achieve this, the country mainstreams climate adaptation and mitigation through Medium-Term Plans (MTS) and County Integrated Development Plans (CIDPs) and implementing mitigation and adaption actions (United Nations Framework Convention on Climate Change, 2020). Further, the country committed 21% totaling to $3.725 million to bear mitigation costs.

Solar photovoltaic technology creates and avenue for the country to reduce her greenhouse gas emissions and reduce the increased dependency on wood fuel-related sources of energy. According to (KiPPRA, 2024), there has been significant energy transition witnessed, with 89% of electricity generated from renewable resources with 1% coming from solar power in 2021. With the country’s location close proximity to the equator has an average of 5-7 hours of sunshine leading to solar energy potential of 4-6kWh/M2/day.

Creating and enabling environment by the government through the introduction of favorable subsidies and policies, creation of feed-in-tariffs and net metering through engagement with relevant stakeholders and local communities, and control importation and production of solar photovoltaic products ensuring their quality and reliability. These are some interventions that can promote harnessing of renewable energy contributing to reduction of greenhouse gas emissions and the achievement of global environmental goals.

2.8 Research Gap

According to (Schelly, 2014), there are many factors which highly affect household decision making regarding the uptake of solar photovoltaic. The author outlines that household uptake of solar photovoltaic is shaped not only by economic and biophysical structure but also by different lifestyle choices, information access, and an interplay of different indicators of household conditions. Furthermore, with the Bangladesh case, a study showed that several factors greatly determine the user satisfaction with respect to the uses of installed home solar systems (Komatsu, *et al.*, 2013). The study indicates that when the users have positive perception on the benefits accrued from uptake of solar home system resulted into increased satisfaction levels of the adopter, some of the perceived benefits included, changes in household lifestyle and quality equipment like increased study time for the children. Also, there is a peer influence that impacts the uptake of solar PV or energy by households and the society at large (Rai, , *et al.*, 2016). Other studies Crago and Ilya (2014) & Qureshi, *et al.*, (2017), found clear evidence indicated that financial aid or support from the government in uptake of the small solar photovoltaic systems greatly influenced their decision making. Other determinants of the solar energy adoption behavior by households are political, social, and economic De , Guido , & Frank, (2016); Davidson, *et al.,(*2014) and Rahut, , *et al.*, (2018) used (LSMS) the living standards measurement surveys of East Africa countries i.e., Uganda, Ethiopia, and Kenya to aid in investigating the various parameters affecting households' decisions on uptake of solar PV technology for various domestic needs. Some of the household demographic factors identified by authors included, wealth, family size, the house head education level, number of children and male adults in the household, all these factors have significant influence on household decision regarding solar energy. Comprehensively, through the concise review of the various existing literature clearly indicates limited but constantly growing and expanding evidence indicating the indicators of solar PV technology uptake. Nevertheless, meticulous minute household analysis of the uptake of solar photovoltaic technology in Kenya remains under-researched.

2.8.1 Climate Change Mitigation Strategy

Mitigation in climate change defines the different efforts put in place to help curb, prevent or reduce greenhouse gas emissions. Climate change mitigation encompasses different mechanisms including the use of renewable energies, making the older equipment more energy efficient or changes in consumer behavior or a change in existing management practices (United Nations Environment Programme, 2022). Solar photovoltaic is a clean and renewable source of energy as it directly absorbs the sun’s rays and converts it into usable energy. Compared to fossil fuels it helps reduce the carbon footprint and helps in reducing the overreliance of fossil fuels like coal and petroleum products. When generating energy using solar photovoltaic greenhouse gas emissions drastically reduce, especially carbon dioxide which eventually helps curb global warming which impacts climate change. By the uptake of solar photovoltaic at national, international, and local level it helps mitigate against climate change and promote a healthy and sustainable environment.

2.8.2 Climate Change Adaptation Strategy

Adaptation in climate changes implies the different sociological, ecological and economic system adjustments put in place by a community or the society in response to expected or actual climatic stimuli and their related impacts or effects (United Nations Framework Convention on Climate Change, 2022). Due to climate change impacts in the world including increased temperatures there is an increased need to curb the use of greenhouse gases emitting products and focus on green alternatives (Intergovernmental Panel on Climate Change, 2021). Uptake of solar photovoltaic helps in curbing the release of greenhouse gases as well as other sources of renewable energy like wind and hydro power. Overreliance on fossil fuels has been a great contributing factor to climate change. Adopting renewable energy will reduce the demand of fossil fuels and eventually help in climate change adaptation.

CHAPTER THREE: METHODOLOGY

3.1 Study Area

3.1.1 Study Area

Embu county is located Kenya with a population of over 608, 599 persons (Kenya Bureau of National Statistics , 2019). It borders with Kitui to the east, Kirinyaga to the west, and Machakos to the south and Tharaka Nithi to the North and occupies an area of 2,821km^2. It is divided into five sub counties, fifty-one locations and one hundred and twenty-seven sub locations and the people are mainly dependent on agriculture. The local people comprise of Mbeere, Embu and Kamba ethnicities. Embu people are mostly located in Runyenjes and Manyatta constituencies while Mbeere and Kamba are in Mbeere South and Mbeere North constituencies.

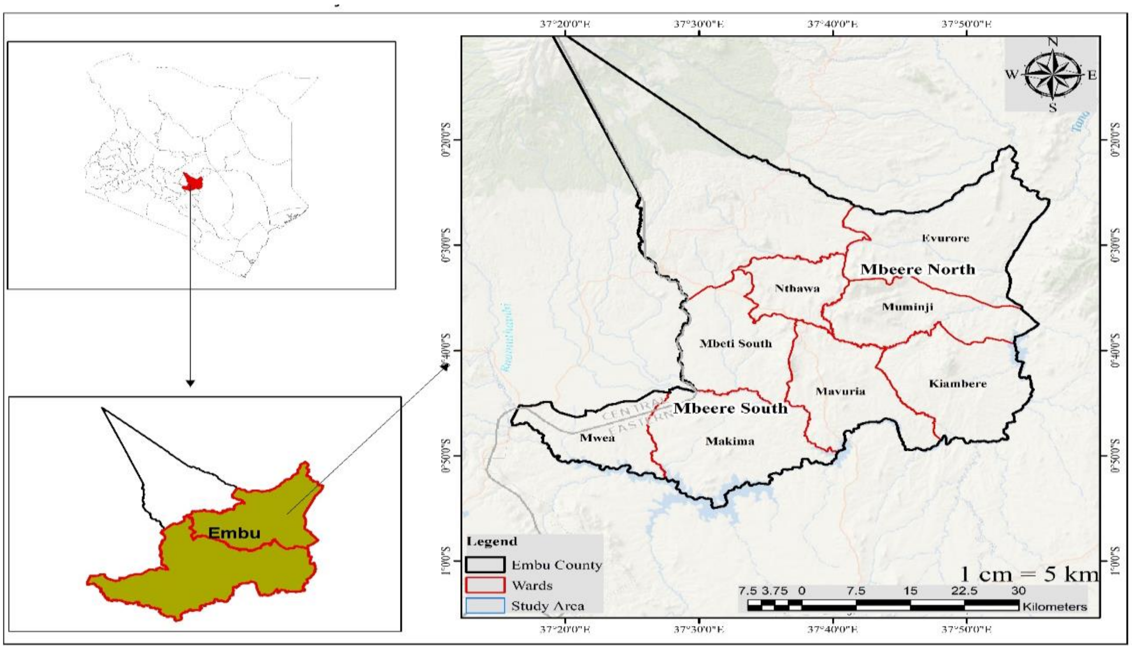

Figure 3.1: Study area showing Embu County

3.1.2 Topography and climate

Embu County is located towards South-East and East from North-West with some isolated hills like Kiang'ombe, Kiambeere and Kianjiru which rise above the general slope and height and has lowlands and highlands. The county is served by Several Rivers including Ruvingasi, Kii, Tana, Thuci, Thiba and Ina and they all are perennial rivers. The mean temperatures experienced are 21 °Cand July is the coldest month with a minimum of twelve degrees Celsius. March has the highest temperatures of up to 31℃. The rainfall experience goes to as high as 1,495 mm per year.

3.1.3 Climate in Embu County

Climate change is felt globally including Embu County. Some of the observed climate changes are changes in the amount of rainfall per season, reduced agricultural activities and yields, increased temperatures, increased pests and diseases, and reduced vegetation cover. There is a great need to formulate policies and educate the local community about climate change and the best mitigation mechanisms applicable to facilitate climate change impacts reduction.

3.2 Study Design

A descriptive survey design was utilized to assess and investigate the uptake of solar photovoltaic as mitigation measure to climate change in Embu County, which is a descriptive survey design. Data was collected using surveys and questionnaires then recorded the findings on how the resident's uptake solar photovoltaic, and mitigation actions towards climate change. Descriptive survey was used in the study where the researcher observes different variables, describes, and documents the gathered information as observed, carry out analyses and draw conclusions to the occurrences. In addition, the chosen approach offers the researcher an opportunity of collecting data, summarizing, interpreting it, and present the gather information in a clear, concise and easily understandable manner. Simply, this study will directly involve households in the study area that will suit well in a descriptive manner.

3.3 Population

The estimated population in Embu County is of 608, 599 people in Kenya and Mbeere North sub-county has a population of 53,517 (Kenya Bureau of National Statistics , 2019) and number of households is 29,528 (Kenya Bureau of National Statistics , 2019) and an annual growth rate of 1.7%. The unit study was individual households. The target population is the households in Embu County, Mbeere North Sub County.

3.3 Sampling Procedures

This study employs simple random sampling to obtain the required sample size from the identified target population in Embu County, Mbeere North Sub County.

3.7 Data Collection Procedures

Key informants and chosen households were used as the primary data sources. The key informants included community leaders and individuals who have lived in the study area for over 20 years. The reason behind this is that the people possess vital information of the area evolution and traditional knowledge of the area. In addition, secondary data sources were also utilized to further gather information about the study area. Some of the secondary data sources include unpublished and published reports from libraries and institutions which contain prior research carried out in the area, maps, and other relevant materials.

3.7.1 Interview Guides

The key informants in this study were households from the sub county and included /areas with and without electricity. The structure of the interview guides was in a manner that they captured all the five objectives of the research.

3.7.2 Observation Checklist

This was covering data on the type of mitigation mechanisms evidenced by the solar systems, water storage, sustainable agricultural activities and creation of retention dams observed in the area which promote climate change mitigation measures, data in this section was collected by photographs.

3.4 Sample Size

The Yamane formula (Yamane, 1973); was used to calculate the sample size

$$n = \frac{N}{1 + N(e)^2}$$

n= sample size N= population e= standard error – 0.06

Thus, the sample size was calculated as follows.

$n = \frac{29{,}528}{1+29{,}528(0.06)^2}$ =395. The sample size was of 395 respondents who was interviewed in the study area.

3.6 Instruments

For the first objective data was collected using questionnaires, which was administered to 395 respondents to get information through identifying the sources of energy utilized by households in Embu in the era of climate change. The second objective, questionnaires was administered to the respondents and key informant interviews to analyze the awareness about climate change in Embu County and third objective assess the perceptions of households about solar energy. The fourth is to evaluate the determinants of solar photovoltaic uptake by households and questionnaires, observations, and informant interviews was used to collective qualitative and quantitative data. The fifth objective, data was collected using questionnaires and recorded data from the Kenya meteorological department in Embu County.

3.8 Data Analysis

The collected data, consisting of both qualitative and quantitative information, underwent a cleaning process to remove any errors or inconsistencies. It was then entered and coded in Excel (2016), which allowed for efficient organization and management of the data.

For the statistical analysis, various tools were utilized. SPSS was primarily used for conducting statistical tests and generating descriptive statistics. The software provides a wide range of analytical capabilities, such as chi-square tests for non-parametric data, t-tests for parametric data, regression analysis, and correlation analysis. These analyses help in examining relationships, determining significance levels, and drawing conclusions based on the data. Objective one, which involved trend analysis, was performed using XSTAT, (2017). Trend analysis is useful for identifying patterns and changes over time, providing insights into the direction and magnitude of specific variables.

Demographic characteristics were subjected to descriptive analysis, which involved summarizing and presenting the data in frequency distribution tables, graphs, and pie charts. This analysis helps to provide an overview of the participants' characteristics and allows for easy interpretation and comparison.

By employing these statistical and descriptive analyses, researchers can gain a comprehensive understanding of the collected data. The statistical tests enable the examination of relationships, differences, and trends, while the descriptive analysis provides a clear and concise representation of the data through visualizations and summary statistics.

Table 3.1 Data analysis matrix showing the data collection procedures and data analysis to be used in the study for each objective.

Research objective	Type of data	Obtained data sources	Method of analysis applied	Statistical test
1	Temperature and rainfall trends	KMD	Man Kendall's Tau trend analysis	Man Kendall's and Sens slope
2	Sources of energy	Observations, questionnaires, interviews	Bar graphs	N/A
3	Solar energy uses	Questionnaires, observations	Bar graphs	N/A
4	Awareness	Questionnaires	Likert scale	N/A
5	Determinants of solar energy uptake	Questionnaires, field observations, interviews	Binary probit regression	Z test

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter is centered on the analysis, interpretation, and presentation of data. Its aim was to examine the various factors that affect the uptake and utilization of solar technology. The study had several objectives: first, to evaluate the rainfall and temperature trends in Embu County, second, to evaluate how the knowledge and awareness of solar technology impact the adoption of solar power systems in households; third, to identify the sources of energy utilized by households in Embu County; fourth, to classify solar energy uses at household level, and lastly, to evaluate the socioeconomic determinants of solar energy adoption by households in Embu County.

4.1 Demographic Characteristics

4.1.1 Age distribution

Determining the distribution of the respondents was important in two dimensions. One, different age groups have varying levels of awareness, knowledge, and attitudes towards climate change and renewable energy. Younger generations tend to be more concerned about environmental issues and are more likely to support renewable energy initiatives like solar power. Older generations may have different priorities and may be less inclined to adopt new technologies. Second, age influences decision-making power in households and organizations. Understanding the age demographics of respondents helps identify the key decision-makers who can drive the adoption of solar energy. For example, if a survey shows that older homeowners are more likely to make decisions about home renovations, targeting them with information about the benefits of solar energy could be more effective.

Table 4.1: Respondents' Age-Gender Distribution

	Age (Years)										
	18-25		**26-44**		**45-59**		**> 60**		**Total**		
Gender	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**Mean Age**	**Std**
Male	26	18.31	82	57.75	27	19.01	7	4.93	142	37.89	13.20
Female	32	12.65	171	67.59	46	18.18	4	1.58	253	37.12	10.61
Total	**58**	**14.68**	**253**	**64.05**	**73**	**18.48**	**11**	**2.78**	**395**	**37**	**0.7**

From table 4.1, the mean age of female respondents was 37.12 years, and male respondents was 37.89 years. This shows that male members were older than the female counterparts. There was a larger standard deviation among males, an indication means that male respondents ranged between the mean age and individual age was higher compared to the female group.

According to the Kenya National Bureau of Statistics census reports, (2019) in Embu County the mean age is 35.6 years-based results of people who were 18 years and above during the census period, The same reports indicated that region had slightly higher number of females forming up to 51% of the total population compared to the male population, contrary to our study finding which placed men to the dominating the target population.

4.1.2 Religion

In understanding Cultural Factors: Religion often plays a significant role in shaping cultural beliefs, values, and practices as argued by (Tarakeshwar *et al*., 2003). By collecting data on respondents' religion, the study intended to gain insights into how religious beliefs and practices influence individuals' attitudes and behaviors towards solar energy adoption. This information can help identify potential barriers or facilitators to the uptake of solar energy within specific religious communities. The results are presented in Figure 4.1. Majority of the respondents were Christians with only 3% as Muslims, none of the respondents were either Hindus or other religions as represented by others.

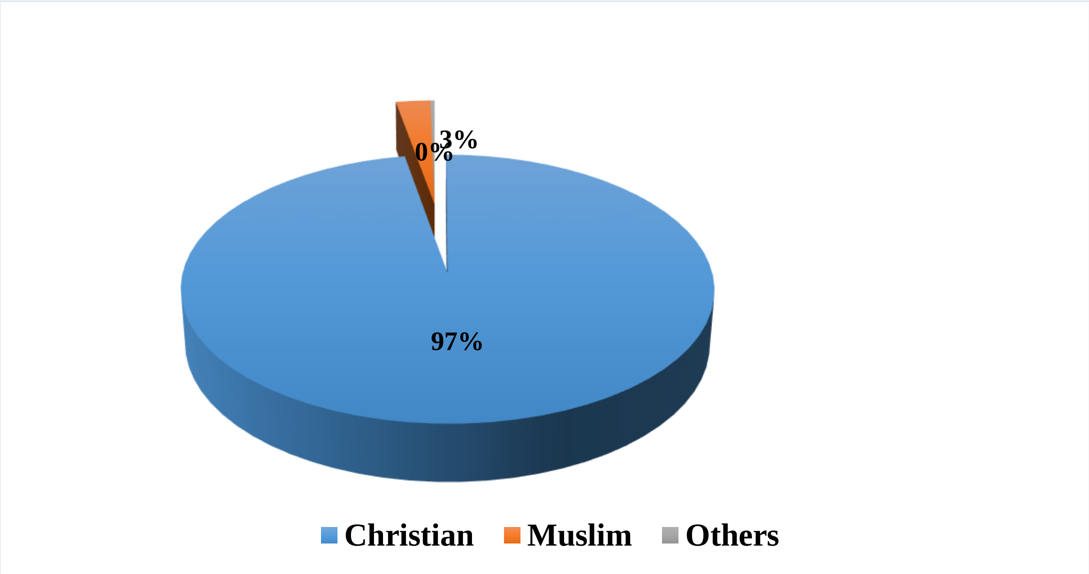

Figure 4.1: Respondents distribution by religion

4.1.3 Education Level

Table 4.2: Respondents' Gender-Education Distribution

	Education Level								**p-value**
	Primary		**Secondary**		**Tertiary**		**None**		**df**
Gender	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	χ^2
Male	41	29.08	70	49.65	29	20.57	1	0.71	-207
Female	116	46.24	114	45.24	21	8.33	1	0.4	3
Total	**157**	**39.95**	**184**	**46.82**	**50**	**12.72**	**2**	**.0.51**	**17.69[a]**

From Table 4.2, a total of 39.95% of the respondents had primary education, while 46.82% secondary, 12.72% had tertiary (diploma, degree and postgraduate) and only 0.51% had no education. However, male respondents had higher education level compared to the female as illustrate in table 4.2. This implies that most of the respondents had secondary education as their highest level of education. The table also shows that all the graduate students responded that their highest level of education graduate level, while most of the female members had primary education, and the almost an equal number with secondary education, graduate and post graduate education. The respondents had secondary school as their highest level of education.

The results compare with reports of Kenya Demographic and Health survey, Kenya National Bureau of Statistics , (2023) most of the samples male respondents had higher education compared to the female counterparts and the cumulatively most of respondents in their sample had up to secondary education which was always as a result of wealth index. Percentage of both women and men with more than secondary education with the wealth quantile of the family. However, there was contrasting evidence in respondents that had low education. Our study reported that most of the who had up to primary education were female which was, this was not the case with reports from KDHS, 2022 and KNBS 2019, that reported most men also had the lowest education (had only attained primary education) at the time of survey.

4.1.4 Marital Status

Tabulating the data across marital status, gender, and household head allows for an examination of the relationship between these factors and their influence on financial stability and decision-making within a household. Married couples, due to their combined incomes and shared expenses, may have different capabilities when it comes to investing in renewable energy technologies such as solar panels. The availability of financial resources and the priorities set by the household play a significant role in determining the adoption of solar energy systems, which often entail upfront costs despite long-term savings.

Table 4.3: Respondents' Household and Marital Status

Household head			**Marital Status**						**Total**	
			Married		**Single**		**Divorced**			
			N	%	N	%	N	%	N	%
Mother	Gender	Male	16	45.71	19	54.29	0	0.00	35	8.86
		Female	54	52.94	47	46.08	1	0.98	102	25.82
	Total		**70**	**51.09**	**66**	**48.18**	**1**	**0.73**	**137**	**34.68**
Father	Gender	Male	75	72.12	29	27.88	0	0.00	104	26.33
		Female	111	75.51	35	23.81	1	0.68	147	37.22
	Total		**186**	**74.10**	**64**	**25.50**	**1**	**0.40**	**251**	**63.54**
Other	Gender	Male	1	33.33	1	33.33	1	33.33	3	0.76
		Female	3	75.00	1	25.00	0	0.00	4	1.01
	Total		**4**	**57.14**	**2**	**28.57**	**1**	**14.29**	**7**	**1.77**
Total	Gender	Male	92	64.79	49	34.51	1	0.70	142	35.95
		Female	168	66.40	83	32.81	2	0.79	253	64.05
	Total		**260**	**65.82**	**132**	**33.42**	**3**	**0.76**	**395**	**100.00**

According to the study, the majority of the respondents were married, with only 1% 0.76% reporting being divorced. Single respondents also formed a significant portion, accounting for 33.42% (n=132) of the total participants. Interestingly, despite there being a higher proportion of female respondents overall, when it came to household heads, fathers dominated at 74.10%, while mothers headed households where the respondents were single.

Regarding gender and marital status, the study found that a larger percentage of females tended to be married compared to their male counterparts, who were more likely to be single. This finding can be attributed to the fact that, in many societies, women often enter marriage as a result of societal expectations and cultural norms, whereas men are more likely to remain single until later in life or choose not to marry at all. Consequently, it was more common to find females in a married status than males.

These findings reflect the socio-cultural dynamics of the study area. It is important to note that cultural and societal norms can vary significantly across different regions and populations, and the study's results may not necessarily be representative of all communities. However, within the specific context of this study, the higher prevalence of married females and single males aligns with the traditional gender roles and expectations that shape relationships and family structures in that area.

4.2 Trends in Temperature and Precipitation for the Last 40 years

Determining the trends in temperature and precipitation over the last 40 years in Embu County (1980-2020) is significant for several reasons when considering the adoption of solar technology. The rainfall and temperature data were obtained from Embu Metrological department for a period of 40 years. Understanding the historical climate data, including temperature and precipitation trends, helps assess the solar energy potential in Embu County. Solar energy generation relies on sunlight, and by analyzing long-term weather patterns, one can estimate the availability and intensity of sunlight in the region which then would influence the uptake of solar technology.

Higher levels of sunlight and lower cloud cover indicate a greater potential for solar energy generation. Similarly, examining temperature and precipitation trends over the past 40 years helped in identifying climate change patterns in Embu County. Evidence of increasing temperatures or shifts in precipitation patterns as presented in figure 4.2 and 4.3, points for necessity adopting for sustainable energy alternatives like solar power.

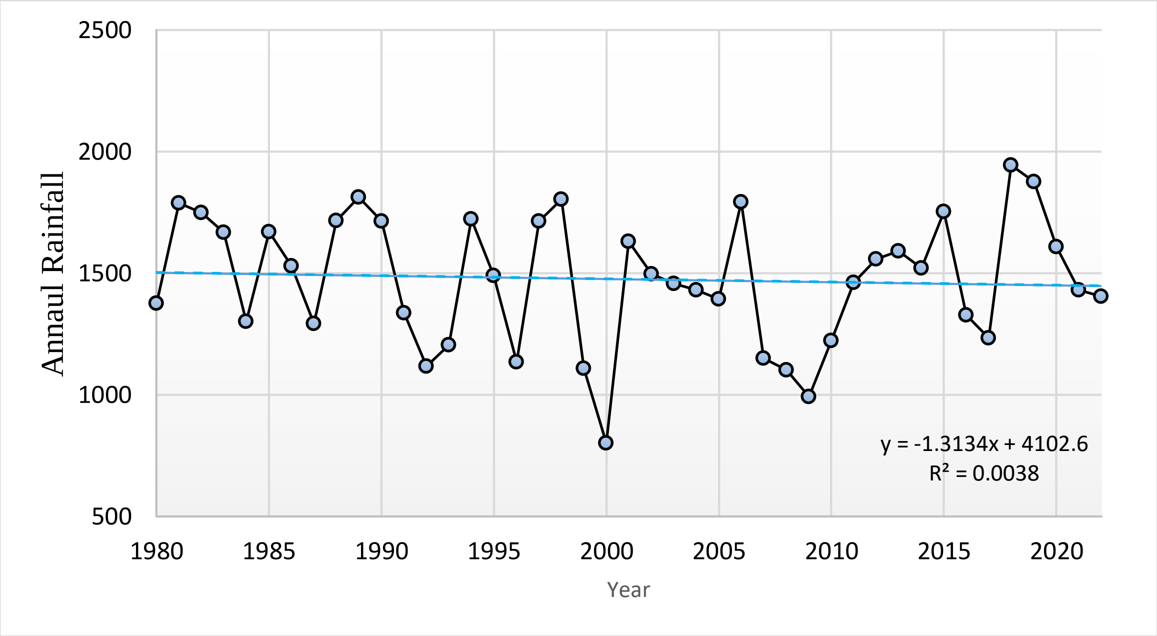

Figure 4.2: Annual Average Rainfall Variation 1980-2022

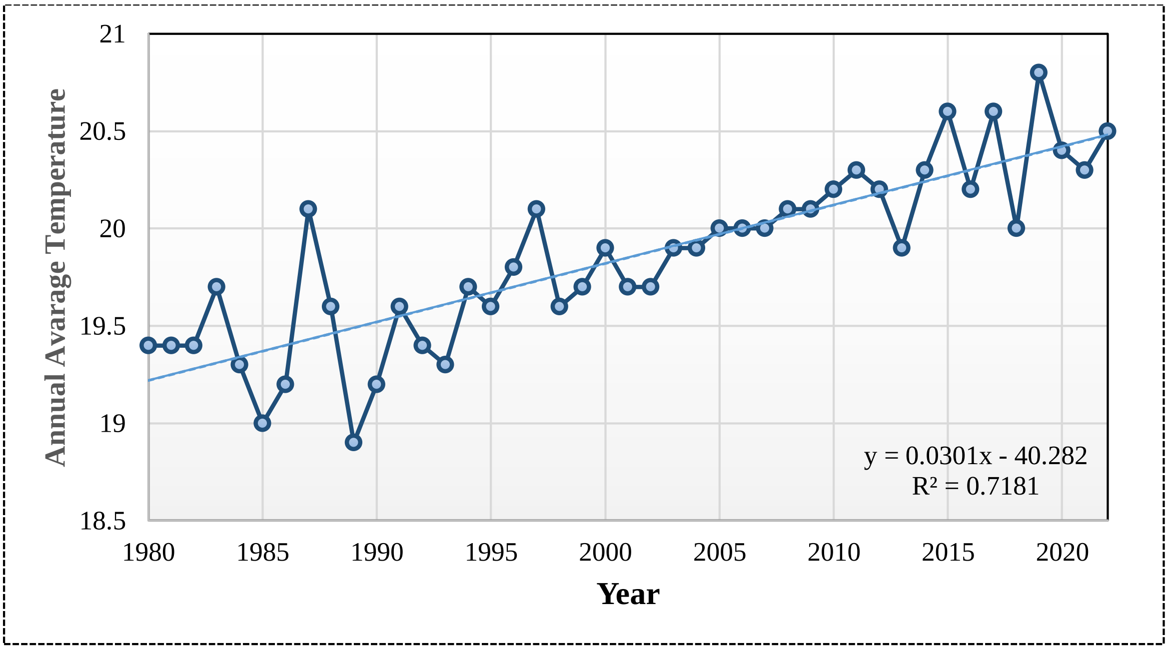

Figure 4.3: Annual Average Temperature variation 1980-2020

Table 4.4: Man Kendall's Trend Analysis of Rainfall and Temperature Variation, 1980-2022

Climate Variation	Kendall's tau	S	Variable (s)	P-value	Sens Slope	Lower bound (95%)	Upper bound (95%)
Temperature	0.713	626	9060	**<0.0001**	0.03	0.025	0.037
Rainfall	-0.059	-53	9128.333	0.586	-2.433	-9.126	5.200

4.2.1 Temperatures Variation, 1980-2022

From the annual temperatures computed from Embu Meteorological department, Kendall's Tau (τ) Value (0.713 indicates a relatively strong positive correlation between the temperatures and years under study over the 40-year period.

Additionally, a Sen's Slope Value of 0.03 suggests a positive trend in the data over the 40-year period implying an overall increase in temperatures by 0.03. The slope value represents the average change in the dependent variable, temperatures (y-axis) per unit change in the independent variable, years (x-axis). Therefore, a slope of 0.03 indicates a positive and significant increase in the variable being analyzed over the 40-year period.

As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.

Overall, based on the Kendall's tau value of 0.713 and Sen's slope value of 0.03, it can be inferred that there is a strong positive correlation between the variables, and there is a significant upward trend in the data over the 40-year period.

A similar study, focused on assessing the determinants of climate adaptation and perception of small holder farmers in Embu County using data from the same meteorological dependent on different time Scale, (1976-2016) recorded similar finding to this study. The analysis demonstrated a statistically significant increase in both the minimum and maximum temperatures over a 40-year period. Specifically, from the Embu station, the minimum temperature has seen a rise of 0.014°C, with a linear equation of y=0.0135x - 24.936. Similarly, the maximum temperature has experienced a rise of 0.032°C, following the equation y=0.0318x - 38.806, (Ruth, *et al.*, 2021). Same scenarios of increasing temperatures have been recorded in other parts of Kenya, indicating an overall increase in temperatures, (Nzau, 2014); (Marigi, 2017); (Chaudhury *et al.*, 2020); (Kogo, *et al.*, 2021).

4.2.1.1 Temperature Variation (MAM) and OND

In the four seasons, short and long rain seasons are always the sensitive periods when people become more conscious about climate, (Marigi, 2017); (Chaudhury, *et al.*, 2020). According to Ruth, *et al.*, (2021), Embu residents recognized climate variability during the planting seasons compared to other seasons in the year.

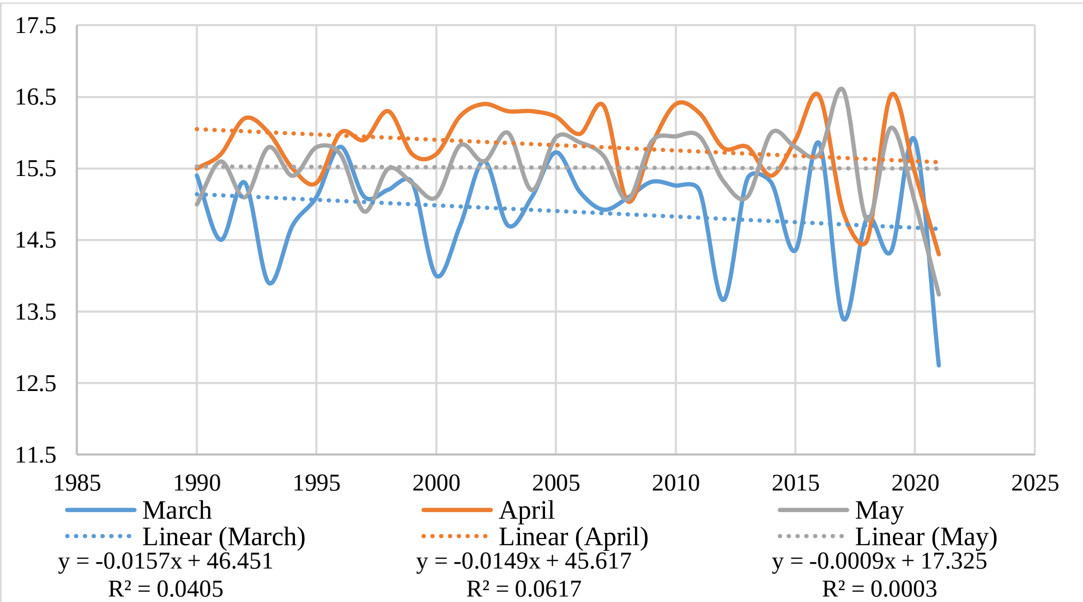

Figure 4.4: March-April-May (MAM) Temperature variations

The results indicate decreasing temperature in all the three months despite the average temperature showing an increasing trend over the study period with a significance of 71.81% (R^2 = 0.301), figure 4.3. The regression analysis showed that time was a significant predictor of the average temperature (p = 0.017). However, on the selected months, (MAM) during the long rains, average temperature showed a non-significant decreasing trend of; 0.03% (R^2 = 0.0003) in May, 6.17% (R^2=0.0617) in April and 4.05% (R^2=0.0405) in March (Figure 4.4). The regression analysis showed that time was not a significant predictor of minimum temperature (p = 0.421) over the study period.

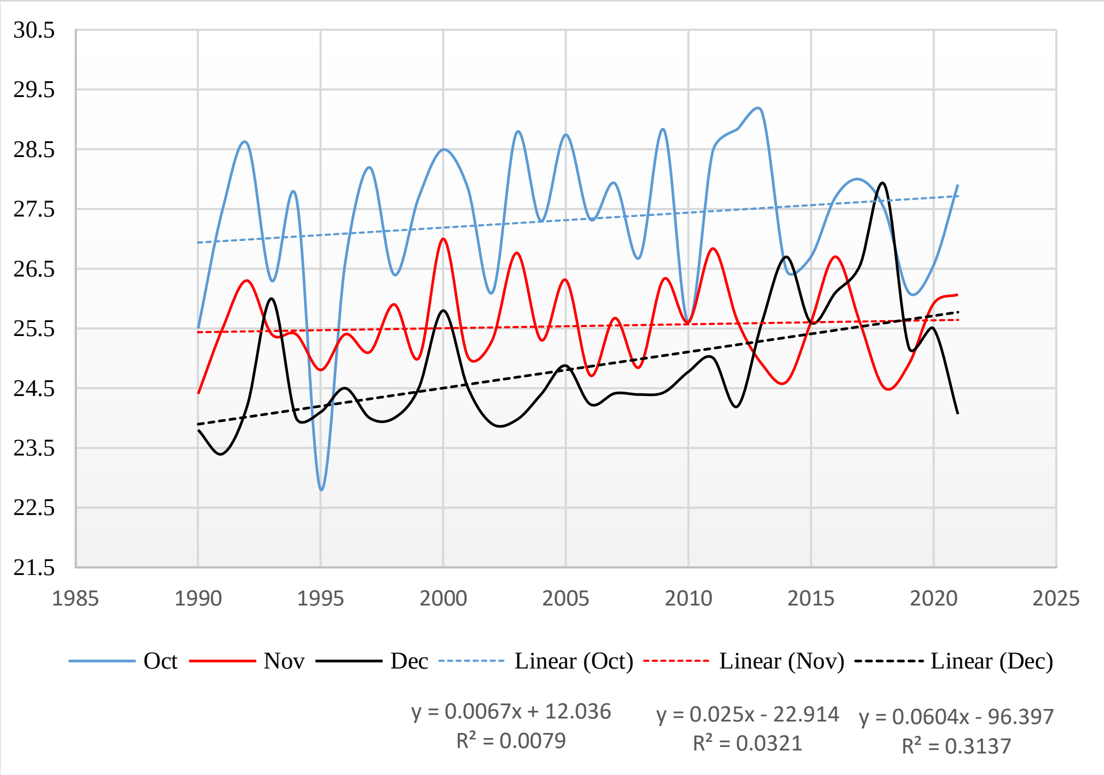

Figure 4.5: October-November-December (OND) Temperature variations

There has been a notable overall temperature increase during the short rain season over the years, specifically in the months of October, November, and December. When comparing the temperatures recorded in these months to those in 1980, we observe an increase of 0.0250°C in October, 0.00670°C in November, and a more substantial increase of 0.06040°C in December.

The analysis of the two selected seasons, the long rains (March-April-May - MAM) and the short rains (October-November-December-OND), paints a revealing picture of temperature trends over time. In the long rain season (MAM), there is a noticeable trend indicating a decrease in temperature over the years. This implies that during this season, the region has been experiencing a cooling effect. The temperatures during March, April, and May have shown a tendency to be slightly lower as time progresses, reflecting a consistent pattern of cooling over the study period.

Conversely, the analysis of the short rain season (OND) displays an opposing trend. In this season, there is a clear and consistent increase in temperatures as the years advance. October, November, and December exhibit a warming pattern, signifying that the region experiences progressively warmer temperatures during this season. The warming trend is particularly prominent, suggesting a significant shift towards warmer conditions during the short rains.

4.2.2 Rainfall Variation Trend, 1980-2022

From the analysis in table 4.4, Kendall's tau value of -0.059 suggests a moderate negative correlation between the variables (rainfall in 40-year period) under consideration. This implies that as one variable (e.g., time) increases, the other variable (e.g., rainfall) tends to decrease, but not in a perfectly linear manner. The magnitude of -0.059 indicates the strength of the negative correlation, with values closer to -1 representing stronger negative relationships. Similarly, an estimation of slope to determine the linear trend the 40-year period (-2.234) suggests a downward trend in the rainfall data over the 40-year period.

Taken together, the Kendall's tau value of -0.059 and the negative Sens Slope value of -2.234 indicate a moderate negative correlation and a significant downward trend in the rainfall data over the 40-year period. This suggests that, on average, rainfall has been decreasing over time during this period. However, it is important to note that this interpretation assumes the validity of the statistical analysis and the representativeness of the data. As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.

The result compares with research conducted by Ruth *et al*., 2021, that examined the variability in East African Oscillation (EOF) rainfall data, focusing on two stations: Embu and Kiambeere. The study found that Embu station experienced an average annual rainfall of 3553 mm, with a standard deviation (SD) of 81.57 and a variance of 6653.96. The linear equation used to model this data was y = -10.0171x + 376.65. Study by Mbaka, *et al.*, (2019), on rainfall variability in eastern Kenya, between 2001 and 2013 indicated that Embu received more average rainfall 2002, 2003 2007 and 2001, similar to our research findings during the same period

4.2.1.1 Rainfall Variation (MAM) and OND

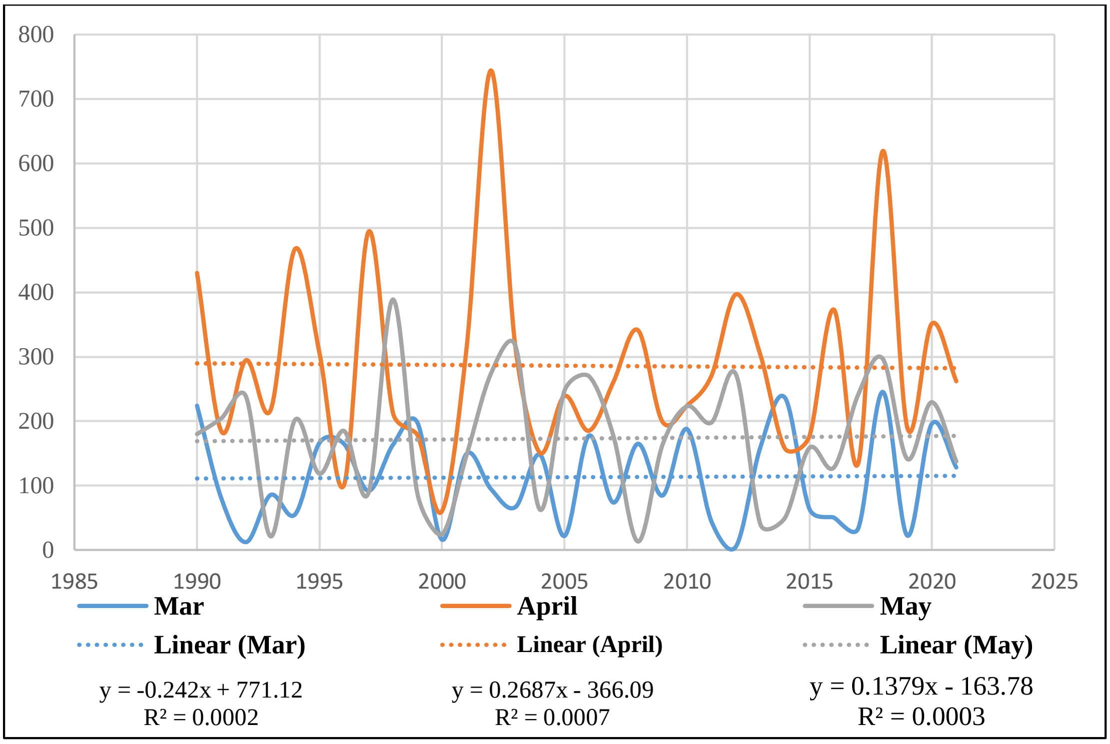

Figure 4.6: March-April-May (MAM) Rainfall variations

Figure 4.6 illustrates a moderate positive trend in rainfall in the months of May and March, implying a consistent rise in temperatures within the studied area from the year 1980 to 2021. However, the months of April and May experienced a general increase in rainfall of the 40-year period. April was the wettest month during the wet seasons, with mean rainfall averaging 285.7mm during this period. In contrast, March stands out as the month with least rainfall at a mean rainfall of 112.75mm. These rainfall fluctuations help in understanding the region's climate patterns and how they evolve over time, as these insights helps in addressing, the possibility climate variability influencing the adoption of adoption of solar power, as a global role in reducing the carbon footprint.

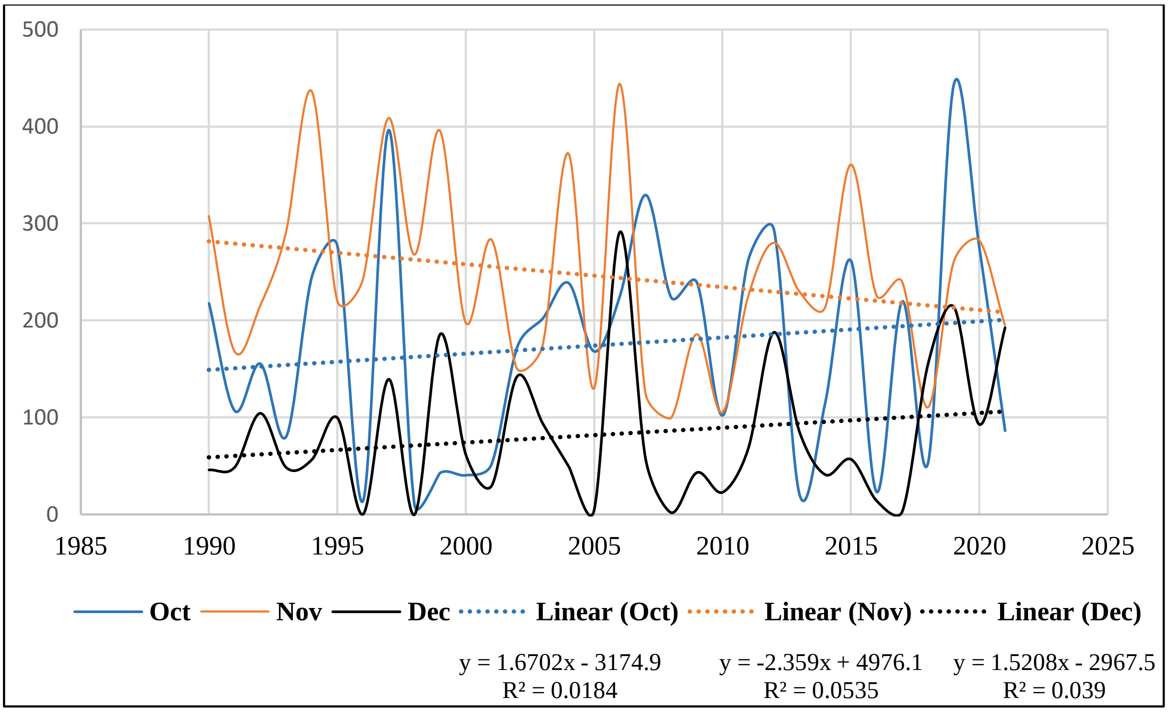

Figure 4.7: October-November-December (OND) Rainfall variations

4.2.3 Effects of Climate Variation on Uptake of Solar Photovoltaic Technology

The perceptions of respondents regarding climate trends align with actual observed climate patterns (rainfall and temperature) in the Embu County. A significant majority of residents within the area have noticed noticeable shifts in the climate over time they have stayed in the study area. Specifically, 88.5% (253 individuals) of respondents acknowledged reduction in precipitation during this period during the long rains (MAM) and the short rains (OND), highlighting the gravity of water scarcity events. Additionally, a substantial portion of the respondents, 86.0% (246 individuals), noted the increasing temperatures in the two seasons. However, different results were recorded by Mbaka, *et al.*, (2019). Further, Mbaka, *et al.*, (2019) stated that rainfall patterns have become increasingly unpredictable, with a noticeable shift in the rainy season. The short rainy season has been observed to start earlier, moving from mid-October to late October and early November. This change indicates a significant alteration in the rainfall cycle, which could have implications for water availability, agriculture, and overall climate change adaptation strategies in the region.

These observations not only resonate with the perceived climate trends but are also consistent with the trend analysis. Their numbers reflect the gravity and frequency of these climate-related events as perceived by the local population, aligning with the objective trend analyses. (Ramalho, *et al.*, , 2022), points to the need of understanding these perceptions and aligning them with scientific analyses is essential for comprehensive climate risk assessment and informed decision-making regarding climate adaptation and mitigation strategies as presented in Table 4.5.

Table 4.5: Climate Variation and Uptake of Solar Photovoltaic Technology

	Solar Photovoltaic Technology Uptake						Total	
Trends in	**Increased**		**Reduced**		**No Impact**			
climate	n	%	n	%	n	%	n	%
Yes	174	47.28	43	11.68	149	40.49	368	93.16
No	6	22.22	4	14.81	17	62.96	27	6.84
Total	**180**	45.57	**47**	11.90	**166**	42.03	**395**	100.00

The respondents were surveyed about whether the trends in climate variation had influenced their adoption of solar technology. Similarities results on perception on climate variation was recorded by (Ruth *et al.*, 2021). Although a majority of the respondents acknowledged the impact of climate variations, less than half of them indicated that it had actually increased their uptake of solar energy. It is worth noting that most of the respondents who reported no climate variations also stated that it had no impact on their decision to adopt solar energy. This finding highlights the complexity of the relationship between climate variation and the adoption of solar technology. While many individuals recognize the existence of climate variations, the actual influence on their decision-making regarding solar energy uptake seems to be more nuanced. It suggests that factors other than climate variations alone may be influencing the adoption of solar technology.

4.3 Energy Sources Utilized by Households

The utilization of energy sources within households plays a central role in shaping energy consumption patterns and has significant implications for climate change mitigation efforts, (Mbaka, *et al.*, 2019). In recent years, there has been increasing attention towards renewable energy technologies, particularly solar photovoltaic (PV) systems, as a sustainable alternative to traditional fossil fuel-based energy sources. Understanding the types of energy sources adopted by households is essential for assessing the uptake of solar PV technology and its potential contribution to climate change mitigation efforts.

Kenya national population and housing census (Kenya National Burea of Statistics , 2019) summed 5 main energy sources for both cooking and lighting to be commonly used as by households. The energy option asses were adopted from KNBS census, respondents were asked to indicate among them which they used in their households as presented in Table 4.6,

Table 4.6: 3 out of the 5 energy sources utilized by the respondents.

	Firewood				**Gas**				**Paraffin**			
	Yes		**No**		**Yes**		**No**		**Yes**		**No**	
	n	%	n	%	n	%	n	%	n	%	n	%
Gender												
Male	62	43.7	79	55.6	34	23.9	108	76.1	31	21.8	111	78.2
Female	86	34	163	64.4	33	13	220	87	38	15	215	85
Total	148	37.5	242	61.3	67	17.	328	83	69	17.5	326	82.5
Education Level												
Primary	58	36.9	98	62.4	19	12.1	138	87.9	22	14	135	86
Secondary	65	35.3	117	63.6	28	15.2	156	84.8	32	17.4	152	82.6
Tertiary	24	48	24	48	19	38	31	62	15	30	35	70
None	1	50	1	50	1	50	1	50	0	0	2	0
Total	148	37.7	240	61.1	67	17	326	83	69	17.6	324	82.4

According to the survey conducted among household heads, it was found that the majority of households opted for firewood as their preferred choice for cooking. Specifically, 37.5% of the surveyed households reported using firewood for their energy needs. This indicates a significant inclination towards renewable energy sources for energy sources. In contrast, 17.6% of the households surveyed mentioned using paraffin as their primary lighting choice. According to, Mbaka, *et al.,* 2019) on their study "**Households' energy preference and consumption intensity in Kenya", they established that** was established that wood fuel was a dominant (91.06%) source of energy for rural households while LPG (70.48%) and electricity (67.53%) are dominant energy sources for urban households. Additionally, the similarity in the results are evidenced by Kimutai and Talai, (2021), that pinned firewood as the most dominate energy source for cooking at 87.5% and 72.4%, in the rural and urban respectively.

Paraffin, although widely used, is a non-renewable energy source that is derived from petroleum. Despite its popularity, its usage poses challenges in terms of sustainability and environmental impact. On the other hand, firewood is a readily available resource in many areas but contributes to deforestation and indoor air pollution, (Mahushi, *et al.,* 2021). It is also worth noting that households at times may have all the named sources of energy and occasionally use one as substitutes to the other. Firewood was reported to be the most used energy source amongst the three-energy sources by both genders. However, more female respondents reported to be using paraffin (15.0%) than Liquid petroleum gas (13.0%) while more male respondents reported the inverse.

Regarding education levels, households led by individuals who had up to primary education exhibited a substantial reliance on wood energy sources, with usage exceeding 86.9%. This trend underscores the correlation between education, socioeconomic status, and energy source selection within households, highlighting the need for targeted interventions to promote sustainable energy practices among diverse socioeconomic groups. Similar results are observed in study by Mbaka *et al.,* 2019). Where most of the respondents with no education relied more on firewood as their primary sources of energy.

4.3.1 Electricity and Solar Uptake

The two energy sources were examined independently as they were commonly used for lighting, charging of phone, and other commercial purposes and not specifically for cooking as the three others, (Baek, *et al.,* 2020). The survey revealed that up to 35.2 % of the households relied on electricity for lighting similar findings, however slightly higher to what (Baek, *et al.,* 2020), on the study involving "Analysis of Residential Lighting Fuel Choice in Kenya: Application of Multinomial Probability Models", got. Their study revealed that 33.39% of the respondents surveyed deepened on electricity at least for lighting. These figures indicate a relatively lower preference for it.

Respondents who utilize solar energy where at 61.3% indicated to be utilizing it as presented in table 4.7. While electricity may be regarded as a convenient option, it often requires infrastructure development and can be costly has highlighted by households who did not install the electricity as presented in Figure 4.8.

Table 4.7: Uptake of Solar and Electricity

Energy Sources		Frequency	Percent
Electricity	Yes	139	35.2
	No	252	63.8
	Missing	4	1
Solar Energy	Yes	242	61.3
	No	146	37.4
	Missing	3	0.5
Total		**395**	**100.0**

Respondents who indicated not to have on grid supply of power were further asked to indicate reasons why they had not installed the energy source, in order to examine main reasons why the respondents had certain level of electricity uptake. Figure 4.4, indicates that most of the respondents (n=182, 72.2%) did not have electricity due to its high cost of installation. Availability of other sources of energy also influenced a significant number of respondents to install electricity in their homesteads with 18.6% attributing so.

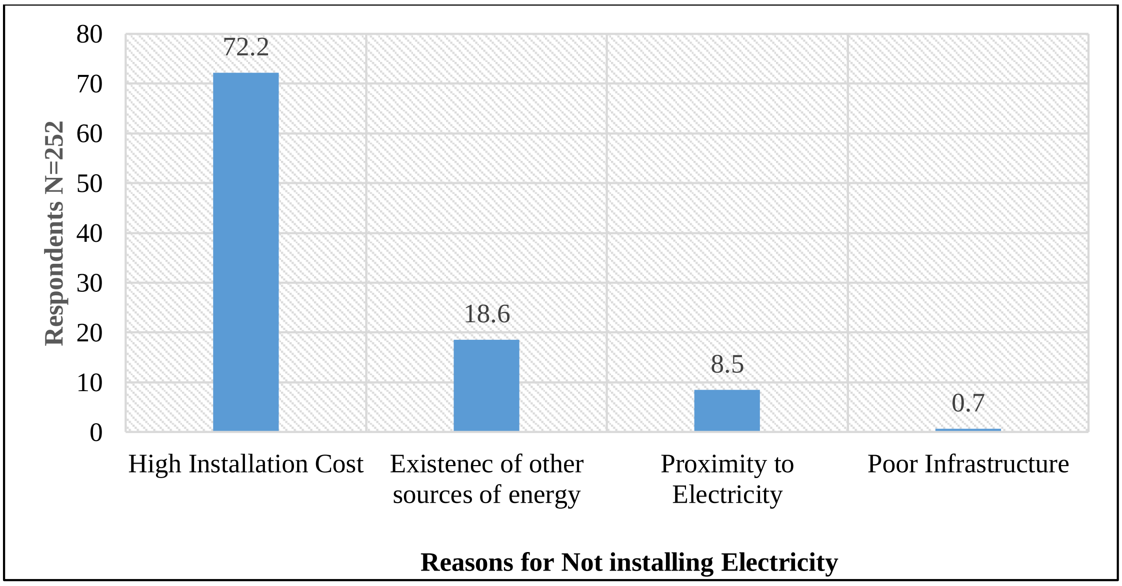

Figure 4.8: Reasons for not Installing Electricity

Among the solar items that were examined from the households, solar panels and solar powered bulbs and, (52.15% and 30.89%, respectively) were common photovoltaic element among most households. This indicates that majority used the solar systems for lighting and no other uses the results aligning with the (Kenya National Bureau of Statistics , 2019) which indicated a rise in usage of solar for lighting at 23.9% compared to those who used it for cooking at 0.2% in Embu County. Figure 4.8 shows the variation in different types of photovoltaic items with the lowest attributed items being the street lighting and solar powered phones at 7.59% and 13.6% respectively.

Survey by (Energy Sector Management Assistance Program , 2021) showcase similar results. The data shows that while households not connected to the electricity grid have higher proportions of solar home systems compared to those connected, the reasons for being unconnected vary significantly. Households that are too far from the grid and those that do not connect due to high connection costs show distinct differences in solar adoption. Specifically, households that cite high connection costs as the primary reason for not being connected to the grid exhibit a lower proportion of solar devices. This suggests that financial constraints, particularly the high cost of connecting to the grid, play a significant role in limiting the adoption of solar energy among unconnected households. The survey delved deeper by inquiring about the perceived usefulness of the solar items owned by the households. By evaluating the respondents' opinions regarding the effectiveness of their solar products, valuable insights can be gained regarding the practicality and satisfaction levels associated with using solar energy for lighting purposes.

4.3.2 Usefulness and Effectiveness of Solar Items

The survey further sought to understand the degree to which the solar items owned by the households fulfilled their intended purpose. Participants were asked to rate the usefulness of their solar products on a scale, allowing them to express their level of satisfaction and reliance on these devices. This assessment aimed to gauge the overall performance and effectiveness of solar lighting solutions in meeting the lighting needs of the households.

By exploring the usefulness of solar items, the survey aimed to uncover the advantages and drawbacks associated with solar energy as a lighting choice. Positive ratings would signify the effectiveness of solar products in providing reliable and efficient lighting, meeting the expectations and needs of the households. Conversely, lower ratings would indicate areas for improvement or potential challenges faced by the households in utilizing solar energy. The rating was 4 scaled typed categorized as very useful, useful moderate and not useful as presented in the Table 4.8.

Table 4.8: Usefulness of Different Solar Photovoltaic Items

Solar Photovoltaic Items	Solar Usefulness									
	Very Useful		Useful		Moderate		Not Useful		Total	
	n	%	n	%	n	%	n	%	n	%
Solar Street Lighting	11	**36.67**	15	50.00	4	13.33	0	0.00	30	7.59
Solar Powered Phones	25	48.08	24	46.15	3	5.77	0	0.00	52	13.16
Solar Panels	126	61.17	48	23.30	32	15.53	0	0.00	206	52.15
Solar Powered Torch	40	50.63	24	30.38	15	18.99	0	0.00	79	20.36
Solar power Lantern	93	50.00	18	39.13	4	8.70	1	2.17	115	29.26
Solar Powered Bulb	51	41.80	42	34.43	27	22.13	2	1.64	122	30.89
Total	**276**	**69.87**	**171**	**43.29**	**77**	**19.44**	**3**	**0.08**	**-**	**-**

Generally, the results indicated that most of the respondents had a positive perception in the uptake of solar energy and perceived them as useful. When individual solar items were cross tabulated with the effectiveness reposes as presented in Table 4.7, solar panels were perceived to be very useful (n=126, 61.17%) among other items. Solar powered torch despite not being popular among the respondent, it was also perceived secondly to be very useful (n=40, 50.63%). Solar powered phones were regarded to be useful. On effectiveness, all the items were very effective (very useful) compared to other rates except for the solar Street lighting where most respondents regard it as useful (n=15, 50%). This would be as result of its unpopularity among the respondents. It is important to also note that only two items were pointed out as not useful, solar powered bulbs and lanterns because of their reduced durability rate.

4.3.3 Usage of Solar Energy

Objective 3 sought to examine solar energy uses at household level. A list of common uses of solar energy with households adopted from (Kenya National Bureau of Statistics , 2019) was adopted and subjected to the respondents to indicate where they often use solar energy. The variable "gender" was included in the model as an intercept to examine the variations in solar energy utilization among different respondents. The analysis of the results is presented below.

Table 4.9: Gender and Uses of Solar Energy

	Cooking		Lighting		Charging		Heating		Commercial		TV and Radios	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Male	20	14.1	96	67.6	65	45.8	16	11.3	10	7.0	65	45.8
Female	17	6.7	177	70.0	76	30.0	25	9.9	12	4.7	60	23.7
Total	37	9.4	273	69.1	141	35.7	41	10.4	22	5.6	125	31.6
P-Value	-0.002		-0.031		0.158		0.28		0.055		0.228	
df	2		2		1		1		1		1	
χ^2	0.859		7.704		9.811		0.74		1.444		20.46	

The findings of the study revealed that, in terms of solar energy usage at home, lighting was the most common purpose reported by respondents. Interestingly, females were found to use solar energy for lighting more frequently than their male counterparts. However, when considering other purposes of solar energy utilization, such as phone charging, powering TVs and radios, and engaging in commercial activities, males were found to dominate over females.

The study acknowledged that the majority of the respondents were male, which may have influenced the reported usage patterns. This bias suggests that the male respondents might have had a better understanding of the actual uses and benefits of different solar appliances once they were purchased, potentially leading to higher reported usage in various areas. Specifically, when it came to solar energy usage, the male respondents reported higher percentages of utilizing it for lighting (67.6%), phone charging (45.8%), and powering TVs and radios (45.8%). In contrast, the usage of solar energy for commercial activities was relatively low in the study area, with only 7% of males and 5.6% of females reporting its use in such activities.

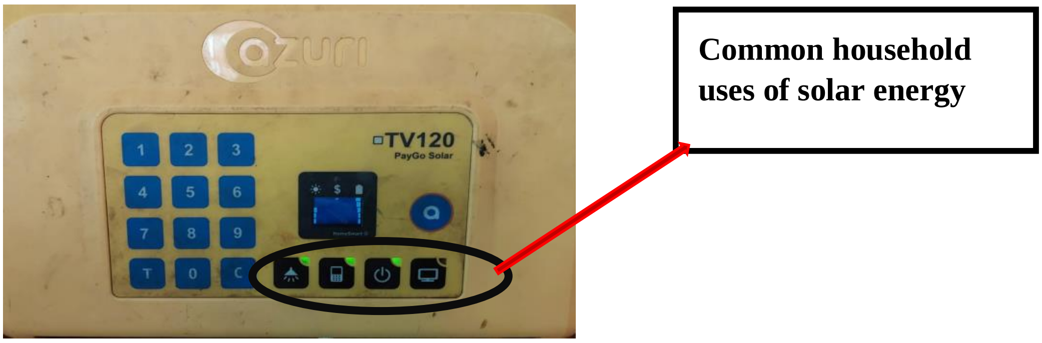

Figure 4.9: Solar Conversion Unit Indicating its Common Supported Uses

These findings highlight the need for further exploration of the factors influencing the reported usage patterns, such as cultural norms, individual preferences, and access to information. Understanding the underlying reasons behind the reported gender disparities in solar energy utilization can inform efforts to promote more inclusive and equitable adoption of solar technologies in the future.

Figure 4.10: Commonly Used Solar Photovoltaic Items in Households

4.4 Factors Influencing Uptake of Solar

In order to achieve the fifth objective of the study the research delved into the socioeconomic determinants that drive the adoption of solar energy among households in Embu County. By comprehensively understanding the intricate interplay between various socioeconomic factors and the propensity to adopt solar technologies, we can glean valuable insights that inform effective strategies for promoting sustainable energy usage, regionally and nationally.

4.4.1 Likelihood of Solar Energy Uptake

The chi-square statistic was employed to assess the fit of the model. The obtained chi-square value was 29.441, with a corresponding p-value of less than 0.05. This statistical analysis confirms the presence of a significant relationship between the dependent variables and the independent variables included in the final model. The findings are illustrated in in table 4.10, 4.11, and 4.12

Table 4.10: Likelihood of adopting solar Energy

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	**-2 Log Likelihood**	**Chi-Square**	**df**	**Sig.**
Intercept Only	282.265			
Final	252.824	29.441	15	.014

	Model Fitting Criteria	Likelihood Ratio Tests		
Solar Uptake	**-2 Log Likelihood of Reduced Model**	**Chi-Square**	**df**	**Sig.**
Intercept	252.824[a]	.000	0	.
Gender	255.184	2.361	1	.124
Age	261.026	8.202	3	.042
Education	257.732	4.908	3	.179
Marital Status	255.082	2.258	2	.323
Religion	256.632	3.808	2	.149
Household head	260.341	7.517	2	.023
Source Income	254.671	1.847	2	.397

According to the results, all the independent variables included in the analysis exhibited positive and statistically significant effects on the uptake of solar energy at homes. However, among these variables, sources of income demonstrated a greater influence compared to other factors in determining the decision to adopt solar appliances at P =0.397. On the other hand, factors such as age and household head showed relatively smaller effects on the likelihood of purchasing solar equipment with a p-value of 0.042 and 0.023 respectively.

The findings suggest that sources of income play a crucial role in influencing the adoption of solar energy technologies. Individuals or households with higher incomes or more diverse sources of income may have greater financial resources and flexibility to invest in solar appliances. This highlights the significance of economic factors in shaping the decision-making process related to solar energy adoption.

In contrast, variables like age and household head, while still contributing to the overall model, exhibited comparatively smaller effects on the decision to purchase solar appliances. This implies that other factors, such as financial considerations or in education, or gender, may have a more substantial impact on the adoption of solar energy technologies than age or the position of the household head.

The findings suggest that sources of income play a crucial role in influencing the adoption of solar energy technologies. Individuals or households with higher incomes or more diverse sources of income may have greater financial resources and flexibility to invest in solar appliances. This highlights the significance of economic factors in shaping the decision-making process related to solar energy adoption that aligns with the results study of (Pepermans, *et al.,* 2016).

Table 4.11: Likelihood Ratios for Uptake of solar Energy

Solar Uptake[a]	**B**	**Std. Error**	**Wald**	**df**	**Sig.**	**Exp(B)**
Intercept	17.247	9556.56	.000	1	.999	
Male	.358	.232	2.368	1	.124	1.430
Female	0[b]	.	.	0	.	.
18-25	17.601	1.529	132.45	1	.000	4.4078
26-44	17.760	1.498	140.64	1	.000	5.163
45-59	17.728	1.517	136.57	1	.000	5.003
Above 60	0[b]	.	.	0	.	.
Primary	-18.571	.364	2595.82	1	.000	1.608
Secondary	-18.432	.349	2790.16	1	.000	9.891
Tertiary	-18.342	.000	.	1	.	9.082
None	0[b]	.	.	0	.	.
Single	-.418	1.316	.101	1	.751	.658
Married	-.050	1.321	.001	1	.970	.951
Other	0[b]	.	.	0	.	.
Christian	-18.367	9556.564	.000	1	.998	1.055
Muslim	-19.842	9556.564	.000	1	.998	2.414
Other	0[b]	.	.	0	.	.
Farming	.276	.383	.521	1	.470	1.318
Business	-.029	.385	.006	1	.940	.971
Employment	0[b]	.	.	0	.	.
Father	1.109	1.136	.953	1	.329	3.030
Mother	1.668	1.127	2.190	1	.139	5.303
Other	0[b]	.	.	0	.	.

Under the Education category, primary, secondary had a significant impact on the uptake and utilization of solar energy. An addition of one-unit odd ration/probability to use solar energy compared to not using was more by 9.891 times. The odds ratio of respondents who had tertiary education was likely to increase their uptake. Notably, households led by mothers were 5.303 more likely to adopt solar power compared to those head by fathers. This would because women interacted more with solar energy sources compared to the male counterparts as indicated in table 4.8. Similarly, respondents who were married indicated a high likelihood ratio of using solar products than the counterparts that were single.

Similarly, the age of household heads was a significant and positively affected solar PV uptake in the current study. This implies that the adoption of solar PV in the Embu case was influenced by age. These results align with other two previous studies indicated that age was a significant factor pointing out that younger people are more willing to pay for renewable energy because of higher awareness of the environmental benefits it does provide (Guido *et al.,* 2016). Contrarily, another study in Kenya concluded that older household heads were wealthier and could easily access productive resources (e.g., land) therefore more likely adopt and invest in renewable energy technologies (Mirzabaev, *et al.*, 2015)

Similarly, results on education compares with those of (Mirzabaev, *et al.*, 2015) indicted that education had low influence on adoption of solar despites other studies associating higher education with more knowledge on climate change therefore likelihood of adopting the renewable energy ((Jabeen, *et al.*, 2021); (Mirzabaev, *et al.*, 2015).

4.5 Awareness of Solar Photovoltaic Energy for Climate Change Mitigation and Adaptation

Table 4.12: Awareness about solar photovoltaic energy

		Frequency	Percent	Valid Percent
Valid	**Strongly Disagree**	76	19.2	19.3
	Disagree	145	36.7	36.9
	Neutral	118	29.9	30.0
	Agree	49	12.4	12.5
	Strongly Agree	5	1.3	1.3
	Total	393	99.5	100.0
Missing	**System**	2	.5	
Total		**395**	**100.0**	
Mean				**2.39**
T-test				**48.606**

Strongly Disagree: I have little to no awareness of climate change and its impact. Disagree I have limited awareness of climate change and its impact, Neutral I have moderate awareness of climate change and its impact. Agree: I have a good understanding of climate change and its impact, Strongly Agree I am highly aware of climate change and its impact, and actively engage in efforts to address it.

The majority of respondents expressed a predominantly negative attitude towards climate awareness, as indicated by the survey results. Specifically, a significant proportion of respondents (36.9%) reported having limited awareness of climate change and its impact. This finding suggests that a considerable portion of the population lacks sufficient knowledge or understanding about the issues surrounding climate change.

Furthermore, the survey revealed that only a small fraction of respondents (1.3%) demonstrated a high level of awareness regarding climate change and its impact. This group actively engages in efforts to address the challenges posed by climate change. Their proactive involvement indicates a clear understanding of the urgent need to mitigate and adapt to climate change, and they are taking action to make a positive difference.

In addition, the survey identified another group comprising 12.5% of the respondents who displayed a moderate level of awareness regarding climate change and its impact. While this group is not as actively engaged as the highly aware respondents are, they still possess a reasonable understanding of the issues at hand and recognize the importance of addressing climate change.

These findings highlight the significance of improving climate awareness among the general population. Limited awareness may stem from various factors, such as lack of accessible information, insufficient education, or a lack of emphasis on climate change in public discourse.

Table 4.13: Climate Awareness and Sources of Climate Information

Climate Awareness	**Community Education**		**Friends**		**Schools**		**Social Media**		**Mass Media**		**Self-Education**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	16	21.1	17	22.4	15	19.7	30	39.5	33	43.4	26	34.2
Disagree	34	23.4	28	19.3	48	33.1	56	38.6	60	41.4	57	39.3
Neutral	44	37.3	31	26.3	45	38.1	58	49.2	42	35.6	22	18.6
Agree	18	36.7	23	46.9	23	46.9	25	51	21	42.9	18	36.7
Strongly Agree	0	0	3	60	3	60	5	100	2	40	0	0
Total	**112**	**28.5**	**102**	**26**	**134**	**34.1**	**174**	**44.3**	**158**	**40.2**	**123**	**31.3**
P-Value	-0.009		-0.178		-0.201		-0.129		0.026		0.082	
df	16		8		8		12		8		12	
χ^2	39.765		22.193		23.961		19.12		3.357		22.928	

Across various sources, it is evident that both social media and mass media play significant roles as primary channels for disseminating climate-related information. In a study conducted by Smith and Leiserowitz (2013), participants identified these media platforms as their predominant sources of climate information.

However, intriguing insights emerge when examining the data through a quadrant analysis. Respondents positioned in the 3rd and 4th quadrants, particularly those who expressed agreement or strong agreement that solar energy was a viable climate adaptation strategy, overwhelmingly cited school and mass media as their primary avenues for accessing climate-related information. Remarkably, 60% of respondents in the 3rd quadrant and a full 100% in the 4th quadrant attributed their climate information to these two sources.

Conversely, those situated in the 1st and 2nd quadrants, comprising individuals who disagreed or strongly disagreed that solar energy was a clean energy solution, leaned more towards social media and mass media as their preferred sources for climate information. Interestingly, regardless of their stance on solar energy, respondents consistently highlighted social media as a predominant information source across these divergent perspectives.

While social media retains its status as a consistent and prominent source of climate information, the differentiation occurs in the usage of mass media and school-based channels. The former being the more prevalent choice among those aware of solar energy's potential as a climate adaptation strategy, while the schools is embraced by individuals who acknowledge solar energy's importance in the climate agenda.

Comparatively, this study aligns with previous research highlighting the significance of media platforms in shaping public perception and understanding of climate-related matters (Smith & Leiserowitz, 2013). Studies by Oluoch *et al.*, (2020) that focused on "Assessment of public awareness, acceptance and attitudes towards renewable energy in Kenya" established that radio was the commonly used source of climate information, followed by newspaper and books. The variation in reliance on sources, particularly in response to differing opinions on specific strategies, emphasizes the interplay between information sources, climate perceptions, and attitudes.

In essence, this study points the significant role of both social media and mass media in influencing climate-related opinions and policies. Additionally, the adaptation strategy's perceived efficacy introduces a dimension that alters individuals' preference for particular information sources. Such insights emphasize the dynamics of climate communication and underscore the importance of tailored approaches in conveying climate-related information to diverse audiences

4.6 Climate Change Awareness and Solar Uptake

In order to examine how climate change awareness influence respondents decision making on solar uptake, responses on climate change awareness, knowledge of solar emerge as clean energy and uptake of solar as a climate mitigation method were cross tabulated to obtain a descriptive statistics and correlated to obtain significance, as presented in table 4. 14 and table 4.15

Table 4.14: Cross Tabulation of Climate Change Awareness and Solar Energy

		Climate Change Awareness		**Total**
		Yes	**No**	
Solar as Clean Energy Source	Yes	266	43	309
	No	45	39	84
Total		**311**	**82**	**393**
Solar Energy as a Climate Change mitigation	Yes	201	48	249
	No	111	31	142
Total		**311**	**80**	**391**

Table 4.15: Correlation between Climate Change Awareness and Perception of Solar Energy

		Climate Change Awareness	**Solar as Clean Energy Source**	**Solar as a Climate Change mitigation**
Climate Change Awareness	Pearson Correlation	1	.354**	.140**
	Sig. (2-tailed)		.000	.006
	N	394	393	390
Solar as Clean Energy Source	Pearson Correlation	.354**	1	.178**
	Sig. (2-tailed)	.000		.000
	N	393	394	391
Solar as a Climate Change mitigation	Pearson Correlation	.140**	.178**	1
	Sig. (2-tailed)	.006	.000	
	N	390	391	391

**. Correlation is significant at the 0.01 level (2-tailed).

The survey results revealed a significant correlation between respondents who displayed awareness of climate change and its impacts and the adoption of solar energy and awareness on solar energy adoption as a solution to climate change at p values of 0.348 and 0.140. However, despite the positive correlation, in both the variables, climate change knowledge had more influence in solar uptake than awareness of solar energy as a green energy. This finding suggests that individuals who are knowledgeable about climate change are more likely to embrace and utilize solar energy as a renewable and sustainable alternative.

Among the respondents, a small percentage (1.3%) demonstrated a high level of awareness regarding climate change and actively engaged in efforts to address its impact. These individuals, who understood the urgency and severity of climate change, were more inclined to adopt solar energy solutions. Their awareness likely stemmed from being well-informed about the environmental benefits of solar power, such as its ability to reduce carbon emissions, mitigate climate change, and promote clean energy generation.

In addition, the survey identified a group comprising 12.5% of respondents with a moderate level of awareness about climate change and its impact. While not as actively engaged as the highly aware group, this segment still possessed a reasonable understanding of the issue. Consequently, they were more likely to consider solar energy as a viable option for reducing their environmental footprint and contributing to sustainability efforts.

The connection between climate awareness and the uptake of solar energy can be attributed to several factors. First, an informed understanding of climate change prompts individuals to seek environmentally friendly alternatives to traditional energy sources. Solar energy, with its renewable and clean nature, aligns well with the goal of reducing greenhouse gas emissions and combating climate change.

4.7 Uptake of Other Sources of Clean Energy

Besides the uptake of solar energy, respondents were asked to indicate usage of other clean energy available to examine how climate change awareness influenced their decision to utilize these green sources of energy and evaluate the relationship between climate conscious respondents and non-climate conscious respondents in utilization of different sources of energy. The results are presented in the figure 4.7

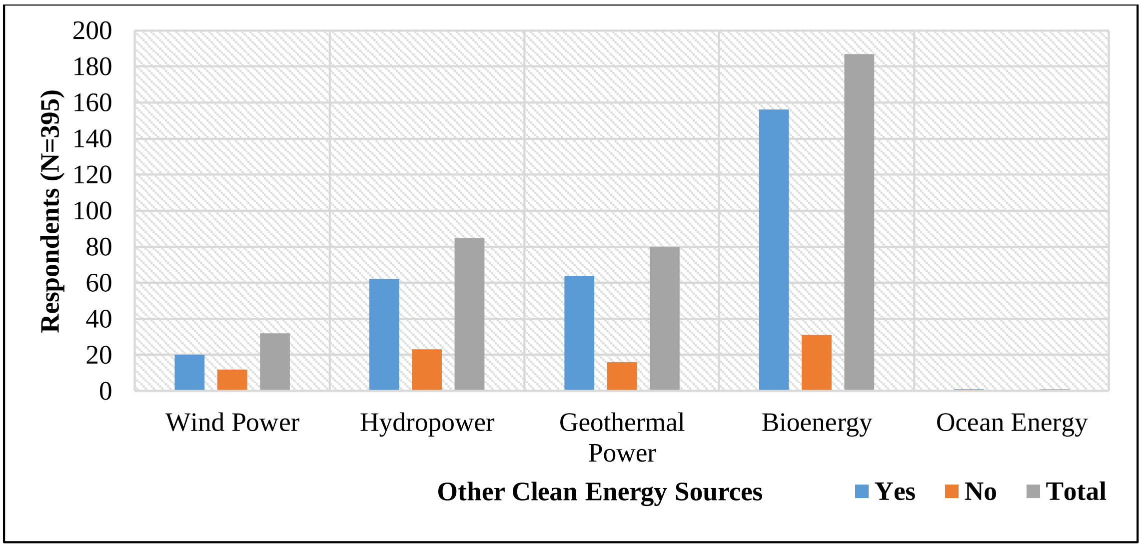

Figure 4.11: Uptake of Other Sources of Clean Energy

According to the survey results, a significant percentage (48.57%) of the respondents reported being aware of and using Bioenergy sources such as charcoal, briquettes, or biomass as a form of energy. This usage was attributed to both climate-conscious individuals (51.49%) who are actively aware of environmental issues, as well as unconscious individuals (37.80%) who may not be consciously aware of the environmental impact but still use these energy sources. On the other hand, the awareness and usage of ocean energy and wind energy were relatively low in both groups. Only a few individuals (0.26% and 8.31% respectively) indicated awareness of these renewable energy sources.

In contrast, there was a moderate level of awareness and knowledge about hydropower and geothermal sources of energy. Approximately 22.08% of respondents acknowledged awareness of hydropower as a renewable energy source, while 20.78% were aware of geothermal energy. This suggests that these two forms of renewable energy have gained some recognition and understanding among the surveyed population. Study by Oluoch *et al.*, (2020) however gives different perception of respondent's attitudes to different types of energy. In their study more people recognized wind (69%), hydro (68%), biomass (56%) and geothermal (56%) respectively as the main known renewable sources of energy.

These findings suggest that while bioenergy sources like charcoal, briquettes, and biomass are widely known and utilized, there is a lack of awareness and adoption of other renewable energy sources like ocean and wind energy within the study areas. This indicates a potential gap in educating the public about the benefits and availability of these alternative energy sources. Furthermore, the relatively equal knowledge of hydropower and geothermal energy sources suggests that efforts to promote these renewable options have been moderately successful, which was been projected to be among the largest sources of energy in 2020 with hydrothermal at 18% and geothermal energy at 36% of the total available energy sources, (Energy Sector Management Assistance Program , 2021).

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Findings

The first objective of the study aimed to examine the trends in temperature and precipitation over the past 40 years in Embu County. The findings revealed a positive increasing trend (0.03) in temperature and a moderate decrease (-2.433) in rainfall in the region. Specifically, 76.7% of the respondents reported experiencing rising temperatures, while 65.6% indicated a decrease in rainfall over the years. The study also explored the influence of climate variability on the uptake of solar technology in the community. It was found that climate variability had a significant impact on the acceptance and adoption of solar technology, as perceived by a considerable percentage of the respondents. However, it is noteworthy that a significant proportion (40.49%) of the household heads indicated that climate variability and trends had no impact on their decision to adopt solar technology. This could imply that other factors, such as economic considerations or access to alternative energy sources, may be influencing their choice of energy technology.

The second objective of the study aimed to investigate the energy sources utilized by households in Embu County. The findings revealed that among the five selected energy sources, firewood emerged as the most commonly used source of energy, with 37.5% of household heads relying on it. Following closely were liquid petroleum gas and paraffin, which were utilized by 17.0% and 17.5% of respondents, respectively. When it came to the choice between electricity and solar power, the majority of respondents preferred solar energy, with a significant 61.17% opting for this renewable option. The primary barrier to adopting electricity was perceived to be the high installation cost, as cited by 72.2% of the respondents. Solar panels were identified as the most commonly used photovoltaic item, with 61.17% of respondents attributing their preference to this technology. This highlights the popularity and acceptance of solar panels as a reliable and accessible renewable energy solution in the surveyed households. Within these households, solar energy was predominantly used for lighting purposes, as reported by 69.1% of the respondents. This suggests that solar power is effectively meeting the basic lighting needs of the households, contributing to energy access and sustainability. The high adoption rate of solar energy despite the cost barrier for electricity installation signifies the growing recognition of solar power as an economically viable and environmentally friendly alternative. It also indicates a level of awareness and understanding among the respondents regarding the benefits of renewable energy sources.

The third objective sought to determine the main uses of solar energy at the household level. Six distinct energy usages were pinpointed among the households surveyed. These encompassed cooking, lighting, phone charging, heating, commercial activities, as well as the operation of televisions and radios. In the resultant findings, it emerged that two particular uses held notable significance, specifically lighting and phone charging. 69.1% of the respondents cited lighting as their primary utilization of solar energy, while an additional 35.7% mentioned phone charging as a prominent application. Remarkably, these trends held consistent across both male and female respondents. In contrast, the utilization of solar energy for cooking and commercial activities emerged as less prevalent. These applications garnered the least adoption among the surveyed households.

The fourth objective sought to analyze the awareness about solar photovoltaic energy for climate change mitigation in Embu County. The results reveal that a significant portion of the population 36.9% had limited awareness of climate change and its impacts. Further, the study indicates only a small fraction of the respondents, 1.3% have sufficient knowledge or understanding about issues surrounding climate change. Additionally, 12.5% of respondents displayed a moderate level of awareness about climate change and its impacts. Both social media and mass media were cited by the respondents as consistent and prominent sources of climate information.

Objective five sought to evaluate the socioeconomic determinants of solar energy adoption by households in Embu County. One of the key findings of our investigation underscores the primary role of income sources in shaping the decision-making process behind the adoption of solar appliances. Our analysis revealed that sources of income exerted a substantial influence, demonstrating a notable correlation with the decision to embrace solar energy solutions (*P-value = 0.397*). This underscored the significance of financial considerations and economic stability as critical drivers in determining the willingness of households to invest in solar technology.

The study unveiled a contrasting pattern when it came to other influencing factors. Specifically, age and household headship emerged as relatively less impactful factors in shaping the likelihood of purchasing solar equipment. While age and the identity of the household head still held some influence, their effects were comparatively smaller, with calculated p-values of 0.042 and 0.023, respectively. This indicates that although these factors play a role, their contribution might be outweighed by other more dominant determinants such as income sources.

To further understand the findings, a rigorous statistical analysis was employed which incorporated a wide array of socioeconomic variables, allowing the capture of the intricate nuances that drive solar energy adoption decisions within the unique context of Embu County. The comprehensive approach ensured the robustness of the conclusions and provided a multifaceted perspective on the factors influencing sustainable energy practices

5.2 Conclusions

Climate variation in temperature and rainfall, their statistical values suggest a consistent trend over the 40-year period. The temperature data shows a clear warming trend, while the rainfall data suggests a decreasing trend. However, it's crucial to consider other factors that might influence these trends, such as local geographical changes, human activities, or natural climate variability, before making definitive conclusions about the underlying causes of these trends. The temperature and rainfall data analyses indicate significant trends over the 40-year period: rising temperatures and decreasing rainfall. However, these conclusions are based on statistical analyses and should be interpreted in the context of broader environmental factors that could be contributing to these trends.

The third objective of the study illuminates the predominant trends in the utilization of solar energy within households. The significance of lighting and phone charging as the primary energy consumption areas is well-supported by an array of primary and secondary references, offering a holistic understanding of the solar energy landscape in residential settings. The differing degrees of adoption across various energy applications underscore the intricate factors influencing usage patterns and present opportunities for expanding the scope of solar energy implementation across a broader array of functions.

This study sheds light on the intricate relationship between socioeconomic factors, determinants and the adoption of solar energy within Embu County. The influence of income sources emerged as a crucial factor, highlighting that households with diversified and reliable income streams are more inclined to embrace solar technology. However, it is important to note that other factors like gender, level of education, climate change awareness, age and household head factors also contribute to the decision-making process, although to a lesser extent. By understanding these determinants, policymakers and stakeholders can formulate targeted strategies to encourage solar energy adoption and uptake and create a sustainable energy landscape within the county and country.

5.3 Recommendations

1. The Study showed that there was a (positive) relationship between climate awareness and solar adoption. Those who were aware of climate impacts and courses were more likely to start using solar energy. The Government of Kenya and especially the Ministry of Energy and the Ministry of Environment need to provide training and education to increase the level of knowledge and awareness on climate change and the use of solar energy. This can be done through social media, mass media seminars, workshops and public Barazas where members are invited for training and demonstration on the causes, and impacts and use and benefits of solar energy mitigation to climate change.
2. A portion of the respondents indicated that climate variability had no influence in their uptake of solar energy. To gain a deeper understanding of these findings, further analysis is necessary. Exploring the reasons behind the perceived lack of impact of climate variability on solar technology adoption could provide valuable insights. Possible factors to consider include economic constraints, lack of awareness about the benefits of solar technology, or competing priorities that overshadow the consideration of climate variability.
3. The respondents utilized other sources of energy, which were mostly biomass based. The county needs to get involved to provide energy solution regardless of the availability of alternative/substitute of other sources of energy, Solar power will eventually help the county achieve better forest cover as individuals will turn to solar and use less and less wood based fuel. The community should be encouraged to harness solar energy since it is cheaper and easily accessible

than the other sources of energy given that the community comes from a remote area where the sun is abundant.

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APPENDICES

Appendix I: Questionnaire

KENYATTA UNIVERSITY

DEPARTMENT OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

NAME: PAMELLA CAMU NJERU

REG NO: N50/CTY/PT/28851/2019

YEAR: 2023

Dear respondent,

I am a student at Kenyatta University, and I am carrying out an educational research on 'Solar Photovoltaic Uptake in Climate Change Mitigation' a case study of Mbeere North Sub-County, Embu County, Kenya. This study is a key requirement for the award of Master's degree in Climate Change and Sustainability. All the answers you provided were treated with ultimate confidence and were used for academic uses only. The information can only be shared with your local government and local CBOs and NGOs to help in promoting creation of awareness and understanding climate change in the area and the benefits of solar photovoltaic, but only with accordance with the Data protection Act 1998.

Section A: Socio- Demographic factors

1. Date ……………………………………
2. Village…………………………………..
3. Sub-location………………………………………
4. Location……………………………………………
5. Gender: Male () Female ()
6. Age Young adult 18-25 { } Adult 26-44 { } middle age 45-59 { } Old age above 60 { }
7. What is your education level? (Kindly indicate by using a tick)
   Primary……Secondary ………Tertiary ………None……
8. Marital status
   Married { }
   Single { }

Divorced { }

9. What is your religion?

   Christian { }

   Muslim { }

   Hindu { }

   Others { }

Section B: temperature and precipitation trends

1. Over the past years have you noticed any temperature and precipitation changes?

   Yes { }

   No { }

2. Has precipitation increased or reduced over time?

   Yes { }

   No { }

3. Have temperatures increased over time

   Yes { }

   No { }

4. Have the temperature and precipitation trends impacted availability of solar energy?

   Yes { }

   No { }

Section C: Sources of energy utilized by households

1. Have you installed electricity in your household?

   Yes { }

   No { }

2. If yes/no why?

High installation costs	Existence of other sources of energy like solar	Geographical location from electricity	Poor infrastructure

3. Do you have any solar photovoltaic technology in your household?

Yes { }

No { }

4. If no do you plan to uptake solar photovoltaic technology in your household?

   Yes { }

   No { }

5. If yes, what type(s) of solar photovoltaic do you have in your household?
   1. Solar powered torch { }
   2. Solar powered lantern { }
   3. Solar powered bulb { }
   4. Solar panels { }
   5. Solar street lighting { }
   6. Solar powered mobile phone { }

6. How useful are solar photovoltaic technologies in your household?

Very useful	Useful	Moderate	Not useful

7. Apart from solar photovoltaic and electricity what are the other sources of energy do you use in your household?

Section D: Solar energy uses in Households

How do you use solar energy in your household?

1. Lighting { }
2. Cooking { }
3. Charging { }
4. Heating water { }
5. Commercial purposes { }
6. Powering electronics like television sets or radio { }

Section E: Awareness about solar photovoltaic technology in climate change mitigation

1. Are you aware of climate change?

   Yes { }

   No { }

2. From a scale of 1-5 how can you rate your knowledge and awareness about climate change? Kindly use a tick for the appropriate scale.

1	**2**	**3**	**4**	**5**

3. How did you become aware about climate change?
   I. Education from the county government or chamas/barazas { }
   II. Friends { }
   III. School { }
   IV. Social media Facebook/Twitter/TikTok/Instagram/Emails/Messages { }
   V. News { }
   VI. Self-education/awareness { }
4. Are you aware that the use of solar photovoltaic technology is a clean source of energy?
   Yes { }
   No { }
5. Did you know that the uptake of solar photovoltaic technology promotes climate change mitigation and adaptation?
   Yes { }
   No { }
6. Apart from solar photovoltaic technology what are the other clean sources of energy do you use in your household?
   I. Wind power { }
   II. Hydropower { }
   III. Geothermal power { }
   IV. Bioenergy like charcoal briquettes or biomass { }
   V. Ocean energy { }

Section F: Social-economic determinants of solar photovoltaic uptake by households in climate change mitigation

1. What is the source of your income
   Formal employment { }
   Informal employment { }
2. Does income affect your uptake of solar photovoltaic technology?

Yes { }

No { }

3. Who is the head of the household?

   Mother { }

   Father { }

4. From a scale of 1-5 how have the government policies supported your uptake of solar photovoltaic technology?

1	2	3	4	5

5. By using a tick identify the reasons supporting your uptake of solar photovoltaic technology

Cost	
Security reasons	
Climate change mitigation	
Cooking	
Microenterprise (business)	
Lighting	
Agriculture	
Television watching	

6. As per your knowledge, do you feel like the existing government policies and regulations contribute your failure of solar photovoltaic technology uptake?

   Yes { }

Appendix II: Approval of Research Proposal

KENYATTA UNIVERSITY
GRADUATE SCHOOL

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P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 4150

Internal Memo

FROM: Executive Dean, Graduate School

DATE: 27th March, 2023

TO: Pamella Camu Njeru
C/o Environmental Sciences &
Education Dept.

REF: N50/CTY/PT/28851/2019

SUBJECT: APPROVAL OF RESEARCH PROJECT PROPOSAL

This is to inform you that Graduate School Board at its meeting of 16th March, 2023 approved your Research Project Proposal for the M.Env. Degree Entitled, "Solar Photovoltaic Technology Uptake in Climate Change Mitigation by Households in Embu County, Kenya.

You may now proceed with your Data Collection, Subject to Clearance with Director General, National Commission for Science, Technology and Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking Forms per semester. The form has been developed to replace the Progress Report Forms. The Supervision Tracking Forms are available at the University's Website under Graduate School webpage downloads.

Also, please ensure that you publish article(s) from your project before submitting it to Graduate School for examination as per the Commission for University Education and Kenyatta University guidelines.

Thank you,

ANNBELL MWANIKI
FOR: EXECUTIVE DEAN, GRADUATE SCHOOL

KENYATTA UNIVERSITY
OFFICE OF EXECUTIVE DEAN
27 MAR 2023
GRADUATE SCHOOL
P. O. Box 43844-00100 NAIROBI

c.c. Chairman, Environmental Sciences & Education Department.

Supervisors:

1. Dr. Ezekiel Ndunda
C/o Department of Environmental Sciences & Education
Kenyatta University

JO/mo

Appendix III: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 359704

Date of Issue: 05/April/2023

RESEARCH LICENSE

This is to Certify that Ms.. Pamela Cama Njeru of Kenyatta University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Embu on the topic: Assessing The Solar Photovoltaic Technology Uptake In Climate Change Mitigation By Households In Embu County, Kenya. for the period ending : 05/April/2024.

License No: NACOSTI/P/23/24938

359704

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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See overleaf for conditions