SOCIO-ECONOMIC IMPACTS OF PHOTOVOLTAIC SOLAR INSTALLATION AND USE: A CASE STUDY OF BORABU DIVISION IN NYAMIRA COUNTY.

BY

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RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF ARTS, DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES,

UNIVERSITY OF NAIROBI

2013

DECLARATION

This research project is my original work and has not been presented for examination to any other university

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DEDICATION

This work is dedicated to my family, parents and to house hold residents in Borabu Division, Nyamira County.

ACKNOWLEDGEMENTS

There are a number of people without whom this thesis might not have been written, and to whom I am greatly indebted. Bishop Mazzoldi secondary school for their support.

To God almighty, for his grace, gift of life and blessings

To my family (wife Mrs Nyandega, son Fabian, father Mr Onsomu and mother Mrs Onsomu) who have always been an encouragement and inspiration to me throughout my life. They have given their financial and moral support, even when the road seemed too bumpy. A special thank you for nurturing in me the appreciation of education and for the many ways in which, throughout my life, you have supported me in my determination to find and realize my potential

I would like to acknowledge the advice and guidance of my supervisor, Prof. Odingo and Mr. Ndolo. Your kindness and willingness to lead me has been profound. May God bless your future endeavors in leading and seeing many, more go through your hands. I also appreciate the work done by my lectures in MA program and the entire university fraternity.

To my siblings many thanks for your prayers, sacrifice and passion for my academic success. To my classmates and friends in particular Dotrice Adhambo whose help and contribution to this research has been realized.

To Borabu Division house hold members, for your support and encouragement.

God bless you all.

LIST OF ACRONYMS AND ABBREVIATIONS

CSP	-	Concentrating Solar Thermal Plants
DC	-	Direct Current
DFID	-	Department for International Development
DFIP	-	Data Fusion Integrity Process
EPIA	-	European Photovoltaic Industry Association
GHG	-	Green House Gasses
GW	-	Gigawatts
KPLC	-	Kenya Power and Lighting Company
LCOE	-	Levelised Cost of Electricity
MDGS	-	Millennium Development Goals
NCCAP	-	National Climate Change Response Strategy
PVs	-	Photovoltaic Solar
REDD	-	Reducing Emission from Deforestation.
S.H.S	-	Solar Home Systems
Sq. KM	-	Square Kilometer
UN	-	United Nations
UNEP	-	United Nations Environmental Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
USA	-	United States of America

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ABSTRACT

This project investigated and assessed the productive use and spread of solar PV (photovoltaic) systems among rural population of Borabu solar home systems and medium enterprises. It analyzed sustainability aspects of productive solar PV usage and the future prospects for this type of activities. As the situation is today there is a lack of electricity in a major part of the country and there is a big need for rural electrification. In recent years there has been a lot of effort and money put into the solar PV industry in order to achieve a higher quality of life for the rural poor. One of the goals except for producing electricity, has been to achieve a self-sustaining market where solar PV are used for generate income in rural areas, i.e. productive use of solar PVs. The main objective of the study was to assess social-economic impacts of photovoltaic solar installation and use. Specific objectives were to determine the impact of governmental organizations in Photovoltaic solar installation and usage in Kenya, Borabu Division; to evaluate the environmental impact of Photovoltaic solar installation and usage in Kenya, Borabu Division; to assess the climatic impact of Photovoltaic solar installation and usage in Kenya, Borabu Division; and to assess the impact of costs in the installation of PV panels in Kenya, Borabu Division.

This research study adopted a cross-sectional research design. The study targeted a population of 58,079 persons in Nyamira County, Borabu Division. A sample size of 30 households was used for this study. Primary data was gathered directly from the households using structured questionnaires. Quantitative data collected using questionnaires was analyzed using descriptive statistics using SPSS (Statistical Package for Social Sciences).

From the findings, the study found out that persistent governmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residents. It found out that existing environmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residents. It further found out that changes of climatic conditions have significantly affected the installation and use of Photovoltaic solar system among household residents. It finally found out that high costs of installing PV solar system have significantly affected the installation and use of Photovoltaic solar system among household residents. The study concluded that the environmental impact had a great impact on the installation and use of PV solar system in the location. It also concluded that cost is a factor that has impacted the installation and use of solar in Borabu location, Nyamira County. The study recommended that a consistent PV strategy be in place on ambitious and long-term targets, a clearly defined implementation Programme and a well-conceived mix of instruments will become the groundwork for success. The basic requirement for each PV policy framework is its longevity and stability.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The sun serves as a giant nuclear furnace in space, constantly bathing our planet with free energy supply. The average amount of solar energy arriving at the top of the atmosphere is 1,330 watts per square meter. About half of this energy is absorbed or reflected by the atmosphere (Milton, 2001).

The photovoltaic cells offers an existing potential for capturing solar energy in a way that will provide clean, versatile and renewable energy (Morris,2005). Today's' energy system-the supply, conversion, transport, and the use of energy is dominated by the fossil fuels. Of the energy used in 2011 worldwide for example, 88% was supplied by fossil fuels and only a small fraction, 12% was provided for non-fossil energy sources such as nuclear, hydroelectric, and solar and wind power (global energy technology strategy, 2007).

The use of fossil fuels is vital input to economic growth and poverty reduction. The Asian Development Bank (ADB) states that "it is, however possible to improve energy security and seeking alternative sources of energy without sacrificing economic growth and living standards".

Kenya's electricity interconnected capacity stands at 1,672 MW (as at January 2013) against an interconnected peak demand of 1,334 MW. The Vision 2030 projects that Kenya will be a middle income country by 2030, with the corresponding required system capacity at 15,000 MW (GoK, 2007). This capacity growth is expected to be met through large scale geothermal projects to deliver base load and regional interconnection of grids. Small-scale renewable, although currently contributing 3% (50MW) to the total installed capacity are expected to grow to 6% (350MW) by 2018. Solar PV is estimated to generate 500 MW of electricity by the year 2030 (Ministry of Energy Kenya, 2010).

The power market in Kenya is characterized by steady and high-demand growth, substantial investment in additional generation capacity during the last decade, persistent power shortages and frequent load shedding, a continuing vulnerability to drought-induced shortfalls in hydro-generation capacity, an increased role of private-sector participation, and a prioritization of large-scale projects.

The potential of small-/medium-scale renewable power generation remains largely untapped. Specifically, solar PV technology continues to play a peripheral role. While Kenya enjoys a very active PV market, this is mostly limited to the below 50W off-grid solar home systems (SHS). There has been no systematic role played by the Government or industry to move solar to the grid-connected category where 95% of the global PV market is today.

There is a close relationship between economic growth and quality of life, on one hand, and demand for energy, on the other. Kenya cannot experience high levels of economic growth if energy supplies are constrained. Lack of adequate and reliable supply of energy reduces the potential for achieving major structural changes in rural economies. There is also the critical relationship between energy and the environment. The environment provides raw materials for the energy industry. The environment, on the other hand, is the recipient of the residues of energy production and consumption, and fossil fuels are the largest contributors to air pollution. The emissions, especially carbon dioxide, methane, nitrogen and sulphur oxides are responsible for changes in the atmosphere that are affecting the global climate (KIPPRA, 2007).

Rural communities in Kenya, where more than 95 percent of rural households have no access to electricity, solar energy has the power to transform lives. Those who can afford any power at all spend large proportions of their income on kerosene for lamps or travel to larger towns to charge their batteries several times a week. Burning kerosene contributes to indoor air pollution, which is estimated to kill 1.6 million people each year. Kerosene lamps also lead to fires that cause severe burns and deaths. Solar energy saves families money as well as allowing children to study in the evenings and giving families access to information through radio and television and mobile phone chargers. The light from a solar-powered bulb is also between 10 and 20 times brighter than from a kerosene lamp (Davies, 2010).

Before the emergency of the PV market, there was enormous demand for electricity from the rural sector not being met by the national electricity company Kenya Power and Lighting Company (KPLC). As the sole provider of electricity, only 3.4% of the power KPLC supplied was for rural consumers while rural Kenya constituted 75% of the total population.

KPLC effective monopoly on electricity made it inefficient and unresponsive to demand. Coupled with difficulties associated with grid extension, rural Kenyans have realized the unlikelihood of the electricity from the grid in future. Thus, began the search for an alternative. Non-governmental organization (NGOs) have funded projects have introduced photovoltaic technology to rural Kenya and provided empirical evidence of its legitimacy (ESDA, 2003; Jacobson, 2004). This became the "technological seed" that generated the demand for phovoltaic technology. In the beginning of the PV market, most of the buyers were upper and middle class households, as the price of the solar was relatively high (and due to the inevitable lowering the cost) described by the "experience curve associated with the new technology.

1.2 Statement of the Problem

At least 2 billion people around the world do not have access to electricity (Environmental Protection Agency, 2006). Most would like to have a modern power source if it were affordable. They may be able to enjoy the benefits of electrical power without the whole complex of power plants, transmission lines, air pollution and utility of companies (Environmental Protection Agency, 2006). During the last 25 years, the efficiency of energy capture voltaic cells in Africa has increased from less than 1percent of incident light to more than 15percent under field conditions (Fiannery, 2005). Photovoltaic cells are now dropping in price about 7 percent per year. When they reach one dollar per watt (perhaps by 2020) their electricity should be competitive with nuclear or coal fired plants (Smith, 2005). As fossil fuel prices have raised concerns over greenhouse gases and global climate change have increased, alternative technologies for producing electricity have received cells (Pv's), which capture solar radiation and convert it directly into electrical energy. Such cells are generally located at the site of the end user and thus form a distributed generation. The current direct cost of photovoltaic solar cells is widely acknowledged to be much greater than fossil fuel generation for many other than renewable sources (ESDA, 2003; Jacobson, 2004).

The Kenyan energy sector is characterized by a rapidly growing demand, large geographical imbalances in power demand and supply, and accelerating private sector involvement. In addition, substantial potential exists for exploiting domestic potential of other renewable energy sources, not least solar power. Interest in solar energy is rapidly increasing. Kenya was among the first countries in the world to install hundreds of thousands of solar electric systems for households. In Kenya, all of the PV systems were off-grid solar home systems (averaging less than 50 Wp). Kenya has an active market for solar equipment; however, there has been no systematic effort on the part of the industry or Government to bring solar on to the grid.

The use of solar PVs as means for rural electrification in Kenya has shown to be of great advantage. Further, there are several policies and strategies that have been implemented to stimulate the market for solar photovoltaic (PV) systems with mostly positive results as the existing Solar PVs out in the rural areas are generating enough electricity to operate the most basic domestic appliances such as radio, TV and light (ESDA, 2003; Jacobson, 2004). Moreover, the technology is often indirectly associated with other multidimensional advantages such as being a carbon neural source of energy, providing socio-economic advantage and being a possible stimulant for economic growth. The economic growth and socio-economic advantages are supposed to be achieved by using Solar PV as an aid for income generation is often referred to as productive use.

Kenya has emerged as one of the global leaders, per capita, in the use of renewable energy technology. This is due largely to a growing market for solar PV systems among rural households, with cumulative sales since the mid-1980s in excess of 200,000 PV systems, and current annual sales topping 25,000 units (ESDA, 2003; Jacobson, 2004). Data from the year 2000 survey conducted by the Tegemeo Institute indicated that 4.2% of rural Kenyan households owned a solar system.

The same survey found that 4.3% of rural households were connected to the national electrical grid, and other sources indicate that solar sales are growing faster than the rate of new rural grid connections (ESDA, 2003; Jacobson, 2004). In other words, solar electricity has emerged in Kenya as a key alternative to grid-based rural electrification. The Kenya solar market is also notable, and in fact has served as a model in energy and development policy circles, because it developed with a minimal direct government support and only very moderate inputs from international donor aid groups. Solar sales in Kenya have long been (and continue to be) driven largely by subsidized over-the-counter cash purchases of household solar systems (Acker and Kammen, 1996; Hankins, 2000; Hankins & Bess, 1994; van der Plas and Hankins, 1998). This makes Kenya an important example of a growing international trend toward market-based approaches to rural energy service delivery.

While there is little doubt about the size and rapid growth of the Kenya solar market, there is an ongoing debate about how to interpret its significance. Solar advocates commonly make claims about the rural productivity, and poverty alleviation benefits of solar PV (Greenpeace, 2001; Kaufmann, 2000; Martinot et al., 2002). Some skeptics challenge these claims, contending that the environmental benefits of solar electrification are minimal, economically productive uses are few and far between, and that, in the absence of large subsidies, solar sales are primarily to the rural elite rather than the rural poor (Inverson, 1996; Karekezi and Kithyoma, 2002; Leach, 2001; Villavicencio, 2002).It is against this background the study will survey the uses of PV solar panels and their significance in the Borabu Division.

1.3 Research questions

i. To what extent do governmental organizations influence Photovoltaic Solar installation and usage in Kenya, Borabu Division?

ii. What are the environmental impacts of Photovoltaic solar installation and usage in Kenya, Borabu Division?

iii. What are the climatic impact of Photovoltaic solar installation and usage in Kenya, Borabu Division?

iv. How does cost impact the installation of PV panels in Kenya, Borabu Division?

1.4 Research Objectives

i. To determine the influence of governmental organizations in Photovoltaic solar installation and usage in Kenya, Borabu Division.

ii. To evaluate the environmental impact of Photovoltaic solarinstallation and usage in Kenya, Borabu Division.

iii. To assess the climatic impact of Photovoltaic solar installation and usage in Kenya, Borabu Division.

iv. To assess the impact of costs in the installation of PV panels in Kenya, Borabu Division.

1.5 Research Hypotheses

1. H_0: Persistent government impacts do not influence the installation and use of Photovoltaic solar system among household residents in Borabu.

   H_1: Persistent governmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

2. H_0: Existing environmental impacts have not significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

   H_1: Existing environmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

3. H_0: The changes of climatic conditions have not significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

   H_1: The changes of climatic conditions have significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

4. H_0: High costs of installing PV solar system have not significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

   H_1: High costs of installing PV solar system have significantly affected the installation and use of Photovoltaic solar system among household residentsin Kenya, Borabu Division.

1.6 Justification of the study

Kenya is heavily reliant on fossil fuels for its energy needs. This has proved to be double-edged sword in recent past in the following aspects. First, this has meant that with continued economic development, GHG emissions from the fossil fuel combustion will continue to exacerbate climate change. Secondly, owing to escalating cost of fuel in the world market, this has had a negative effect on local inflation rates driving up the cost of living as well as the cost of electricity generation and consumption.

As such, it is necessary to scale up the use up the use of renewable, low carbon emitting technologies to reduce dependence on fossil fuels and ameliorate the effects of climate change (ESDA, 2003; Jacobson, 2004). Therefore this research will provide more information to the residents on the importance of using renewable sources of energy.

The U.S Department of Energy (2006) state that photovoltaic solar power is one of the most promising renewable energy sources in the world, compared to non-renewable sources such as coal, gas, oil and nuclear, the advantages of solar are clear:

- Generates free energy from the sun.
- Has no moving part to break down thus requiring minimal maintenance.
- Non-polluting energy thus reduces GHG emissions, thus mitigating climate change.
- Phovoltaic cells are modular, someone can start with a small system and expand as your needs increase.
- Can be installed and operated anywhere including areas of difficult access and remote locations.
- They reduce dependence on fossil fuels, whose combustion has contributed the most towards the release of GHS emissions to the atmosphere.
- PV cells make no noise noise and give off no exhaust.
- They are an alternative for use in remote areas where it will be expensive or impossible to run power lines
- Have electrical power during power blackouts, a frequent phenomenon in developing countries

Solar electrification has emerged as a leading alternative to grid-based rural electrification in many developing countries. This may seem like a victory for appropriate technology advocates, but this research in Kenya indicates that solar electrification is, at best, only loosely linked to Schumacher’s classic ‘‘small is beautiful’’ vision of building small scale, locally self-reliant alternatives to global capitalism. Instead, the social uses of solar electricity in Kenya are expansion of consumer goods markets, more rural–urban communication, and other processes that increase social and economic interconnection between rural people and their counterparts in national and international urban centers.

In line with the laptop projects and vision 2030 in the country, most of the schools in local areas do not have electricity. Green energy will be important in ensuring that schools get power in a low cost without having to incur daily costs of electricity.

1.7 Scope of the Study

The study seeks to assess the socio-economic and environmental impacts of photovoltaic solar in Borabu division, Nyamira County at household level. The study was limited to governmental impacts, environmental impacts, climatic impacts and cost impacts of photovoltaic solar.

This included household residents of Borabu Division. Borabu division has a population of 58,079 people. (Population Census, 2009). Nyamira County is an administrative district in the old Nyanza Province of Kenya. It was formely part of the Kisii District. Nyamira district is administratively divided into five divisions namely; Rigoma, Nyamira, Manga, Ekerenyo and Borabu (the research area).

1.8 Limitation of the Study

Given the illiteracy level of the members of Nyamira County, Borabu Location, Household members found it difficult to read and understand the research instrument thus the researcher experienced a limitation of having to explain to them what the questions were asking.

Given the fact that the study was focused on one location in Kenya, the possibility exists that the study might not reflect the true picture of the entire country with regard to PV solar installation and use.

The study faced limitation of time. Due to this, the study did not look at the linkages of affordability which can be used as an index level of prosperity of the facilities.

1.9 Operational Definition of Terms and Concepts

Environmental sustainability: This refers to the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs (World Commission on Environment, 1987).

Photovoltaic (PV): It is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect(Photovoltaic Industry Association,2012).

Adaptation: Refers to an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderate, harm or exploit beneficial opportunities.

Climate change: The United Nations Framework Convention on Climate Change (UNFCCC), defines climate change as a "change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" or It is what we experience when the climatic conditions permanently shift either upwards or downwards of the average. Shifts in the start or end of the rainfall season, the length of the season, the number of rainy days, the number, length and intensity of dry spells, or changes in the total seasonal rainfall, among others, can also signify climate change.

Climate variability: Refers to fluctuations of the climate about the mean average conditions, with some periods experiencing 'normal' climatic conditions, others experience below 'normal' conditions and still others experiencing above 'normal' conditions.

Resilience: Refers to the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning and its capacity for self-organisation and to adapt to stress.

Vulnerability: is the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes.

Rural electrification: Refers small scale solar home systems covering basic needs in a single household, or larger mini-grids, which provide enough power for home use.

Greenhouse gases: Refers to many chemical compounds that are found in the Earth's atmosphere. These gases allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth's surface, some of it is reflected back towards space as infrared radiation (heat).

Pollution: Pollution is the contamination of the environment. It is a serious problem that causes instability, disorder, harm and discomfort to the ecosystem.

Poverty: Refers to the inability of the households in accessing key human attributes, including health. They are exposed to greater personal and environmental health risks, are less well nourished, have less information and are less able to access health care.

Urbanization: An increase of population in cities and towns versus rural areas.

Micro-enterprise: Is a sole proprietorship, partnership or family business that has fewer than five employees. It is small enough to benefit from loans and generally too small to access commercial banking services.

Grid-connected: This is the most popular type of solar PV system for homes and businesses that is connected with the solar for various uses.

Off-grid: This type of PV is used to connect to a battery via charge controller in circumstances where main electricity is not available.

Hybrid system: This type of PV system can be combined with another source of power-biomass generator.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter focused on the past researches that have been done relevant to this research study on socio-economic impacts of photovoltaic solar system. The chapter will explore relevant information from the past researches so as to narrow the gaps within the existing literature, methodologies and past findings within the aim of filling them. This chapter will and has helped in gaining a better understanding of the research under study in terms of the theoretical and empirical literature. The literature review will focus on the general information about PV solar, empirical studies and rural household installation examples from Africa and beyond.

2.2 Photovoltaic Solar

Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the increased demand for renewable energy sources, manufacturing of solar cells and PV arrays has advanced considerably in recent years.

Solar photovoltaic's have long been argued to be a sustainable energy source (Pearce,2002). By the end of 2011, a total of 67.4 GW had been installed, sufficient to generate 85 TWh/year and by end of 2012, the 100 GW installed capacity milestone was achieved. Solar photovoltaic's is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. More than 100 countries use solar PV. Installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building (either building-integrated photovoltaics or simply rooftop).

Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of photovoltaics has declined steadily since the first solar cells were manufactured, and the levelised cost of electricity (LCOE) from PV is competitive with conventional electricity sources in an expanding list of geographic regions (Swanson R.M,2009). Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity; have supported solar PV installations in many countries. With current technology, photovoltaics recoup the energy needed to manufacture them in 1 to 4 years. Solar cells produce electricity directly from sunlight (Green Tech Media, 2012). Note that this is for a horizontal surface, whereas solar panels are normally mounted at an angle and receive more energy per unit area.

The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy. Virtually all photovoltaic devices are some type of photodiode. Solar cells produce direct current electricity from sun light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaics was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines (Jacobson,2009).

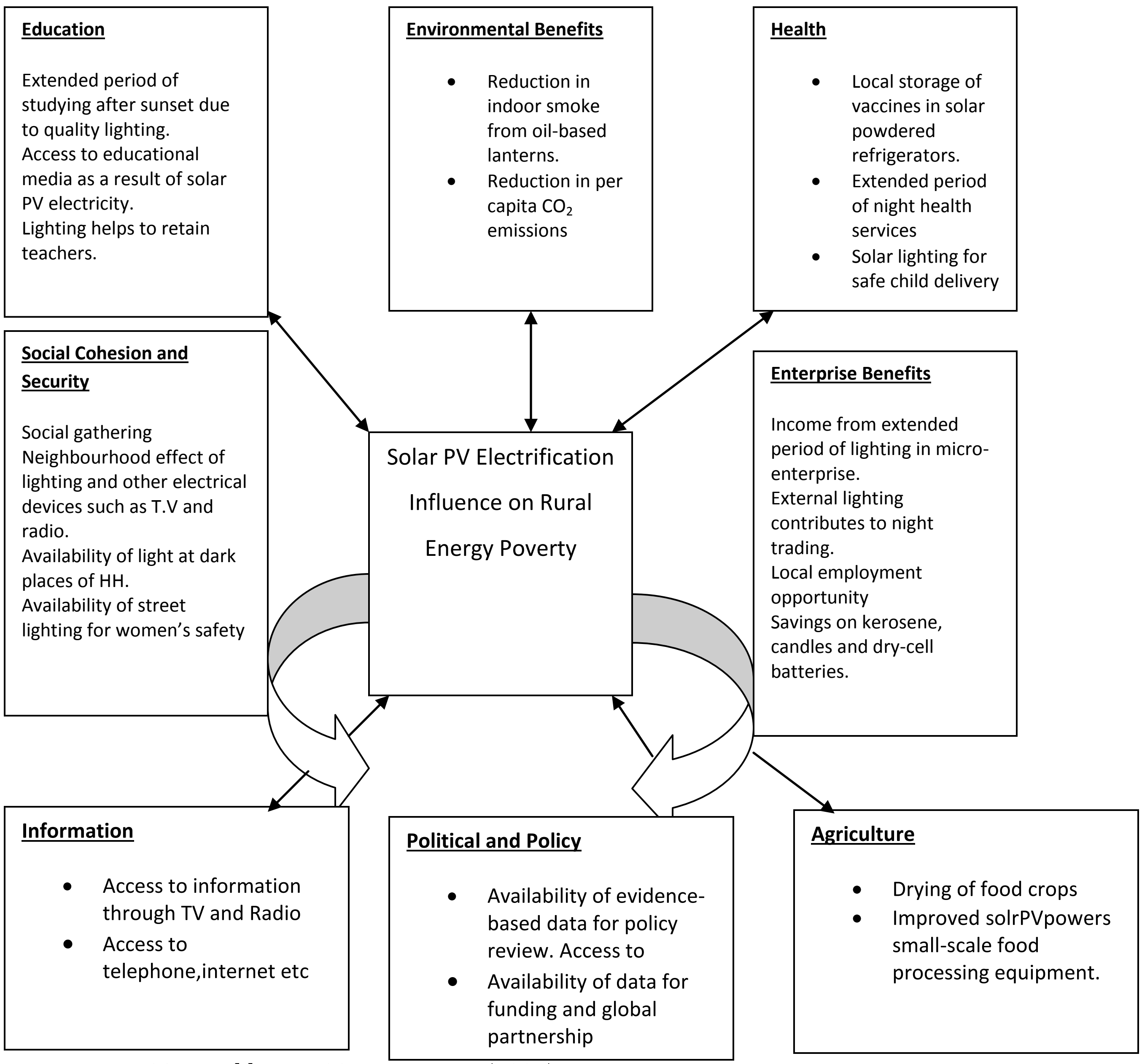
Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaics include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide (Jacobsons, 2009). Copper solar cables connect modules (module cable), arrays (array cable), and sub-fields. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays.

Photovoltaic power capacity is measured as maximum power output under standardized test conditions (STC) in "Wp" (Watts peak). The actual power output at a particular point in time may be less than or greater than this standardized, or "rated," value, depending on geographical location, time of day, weather conditions, and other factors (Renewable energy access.com, 2012). Solar photovoltaic array capacity factors are typically under 25%, which is lower than many other industrial sources of electricity. A significant market has emerged in off-grid locations for solar-power-charged storage-battery based solutions.

2.3 Theoretical Framework

This illustration below is based on a combination of models and findings from relevant literature (DFID cited in UNDP 2004; Fishbein, 2003; Martinot, 2004).

The Energy Quality of Life theoretical Framework .



Source: UNDP 2004; Fishbein, 2003; Martinot, (2004) The framework below is multi-sectoral linkages of solar PV influence on quality of life in off-grid rural communities. It indicates as well some social and economic benefits that may accrue to rural beneficiaries. Though solar PV rural electrification has linkages with several sectors, it also focuses on specific niches, particularly goals relating to education, health, information, agriculture and microenterprise known hereafter as the Energy quality of life framework. This is the authors' concept of how solar PV influences energy poverty reduction and contributes to quality of life improvement within the selected niches.

Solar PV Electrification as a Means of Promoting Education

It is reported that solar electricity lighting in remote rural schools permits children to extend their studies in the evening and helps retain teachers, especially if their accommodation has electricity (Allderdice and Rogers, 2000; PPIAF, 2002; DFID, 2002; UNDP, 2004). For many children, especially girls in rural areas the lack of electricity translates into a missed opportunity to attend school because they are overloaded with menial tasks such as fetching water and fuel during daylight hours (Allderdice and Rogers, 2000).

A survey to explore user perception about the positive linkage between rural electrification and education in Tunisia revealed that women and children especially benefited from improved access to education as a result of rural electrification (Cecelski, 2003). Although the study was not specifically on solar PV electrification, the findings may also apply to the linkage between solar PV electrification and children's extended study, particularly after sunset when lighting services are most needed.

PV and Health

In a rural clinic where there is no electricity, women deliver under very uncomfortable conditions due to the lack of essential equipment, medical facilities and poor visibility after sunset. Lastly, solar lighting in remote locations helps to maintain qualified health staff, who would otherwise opt to work in grid-connected towns and cities (DFID cited in UNDP, 2004).

Electrification, Information and Communication

There is a growing under-provision of investment in both grid-electricity and telecommunication facilities in rural areas of most developing countries (Economic Commission for Africa, 2004).

For this reason, solar PV provides alternative power to meet the information and communication needs of offgrid rural and peri-urban communities. By powering radios, televisions or computers with solar PV, rural households are able to access health, education, business, agricultural and environmental information to better their standard of living (Greenstar, 2004; Amankwaah, 2005).

Solar PV Electrification, Agricultural Processing and Rural Enterprises

Typically electricity to run a motor for a grain mill can transform a manual subsistence household activity into an income-generating enterprise, or help transform a barely viable enterprise into a more sustainable one (Allderdice and Rogers, 2000).

Small rural stores can also expand their inventory by adding items that can be preserved using solar-powered refrigerators (Allderdice and Rogers, 2000, Etcheverry, 2003). For example, solar PV-powered icemakers can assist village micro enterprises in fishing, sale of ice cubes and cold drinks especially in tropical countries. Solar crop drying by small electric fans that circulate air around a heated surface, can also be used to preserve crops for export.Solar PV electricity helps micro-enterprises to generate additional income by extending their working hours after dusk (Grameen Communications, 1999; Allderdice and Rogers, 2000; DFID 2002). However, there are so few published data that indicate in quantitative terms the additional incomes likely to be generated after sunset by different solar-electrified enterprises.

2.4 Social-Economic Impacts of PV Installation and Use

2.4.1 Governmental Impacts

The 1973 oil shocks and concerns about global warming from the late 1980s are two developments that could have led to greater use of renewable energies (Russell and Bunting, 2002). However, national policies and political support have remained weak. The global growth rate of 20 percent for solar PV is a reflection of the current lack of political support for the rural off-grid sector (Plastow and Goldsmith ,2001).

In the recent past, Kenya has undertaken substantial and highly encouraging reforms related to the power market: an energy policy was formulated calling for increased private involvement, and paving the way for tapping of enormous Renewable Energy potentials.

2.4.2 Environmental Impacts

Hazardous Materials

The PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals, similar to those used in the general semiconductor industry, include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone. The amount and type of chemicals used depends on the type of cell, the amount of cleaning that is needed, and the size of silicon wafer (Hand and Baldwin, 2012). Workers also face risks associated with inhaling silicon dust. PV manufactures must follow laws to ensure that workers are not harmed by exposure to these chemicals and that manufacturing waste products are disposed of properly.

Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride (National Renewable Energy Laboratory, 2010). If not handled and disposed of properly, these materials could pose serious environmental or public health threats. However, manufacturers have a strong financial incentive to ensure that these highly valuable and often rare materials are recycled rather than thrown away.

Life-Cycle Global Warming Emissions

While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour. Most estimates for concentrating solar power range from 0.08 to 0.2 pounds of carbon dioxide equivalent per kilowatt-hour. In both cases, this is far less than the lifecycle emission rates for natural gas (0.6-2 lbs of CO2E/kWh) and coal (1.4-3.6 lbs of CO2E/kWh) (IPCC, 2011).

Land Use

Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss. Total land area requirements vary depending on the technology, the topography of the site, and the intensity of the solar resource. Estimates for utility-scale PV systems range from 3.5 to 10 acres per megawatt, while estimates for CSP facilities are between 4 and 16.5 acres per megawatt. Unlike wind facilities, there is less opportunity for solar projects to share land with agricultural uses. However, land impacts from utility-scale solar systems can be minimized by siting them at lower-quality locations such as brownfields, abandoned mining land, or existing transportation and transmission corridors (Hand and Baldwin, 2012). Smaller scale solar PV arrays, which can be built on homes or commercial buildings, also have minimal land use impact.

Water Use

Solar PV cells do not use water for generating electricity. However, as in all manufacturing processes, some water is used to manufacture solar PV components. Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system. CSP plants that use wet-recirculating technology with cooling towers withdraw between 600 and 650 gallons of water per megawatt-hour of electricity produced. CSP plants with once-through cooling technology have higher levels of water withdrawal, but lower total water consumption. Dry-cooling technology can reduce water use at CSP plants by approximately 90 percent (Hand and Baldwin, 2012). However, the tradeoffs to these water savings are higher costs and lower efficiencies. In addition, dry-cooling technology is significantly less effective at temperatures above 100 degrees Fahrenheit.

2.4.3 Climate Impacts

According to National Climate Change Action Plan (2013-2017), climate change is the most global challenge of our time. The impacts of climate change on societies around the world are evident. Kenya is one of the most vulnerable countries to climate change, and economic sectors and livelihoods are already experiencing the manifestations of the problem. The plan will guide the country's' development so that it can work on climate resilient and low carbon path. Climate change is no longer contested-there is significant evidence, and it is happening now, with severe impacts expected over the short, medium and long term. The 2010-2011 Horn of Africa crisis demonstrated Kenyans vulnerability to climate change and variability, and also presented an opportunity for Kenya to find sustainable solutions to climate related crises by scaling up and joining up social protection to cushion the poor.

The NCCAP'S adaptation analysis explains that the key climate change impacts for Kenya are drought and water scarcity, flooding and sea level rise. Research suggests that temperatures will continue to increase, and the frequency of hot days and nights will rise. Climate changes have adverse impacts on human activities. It can also pose major threats to the environment, economic growth and to sustainable development in Kenya. (NCCAP report ,2012).According to National Climate Change Action plan for Kenya 2012,a range for adaptation and mitigation actions in the context of a low carbon climate resilient development pathway. The big wins identified will make a significant impact on sustainable socio-economic development, adaptations and mitigation in Kenya. One of them is to distribute evenly clean energy solutions.

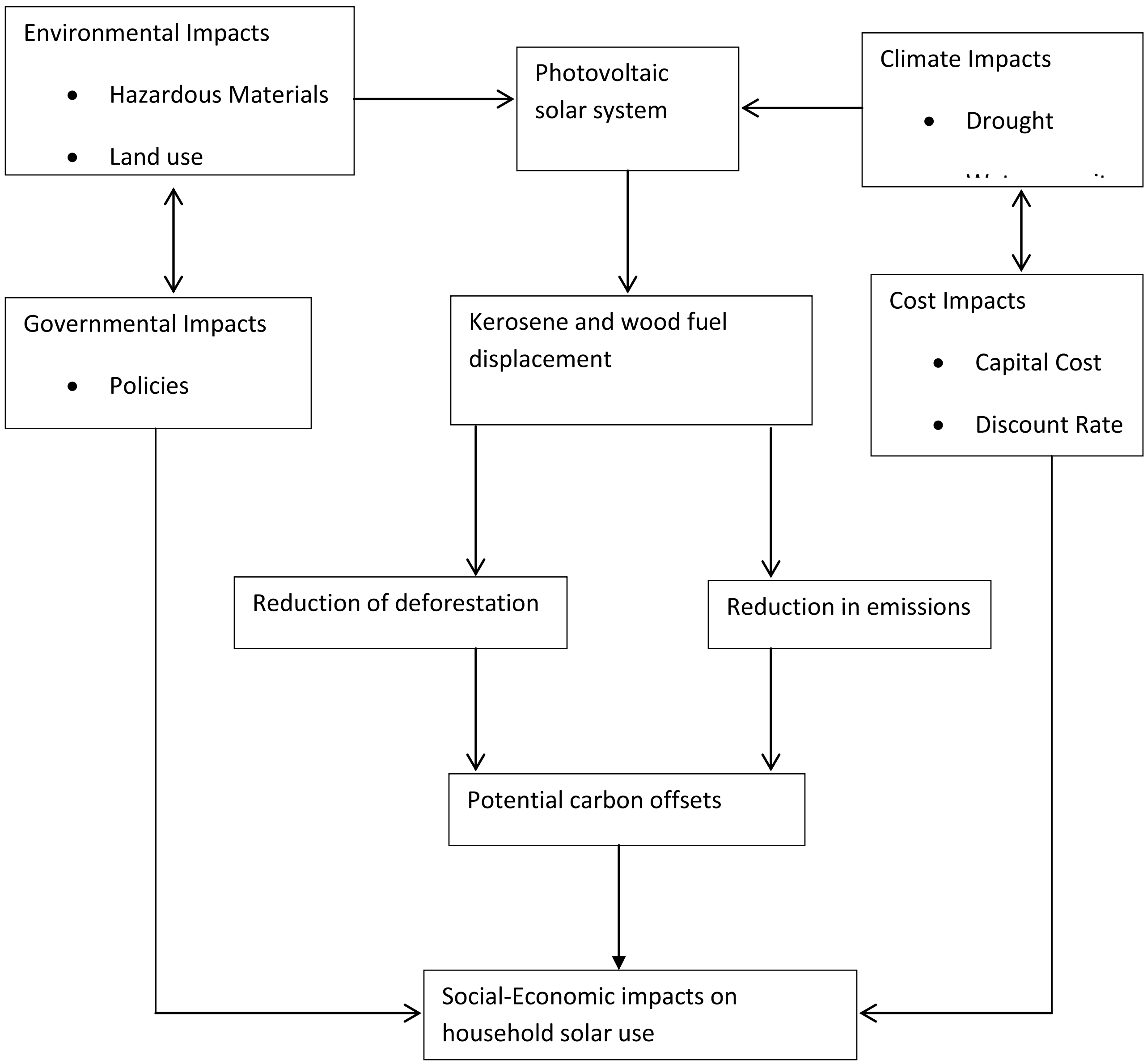
2.4.4 Cost impacts

The cost of the electricity generated by a PV system is determined by the capital cost (CAPEX), the discount rate, the variable costs (OPEX), the level of solar irradiation and the efficiency of the solar cells (Bank, 2010). Of these parameters, the capital cost, the cost of finance and efficiency are the most critical and improvements in these parameters provide the largest opportunity for cost reductions. The capital cost of a PV system is composed of the PV module cost and the Balance of system (BOS) cost. The PV module is the interconnected array of PV cells and its cost is determined by raw material costs, notably silicon prices, cell processing/manufacturing and module assembly costs (Bank, 2010). The BOS cost includes items, such as the cost of the structural system, the electrical system costs and the battery or other storage system cost in the case of off grid applications (Kersten, et al. 2011).

According to Komoto (2010), the absolute cost and structure of PV modules varies by technology. Conventional c-Si PV modules are the most expensive PV technology, with the exception of CPV modules, but they also have the highest commercial efficiency. However, CIGS modules are approaching the efficiency levels of c-Si modules and are cheaper. Accurate data on global average PV module prices are difficult to obtain and in reality there is a wide range of prices, depending on the cost structure of the manufacturer, market features and module efficiency (Komoto 2010).

In densely populated and concentrated rural areas of poor developing countries grid extension may be feasible and cost effective (Chaurey et al, 2004). However, in practice, utility companies are usually not attracted to extend grid electricity to 'isolated' or remote rural areas because of cost implications and the relatively low revenue per kilometer (Chaurey et. al., 2004, Munda and Russi, 2005). For example, the high cost of electrification makes it financially unbearable to provide electricity to rural areas in Pakistan where 67.5% of the people lived (Aslam, 2000). In remote areas, where the extension of grid-electricity is found to be expensive, solar PV systems and other energy sources including mini-hydro, wind, bio-fuel powered generators have largely demonstrated their potential for meeting the expectations of off-grid rural communities (Lorenzo, 1997). Although solar PV systems are cost-effective alternatives for low voltage applications, high installed system cost, lack of local market, lack of sustainable financing among others impede the expansion of solar PV electrification in poor developing countries (Basnyat, 2004;Johansson et al, 2004; Sawin, 2004; WCRE, 2004).

2.5 Conceptual Framework



(Source: Modified from Author UNDP 2004)

2.6 Types of Photovoltaic (PVs) System

2.6.1 Grid-connected

This is the most popular type of solar PV system for homes and businesses in the developed world.

Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC produced by the system to AC power for running the electricity equipment.

2.6.2 Off-grid

Where no main electricity is available, the system is connected to a battery via charge controller .This stores the electricity generated for future use and acts as the main power source and supply. An inverter can be used to provide AC power, enabling the use of normal electrical appliances. Typical off-grid applications are used for stations with mobile phones, electrification for remote areas or rural electrification in remote areas.

2.6.4 Hybrid system

A solar system can be combined with another source of power-biomass generator, a wind turbine or diesel generator to ensure consistent supply of electricity. A hybrid system can be grid-connected, stand alone or grid support (European Photovoltaic Industry Association, 2008).

2.7 Growth of Renewable Energy Sources in Kenya

Renewable energy source have grown to a supply an estimated 16.7% of global final energy consumption in the year 2010.Of this total, modern renewable energy accounted for the estimated 8.2%,a share that has increased in the recent years, while the share from traditional mass has declined slightly to an estimated 8.5%.During 2011,modern renewable continued to grow strongly in all end use sectors: Powers, heating and cooling (Ren21 report 2012)

In the power sector, renewable accounted for almost half the estimate,208gigawatts (Gw) of electric capacity added globally during 2011.Wind sand photovoltaics solar accounted for almost 40% and 30% of renewable capacity worldwide exceeded 1,360 Gw,up to 8% over 2010;renewable comprised more than 25% of the total global capacity(estimated 20.3% of global electricity in 2011).Non-hydropower renewable exceeded 390GW,a 24.0% capacity increase over 2010.

German continues to lead in Europe and to be in the forefront globally, remaining among the top users of many renewable technologies for power; heating and transport.

In 2011, renewable provided 12.2% of Germans final energy consumption (up from 11.6% in 2006), 10.4% of heating demand (up from 6.2%),and 5.6% of transport fuel excluding air traffic.(Ren21 renewable energy report 2012).

2.8 Main sources of energy in Kenya

The main sources of energy supply in Kenya are electricity, wood fuel, petroleum and renewable energy. Commercial energy in Kenya, dominated by petroleum on-grid and off-grid electricity, the charcoal and portion of wood fuel. Biomass including agricultural waste constitutes the non-commercial proportion of the energy sector. Kenya consumed a total of 15,108kilotones of oil equivalent in 2008 according to IEA(2011),with energy per capita of 468kg of oil equivalent which is less than one quarter of worlds average per capita. Solid biomass remains the dominant source of energy in Kenya meeting the estimated 77% of the entire demand.

The Kenya vision 2030 has identified energy as the key foundation and one of the infrastructural “enablers” upon which the economic, social and political pillars of this long-term development will be built. The successful implementation of the flagship projects highlight in vision will greatly depend on the supply of adequate, reliable, clean and affordable energy. In particular, the demand of electricity will increase since it is the prime mover of the commercial sector of the economy. The level and intensity of commercial use in the country is a key indicator of the degree of economic growth and development. The energy sector is therefore expected to remain a key player in tackling such challenges as reduction of poverty by half by the year 2015 as per the millennium Development Goals(MDG’s) and overall improvement in the general welfare of the population.(Kenya Vision 2030 report).

2.9 Rural Photovoltaic Household Solar Installation

Unlike the past decade, which saw solar solutions purchased mainly by international donors, it is now the locals who are increasingly opening their wallets to make the switch from their traditional energy means. That is because solar products prices in recent years have declined to become cheaper than kerosene and batteries (Green Tech Media, 2012).In Cambodia, for example, villagers can buy a solar lantern at US$25 and use it for years without any extra costs, where their previous spending on kerosene for lighting was about $2.5 per month, or $30 per year. In Kenya a solar kit that provides bright light or powers a radio or cell phone costs under $30 at retail stores. By switching to this kit Kenyans can save $120 per year on kerosene lighting, radio batteries and cell phone recharging fees.

Developing countries where many villages are often more than five kilometers away from grid power are increasingly using photovoltaic. In remote locations in India a rural lighting program has been providing solar powered LED lighting to replace kerosene lamps. The solar powered lamps were sold at about the cost of a few months' supply of kerosene(B.B.C news,2007).Cuba is working to provide solar power for areas that are off grid(Barclay,2003). These are areas where the social costs and benefits offer an excellent case for going solar though the lack of profitability could relegate such endeavors to humanitarian goals. These interconnections are facilitated when rural Kenyans, in most cases from the rural middle class, use solar electricity to power ‘‘connective’’ appliances, including televisions, radios, and cellular telephones. Connective applications are especially prevalent in households with the small solar photovoltaic (PV) systems (<25 W) that are most common in unsubsidized solar markets like the one in Kenya .Thus, while solar PV is commonly framed as an element in efforts to promote sustainable development through the delivery of lighting services to un electrified areas, evidence from Kenya indicates that the development implications of solar electrification are closely linked.

Kenya has emerged as one of the global leaders, per capita, in the use of renewable energy technology. This is due largely to a growing market for solar PV systems among rural households, with cumulative sales since the mid-1980s in excess of 200,000 PV systems, and current annual sales topping 25,000 units (ESDA, 2003; Jacobson, 2004). Data from a year 2000 survey conducted by the Tegemeo Institute indicated that 4.2% of rural Kenyan households owned a solar system. The same survey found that 4.3% of rural households were connected to the national electrical grid, and other sources indicate that solar sales are growing faster than the rate of new rural grid connections (ESDA, 2003; Jacobson, 2004). In other words, solar electricity has emerged in Kenya as a key alternative to grid-based rural electrification. The Kenya solar market is also notable, and in fact has served as a model in energy and development policy circles, because it developed with a minimal direct government support and only very moderate inputs from international donor aid groups.

Solar sales in Kenya have long been (and continue to be) driven largely by unsubsidized over-the-counter cash purchases of household solar systems 4 (Acker & Kammen, 1996; Hankins, 2000; Hankins &Bess, 1994; van der Plas & Hankins, 1998).

This makes Kenya an important example of a growing international trend toward market-based approaches to rural energy service delivery. While there is little doubt about the size and rapid growth of the Kenya solar market, there is an ongoing debate about how to interpret its significance. Solar advocates commonly make claims about the environmental, rural productivity, and poverty alleviation benefits of solar PV (e.g., Greenpeace, 2001; Kaufmann, 2000; Martinot et al., 2002). Some skeptics challenge these claims, contending that the environmental benefits of solar electrification are minimal, economically productive uses are few and far between, and that, in the absence of large subsidies, solar sales are primarily to the rural elite rather than the rural poor (e.g.,Inverson, 1996; Karekezi&Kithyoma, 2002;Leach, 2001; Villavicencio, 2002).

Africa, with its low electrification rates and low per capita income, has not seen significant growth in solar with exception of a few countries. Kenya had 150,000 Solar home systems (as of 2005), almost half of the installed base in Africa, and continuing market growth.

Growth has been driven by cash sales of small modules to households in rural and peri-urban areas (Inverson, 1996; Karekezi&Kithyoma, 2002; Leach, 2001; Villavicencio, 2002). Most income source comes from farming activities which is small scale. This means that income per household is limited. It will be an important asset to substitute a low cost technology to raise their standard of living.

As this has generated a greater demand for PV technology, large numbers of middle class and rural households started to buy small PV panels for lighting and television, thus driving down the cost and creating a local industry for technicians trained in PV installation and repair. It is on this basis that the research would open up a forum for economic activities associated with solar in the region to spur up economic development. Another reason why this research should be carried out is that there emergency of hire purchase agencies, which have allowed Kenyans without Marginal income to afford the startup costs to purchase a PV system on credit, further eliminating the price barrier of the system.

According to Kenya Vision 2030, solar power system costs of $2.33 per watt, solar electricity prices of 3.8 cents per kilowatt-hour (kWh) delivered to the customer, installed solar power generation of 200 gig watts (GW), and direct employment of 260,000 people.

If this is the trend from the government, then the research will provide information to the government for better planning on PV solar socio-economic activities. Development projects recommended under vision 2030 and overall economic growth, will increase demand on Kenya's energy supply. Currently, Kenya's energy costs are higher than those of higher competitors. Kenya must, therefore, generate more energy and increase efficiency in energy consumption. New sources of energy will be found through exploitation of geothermal power, coal, renewal energy sources.

While its use is small today, solar photovoltaic (PV) power has particularly promising future. Global PV capacity has been increasing at an average annual growth of more than 40% since 2000 and it has a potential for long term growth over the next decades. This roadmap envisions that by 2050, PV will provide 11% of global electricity production (4500 TWh per year), corresponding to 3000 gigawatts of cumulative installed PV capacity. In addition to contributing to significant greenhouses reduction, this level of PV will deliver substantial benefits in terms of the security of energy supply and socio-economic development not forgetting environmental conservation and sustainability. Achieving this target will require strong policy effort in the next decade to allow optimal technology progress, cost reduction and ramp up of industrial manufacturing. PV is expanding rapidly due to effective supporting policies and recent dramatic cost reductions. PV is a commercially available and reliable technology with significant potential for long term growth in nearly all world religions.

PV is projected to provide 5% of global electricity consumption by the year 2030,arising to 11% in 2050(ESDA, 2003; Jacobson, 2004).Achieving this level of PV, electricity supply and the associated environmental, economic and societal benefits will require more concerted policy support, sustained, effective and adaptive incentives. Schemes are needed to help bridge the gap to PV competitiveness, along with a long-term focus on technology development that advances all types of PV technologies, including commercially available systems. One of the studies carried out in the year 2005, found out that more than 2million households in developing countries were receiving electricity from solar home systems.

Most of these systems and most of the global growth in recent years are occurring in few specific Asian countries such as India, Sri-lanka, Nepal, Bangladesh, Thailand and China where affordability problem has been overcome either by micro-credit or by selling small systems for cash or where government and international donor programs have supported the markets.

In each of these countries hundreds or thousands of new household installations are now occurring monthly (10,000) per month reported in china in 2005. Outside Asia, other large markets include Kenya, Morocco and Mexico (ReN 21, 2005).A study by the German Development Organization (GTZ) IN 2001, noted that the lack of financial services for users of solar home systems (SHS) is often regarded as the main barrier for their commercial dissemination and are often the justification for donor assisted programmes. The study wished to shed more light on the question whether commercial SHS is often dissemination in remote areas could be made easier if financial services were available. It was based on the thesis that carefully designed target-group oriented financial services may speed up the widespread of solar systems. This study did not focus or show the significant growth of solar panel users with reference to household individuals.

Another study commissioned by the world bank in Bangladesh by Wang etal (2011) concluded that dissemination of solar home systems brings about significant carbon beneficio, this was a case study which was carried out in Bangladesh where solar system subsidies in rural Bangladesh are progressive. The study concluded that if micro-credit schemes are made available, and the propensity to install solar home systems is very responsive to income. Specic impacts of solar use and the factors that hinder the growth of the PV system were not brought out clearly in this study. A report from renewable energy policy project in 1999, stated that for adopters, solar home systems (SHS) are assumed to substitute kerosene lighting and battery charging or use of wood fuels. And the baseline consumption is assumed to be relatively high, example if 10 litres of kerosene consumed per month, around 0.3 metric tons of carbon dioxide (CO2) per year is released or about 6 tons over 20years.Therefore installation of Solar home systems displaces the above emissions. According to Jacobsons (2009), very few people in the village are aware of carbon emissions, therefore the people need to be aware of other productive use of solar first before talking about carbon emissions. It’s about this background that this study will assess the various productive use of solar.

According to Kenya's vision 2030, energy is one of the infrastructural "enablers" of the three pillars of vision 2030.As incomes increase and urbanization intensifies, household demand for energy will also rise. The vision further points out that commercial energy in Kenya is dominated by petroleum and electricity as the prime movers of the modern sector of the economy, while wood fuel and biomass account for 68% of the total primary energy consumption, followed by petroleum at 22%, electricity 9% and others including coal at less than 1%.Solar energy is also extensively used for drying and, to some extent, for heating and lighting.

Electricity remains the most sought after energy source by Kenya society and access to electricity is normally associated with rising quality of life. However consumption in Kenya is extremely low at 121 kilowatt hours (kWh) per capital. It is against this backdrop that PV technology can provide a viable, cost effective, low carbon by emitting means to bridge the need for a rising quality of life without compromising on the quality of atmosphere in Kenya. Also the study only focused on the challenges of installing electricity and not solar. The researcher in this work will specifically weigh the challenges the adopters face in installation of the PV systems (Kenya Vision 2030, 2007).

In general, energy is not considered as a basic human need. In the past, rural energy, in particular, was not widely accepted as a basic need like water and food in the development circles (Clancy, 1999 by Cecelski, 2003). Nonetheless, energy, particularly electricity is required for meeting basic needs such as health, agriculture, education, information and other infrastructural services and shows a clear correlation with per capita income and human development index (Anderson, 2000; Gillis et al, 1992; Rehling, 2002).

A study carried out in Ghana and other African countries, increased use of renewable energies such as solar, wind, biomass and biogas have been identified as alternatives to grid-electricity supply in remote rural areas for poverty reduction (World Bank, 2003).In recent times efforts at the global, regional and local levels have been intensified to link energy to sustainable development and poverty reduction. It is understood that unavailability of electricity services in rural and peri-urban areas is usually associated with poverty and it is among the most serious problems confronting everybody (Lorenzo, 2000; UNDP, 2004).At the ninth session of the United Nations Commission on Sustainable Development (CSD-9) renewables and rural energy were identified among the key energy issues for sustainable human development (Chaurey et al, 2002). The study tried to link electricity supplies with poverty reduction. In this research we will look at the general contributions of solar energy on the economic development.

Several authors have provided analysis of the link between energy (electricity) and major global issues such as health, education, water, gender etc (Cecelski, 2003; DFID, 2002; UNDP, 2004). PV must be linked to development strategies for education, health, agriculture, infrastructure, political and economic. Improvements within these contexts, the linkages of energy strategies to poverty reduction and quality of life have been under-explored. This is partly because the definition of poverty has been centered around the money metric measures of income, expenditure, or consumption. Therefore, in addition to consumption poverty, the Ghana Living Standards Survey (GLSS) considered other dimensions of poverty including lack of access to services and limited human development (Ghana Statistical Service, 2007). The Ghana study focused on poverty reduction through the use of electricity supply to the rural areas, this research will focus on household use of solar panels and how this can contribute to socio-economic sustainability.

Quality of life is simply life goals expected to be fulfilled: better education, health, access to information, indoor lighting, among others. Significant impacts of solar PV systems include better quality of light, car batteries do not have to be transported, and indoor smoke and fire hazards from kerosene lanterns are reduced (Posorski, 1996; Obeng et al 2008b).Furthermore solar PV electrification contributes to improve quality of life in off-grid rural communities through the direct effect of the technology on household wellbeing and enterprise income (Cabraal et al, 1996; Fishbein, 2003; Martinot et. al., 2002; Posorski, 1996). It should be stressed that the gradual replacement of fossil energy electrification with renewable will not provide all the energy needs for quality of life improvements. However, there are many applications that can improve the quality of life of rural households. These include among others the replacement of kerosene lanterns and candles with solar PV lighting (Plastow and Goldstone, 2001).

On the expenditure side, rural households in developing countries typically spend between US$3 and US$20 per month on kerosene, candles, or other energy products. With the use of kerosene and dry-cells, it is observed that monthly expenses can be as costly as US$ 10 per family (Lorenzo, 1997).

Cabraal et al. (1996) repored that in Sri Lanka and Indonesia, recurrent costs on kerosene, candles and batteries could reach $10-$30 per month. These are relatively high expenditures.

Though the use of solar PV may reduce the recurrent costs associated with the use of kerosene, candles, and batteries, the amount of the reduction is uncertain and therefore deserves research attention. Many of the studies that have been carried out are about the use and impacts of non-renewable fossil fuels such as electricity. Very few researches that have been carried out about renewable sources of electricity. Therefore on this research will evaluate different impacts of PV use in the society how this can lead to socio-economic sustainability. And while majority of the researches have been carried out in the peri-urban areas, this research will focus on purely rural set up.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter sets out various stages and phases that were followed in completing the study. The following subsections were included; study area, target population, Sampling Procedure and finally research design, data analysis.

3.2 The Study Area

Position and size

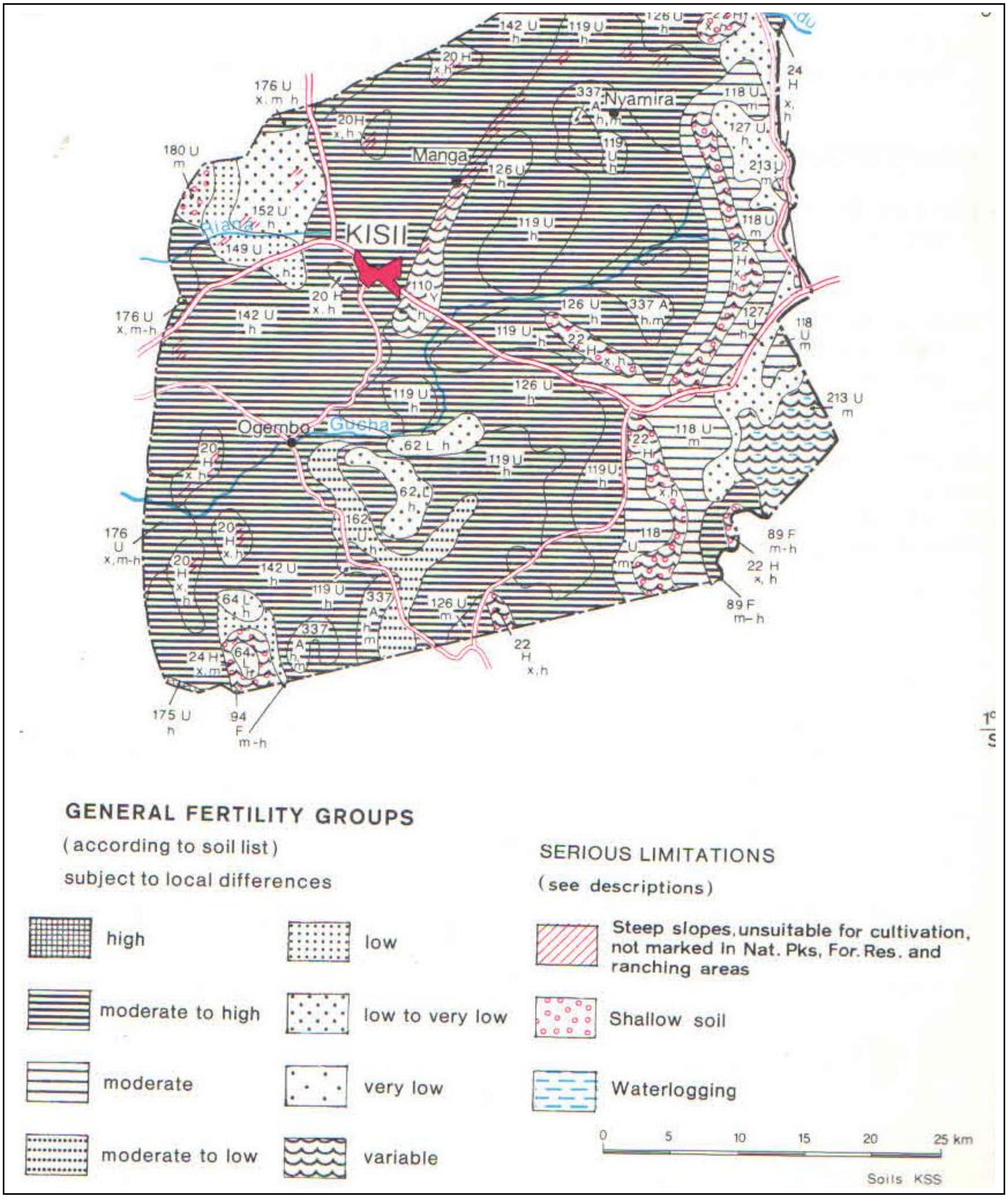
Nyamira County is one of the nine counties that make up Nyanza Province. It shares boundaries with Rachuonyo County to the North, Transmara County to the South, Kericho County to the South East. The county lies between latitudes 0˚45" and 35˚ 00" South, and longitudes 30˚45" and 35˚ 00" East. The total area is approximately 879 square kilometers shared among five divisions as indicated in the table below.

Table 3.1: Area in Square kilometers.

Division	**Area(sq.km)**
1.Nyamira	180
2.Ekerenyo	215
3.Borabu	297
4.Manga	91
5.Rigoma	141
Total	**879**

Source: population census (2009)

Soils in Kisii



Source: Ralph J. (1978). Farm Management Hand Book of Kenya: Ministry of Agriculture. Vol. II/A

Majority of the land in the district belongs to the south-western highlands with undulated topography. Several levels which are occasionally separated from each other by scarps can be distinguished. The parent rock is mainly volcanic and out-crops in a few hills. Majority of the soils in Kisii are clay and loam soil which support subsistence crops and cash crops.

Population

According to the national census exercise that was carried out in 2009, the total number of people living in Nyamira County was approximately 598,252 making it one of the less populated counties in the country. 14% of the total population was found to be living in the urban areas while the rest of the population resides in the rural areas. Nyamira County is a county in the Nyanza Province of Kenya. It has a Total Population of 598,252; 131,039 Households and covers an area of 899.3 sq. km. The Population density is 665 persons per square kilometer and 46.6% of the population lives below the poverty line. Borabu division has a population of 58,079 (Population Census, 2009).

Topography and climate

The topography of Nyamira County is mostly dissecled by several ridges and hills. Kiabonyoru hills, Manga Escapment and Nyamabisimbi Hill are the most prominent features according to Nyamira District plan 2007.The two topographical zones found in the district lie between 1,500M and 1800M above the sea level .Areas lying above 1,800M altitude comprise the Sourthern part of Nyamira Ekerenyo Divisions.

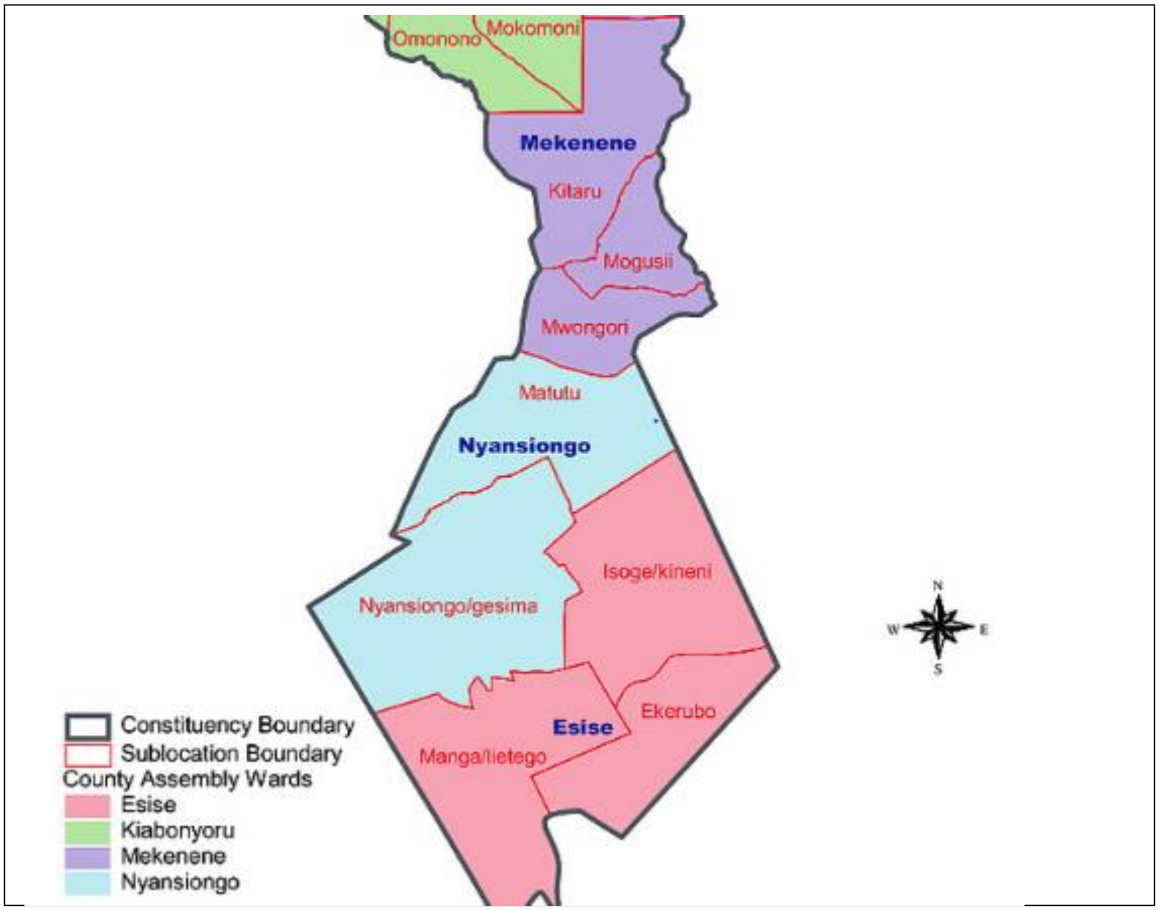
Drainage patterns

The drainage pattern in the district is that rivers and streams drain into Lake Victoria. The climate of the area is of a highland equatorial type which enables it to receive high and reliable rainfall that is well distributed throughout the year. The district has got two rainy seasons of which the long rainy season occurs in March to June while short rainy season is from October to December. The highest amount of rainfall is received during the month of April, while the least is received in the months of January and August. The division receives an average rainfall of 2000mm per annum.

Temperatures

The district generally experiences maximum mean monthly temperatures between 24.7˚C and minimum mean monthly temperatures of between 9.9˚C to 11.9˚C.

Figure 3.1: Map of Borabu Location (Study Area)



Source: IIBC, 2012

3.3 Research Design

This research study adopted a cross-sectional research design. This type of study utilized different groups of people who differed in the variable of interest, but share other characteristics such as socioeconomic status, educational background, and ethnicity.

3.4 Target population

The study was undertaken in Borabu division in Nyamira County. This included household residents. It was formerly part of the Kisii District. Nyamira district is administratively divided into five divisions namely; Rigoma, Nyamira, Manga, Ekerenyo and Borabu (the research area).Borabu division has a population of 58,079(Population Census, 2009).

3.5 Data types and sources

The study ued both primary data and secondary data in an attempt to answer the stated research questions.

Primary data

Primary data was obtained from field observations, field interviews were designed to capture information of the following variables. Two reconnaissance surveys were carried out at the Division and its surrounding environment.

The first section of the questionnaire was drafted using a psychological model of home school and community partnerships: implications for research and practice journal of educational and psychological consultation (Smith and Connel, 1997).

Enumerators were engaged in the administration of the questionnaires in the study area with a total of over 30 respondents being interviewed. The ages of the respondents ranged from 20-60 years old. Each respondent was asked a series of questions which were expected to be answered as honestly as possible.

Secondary data

Secondary data was obtained from Government publications such as economic surveys, population census reports, statistical reports, statistical abstracts and development plans among others.

A systematic study was done from already published literature with respect to physical, biological and social environment of Borabu in order to establish facts and to analyze questionnaires so as to reach informed conclusions.

In order to assist in the assessment and dissemination of the significant environmental impacts, various international and local planning guidelines and regulations were carried out by the study and used as reference points. The pertinent national Legislation on environment, national regulations and standards, conventions and treaties were part of the secondary sources of data that was used in this study.

3.6 Sampling procedure

Random sampling method was used to determine the sample size. Then the selection of an element/sample was based on equal intervals, starting with randomly selected element on a population list. And for the researcher to have a good representation the number of the sample were more than 30 so as to have more accurate information.

3.7 Data collection

The research instruments, which were used for this study included: structured questionnaires, direct observation in culmination with photography of the PV panels in use. The researcher pre-tested the research instruments such as the questionnaire to ascertain the tool's capability to collect necessary data. The researcher ensured the tools met the construct validity, internal validity, external validity and reliability. This was done first through a mini-pilot survey so as to determine the correct measures for the concepts being studied.

3.8 Data analysis

After data collection, analysis was done using. Both qualitative and quantitative methods of data analysis were used. The data collected was used to test the null hypotheses. The nature of the data which was collected prompted the use of chi-square.

This was because it provided a relationship between the two variables. It measured the discrepancy between the observed and the expected frequencies. So the test was easy to use (Mugenda, 1999).This also matched because a chi-square is a non-parametric test.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

1.1 Introduction

In the previous chapters, the concepts and theoretical background to the impacts of photovoltaic solar system were discussed through a comprehensive literature study. In order to address the research objective highlighted in Chapter one, a research study was conducted to provide an understanding of the impacts. The purpose of this chapter is to present responses obtained from various participants in the research project.

4.2 Analysis of Data Collected

In Chapter one, an assumption was made that there are impacts of photovoltaic solar system and these impacts affect the installation and use of photovoltaic solar system. To test this study problem, data was collected from household residents in Borabu Division in Nyamira County.

Data was collected through a questionnaire consisting of two sections. The first section of the questionnaire obtained data on general information of the respondents. Continuous variable such as years shall be presented using tables and figures. The second section obtained data on the impacts of photovoltaic solar installation and use.

4.3 Response Rate

A total of 30 questionnaires were distributed to the potential respondents who were the house hold residents of Borabu Division, Nyamira County. All the questionnaires were filled and received back and therefore none of the questionnaire was returned without being filled. This represents a 100 percent return rate.

Based on this response, the researcher was satisfied and continued with the data analysis and presents the findings. In the following section, the researcher presents the results according to sections as highlighted on the research instrument.

4.4 General Information

This section sought information about the general information of the respondents. Among the questions that were used include the sex of the respondents, age of the respondents, education level and the marital status. The information on this section will be presented using tables and figures.

4.4.1 Sex

This part of the question sought information about the gender of the respondents. The results are presented using a table and a figure chart.

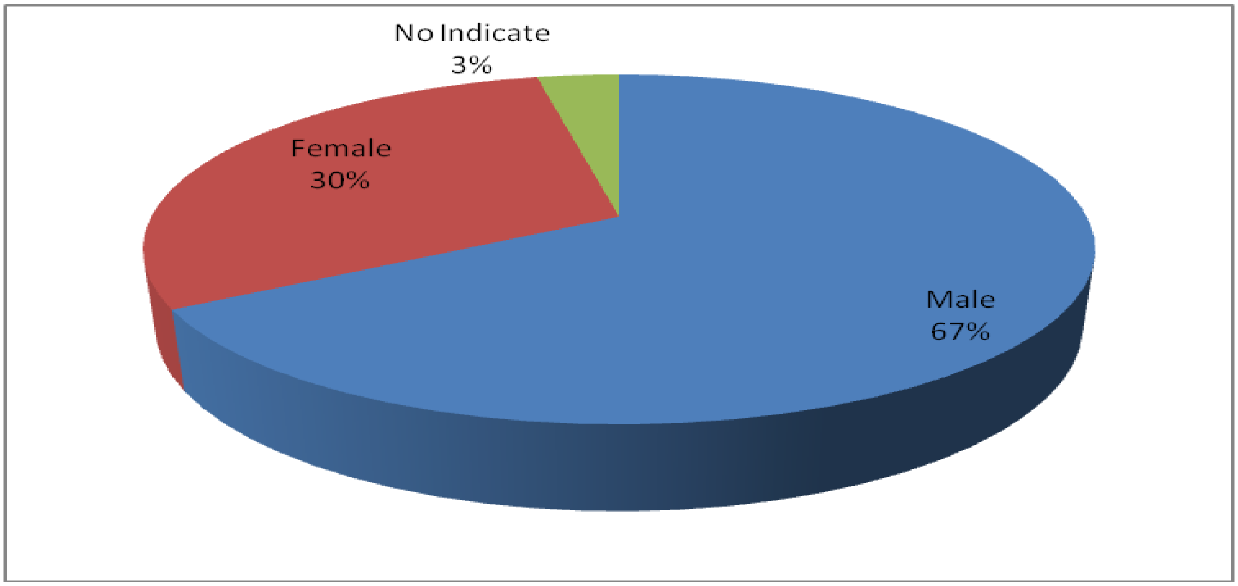
Table 4.2: Sex of the Respondents

Sex	**Frequency**
Male	20
Female	9
No Indicate	1
Total	**30**

Source: Research Data

From the table above, there were 20 male and 9 female who responded to the questionnaires. However, 1 respondent did not indicate his/her gender on the research instrument. The proportions of the respondents are shown on the figure below.

Figure 4.2: Sex of the Respondents



Source: Research Data

On figure 4.2 above, there were there were 67 percent male and 30 percent female who responded to the questionnaires. However, 3 percent of the respondents did not respond the question on the research instrument as required.

4.4.2 Education Level

This part sought information about the education level of the respondents. Primary level, secondary level, tertially and none were the levels provided by the researcher. The results are presented below.

Figure 4.3: Education Level of the Respondents

Education Level	Frequency	Percent
Primary	2	6.70%
Secondary	9	30.00%
Tertially	19	63.30%
Total	**30**	**100.00%**

Source: Research Data

Table 4.3 above shows that the majority of the respondents are at tertially level. There are 19 respondents on this level with a 63.3 percent of the respondents. 2 respondents belong at primary level with 6.7 percent and 9 respondents at secondary level with 30 percent.

4.4.3 Marital Status

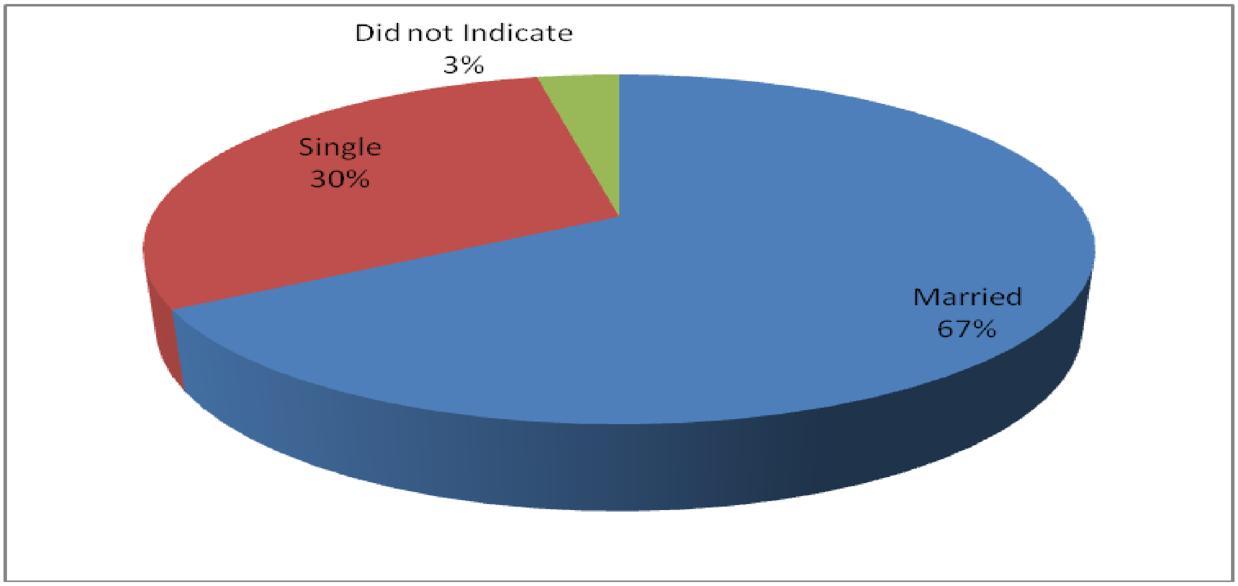
Table 4.3: Marital Status of the Respondents

Marital Status	Frequency
Married	20
Single	9
Did not Indicate	1
Total	**30**

Source: Research Data

From table 4.4 above, 20 respondents are married and 9 are single. 1 respondent did not indicate the marital status. From the information, the majority of the respondents are married. The proportions of the respondents are shown on figure 4.4 below

Figure 4.4: Marital Status of the Respondents



Source: Research Data

From the figure above, 67 percent of the respondents are married and 30 percent of the respondents are single. 3 percent of the respondent did not indicate the marital status. From the information, the majority of the respondents are married.

4.5 Types of Solar Systems in Borabu Location, Nyamira County.

This section presents some of the pictures that were taken in Borabu location Nyamira County. The images are presented below.

Figure 4.5: PV Solar System on the Roof.

Source: Field Data (20/06/2012)

The figure above shows the PV solar system installed on the roof of one of the household residents in Borabu Location, Nyamira County. The PVsolar system turns heat energy into power energy and transmits it into the inverter. The following figure presents the image of the inverter that was installed in one of the households in the location.

Figure 4.6: Solar Inverterin a Building

Source: Field DataData(20/06/2012)

The inverter stores the power and distributes the power into various uses in the house. The uses include lighting, cooking, television watching and many more uses. The following figure presents one usage of power which is lighting.

Figure 4.7: PV Solar power used for Lighting in Borabu Household

Source: Field DataData(20/06/2012)

From figure 4.7 shows PV solar system power used for lighting at night in Borabu Location, Nyamira County. PV solar systems can be installed using stands on the roofs and some can be used directly into the batteries without passing through the inverter (Appendix Four).

4.6 Solar Panel and Installation

This section of the questionnaire presented data about the impacts of PV solar installation and use. The section was arranged to in order to have an understanding of the impacts that come along with the installation of PV solar system.

The section started by asking the respondents whether they use PV solar system. The results are presented on the table and figure below.

Table 4.4: Usage of PV Solar System

Do you Use PV Solar System	Frequency
Yes	15
No	15
Total	**30**

Source: Field Data

Of the respondents, 15 of them responded that yes they use the PV solar system and 15 responded by saying no they don't use PV solar system. This gave a 50 percent of the respondents. This shows that half of the household residents in Borabu Division use PV solar system.

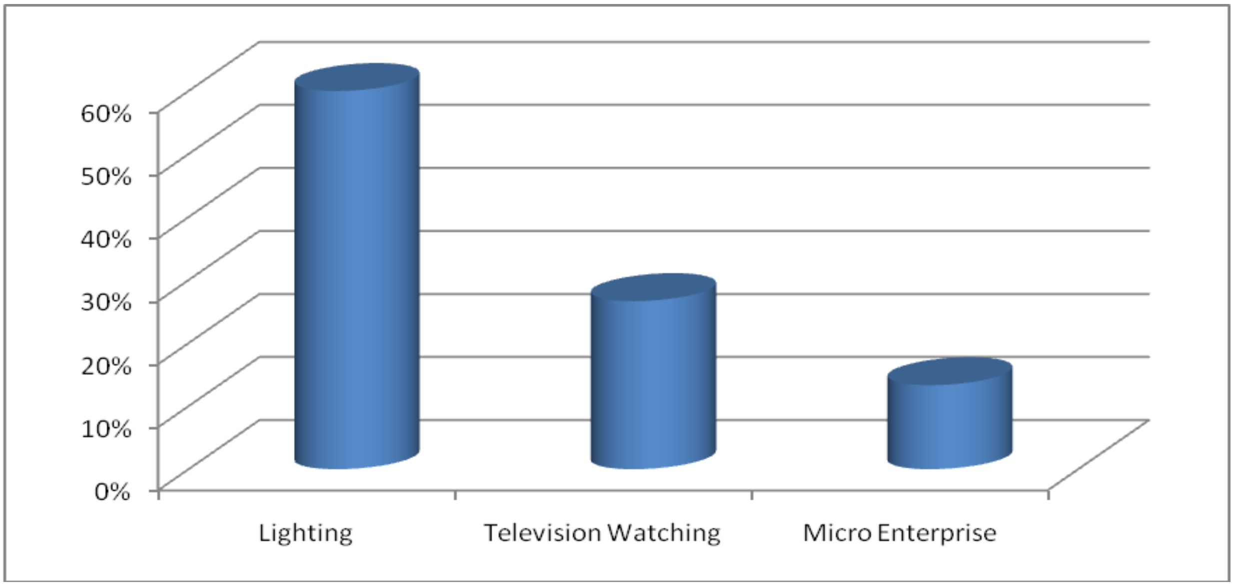
For those who responded that they use solar system, the researcher wanted to know what they use the solar for. The researcher limited the use into five uses namely lighting, television watching, microenterprise, agriculture and cooking. The results are presented below.

Table 4.5: Uses of PV Solar System

Uses of PV Solar System	Frequency
Lighting	9
Television Watching	4
Micro Enterprise	2
Total	**15**

Source: Field Data

Figure 4.8: Uses of PV Solar System



Source: Field Data

From table 4.6 above, 9 of the 15 respondents who responded that yes they use PV solar indicated that they use it majorly for lighting purposes. This gives a 60 percent of them. 2 respondents use the PV solar for micro enterprise which gives a proportion of 13 percent.

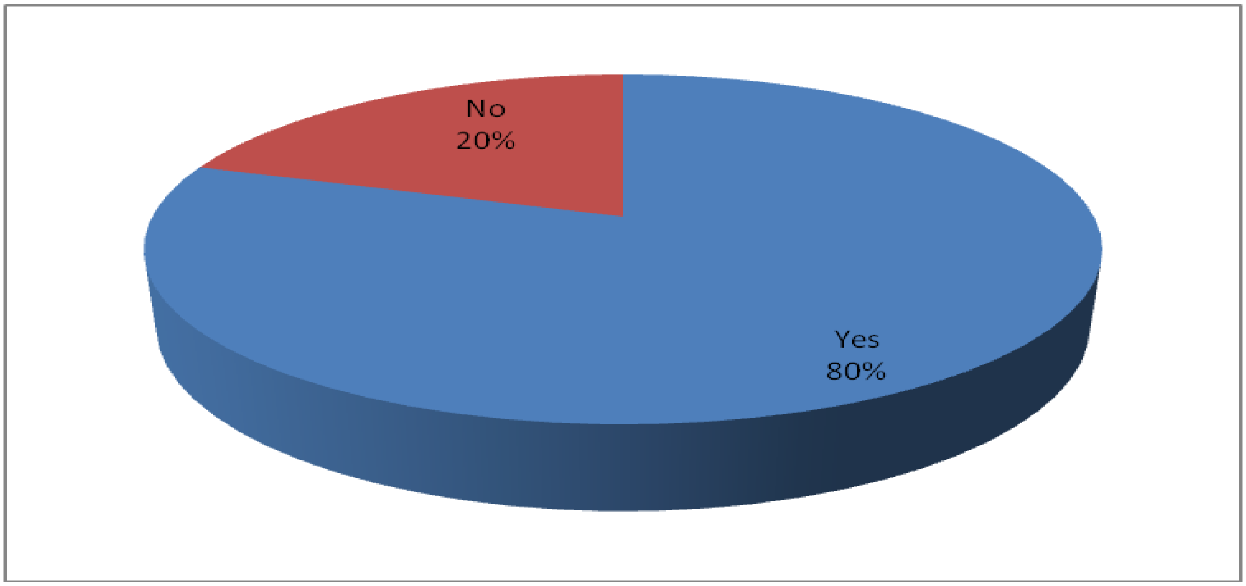
The researcher went further on this part and asked those respondents who stated that no they don't use PV solar whether they will want to install and use PV solar system. The results are presented below.

Table 4.6: Use PV Solar System

Will you want to Install and use PV Solar System	Frequency
Yes	12
No	3
Total	15

Source: Field Data

Figure 4.9: Use PV Solar System



Source: Field Data

From table 4.7 above, 12 of the respondents indicated that yes they do want to install and use PV solar. 3 of them did not want to install and use PV solar. Figure 4.7 above shows that 80 percent of the respondents wanted to install and use the PV solar system and 20 percent did not.

4.6.1 Usefulness of Solar Systems

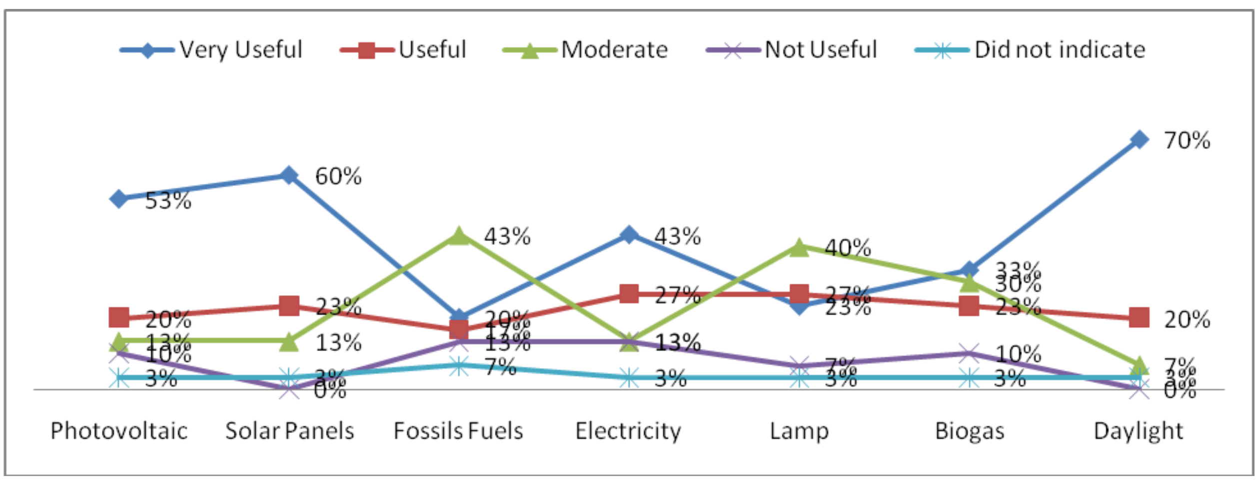
This part of the section provided different types of solar systems and asked the respondents to rate them on a scale that was provided in the research instrument. Seven types of solar systems were used for this study. The results are presented using a table and a figure below.

Table 4.7: Usefulness of Solar Systems

Solar Systems	Very Useful	Useful	Moderate	Not Useful	Did not indicate	Total
Photovoltaic	16	6	4	3	1	30
Solar Panels	18	7	4	0	1	30
Fossils Fuels	6	5	13	4	2	30
Electricity	13	8	4	4	1	30
Lamp	7	8	12	2	1	30
Biogas	10	7	9	3	1	30
Daylight	21	6	2	0	1	30

Source: Field Data

Figure 4.10: Usefulness of Solar Systems



Source: Field Data

The first solar system that was focused on was photovoltaic solar system. The majority ofthe respondents, 53 percent were in agreement that the solar system is very useful to them while only

10indicated that the solar system is not useful to them. 3 percent of the respondents did not indicate the usefulness.

On solar panels, the majority of the respondents, 60 percent were in agreement that the solar system is very useful to them while only 13 percent indicated that the solar system is moderately useful to them. No respondent indicated that the system is not useful. 3 percent of the respondents did not indicate the usefulness.

On the fossils fuel solar system, the majority of the respondents, 43 percent were in agreement that the solar system moderately useful to them while only 13 percent indicated that the solar system is not useful to them. 7 percent of the respondents did not indicate the usefulness of this type of the solar system.

On the electricity solar system, the majority of the respondents, 43 percent were in agreement that the solar system very useful to them while only 13 percent indicated that the solar system is moderately useful and not useful to them. 3 percent of the respondents did not indicate the usefulness of this type of the solar system.

On the lamp element, the majority of the respondents, 40 percent were in agreement that the solar system moderately useful to them while only 7 percent indicated that the solar system is not useful to them. 3 percent of the respondents did not indicate the usefulness of this type of the solar system.

On the biogas type, the majority of the respondents, 33 percent were in agreement that the solar system very useful to them while only 10 percent indicated that the solar system is not useful to them. 3 percent of the respondents did not indicate the usefulness of this type of the solar system.

On the daylight type, the majority of the respondents, 70 percent were in agreement that the solar system is very useful to them while only 7 percent indicated that the solar system is moderately useful to them. 3 percent of the respondents did not indicate the usefulness of this type of the solar system.

4.6.2 Government Influence on Solar Panel Installation

This part of the research instrument sought information about the government influence on the installation and use of PV solar system. The respondents were given a scale of 1 – 5 were 1 represented low impact and 5 represented high impact. The results are presented using the table below.

Figure 4.11: Government Influenceon Solar Panel Installation

1 – Low	**2**	**3**	**4**	**5 – High**	**Did Dot Indicate**	**Total**
15	8	3	1	0	3	30

Source: Field Data

The majority of the respondents, 50 percent, indicated that the government influences installation and use of PV in a low rate and 3 percent felt that it does on fairly high rate. 10 percent did not respond on this question.

4.6.3 Government Regulations on Solar Panel Installation

This part sought information about government regulations on PV system. The researcher wanted to know if government regulations contribute to the failure of PV installation and use. The results are presented using a figure below.

Table 4.8: Government Regulationson Solar Panel Installation

Government Regulations	**Frequency**	**Percent**
Yes	20	66.70%
No	9	30.00%
Did Not Indicate	1	3.30%
Total	**30**	**100%**

Source: Field Data

The majority of the respondents, 66.7 percent were for the idea that yes the government contributes to the failure of PV installation and use. 30 percent felt that the government does not contribute to the failure. 3.3 percent did not respond on this question.

4.6.4 Environmental Impacts on Solar Panel Installation

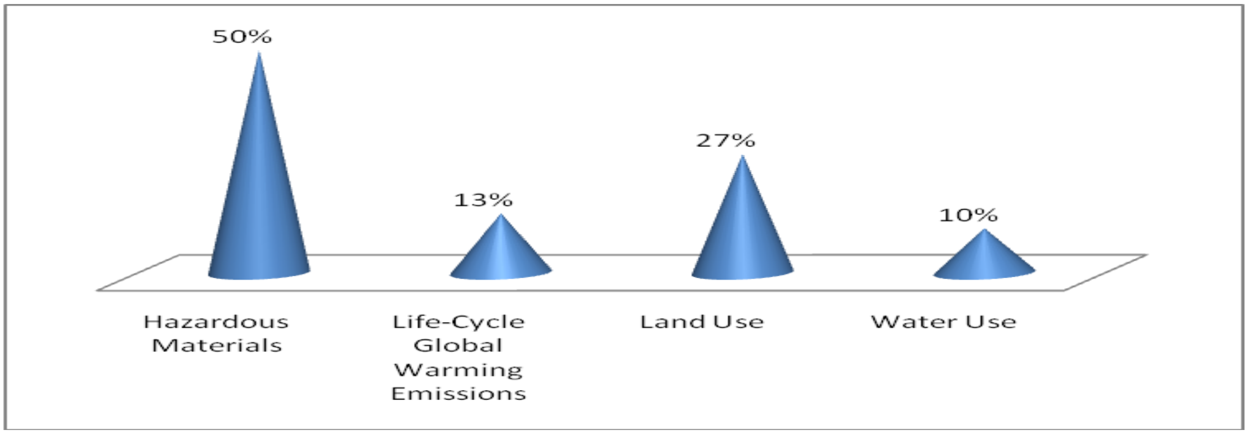
This part of the questionnaire sought information about the environmental impacts that have the most impact on the locality. Hazardous materials, life – Cycle global warming emissions, land use and water are the elements that were looked at. The results are presented below.

Table 4.9: Environmental Impactson Solar Panel Installation

Environmental Impacts	Frequency
Hazardous Materials	15
Life-Cycle Global Warming Emissions	4
Land Use	8
Water Use	3
Total	**30**

Source: Field Data

Table 4.10: Environmental Impactson Solar Panel Installation



Source: Field Data

The majority of the respondents, 50 percent indicated that hazardous materials has the most impact on the location while 10 percent indicated that the water use has an impact on PV installation and use.

4.6.5 Climatic impactson Solar Panel Installation

This part of the questionnaire sought information about the extent to which climatic impacts impact PV solar installation and use. Drought, Water Scarcity, Flooding and Rain are the elements that were looked at. The results are presented below.

Table 4.11: Climatic impactson Solar Panel Installation

Climatic Impacts	Mean	Std. Deviation
Drought	1.5926	1.04731
Water Scarcity	2.5357	1.03574
Flooding	2.037	1.22416
Rain	1.6786	1.12393

Source: Field Data

The majority of the respondents with a mean of 2.54 and a standard deviation of 1.03 were in agreement that water scarcity has an impact on PV solar while drought with a mean of 1.59 and a standard deviation of 1.05 was indicated the one with the least impact.

4.6.6 Cost of PV Installation and Use in Borabu

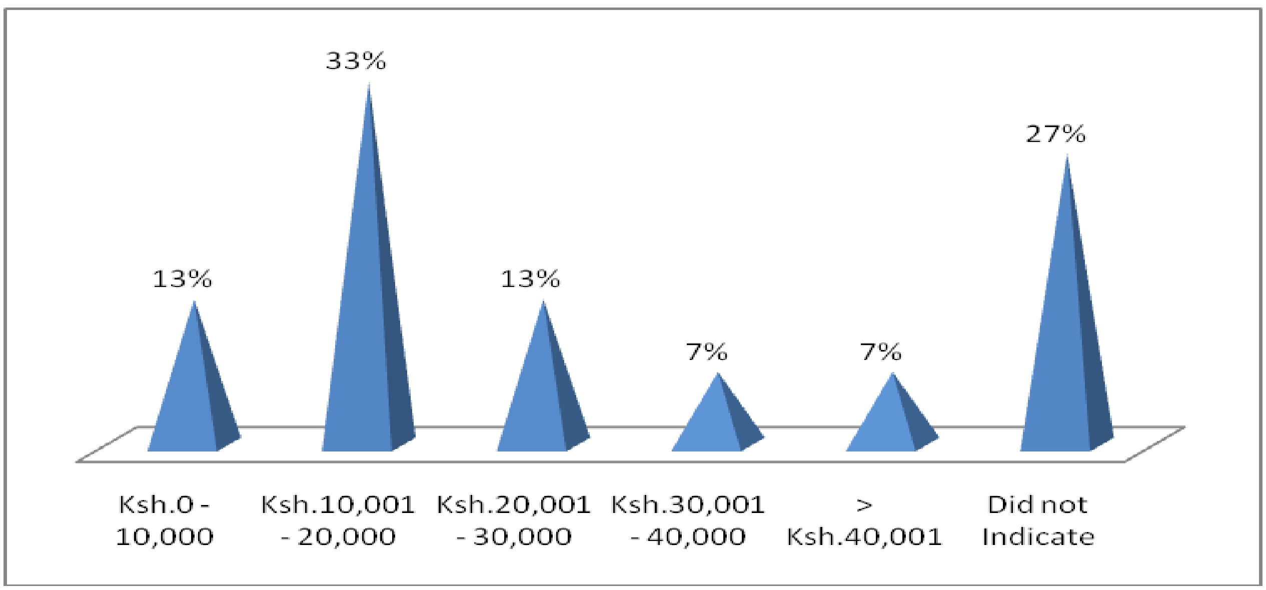
This part of the section sought information about the cost incurred in the installation of PV solar system. Ranges were given over which the respondent indicated the range of the costs. The information is presented using the table and figure below.

Table 4.12: Cost of PV Installation and Use in Borabu

Cost	Frequency
Ksh.0 - 10,000	4
Ksh.10,001 - 20,000	10
Ksh.20,001 - 30,000	4
Ksh.30,001 - 40,000	2
> Ksh.40,001	2
Did not Indicate	8
Total	**30**

Source: Field Data

Table 4.13: Cost of PV Installation and Use in Borabu

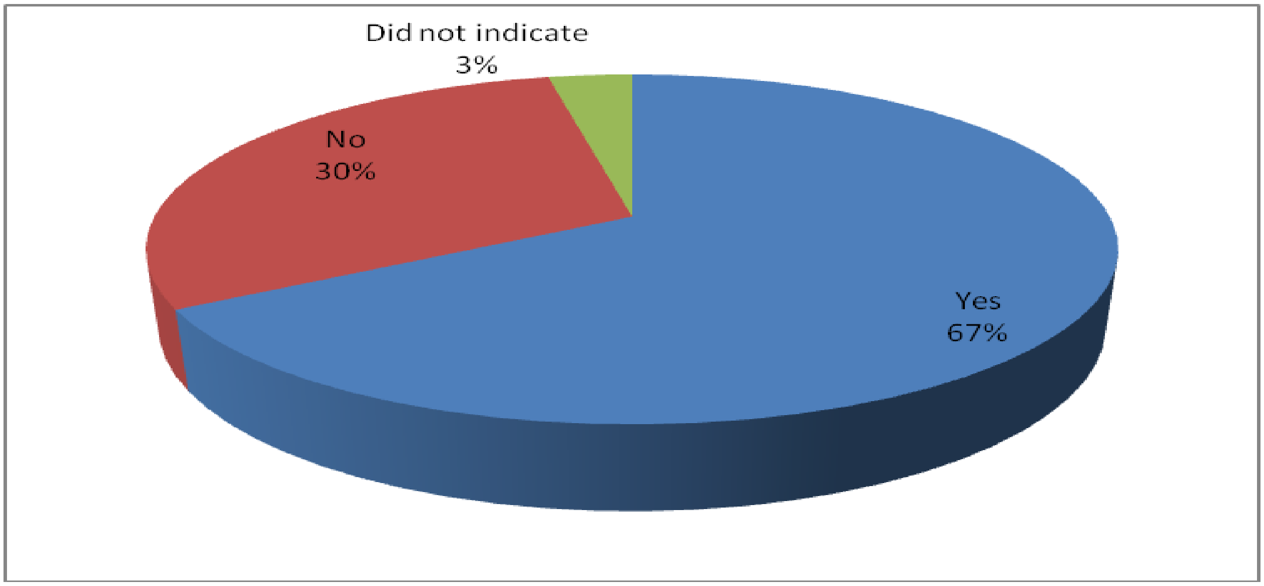


Source: Field Data

The majority of the respondent, 33 percent indicated that the range of installing PV solar is Ksh.10, 001 - 20,000 while 7 percent of the respondents indicated that the cost is Ksh.30,001 - 40,000 and more than Ksh.40,001.

Based on those ranges, the researchers sought to find out if that cost has an impact on the installation of PV solar system. The result is presented on a figure below.

Figure 4.12: Cost Impacton Solar Panel Installation



Source: Field Data

The majority of the respondents, 67 percent were in agreement that yes the cost has an impact while 30 percent did not feel that cost had impact. 3 percent did not respond on this question as asked on the research instrument.

4.6.7 Benefits of Solar Over Non-Renewable Sources of Energy

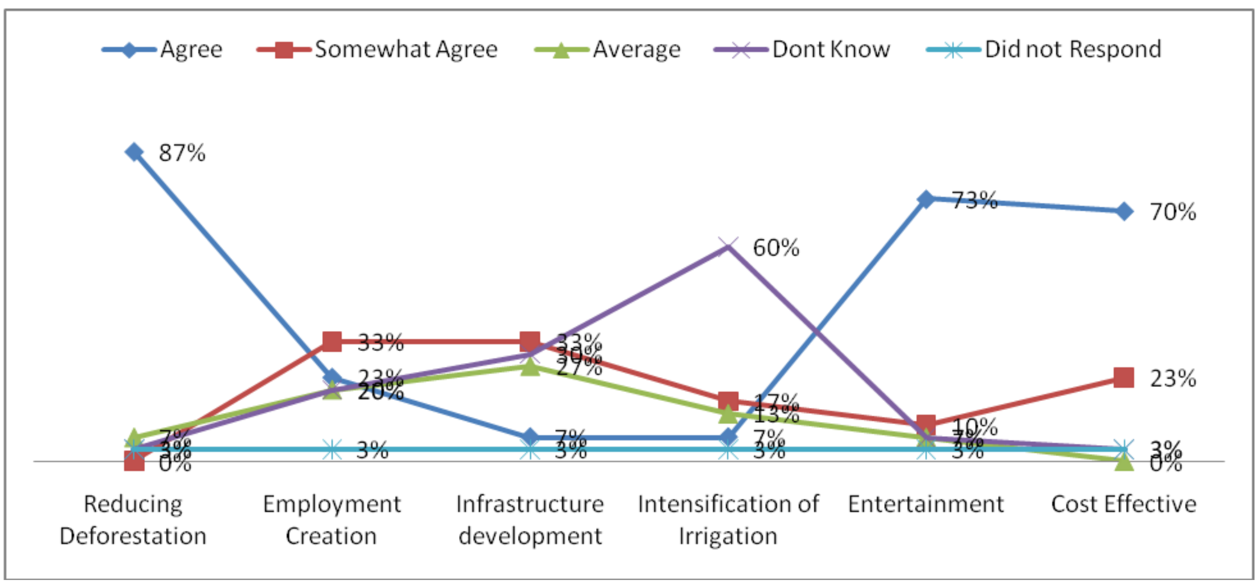
This part of the section sought information about the benefits of solar over non-renewable sources of energy. Reducing Deforestation, Employment Creation, Infrastructure development, Intensification of Irrigation, Entertainment and Cost Effective are the elements that were looked into. The results are presented below.

Table 4.14: Benefits of Solar Over Non-Renewable Sources of Energy

Benefits of Solar Over Non-Renewable Sources of Energy	Agree	Somewhat Agree	Average	Don't Know	Did not Respond	Total
Reducing Deforestation	26	0	2	1	1	30
Employment Creation	7	10	6	6	1	30
Infrastructure development	2	10	8	9	1	30
Intensificationof Irrigation	2	5	4	18	1	30
Entertainment	22	3	2	2	1	30
Cost Effective	21	7	0	1	1	30

Source: Field Data

Figure 4.13: Benefits of Solar Over Non-Renewable Sources of Energy



Source: Field Data

The first solar benefit that was focused on this part which is reducing deforestation,the majority of the respondents, 87 percent were in agreement that PV solar system has a benefit of reducing deforestation while only 3percent don't know if the system is beneficial to reducing deforestation.

On employment creation, the majority of the respondents, 33 percent were in agreement that the solar system is beneficial while only 20 percent averaged and other 20 percent dint know.

On infrastructure development, the majority of the respondents, 33 percent somewhat agreed that the solar system is beneficial while only 7 percent agreed that it was beneficial.

On intensification of irrigation, the majority of the respondents, 60 percent dint know if the solar system is beneficial while only 7 percent agreed that it was beneficial.

On entertainment, the majority of the respondents, 73 percent were in agreement that the solar system is beneficial while only 7 percent felt that averagely it is beneficial and 7 percent dint know if it was beneficial.

On cost effective, the majority of the respondents, 70 percent were in agreement that the solar system is beneficial while only 3 percent dint know if it was beneficial.

4.6.8 Growth of Solar Installation in Borabu

This part of the research instrument sought information on how some of the factors have led to the slow growth pace of PV solar system. 9 factors were used in this part were each factor was rated on a scale of strongly agree, agree, average, disagree and strongly disagree. The results are presented using means and standard deviations below.

Table 4.15: Growth of Solar Installation in Borabu

Factors that have led to slow growth of PV solar installation	Mean	Std. Deviation
Labour	3.00	1.44
Materials	2.64	1.42
Opportunity Cost	1.86	1.19
Maintenance Cost	2.93	1.60
Replacement	3.00	1.73
Capacity Building	2.62	1.54
Transportation Cost	3.10	1.76
Consultancy	3.24	1.79
Professional Valuation	2.07	1.39

Source: Field Data

The majority of the respondents with a mean score of 3.24 and a std. deviation of 1.79 rated the highly on consultancy as one of the factor that leads to the slow growth of PV installation. Transportation cost followed with a mean score of 3.1 and a std. deviation of 1.76. Opportunity cost was last with a mean score of 1.86 and a std. deviation of 1.19 and Professional valuation come in with a mean score of 2.07 and a std. deviation of 1.39.

4.6.9 Results on open-ended question

The results under this section were sourced through open-ended question comments made by respondents. The open – ended question asked the advantages and disadvantages of using solar as a source of energy.

The following are the advantages raised by respondents.

- Reduces environmental adverse impacts

- Saves costs like electricity bills and maintenance costs are also low
- Helps in the development of infrastructure
- Reduces deforestation
- Easy to harvest energy
- Does not produce noise

The following were the disadvantages raised by respondents.

- Not applicable in poor weather conditions
- Must be used in the presence of sunlight hence not useful during cold or cloudy seasons
- Solar panels efficiency levels are relatively low as compared to renewable energy
- PV panels are fragile, can be broken easily
- Investment costs are high
- Has low strength than electricity

4.7 Hypotheses Testing

The study used chi-square to test the research null hypotheses because the study required the test of independence of variables in order answer relevant questions. Under chi-square, If the calculated value is less or equal to α (.05) then you can reject H_0.

4.7.1 Hypothesis One

H_0: Persistent governmental impacts have not significantly affected the installation and use of Photovoltaic solar system among household residents.

The questions that were used in this case were whether government influence affects the installation and use of Photovoltaic solar system and whether government regulations affect the installation and use of Photovoltaic solar system.The resultis presented below.

Table 4.16: Results on Governmental Impacts

Chi-Square Tests	Value	df
Pearson Chi-Square	8.34	3

Source: Field Data

In this case, the calculated chi square value is 8.34. This value is greter the critical value which is 7.82 at0.05 significance level; hence the null hypothesis is rejected. That is, there is sufficient evidence to conclude that persistent governmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residents.

4.7.2 Hypothesis Two

H_0: Existing environmental impacts have not significantly affected the installation and use of Photovoltaic solar system among household residents.

The question that were used in this case were how hazardous materials, lifecycle global warming emissions, land use and water use affect the installation and use of Photovoltaic solar system. The result is presented below.

Table 4.17: Results on Environmental Impacts

Chi-Square Tests	Value	df
Pearson Chi-Square	8.33	2

Source: Research Data

In this case, the calculated chi square value is 8.33. This value is greater than the critical value which is 5.99 at 0.05 significance level, hence the null hypothesis is rejected. That is, there is sufficient evidence to conclude that existing environmental impacts have significantly affected the installation and use of Photovoltaic solar system among household residents.

4.7.3 Hypothesis Three

H_0: The changes of climatic conditions have not significantly affected the installation and use of Photovoltaic solar system among household residents.

The questions that were used in this case were how Drought, water scarcity, flooding and rise of sea level affect the installation and use of Photovoltaic solar system. The result is presented below.

Table 4.18: Results on Climatic Impacts

Chi-Square Tests	Value	df
Pearson Chi-Square	8.43	2

Source: Field Data

In this case, the calculated chi square value is 8.43. This value is greater than the critical value which is 5.99 at 0.05 significance level hence the null hypothesis is rejected. That is, there is sufficient evidence to conclude that the changes of climatic conditions have significantly affected the installation and use of Photovoltaic solar system among household residents.

4.7.4 Hypothesis Four

H_0: High costs of installing PV solar system have not significantly affected the installation and use of Photovoltaic solar system among household residents.

The question that was used in this case was whether cost has a hug effect on the installation and use of Photovoltaic solar system among household residents. The result is presented below.

Table 4.19: Results on the Impact of Cost

Chi-Square Tests	Value	df
Pearson Chi-Square	8.43	3

Source: Field Data

In this case, the calculated chi square value is 8.43. This value is greater than the critical value which is 7.82 at 0.05 significance level hence the null hypothesis is rejected. That is, there is sufficient evidence to conclude that high costs of installing PV solar system have significantly affected the installation and use of Photovoltaic solar system among household residents.

4.8 Discussion of the Findings

From the findings, the study found that installation of PV solar panels will benefit children who study at night. In literature, It is reported that solar electricity lighting in remote rural schools permits children to extend their studies in the evening and helps retain teachers, especially if their accommodation has electricity (Allderdice and Rogers, 2000; PPIAF, 2002; DFID, 2002; UNDP, 2004). For many children, especially girls in rural areas the lack of electricity translates into a missed opportunity to attend school because they are overloaded with menial tasks such as fetching water and fuel during daylight hours (Allderdice and Rogers, 2000).

The study also found that electrification plays a mojour role in education and this is supported by literature where a survey to explore user perception about the positive linkage between rural electrification and education in Tunisia revealed that women and children especially benefited from improved access to education as a result of rural electrification (Cecelski, 2003).

The study found out that cost is an important factor that contributes to the success of PV installation and use. Majority of the respondents indicated that cost is high and has impacted the installation and use of PV solar system in Borabu Location, Nyamira County. In literature, the cost of the electricity generated by a PV system is determined by the capital cost (CAPEX), the discount rate, the variable costs (OPEX), the level of solar irradiation and the efficiency of the solar cells (Bank, 2010). Of these parameters, the capital cost, the cost of finance and efficiency are the most critical and improvements in these parameters provide the largest opportunity for cost reductions.

The study found out that environmental impacts affect the installation of PV solar system. Majority of the respondents responded that hazardous materials that come out of the PV solar to the environment were found to be the key effect that affects the installation and use of PV solar system in the location. In literature, The amount and type of chemicals used depends on the type of cell, the amount of cleaning that is needed, and the size of silicon wafer (Hand and Baldwin, 2012). Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride (National Renewable Energy Laboratory, 2010).

4.9 Conclusion

The chapter highlighted in detail the findings of the study. The result showed that impacts of PV solar exists and need to be addressed carefully.

The following chapter will highlight recommendations and conclusions drawn from the study and some shortcomings on the study that would require some further research.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The theoretical background and objective of the study were set out in Chapter one. To expand on the theoretical background to the study, a literature review was done in Chapter two. The concepts and issues related to the impacts of PV solar installation and use were explained.

Chapter three highlighted the research methodology adopted to obtain the data for the study while Chapter four presented the detailed interpretation of the data. Research findings and interpretation of data obtained during the research project were explained in chapter four.

In this chapter, the most crucial points of concern highlighted in the previous chapters are summarized together with a number of conclusions. Certain recommendations will be put forward.

The problem statement under investigation as set out in the study was to determine the socio-economic impacts of photovoltaic solar installation and use.

This problem was accepted since respondents stated clearly that those impacts are the once affecting the installation of the PV panels in Borabu area.

This being the case, it serves as an indication that the objective of the study has been achieved. It is now proper to highlight some recommendations in this study.

5.2 Summary of the Findings

From the findings, half of the household residents in Borabu Location, Nyamira County use PV solar system. Among the users of PV solar the majority are reported to use the solar majorly for the purpose of lighting. Very few use the solar for micro enterprise. The study also found out that the majority of the household residents who do not use PV solar system wanted to install and use it. This shows that residents in Borabu Location in Nyamira County have a positive approach to the use of solar in the location. The study also found out that photovoltaic solar system useful to the location as it was also preferred by the residents.

The study found out that government influence has a great impact on the PV installation and use. Government influence was found to have a very low rating with regard to its influence on the installation and use of PV solar system in the location. The study also found that government influence to the installation and use of PV solar is a significant factor and therefore the government must play part in supporting PV solar use. The study found out that government regulations impact PV solar installation and use. The government should also ensure that the regulations do not affect the installation and use of PV solar system.

The study found out that environmental impacts affect the installation of PV solar system. Majority of the respondents responded that hazardous materials that come out of the PV solar to the environment were found to be the key effect that affects the installation and use of PV solar system in the location. The study showed that control of these materials should be put in place in order to avoid the emissions for better use of PV solar in Borabu Location, Nyamira County.

The study found out thatclimatic conditions are major key factors that lead to the installation and use of PV solar system in Borabu Location, Nyamira County. The majority of the respondents expressed that water is crucial for the installation and use of the system. The issue of water scarcity should be solved for the residents in Borabu Location in Nyamira County to be able to install and use PV solar system. Flooding also is another climatic impact that the respondents indicated has a challenge.

The study found out that cost is an important factor that contributes to the success of PV installation and use. Majority of the respondents indicated that cost is high and has impacted the installation and use of PV solar system in Borabu Location, Nyamira County. The study also found out that PV solar system is not cost effective.

5.3 Conclusions

The study concludes that lack of government influence impacts the installation and use of PV solar system in Borabu Location, Nyamira County.

It further concludes that government influence is not effective and therefore the residents in Borabu Location, Nyamira County do not get support from the government with regard to PV installation and use. The study also concludes that government regulations impact PV solar installation and use in the location.

The study concludes that environmental impacts have a great impact on the installation and use of PV solar installation and use in the location. The emissions that are produced from the solar panels have a great impact on the environment thus affecting the installation of the solar system. Environmental impacts are not reduced in Borabu location through increasing production scale and optimizing the production process, simultaneously resulting in material and energy requirement reduction. The study concludes that climatic conditions are major key factors that lead to the installation and use of PV solar system in Borabu Location, Nyamira County. The location has cold seasons in which the PV solar system is not of benefit to them. The study also concludes that water scarcity and flooding impact the use of solar system. The study concludes that cost is a factor that has impacted the installation and use of solar in Borabu location, Nyamira County. This has made the majority of the residents not to use PV solar because they cannot afford.

5.4 Recommendations

The study recommends that government take part in influencing citizens towards that use and installation of PV solar system. Also regulations should be in a way that supports the installation of the PV solar system. The study also suggests the revision of the existing set of governmental regulations and increasing the legal security for PV.

The study recommends that a consistent PV strategy be in place on ambitious and long-term targets, a clearly defined implementation Programme and a well-conceived mix of instruments becomes the groundwork for success. The basic requirement for each PV policy framework is its longevity and stability.

The study recommends that the government put in place the PV policy framework which needs to be carefully designed in accordance with the location specific conditions in the country.

The study again recommends that procedures to apply for support and to install a grid connected PV system should be simple and clear.

PV policy and market monitoring is crucial. The study therefore recommends that those policies be in place to support the installation of PV system.

5.5 Suggestion for further studies

Further research is necessary as the findings were based on a relatively small sample that may have influenced the nature of results that were obtained. There is need to expand on the sample size and carry out similar research in other locations.

The analysis that was used is always not sufficient to draw conclusions on a phenomenon, and to provide adequate information that can be used for policy development. Further research focusing on assess the perception of employees in strategy implementation is recommended.

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APPENDICES

Appendix One: Questionnaire

UNIVERSITY OF NAIROBI

DEPARTMENT OF GEOGAPHY AND ENVIRONMENTAL STUDIES

NAME: LABAN NYANDEGA ONSOMU

YEAR: 2013

Dear respondent,

I am a student at the University of Nairobi and I am conducting a research on "Socio-economic impacts of Photovoltaic solar installation and use", a case study of Borabu Division in Nyamira County. This research is a requirement for the award of M.A in Environmental planning and Management. Your answers will be treated with confidentiality and used only for academic purposes only.

SECTION ONE: GENERAL INFORMATION

Date……………………………………………….Questionnaire number……………………

Name of your Village……………………………….Location……………………………........

Sub-location……………………………………….

a) Sex: Male [ ] Female [ ]

b) Age: Below 20 Years [ ] Between 21-30 Years [ ] Between 31-40 [ ]Between 41-50 Years [ ] Between 51- 60 [ ] above 60 Years [ ]

c) Education level: (please indicate in the box using a tick)Primary [ ]

Secondary [ ] Tertially [ ] None [ ]

d) Marital Status: Marital status: Married [ ] Single [ ]

SECTION TWO: SOLAR USE AND INSTALLATION

1. Do you use solar as your main source of energy? Yes [ ] No [ ]

2. If yes, what do you use solar for ;(indicate using a tick)

   Lighting [ ] Television watching [ ] Microenterprise [ ] Agriculture [ ] Cooking [ ]

3. If no, will you like to install and use PV solar? Yes [ ] No [ ]

4. How useful do you believe the following solar systems are to you? (Place the tick inside the box)

		Very useful	Useful	Moderate	Not useful
a)	Photovoltaic	[ ]	[ ]	[ ]	[ ]
b)	Solar panels	[ ]	[ ]	[ ]	[ ]
c)	Fossils fuel	[ ]	[ ]	[ ]	[ ]

d) Electricity [ ] [ ] [ ] [ ]

e) Lamp [ ] [ ] [ ] [ ]

f) Biogas [ ] [ ] [ ] [ ]

g) Daylight [ ] [ ] [ ] [ ]

5. According to your knowledge, up to which extent do the government influence the installation and use of the PV solar system in your locality? Use a scale of 1 – 5, where 5 is the highest impact and 1 no impact

Scale	1	2	3	4	5
Use a tick					

6. According to you, does you feel that government regulations contribute to the failure of PV installation and use? Yes [ ] No [ ]

7. On the following environmental influences on PV installation and use, which one has the most impact on your locality? Use a tick

   Hazardous Materials [ ]

   Life-Cycle Global Warming Emissions [ ]

   Land Use [ ]

   Water Use [ ]

8. Using the following climatic impacts, to what extent do you feel they impact PV solar installation and use? Use a scale provided to rete them.

	Agree	Somehow agree	Average	Don't know
a) Drought	[ ]	[ ]	[ ]	[ ]
b) Water Scarcity	[ ]	[ ]	[ ]	[ ]
c) Flooding	[ ]	[ ]	[ ]	[ ]
d) Rise of Sea Level	[ ]	[ ]	[ ]	[ ]

9. From your experience, kindly indicate by a tick the approximate cost you incurred during PV installation.

Ksh.0-10,000	[ ]
Ksh.10, 001-20,000	[ ]
Ksh.20, 001-30,000	[ ]
Ksh.30, 001-40,000	[ ]
More than Ksh. 40001	[ ]

10. Does cost have huge impact in PV installation and use? Yes [ ] No [ ]

11. In your opinion, how is solar beneficial over nonrenewable sources of energy in the following.

	Agree	Somehow agree	Average	Don't know
e) Reducing deforestation	[ ]	[ ]	[ ]	[ ]

f)	Employment creation	[ ]	[ ]	[ ]	[ ]
g)	Infrastructure development	[ ]	[ ]	[ ]	[ ]
h)	Intensification of irrigation	[ ]	[ ]	[ ]	[ ]
i)	Entertainment	[ ]	[ ]	[ ]	[ ]
j)	Cost effectives	[ ]	[ ]	[ ]	[ ]

12. According to your knowledge, how have the following factors led to slow pace growth of solar installation in Borabu Division?

		Strongly agree	Agree	average	disagree	strongly disagree
a)	Labour	[ ]	[ ]	[ ]	[ ]	[ ]
b)	Materials	[ ]	[ ]	[ ]	[ ]	[ ]
c)	Opportunity cost	[ ]	[ ]	[ ]	[ ]	[ ]
d)	Maintenance cost	[ ]	[ ]	[ ]	[ ]	[ ]
e)	Replacement cost	[ ]	[ ]	[ ]	[ ]	[ ]
f)	Capacity building	[ ]	[ ]	[ ]	[ ]	[ ]
g)	Transportation cost	[ ]	[ ]	[ ]	[ ]	[ ]
h)	Consultancy cost	[ ]	[ ]	[ ]	[ ]	[ ]
i)	Professional valuation	[ ]	[ ]	[ ]	[ ]	[ ]

13. What are some of the Advantages and disadvantages when you are using solar as a source of energy?

Advantages: a) ____

b) ____

c) ____

Disadvantages: a) ____

b) ____

c) ____

Appendix Two: Research Time Schedule

Activity	**Dates**
Proposal writing	Jan-13
Submission of proposal	May-13
Defense of proposal	May-13
Forwarding of proposal to graduate	May-13
Registration as research student	Jun-13
Commencement of field work	Jul-13
Data analysis	Aug-13
Defending the project work	Oct-2013
Writing of the final draft	Oct-26
Submission of the final draft	Nov-2013

Appendix Three: Estimated research project budget

Item	**quantity**	**Unit Cost**	**Tota Cost**
Materials			
Foolscap	2	650	1300
Pens	6	20	120
Transport			
Trips	8	5000	40000
Computer services			0
Typing /printing	110	20	2200
Photocopying	10	150	1500
Photocopying of questionnaire	102	12	1224
Binding	6	150	900
Subtotal			**47244**
Contingency 10% of subtotal			**4724.4**
GRAND TOTAL			**51968.4**

Appendix Four: PV Solar System Pictures.

PV Solar installed on the roof using stands.

PV solar system power transmitted into the battery directly without passing through the inverter.