THE ROLE OF SOLAR PHOTOVOLTAIC (PV) SYSTEM TECHNOLOGY FOR SUSTAINABLE ENERGY USE: A CASE STUDY OF MKURANGA DISTRICT, PWANI (COAST) REGION IN TANZANIA

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DECLARATION

I Bisarara S. Ayoub declare that this dissertation is my own original work and has never been submitted for the award of any academic diploma or degree in any other university or institutions of higher learning.

Student

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Date …24/09/2012…

APPROVAL

This dissertation entitled: "The role of Solar photovoltaic (PV) system technology for sustainable energy use: A case study of Mkuranga district, Pwani region (Coast) in Tanzania" was conducted under my supervision and is ready for submission to the department of Biological and Environmental Sciences of Kampala International University for examination.

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Signature ....

Date ...24th SEPT 2012..........

DEDICATION

I dedicate this work to almighty God "Allah (s.w)" for the far he has brought me and where he is taking me to, he is my savior. It is also dedicated to my lovely parents, sister, brother and all who helped and encouraged me to pursue this career of managing the environment.

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Definition of Key terms

Energy- Power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work machines. It is an indirectly observed quantity. It is often understood as the ability a physical system has to do work on other physical systems. Since work is defined as a force acting through a distance (a length of space), energy is always equivalent to the ability to exert pulls or pushes against the basic forces of nature, along a path of a certain length.

Solar Photovoltaic (PV)- Is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material.

Renewable Energy- Is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished).

Sustainable Energy- Is the sustainable provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Technologies that promote sustainable energy include renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, and tidal power, and also technologies designed to improve energy efficiency.

LIST OF ABBREVIATIONS

Ah	Ampere hour
EWURA	Energy and Water Utilities Regulatory Authority
FAO	Food and Agriculture Organization
km^2	Kilometer(s) square
kWh	Kilowatt hour
m^2	meter(s) square
MW	Mega Watt
MWp	Peak Mega Watt
NGO	Non-Governmental Organization
PV	Photovoltaic
REA	Rural Energy Agency
TANESCO	Tanzania Electric Supply Company Limited
TASEA	Tanzania Solar Energy Association
TSH	Tanzanian Shilling
TV	Television
UNDP	United Nations Development Programme
Wp	Watt peak
RETs	Renewable Energy Technologies
SHS	Solar Home System
USAID	United States Agency for International Development
LED	Light Emitting Diodes
QUETSOL	Iluminando tu futuro
SOLUZ	Architectuur_Ontwerp_Advies
TECNOSOL	Energia En Sus Manos
SELCO	Solar Electric Light Company

ABSTRACT

The study looked at the feasibility of adopting renewable energy technology such as Solar PV system in rural household and the role of such technology on sustainable energy use in Mkuranga district Tanzania. The objectives of the study were to determine the availability and affordability of Solar PV system in Mkuranga district, to identify the uses of Solar PV system technology and its advantages over available energy sources in Mkuranga district and lastly to find out the constricting factors in the accessibility of the Solar PV in Mkuranga district. The study was carried out in three (3) villages namely Mkuranga centre, Mwanambaya and Vikindu of Mkuranga district from March 2012 to September 2012. Literature materials were sourced from different sources. The literature include information pertaining the availability and affordability of Solar PV, the uses of Solar PV and its advantages over other energy sources and lastly the factors which hinders the accessibility of Solar PV in rural households. The study involved a total of 100 respondents. Simple random sampling and purposive sampling were used to select the respondents. Questionnaire, interview guide and group discussion were used to collect data during the study. The results from this study indicate that 100% of interviewed households in Mkuranga district are using biomass fuel as source of energy for heating and cooking. Other sources of energy found were grid electricity, petroleum and other sources such as dry cells. Solar PV was found to be used only by 17% of interviewed household in Mkuranga district. Solar PV was seen to be used as source of energy to power up appliances such as radio, TV, battery charging and lighting. The reason behind such lower percentage of Solar PV usage was that some villages like Mkuranga centre was connected to grid electricity and that most of their household energy needs are met by grid electricity. Another being lack of information on the cost of Solar PV systems and the technology itself. Generally, the study concludes that, to promote short terms plans for grid electricity in rural areas may prove costly, emphasis should be on promotion of affordable and environmentally friendly RETs such as Solar PV technology. The supply of RETs such as Solar PV in rural areas will play a crucial role in raising the living standards of rural population. It also argues that dissemination of renewable energy in rural areas has a potential to protect the environment and may contribute to sustainable development in rural areas.

CHAPTER ONE

INTRODUCTION

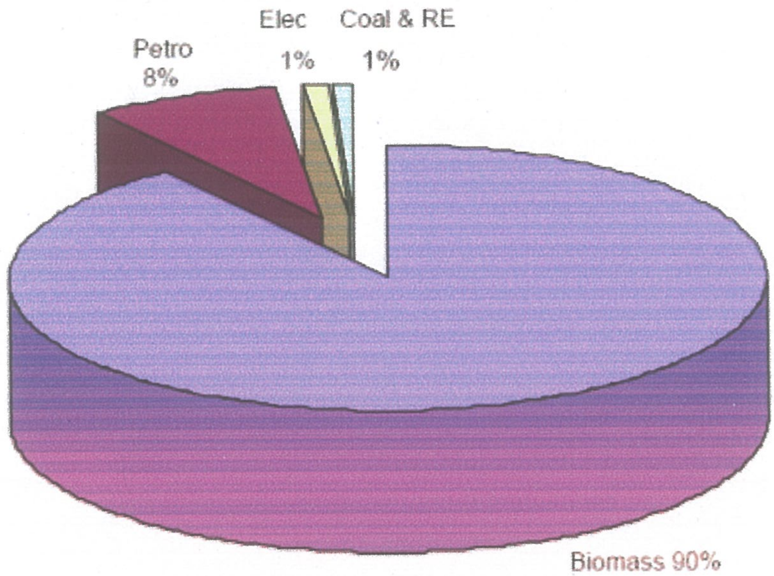
1.1 Background of the study

Solar energy is radiation from the sun that contains huge amounts of energy in the form of heat and light and other forms of radiation. Solar energy is the driving force behind almost all natural processes on Earth and it is the cleanest and most inexhaustible source of renewable energy (Maisha Islam, 2010). Solar energy technologies utilize radiation form the sun in innovative ways to provide electricity. The most common form of solar technology used worldwide is solar photovoltaic (PV). It is a method that generates electric power by converting the sun's energy directly into electricity via silicon-based cells called photovoltaic cells. The Pv cells use semiconductor-based technology to convert solar radiation directly into an electric current that can either be used to power appliances immediately, or stored in a battery, for later use. Solar photovoltaic (PV) system have shown their potential in rural electrification projects around the world, especially concerning Solar Home System (SHS) with continuing price decreases of PV systems in 1976 the average market of price for photo voltaic modules was $30, by 2002 this price already fallen to $3.75 (FAO, 2002).

Countries around the world face increasing needs regarding the provision of environmentally sound and sustainable energy. Developing countries like Tanzania in particular, face situations of limited energy resources, especially the provision of electricity in rural areas, and there is an urgent need to address this constraint to social and economic development (FAO, 2010). The development of these rural areas in Tanzania is very important if efforts to alleviate poverty are to succeed. The supply of energy to household's areas would create opportunities for better health care, education and income generating activities which are important for household development, (Masoud Dauda, 2005). Solar PV systems can address problems associated with rural household energy supply and use in Tanzania. Solar PV will aim at evaluating the threat posed by an increasing use of firewood in the country. This problem caught government attention which led into conducting various surveys which found out that biomass was major source of energy for cooking, heating and in some cases lighting in most rural households, (Masoud Dauda, 2005).

Biomass fuels such as firewood, charcoal and agricultural residues are dominant energy sources accounting for more than 90% of total energy used in the country. Petroleum accounts for 8% of the total energy used while grid electricity is estimated to account for only 1% of the primary energy used in the country. Others include renewable energy sources such as solar, wind, geo-thermal, and biogas account for 1% of the total energy consumed in Tanzania, (REA, 2010).

Figure 1: Total energy consumption in Tanzania, 2010



Source: EWURA (Energy and Water Utilities Regulatory Authority, 2010)

Such consumption pattern as shown (figure 1) shows that biomass energy is the major source of energy in both urban and rural areas. Reliance on biomass fuels can have severe consequences on both environment (through deforestation and soil erosion) and human health (indoor air pollution). Efforts to promote affordable and clean supplements of energy sources have to continue so as to address such problems (Masoud Dauda, 2005).

Grid electrification of rural areas in Tanzania could be hard to achieve in a short time due to the dispersed nature of rural settlements in most of the regions. Sparsely populated areas have made it difficult and it may prove too costly if all rural areas in Tanzania were to have access to grid electricity. This is due to not only the cost of production and maintenance but also the low purchasing power of the envisaged rural customers (Ministry of Energy and Minerals, 2003). Considering such barriers, plans for transmission of grid electricity in all rural areas seems to be a long term strategy which may take many years to fulfill.

1.2 Statement of the problem

The problems associated with rural household energy supply and use in Tanzania caught the government's attention when it started implementing various initiatives in the early 1970s and 1980s, by conducting surveys which aimed at evaluating the threat posed by an increasing use of firewood in the country. These surveys have revealed that the usage of biomass such as firewood has led into problem of insufficient energy supply where by people who live in rural areas do not have access to affordable modern energy services and thus, suffer from low productivity (time wasted in searching for firewood instead of other economic activities), low quality of life, and great health risk (exposing primarily women and children to indoor air pollution, which according to the World Health Organization, is responsible for the premature death of over 2 million women and children a year worldwide from respiratory infections.). This lack of access to modern energy services leads to an unsustainable use of biomass. Biomass accounts for about 90% of the total primary energy use and it is used both in rural and urban areas, due to its accessibility and affordability than any other energy sources. The rate of deforestation is alarming; it is estimated at a rate of 412,000 hectares per annum and will jeopardize the availability of future biomass sources (Helio International, 2009). Deforestation will also affect Tanzania's energy supplies through climate change. Studies show that temperatures will increase in many parts of the country and that rainfall will decrease. Reduced water flow in Pangani River (where three dams are situated) will affect electricity production. The largest three hydro dams are fed by rivers originating in areas which receive unimodal rainfall, which is expected to decrease by as much as 20% by 2100. Insufficient rainfall, increases in temperature coupled with other stress such as population growth and expansion of agricultural activities will increase competition over water resource and will impact electricity generation (Helio International, 2009).

1.3 Objectives of the study

1.3.1 General Objective

To determine the contribution of solar PV system technology use as a sustainable energy source

1.3.2 Specific Objectives

i) To determine the availability and affordability of solar PV system technology in Mkuranga district

ii) To identify the uses of solar PV system technology and its advantages over available energy sources in Mkuranga district

iii) To find the constraining factors in the accessibility of the solar PV system technology in Mkuranga district.

1.4 Research questions

i) How available and affordable is the solar PV system in Mkuranga district?

ii) What are the uses of solar PV system technology and what advantages does it have over the available energy sources in Mkuranga district?

iii) What are the constraining factors in the accessibility of the solar PV system technology in Mkuranga district?

1.5 Scope of the study

The study was carried out in Mkuranga which is bordered to the north by Dar es Salaam, to the east by the Indian Ocean, to the south by the Rufiji district and to the east by the Kisarawe district. It is also one of the six (6) districts of the Pwani (Coast) region of Tanzania refer to (figure 11) on page 39th of appendices; it was conducted from March 2012 to September 2012. The study looked at the contribution of solar PV system technology as sustainable energy use in Mkuranga district. The study was mainly looking at the affordability and availability of solar PV systems; identify their uses to community and advantages it have over the available energy sources of Mkuranga district and the factors that constrain the accessibility of solar PV technology in Mkuranga district. The researcher sourced the information from the community members, local leaders, government leaders and NGO representative.

1.6 Significance of the study

The study will help students in universities and colleges to act as ground information for further researches on solar PV technology for sustainable energy source within and outside Mkuranga district

The study will raise environmental awareness to the people in Mkuranga district; hence they will start conserving their environment so that it can continue to support their life and that of unborn generations.

The study will be very helpful to the government of Tanzania as it will provide useful information about Solar PV technology issues, which a researcher hopes that it will help the government in promoting Solar PV projects in places suffering from poor household energy supply and use.

CHAPTER TWO

LITERATURE REVIEW

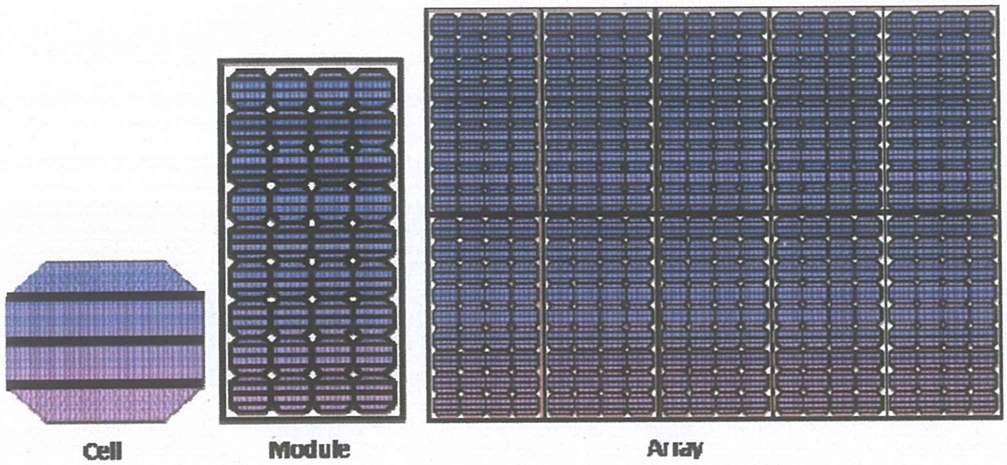
2.0 Introduction

This chapter reviews relevant and available literature related to the topic, which is "The role of solar photovoltaic (PV) system technology for sustainable energy use", according to the objectives set forth in the previous chapter.

2.1 The availability and affordability of Solar PV technology

This technology relies upon the direct conversion of solar radiation into electricity using semiconductors that exhibit a photoelectric effect, such as crystalline silicon or different combinations of thin-film materials. This technology is made up of PV cells which are the basic unit or building block of a PV system as they utilize the photoelectric effect to convert sunlight into electricity. Although crystalline silicon PV cells are the earliest and most successful PV devices used largely in the world today they are being gradually replaced by the cheaper thin films or ribbons, mainly composed of Cadmium Telluride (CdTe), Copper Indium Gallium Selenide (CIGS), amorphous and microcrystalline silicon (Wajid Muneer, 2011). Generally, PV cells are a few inches across in size and are connected together to form PV modules which are typically 1 square meter in size. These PV modules may be connected and/or combined to form PV arrays which yield a desired output (Figure 2). These PV modules represent the core of any PV system, A Solar PV modules produce a maximum output of 250 watts each in bright sunlight (warranted under standard test conditions 'STC'). This is written as 250Wp (watts peak). For example, if 4 modules are connected together they will produce 4 x 250 =1000 Wp or 1.0kWp (kilowatts peak).

Figure 2: Depiction of solar PV system modularity



Source: (Wajid Muneer, 2011)

2.1.1 Classification of solar PV systems

Solar PV systems technology can be categorized based on the way it supplies power to the consumer, as shown in Table 1 next page.

Table 1: Classification of solar PV systems

Types of systems	Application	Features
Off-grid, domestic (Solar Home System SHS)	To meet the energy demand of remote household and villages, far off from the grid	Most appropriate technology utilized globally to provide electricity for off-grid communities.
Off-grid, non-domestic	Provide power for telecommunication, water pumping, vaccine refrigeration and navigational aids.	The first commercial application of terrestrial PV system. Instigated competition with small conventional generation technologies.
Grid- connected, distributed	Provide power to a number of	Can be integrated into the

	grid-connected customers on their premises or directly to the grid.	customer's premises to increase reliability and reduce dependency on the grid. Plays a role in the smart grid.
Grid-connected, centralized	Provide bulk power as a centralized power station	Oil independence and reduction in green-house gases with minimum operation and maintenance expenditure.

Source: TASEA, 2005

2.1.2 Solar PV situation in the world: case study developing countries

In developing countries, some social enterprises such as **SELCO** in India, **Tecnosol** (Nicaragua), **Soluz** (Dominican Republic), **Quetsol** (Guatemala), **Grameen Shakti** (Bangladesh), have made possible the promotion of Solar PV system in distributing, selling at an affordable price to rural people of the mentioned countries.

SELCO India

SELCO is a for-profit social enterprise that provides sustainable energy solutions and services to under-served households and businesses in southern India. They aim to empower their customers by providing a complete package of product, service, and consumer financing. Founded in 1995, SELCO has become one of the world leaders among energy development social enterprises in terms of volume of units sold and company innovation. It is based in Karnataka, and operates in the surrounding rural areas. SELCO employs about 170 employees spread out geographically. Since 1995 it has sold, serviced, and financed over 115,000 solar home lighting systems (Steve Dahlke, 2011). They are now a profitable, multi-million dollar enterprise. SELCO has 25 regional services spread out across the Indian states of Karnataka and Gujarat. Their product line consists of standard home lighting solutions ranging from 1-10 lights and fans. They also will customize their systems depending on the energy requirement of the client. A typical SELCO SHS will cost a little over 400 U.S. dollars, and the majority of their products are sourced locally. The customized system will depend on local factors like lighting needs, available financial institutions, and other community dynamics. Furthermore, SELCO has pioneered rural microcredit in India. Since their inception they have forged partnerships with nine regional rural banks, as well as commercial banks, NGOs, and rural farmer cooperatives. Interest rates on their loans depend on the credit source and range from 5%-14%. Customers typically put between 10%-25% down, paying the balance over three to five years. SELCO employees do sales, installations, user education, and maintenance. Before closing a sale, a local installation technician visits to install the system and teach the customer on proper use and care. They will also periodically visit after the installation to check on performance. They service systems for free during the first year, including planned quarterly visits. SELCO's success with customized product and financial solutions show the power of "door-step service." (Steve Dahlke, 2011)

Tecnosol

Tecnosol is a for-profit enterprise based in Nicaragua, with small operations in El Salvador and Panama. Founded in 1998, they have installed more than 40,000 systems in Central America and have executed over 300 energy projects of various types (Steve Dahlke, 2011). Tecnsol has 17 offices throughout Nicaragua, and one each in El Salvador and Panama. Similarly to SELCO, various micro financiers have integrated Tecnosol's systems in their loan options. Their most basic product is called a pico lamp, imported from Germany, and costs $80 per lamp. Each lamp includes a battery and universal charger, but does not include a solar panel. They also offer a variety of LED lamps, batteries, solar panels, and more. The majority of their technology is imported from abroad, with solar panels imported from the U.S., China, and Germany. The battery for a pico lamp lasts from 2-5 years, and replacement costs $8. In terms of providing credit, they partner with micro-credit organizations and various foundations. They also have their own pot of money that they use (Steve Dahlke, 2011).

Soluz

Soluz is one of the oldest enterprises working with solar home systems. It was founded in the mid-1990's by Richard Hansen, an engineer who has been working in the Dominican Republic since the 1980's installing solar home systems. They have established operations in the Dominican Republic and Honduras. Since inception they have served over 10,000 households and small businesses in off-grid areas (Steve Dahlke, 2011). There are negligible micro-finance options available in these regions, and government policies are largely unfavorable for social enterprise development. As a result, Soluz has pioneered a different financial approach, with a business model based on unsubsidized micro-rentals. They have been able to offer household PV systems starting at $5 a month. Renting systems is a good idea if microfinance is not available, or if there is potential of national grid extension in the near future. Renting allows the customer to avoid the expensive up-front payment. It is also a good idea for customers who face a risky and unstable financial future (like farmers who depend on an unpredictable growing season), since there is no long-term commitment. The downside to renting is that it requires significant capital investment from the enterprise to make the business viable. Soluz is one of the world leaders in innovation, and has pioneered their model of rentals to become the world leader in rural PV rental systems (Steve Dahlke, 2011).

Quetsol

Quetsol is a for-profit company that provides solar home lighting systems for customers in rural Guatemala. In Guatemala there are around 500,000 homes without light, about 20% of the population. They provide a simple, easy to use "plug n' play" kit that consists of up to 3 LED light bulbs and a universal cell-phone charger. Their solar panels will last about 20 years, LED light bulbs about 7-8 years, and the batteries about a year and a half. The biggest maintenance challenge is replacing the batteries, which needs to occur every couple of years and costs about $20-$30 (Steve Dahlke, 2011). Therefore, when they sell kits, customer training consists of informing them how to operate the system to optimize battery life and to make them understand the costs of replacement. Furthermore, they plan specific maintenance days where they invite all consumers in a certain area to bring in their systems to change the batteries. A large indigenous population lives in rural areas of Guatemala, and there are 22 indigenous languages spoken among them. This presents a cultural barrier, and to overcome it they use local sales people. 90% of their systems are sold through microcredit. They have partnered with banks, including one of the biggest banks in Guatemala, Banrural, as well as one of the largest micro-finance institutions in Central America, Genesis Empresarial. Quetsol also partners with local NGO's to better connect themselves to the community, and have received funding from a variety of foundations. They have recently constituted the Quetsol foundation, a non-profit arm designed to bring lighting solutions to people unable to afford systems through commercial operations (Steve Dahlke, 2011).

Grameen Shakti

Grameen Shakti ('shakti' means 'energy' in Bengali) was created in 1996 as a nonprofit organization designed to deliver climate-friendly and reliable energy to the poor in Bangladesh. It is a subsidiary of Grameen Bank, the well-known pioneer organization of micro-finance started by Muhammad Yunus. They utilize their expertise in micro-finance to make renewable energy applications affordable to rural people. As of October 2011, they have opened 1,348 total offices, employed 10,800 people, and installed 718,146 solar systems (Steve Dahlke, 2011). For a year-by-year breakdown of growth in installations of solar home systems. They have calculated that one of their solar home systems replaces about 374 kg Carbon Dioxide (CO_2) from entering the atmosphere annually, and saves between \$6.00–\$7.50 per month on kerosene fuel costs. In terms of financing, the organization has developed four different credit schemes to make solar home systems affordable. Customers pay different proportions of downpayments and monthly installments based on their financial circumstance. These are supported by low-interest loans made possible by foundations and the World Bank. Grameen Shakti has also received grants from USAID to cover overhead costs. Grameen Shakti has tried to involve the local community by starting a network of technology centers. These are managed mainly by women engineers, who then train other women as solar technicians. They serve to service and repair systems in their areas, and manufacture solar home system accessories. They have also received the European Solar Award in 2003 and the Ashden Award for Sustainable Energy in the UK in 2006 (Steve Dahlke, 2011).

2.2.1 Solar PV system technology uses

Electricity generated from sunlight is called solar electricity and the process of converting solar light into electricity is known as the photovoltaic process. Solar-home-systems (SHS), these are small stand-alone electrical systems. They consist of a photovoltaic (PV) module which generates electricity from sunlight; a re-chargeable battery which stores electricity so that it can be used during both day and night; a charge controller which prevents the battery from being over-charged or deep-discharged; and a number of fluorescent lamps, wiring and fixtures.

The major components of solar PV systems are;

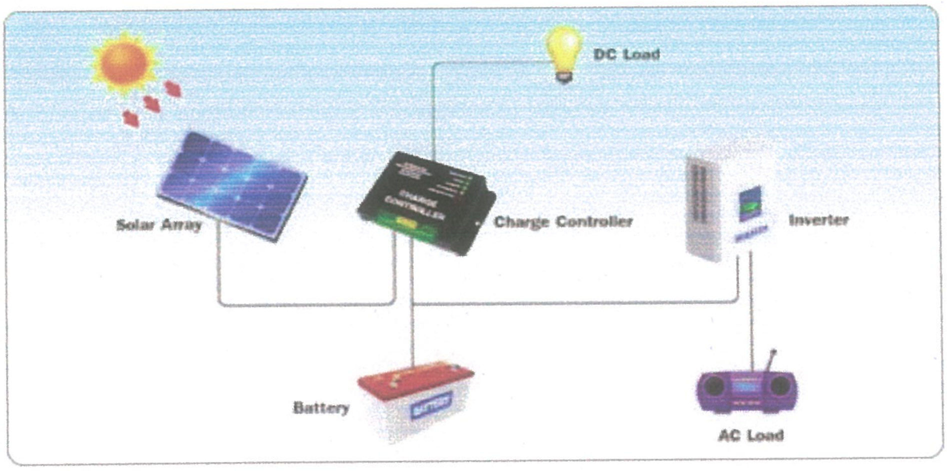
a) solar panels,

b) batteries,

c) charge controllers, and

d) DC electric appliances (e.g., lamps, small fans, or televisions).

Figure 3: Conversion of Solar Radiation into Electricity (A standard SHS)



Source: www. reein.org

A solar panel consists of many cells produced from silicon. Each silicon solar cell can yield 0.5 volt DC. Solar panels produce current during daylight hours, so to utilize power at night the customer may need to store the current in a bank of batteries that can release the power when needed. Solar PV systems have already made significant headway around the world. (Table 2) indicates the existing and potential uses of solar PV around the world (TASEA, 2005).

Table 2: Existing and Potential uses of Solar PV

Type	**Description of usage**
Rural Electrification	Power supply to remote villages Battery-charging stations
Water Pumping and treatment system	Pumping for drinking water

	Pumping for irrigation Water purification
Health-care system	Lighting in rural clinics Vaccine refrigeration Blood storage refrigeration
Communication	Remote TV and radio receiver Mobile radios Remote weather measuring
Agriculture	Livestock watering Irrigation pumping
Transportation	Road sign lighting Railway crossing and signals Runway lighting Navigation buoys
Income generation	Battery- charging stations Radio, TV, and video pay stations Village industry power Refrigeration services Electrification of rural markets

Source: TASEA, 2005

2.2.2 Advantages of using solar PV technology over other energy sources

The installation of Solar PV technology in households provide a convenient and sustainable way to power house households by supplying high quality, reliable, clean and environmentally friendly energy services. Solar PV technology has a huge impact on the livelihood of the rural people around the world by providing them with numerous direct and indirect socio-economic and environmental benefits as follows, (Wajid Muneer, 2011).

2.2.2.1 The conservation of non-renewable energy resources

Photovoltaic (PV) solar power eases the usage of diminishing natural resources such as oil, coal and gas. Today, we live in an exceptionally demanding environment where the use of energy is growing at an alarming rate. It is vital to preserve the earth's fossil fuels and other natural resources, not only for a healthier environment but also for the ability of future generations to meet their own needs. (http://www.solar-energy-advantages-blog.com/, viewed 17th Feb 2012)

2.2.2.2 Lower Rates of Waste

PV solar power systems minimize the amount of waste production. For example, the entire process of converting coal to electricity produces a lot of dust, discarded solid waste, spillages of toxins and harmful emissions, as well as wasting energy, heat, land and water pollution from non-renewable fuels is inevitable. Emissions such as Sulphur Dioxide, Nitrogen Oxide and Carbon Dioxide all can have a negative effect on farming, people's health and water. Ecosystems are also at risk of being destroyed. Furthermore, pollutants from kerosene used for lighting purposes is reduced with the use of solar power systems, as well as the decrease in use of diesel generators for the production of electricity (http://www.solar-energy-advantages-blog.com/, viewed 17th Feb 2012)

2.2.2.3 Reduction of air pollution

When fossil fuels are burned, particulate matter is released into the air, regardless of efforts to reduce these emissions. The result can affect the environment in the form of smog, and in certain cities, this can pose serious health problems for residents. Also, carbon monoxide is created when fuel combustion is incomplete. This gas is a health hazard, even in low doses. Energy produced by solar systems does not contribute to air pollution. PV Solar power systems produce electricity without giving off carbon dioxide. One PV Solar system can offset approximately six tons of CO_2 emissions over a twenty year life span (http://www.solar-energy-advantages-blog.com/, viewed 17th Feb 2012)

2.2.2.4 Reduction of Energy Usage

Solar power improves energy efficiency and is therefore very beneficial for Third World countries. Solar power electricity reduces the costs of conventional power for built up cities, and is cheaper for industrial and commercial purposes to run their operations. This leaves the use of PV systems to generate power for most of the developing world's population in rural areas (Maisha Islam, 2010)

2.2.2.5 Zero effect on Climate

Generation of electricity by solar power does not produce or emit greenhouse gases like CO_2 (Carbon dioxide) into the atmosphere like the combustion of fossil fuels. Many scientists now believe these gases may be affecting our climate. CO_2 can create a "greenhouse effect" in the atmosphere, causing global warming. This may lead to an increase in hurricanes, flooding and other weather conditions that can result in injuries, deaths and loss of property (Masoud Dauda, 2005).

2.2.2.6 Social benefits of Solar PV

The installation of Solar PV systems enables children to study for longer hours and eliminate the time, hassle and cost involved with kerosene usage. About ninety percent of rural users in Bangladesh have admitted that the use of solar home systems have drastically improved the quality and reliability of light usage, enabling their children to study for longer hours and eighty percent have agreed to the fact that Solar PV technology are much more convenient and cleaner than kerosene (Maisha Islam, 2010). Apart from these benefits, the Solar PV technology programs have other positive long term impacts on the lives of the rural people. By reducing the use of kerosene wick lamps, candles and traditional fuels for lighting purposes, Solar PV have reduced the smoke and smell associated with these energy sources and have improved the overall health and environmental condition in the rural areas of Bangladesh (Maisha Islam, 2010).

2.2.2.7 Low running costs

With prices of traditional fuels elevating, the cost advantages of solar energy are becoming obvious. After installation of the appliance (Solar PV), solar energy is free (Wajid Muneer, 2011).

2.3 Factors which constrict the accessibility of solar PV system

Despite the positive aspects of Solar PV systems, up-scaling and large-scale dissemination of solar technology faces great challenges and barriers. However, Programmes in the renewable energy sector have not been implemented according to expectations due to a number of reasons. One of the reasons for this situation is that as it has been in many countries in the world, projects involving large commercial and decentralized electricity generation from fossil fuels have been receiving considerable support from the government and key development cooperating partners. Technical and financial support for renewable energy such as Solar PV projects have always been limited (Kimambo and Mwakabuta, 2005, Miller, 2004). Other problems are explained below.

2.3.1 Low energy density

One of the major limitations of solar energy and indeed all other non-conventional renewable energy resources is that **the energy density is relatively low**. As a result of this constraint, they require large areas of land and space to produce energy that would be sufficient to cover all uses such as cooking, heating, and powering of machines such as milling machines etc. and industrial processes. Although theoretically all renewable energy sources can produce sufficient power to cover all the above mentioned applications, the investment costs required to produce the amounts of power required for the applications mentioned above is expensively high. As a result of this situation, renewable energy resources such as solar and wind energy are used only to produce power for low energy requirements such as lighting, refrigeration, water pumping, and power supply for electronic equipment.

2.3.2 High cost

Affordability of Renewable Energy Technologies (RETs) including Solar PV has also been one of the setbacks since the majority of the populations in rural areas are poor. An ongoing effort in marketing Renewable Energy technologies has to consider the strategies to address the affordability barrier. The majority of the poor rural households, which constitute a large part of the targeted population to be supplied by Solar PV technology, may only afford the expenses for Renewable Energy Technologies, if they could find financing since available household income can hardly afford cash payment for the desired energy technologies (Mwihava, 2002).

2.3.3 Renewable Energy equipment

The slower response from the rural households to acquire renewable energy technologies such as Solar PV systems may be due to the past negative experiences attributed from poor renewable energy equipment standards. This may have been the result of importation of sub-standard equipment, which does not meet the expectation of the rural households (Mwihava, 2002). Effective monitoring and guidelines on the quality, installation and use of solar PV technology is required when promoting the technologies to avoid such setbacks. Experience has shown that Renewable Energy technologies such as solar PV and wind energy which meet the required standards have been promoted and successfully implemented in many countries (Karekezi, 2002).

2.3.4 High cost of solar PV components and maintenance

Lead-acid storage batteries in Solar PV systems require frequent maintenance and provide a weak technical link in the system. While the PV Panels come with a guarantee of twenty years from their manufacturers, the expensive, deep cycle batteries are given only a five-year warranty. Hence this factor has result into disappointment in purchasing Solar PV by the rural households

2.3.5 Institutional Framework

One of the barriers has been inadequate institutional capacity for promoting Renewable Energy and coordination of Renewable Energy activities. It is argued that development of the Renewable Energy sector cannot be achieved by the private sector alone so there should be support from an efficient institutional framework (Mwihava, 2002, Laing and Rosseli, 1999).

2.3.6 Lack of information

There is still a large lack of public awareness and acceptance on the function ability and the various beneficial aspects of Solar PV. Furthermore, the rural people usually lack financial foresight and base their decisions on short term gains rather than long term financial savings. So, it is very difficult to convince them about the far-reaching positive long term benefits of solar. This lack of awareness and acceptance necessitates a concerted effort on the part of the government and the disseminating organizations to make the benefits of the solar technology known to people through the media and via practical demonstrations.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter describes the methodological approaches which were used in the study to collect, analyze and present the data. It will include the description of the study area, study population, research design, sample size and sampling techniques, data collection methods and instruments, data analysis and presentation and ethical issues.

3.1 Research design

The study used descriptive research design. The design enabled the researcher to describe the role of solar PV system technology for sustainable energy use in Mkuranga district by examining the availability and affordability of solar PV system thus helped the researcher to know how many household have access to solar PV and; he was able to identify the different uses of solar PV in households and their advantages of using solar PV over other existing energy sources in Mkuranga district and lastly he was able to identify the constricting factors that which contributed to inaccessibility of solar PV system in Mkuranga district. The study was carried out basing on the research objectives and research questions and it employed both qualitative and quantitative methods.

3.2 Sample size and sampling techniques

3.2.1 Sample size

The study used a total of 100 respondents; the researcher interviewed 70 households respondents in 3 villages of Mkuranga district namely Mkuranga centre, Mwanambaya and Vikindu. Out of this 70 household 10 were children, 26 were women and 34 were men. 20 respondents were interviewed at the district level of which 8 were men and 12 were women. The researcher went on and interviewed 5 respondents who are technical people who install the Solar panels of which all were men from Tanzania Solar Energy Association (TASEA) and other freelance technicians of which all are men. He also interviwed 5 respondents comprising of members from TASEA, Tanzania Traditional Energy Development Organization (TaTEDO) of which 4 were men and 1 were women. Information from the household respondents were sourced using the general questionnaires while the memmbers from TASEA, TaTEDO, technicians who install the Solar panel and some few household respondents were interviewed using the interview guide and focus group discussion. A total 10 children (3 girls and 7 boys), 42 women and 58 men were used in the study.

3.2.2 Sampling techniques

The study used simple random and non-random sampling techniques in selecting the sample size (respondents). Simple random sampling was used to select the respondents from the community members. The method which was used to draw the sample was " Lottery method of sampling". In this method seven villages of Mkuranga district were written on seven pieces of paper, which were later folded and mixed together in a tin. After being mixed in the tin 3 pieces of paper were selected randomly. Out of this 3 pieces of paper three villages were picked, namely Mwanambaya, Vikindu and Mkuranga centre. From each three villages 23 respondents were selected from list of names of household obtained from each village chairman of 3 villages. In each list every 5^{th} name of household was picked for sampling, untill a total of 70 respondents were obtained from the three villages. Purposive non-random sampling was used to select key informants like proffesional worker such as nurses, teachers from hospital and school, technicians, members from TASEA, TaTEDO and also district officials who provided relevant information which increased the credibility and reliability of the study, it also saved time.

3.3 Description of the study area

3.3.1 Location

Mkuranga district is one of the six districts that form the Pwani (Coastal) Region. It was established in 1995, when the eastern part and coastal area of the Kisarawe district was cut off to form the district of Mkuranga. It is a relatively small district, covering 2,432 square kilometers, which is about a quarter of the size of Bagamoyo and about the size of the Zanzibar Islands. The district has about 90 kilometers of coastline, extending from the Temeke to the Rufiji districts. Like much of coastal Tanzania, the district is endowed with coral reefs, mangrove forests, and coastal fisheries. Remote unpopulated islands host endangered species such as the red colobus monkey and attractive birds. In Mkuranga, there are seven coastal villages: Shungubweni, Mpafu, Kerekese, Kisiju Pwani, Mdimni, Magawa, and Kifumangao and several near-shore islands, hosting the Boza, Kuruti, Kwale, and Koma villages (Mkuranga Governance Baseline, 2006). Most of these villages are remote and inaccessible, despite the relative proximity to Dar es Salaam.

3.3.2 Climate

Two key features show the climate of Mkuranga district. These include temperature and rainfall. According to meteorological statistics the average temperature for the district is about 28^0 C. The region experiences average annual rainfall of 800 mm as minimum and 1000 mm as maximum per year. The heavy rainfall covers 120 days between March and June every year and spreads throughout the region. The light rainfall is received for 60 days and common from October to December each year. However, the light rainfall does not cover the whole region and is very unreliable. According to agronomic factors, the heavy rainfalls are used for cultivating crops that require more moisture such as paddy, maize and cotton. On the other hand, short rainfalls are used by smallholder-farmers to cultivate crops that require less moisture. These crops include pulses and vegetables. Apart from that, the interpretation appeals that smallholder-farmers would be practicing intensive farming in areas with large coverage of rainfall in terms of days (Coast region socio-economic profile, 2007).

3.3.3 Population

Almost 190,000 persons live in the 15 wards and 101 villages in Mkuranga District. The population of Mkuranga District comprise of 91,714 males and 95,714 females. The people of Mkuranga primarily belong to four ethnic groups the Zaramo, Ndengereko, Matumbi and Makonde. Most people live in poor and simple houses thatched by grass or coconut leaves, poles, and mud walls on earth floors (Mkuranga Governance Baseline, 2006).

3.3.4 Topography, soil and drainage

The first observation is Indian Ocean coastal belt, which dominates the region. The coastal belt extends from Bagamoyo district (North) to Rufiji district (South). The feature of the coastal belt rises from 0 to 100 meters above sea level. These areas are covered by sandy loam soils and heavy clay waterlogged soils, which are suitable for paddy production. The second observation is the highland plateau. Such area rises from 100 to 480 meters above sea level. The area is dominated by sandy loam and sandy clay and is suitable for vegetables and pulses cultivation. The third portion is lowland areas. Most of these are rivers that discharge water into the Indian Ocean (Mkuranga Governance Baseline, 2006).

Most of the rivers are correlated to drainage. The drainage system is based on rivers. Among them are Rufiji River, Wami River and Ruvu River. According to drainage system in Tanzania, these three rivers in Coastal region are among the largest rivers in the country. These rivers contribute significantly to the economic values of people in the region. They are used either as agricultural potential zones or as source of fishing industry, transportation and water for domestic uses. Approximately, over 90 percent of water consumed in Dar es Salaam city is obtained from Ruvu and Wami rivers. With such features, it is evident that availability of drainage system in Coast region could be a basic instrument in reducing rural poverty through utilization of rivers for irrigation and other necessary construction (Mkuranga Governance Baseline, 2006).

3.3.5 Economic activities

Almost 190,000 persons live in the 15 wards (three coastal) and 101 villages (10 coastal) in the Mkuranga District. Dependency on natural resources is high, with over 90% of households dependent on natural resources for medicinal plants, fuel wood and building poles. Agriculture is the principal economic activity, with over 90% of the households engaged in farming. The most common food crops are cassava, rice and beans. Major cash crops are cashew nuts, coconut, pineapple and orange. The District is one of the largest producers of cashew nuts in Tanzania, with over 35,000 hectares under cultivation and close to 3 million trees (Mkuranga Governance Baseline, 2006). The production of cashews peaked in the early 1970s, but a combination of issues (mildew disease, world market price decline, and Villagization) caused the production to decline. The production started to increase again during the mid-1990s, when extension services improved and farmers began preventing mildew disease by spraying the trees with sulfur dust.

A socioeconomic baseline conducted in 2005 as part of the Songo-Songo Gas Development and Power Generation Project that surveyed four villages in Mkuranga; found that the average income per household was about Tsh 600,000 (less than US $600 per year). With an average household size of about 4.5 persons, this means less than US $150 per person per year. Eighty-seven percent of the respondents stated that they earned less than one dollar per day (Mkuranga Governance Baseline, 2006). Mkuranga has several areas that are attractive for shrimp and finfish fishing. The district has ten official fisheries landing sites, the largest being in Kisiju Pwani. This is the only place where fish landings are recorded. Overall, there is a serious fisheries statistics gap in Tanzania. Compiled and published fisheries statistics are only available up to 1996 (Mkuranga Governance Baseline, 2006).

3.4 Data collection methods and instruments

Data was collected using interview guides, questionnaires and focus group discussions. The study collected both qualitative and quantitative data. Focus group discussions with small groups of respondents were used as the major source of qualitative data while questionnaires were used as the basis of gathering quantitative data.

3.4.1 Questionnaires

The questionnaire was the formal way used to collect information at household level. The questionnaire was intended to collect information on household characteristics, availability and affordability of solar PV systems, uses of solar PV system accompanied with advantages of using solar PV technology over available energy sources and lastly the constraining factors in the accessibility of solar PV system. The questionnaire was designed and pre-tested prior to the field visit. The pre-testing enabled some modifications to be made on the original questionnaire to suit the study area. Due to this, some of the questions were be dropped or reorganized accordingly.

3.4.2 Interview guide

An interview guide was used to collect information from key respondents particularly government officials like district environmental officer and ward executive officer, technicians and members from TASEA and TaTEDO. An interview guide helped the researcher to collect useful information concerning solar PV technology issues from key informative.

3.4.3 Focus group discussions

Discussions were held in small groups of about 5 respondents mainly the local community members and students. Group discussions helped the researcher to obtain relevant information on how solar PV technology can be a source of sustainable energy use in Mkuranga district.

3.5 Data presentation and analysis

Descriptive analysis was used to analyze the data collected from the field by relating them to the study objectives. Tables and charts were used to present the field results.

CHAPTER FOUR

PRESENTATION OF STUDY FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the study findings, analysis and discussions. It includes the socio-demographic information, the availability and affordability of Solar PV system technology in Mkuranga district, the uses and the advantages of solar PV tehnology in Mkuranga district and lastly the constraining factors in the accessibility of solar PV system in Mkuranga district

4.2 Socio-demographic information

The study involved different categories of respondents including local community, local leaders, stakeholders engaging in agricultural related activities such as government officials, CBO's and NGO's and other development partners. The study involved respondents of varying age groups, with gender representation, different level of education and occupations.

Table 3: Age of respondents

Age group (years)	Number of respondents	Percentages
15-25	24	24
26-35	23	23
36-45	32	32
46-55	15	15
>55	06	06
Total	**100**	**100**

Source : From the field by the researcher, June 2012.

The study sourced responses from mainly the people aged between 36-45 years (32% of the total respondents), few of the elderly people were engaged in the study (6% of the total respondents) (table 2). This may be because the people aged between 36-45 years are the one who mostly engage in different economic activities like agriculture, business and formal employment in the village than the elderly people who normally stay at home as most of them are weak/sick, so it was much easier for a researcher to interact with the people aged between 36 and 45 years in the village or on ways than the elderly people. Also most of the elderly people in the village are being taken care of by their sons or daughters who are also the heads of the house, they rarely engage in any economic activities that is why it was hard for a researcher to include most of them in the study.

Table 4: Sex of respondents

Sex	**Number of respondents**	**Percentages**
Male	58	58
Female	42	42
Total	**100**	**100**

Source: From the field by the researcher, June 2012.

The study involved 58% males and 42% females (table 4). The difference in representation between the males and females indicates that the males were more ready and more reliable to provide the information during the study. This is because all the household interviewed are headed by males and females are second in command. Males have more power as they are daily bread earners through different economic activities. However, the researcher noted that despite the female being less representated in the study, they provide more information related to household energy uses than man, as they are the one who gather firewood and use energy for different domestic activities in the house than man.

Table 5: Level of education of respondents

Level of education	**Number of respondents**	**Percentages**
Primary	54	54
Secondary	30	30
Tertiary	16	16
Total	**100**	**100**

Source: From the field by the researcher, June 2012.

There are varying levels of education among the respondents. 54% of the respondents had attained primary education while 30% of the respondents had attained secondary education and 16% of the respondents had attained tertiary education (table 5). Having attained different levels of education the respondents are expected to be able to learn and adopt different renewable energy technologies such as Solar PV, bio gas and many other RETs. This is because the educated household head becomes more aware of the potential benefits of using the RETs. Experience from other studies had shown that, education imfluences people's behaviour, perceptions and their life styles. Education facilitates attitude change among people and in a context of renewable energy, it may influence the knowledge and steps that the rural households take to use renewable energy technologies available (Masoud Dauda, 2005).

Table 6: The occupation of respondents

Occupation	**Number of respondents**	**Percentages**
Farmers	60	60
Formal employment	21	21
Other employments	13	13
No occupation	6	6
Total	**100**	**100**

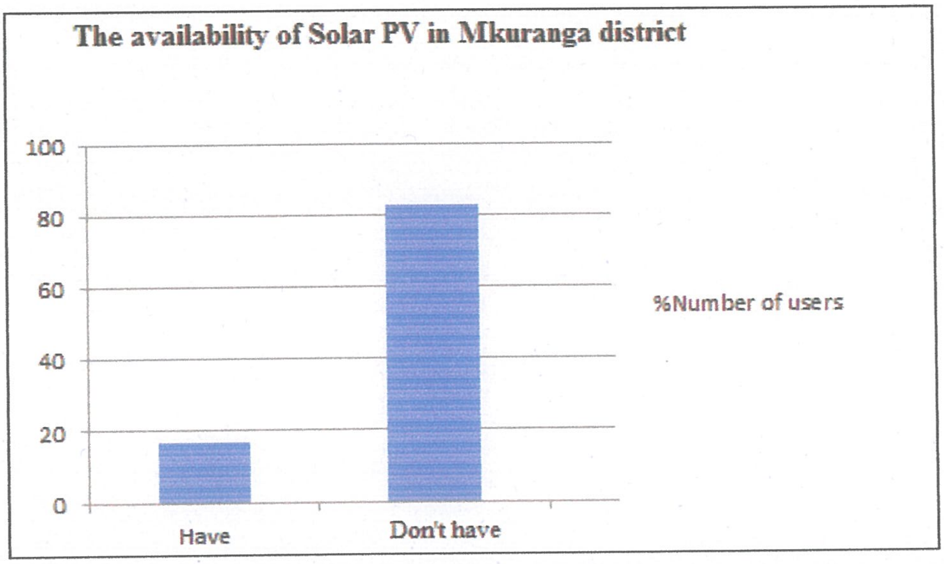
Source: From the field by the researcher, June 2012.

The majority of the respondents used in the study were farmers who accounted for 60% of the total respondents (table 6) engaging in agricultural activities like growing crops such as maize, beans, cassava and many others, they also keep livestock such as cattle, goats and sheep. This may be because agriculture is the major economic activity in the study area. The researcher observed that the majority of the farmers in the village are women.

Formal employers (teachers, nurses and doctor) were also involved by 21% (table 6) and their contributions were important for the study. The study also involved people with other employments such as business persons, government officials, carpenters, fishermen and others who represented 13% (table 6) of the total respondents. However the researcher observed different socio-economic activities carried out by the people in Mkuranga, the socio-economic activities were analysed because of their relationship to energy use. Household heads (mostly men), for example are the main decision makers ceratin innovations or RETs. The study observed that there are people especially youths (19-27 years) who do not have jobs and they spend most of their time sitting in a small trading centre of Mkuranga centre, drinking alcohol, smoking cigarettes/marijuana, waiting to carry luggages and sometimes they steal other people's properties, these represented 6% of the total respondents.

4.3 The availability and affordability of solar PV system in Mkuranga district

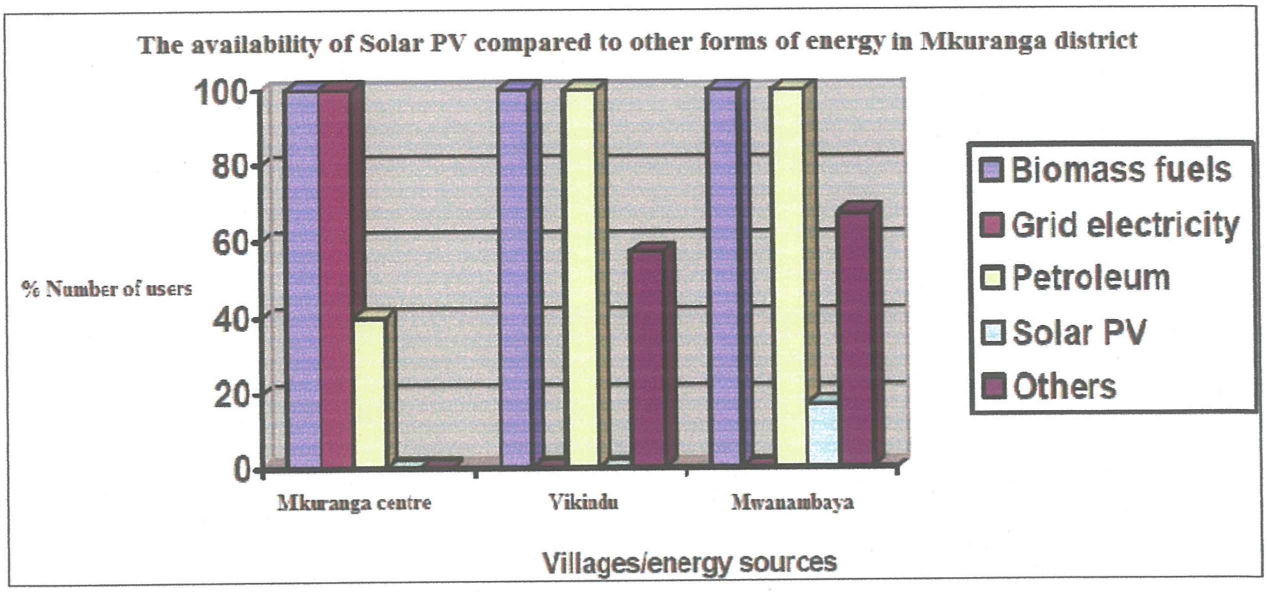
Figure 4: Shows the percentages of people who are using Solar PV in Mkuranga district



Source: From the field by the researcher, June 2012

The study result show that 17% of interviewed household in Mkuranga district have Solar PV system as energy source. Solar Pv systems are used for lighting, power for radio, TV and cell phone battery recharging. The reason for these household to use Solar Pv is that they are not connected to grid electricity. Figure 4 aslo shows 83% of interviewed do not use Solar PV this is because, some households use grid electricity, petroleum and other forms of energy to power up appliances, cooking, heating and lighting. However the interviewed household had another reason to why the technology is not used and that, majority did not have adequate information on the cost of Solar PV system.

Figure 5: Shows the availability of Solar PV compared to other forms of energy in Mkuranga district



Source: From a field by a researcher, June 2012.

Mkuranga centre

The results from this study (Figure 5) indicate that a large proportion (100%) of the interviewed households in Mkuranga district is using grid electricity and biomass fuels. This is because grid electricity is accessible at Mkuranga center. The location of Mkuranga center could be one of the reasons why it has been electrified. The center is located along the main road which connects Mkuranga district with nearby towns. Despite the fact that the households have access to grid electricity, it was found that biomass fuels continue to be their major source of energy for cooking. Grid electricity is mainly used for lighting and powering domestic electrical appliances as opposed to cooking activities. The adoption of solar PV systems for domestic use may supplement electricity from the grid as solar electricity could also be used for lighting and running domestic appliances such as radio and TV.

(Figure 5) shows that 100 % of interviewed households in Mkuranga centre were found to be using biomass fuels. The households that were found to be using petroleum fuels mainly kerosene accounted for 40% (Figure 5) of the interviewed households in Mkuranga centre. Previous studies have shown that kerosene is mainly used for lighting purposes in rural areas (Kimambo and Mwakabuta, 2005). In this study it was found that, kerosene is specifically used for cooking and supplements biomass fuels for the households with slightly higher income when biomass fuels are scarce. The explanation for this could be the high cost of using grid electricity for activities such as cooking. Experience has shown that grid electricity which is supplied by Tanzania Electric Supply Company Limited (TANESCO) is subsidized by the government thus making it affordable to low income users (Kimambo and Mwakabuta, 2005). However, grid electricity prices can still be higher for the rural poor when compared with biomass fuels. The main reason behind is that biomass fuels such as firewood can be cheaply acquired by the rural households. Reliance on biomass fuels as energy sources for cooking is not confined to rural areas alone. Recent studies have shown that most of city dwellers in many developing countries depend on biomass fuels for cooking activities despite the fact that they are connected to grid electricity (Karekezi and Majoro, 1999, Miller, 2004).

Vikindu

The study results show that 100% (Figure 5) of the interviewed households in Vikindu depend on biomass fuels and kerosene as their major source of energy. The households use biomass fuels mainly for cooking. Contrary to the households interviewed in Mkuranga centre, the households in Vikindu were found to be using petroleum fuels such as kerosene specifically for lighting their homes and one household was found to be using diesel generator for operating the TV. (Figure 5) indicates that none of the households were found to be using grid electricity as the source of energy. This is due to the fact that Vikindu has no access to grid electricity. The study has revealed that the more distant the village is from Mkuranga centre, the more difficult it becomes to be electrified from the grid. The dispersed nature of the rural settlements has been noted as one of the setbacks for the grid electrification of rural Tanzania (Ministry of Energy and Minerals, 2010). The study also shows that solar PV is not used as a source of energy among the interviewed households (Figure 5). This is due to inadequate information on solar PV systems in the village. At the same time, 57% of the interviewed households in Vikindu (Figure 5) were found to be using other sources of energy to cater for their domestic use. These were mainly dry cells for powering radio.

Mwanambaya village

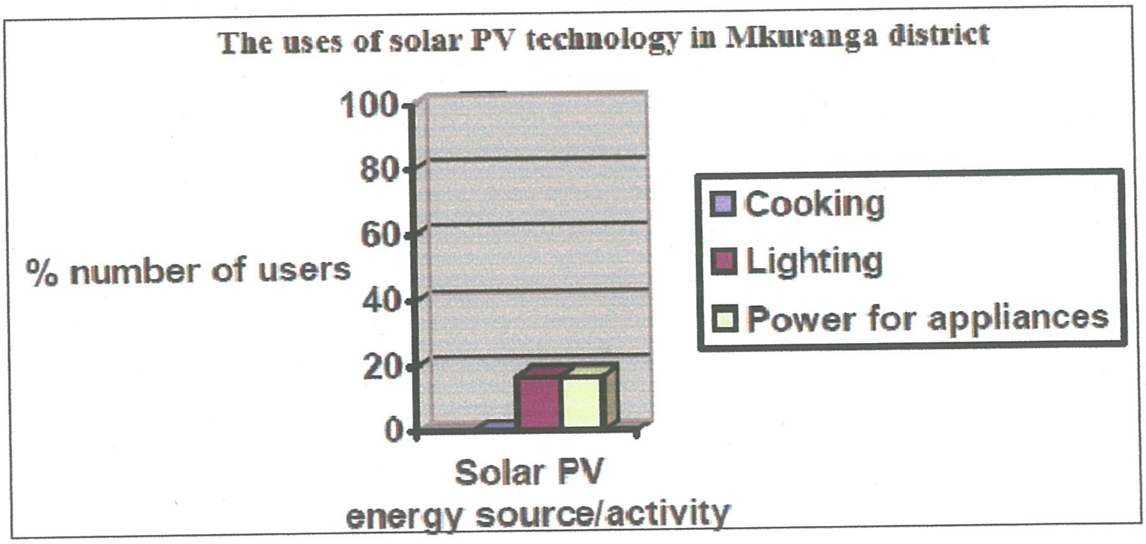
Similarly, study results in Mwanambaya as it is shown in Vikindu (Figure 5) show that 100% of the interviewed households are using biomass fuels and petroleum fuels(i.e. kerosene). All of the interviewed households in Mwanambaya do not use grid electricity as their source of energy. The reason is that the village is not connected to the grid. However, 17% of the interviewed households in Mwanambaya use solar PV systems as their energy source. Solar

PV systems are used for lighting, power for radio, TV and cell phone battery recharging. At the same time, the results show that 67% of the interviewed households use other sources of energy such as dry cells. According to the study the 17% interviewed household purchased their SHS from a company called Zara Solar. The study revieled that the interviewee were using a standard popular 14Wp (Watt peak) Solar Home System (SHS), with battery, charge controller and two lights, costs 234,000 TSH (£94), while a 70Wp system costs 964,000 TSH (£390); an additional 10% which is usually charged for installation by Zara Solar or by one of their freelance technicians. Customers were given a detailed price list to allow them to select the system that best suits their needs and budget. At present most customers pay outright for the systems, although institutions such as health centers have had government assistance or finance from donors to help with the cost. However, Zara Solar has recently started selling through Savings and Credit Co-Operative Societies (SACCOS), and hopes to provide micro-credit facilities to them in future.

4.4 The uses of Solar PV and advantages it has over available energy sources Mkuranga district

4.4.1 The uses of Solar PV in Mkuranga district

Figure 6: shows the uses of Solar PV technology in Mkuranga district



Source: From the field by the researcher, June 2012

The results (Figure 6) show that only 17% of the sample households were found to be using solar PV systems for lighting and powering electrical appliances (Figure 6). The results further show that solar PV electricity was not used for cooking. This means biomass fuel is the source of energy for cooking, thus there is a need of introducing other RETs such as improved-wood fuel stoves so as to reduce the over dependence of firewood which results in to deforestation.

4.4.2 The advantages of Solar PV over other available energy sources

According to 17% percent sample household they were able to justify benefits accrued from using Solar PV system as follow;

- The installation of Solar PV has enabled children to study for longer hours and eliminate the time, hustle and cost involved with kerosene usage. The use of solar home systems have drastically improved the quality and reliability of light usage, enabling their children to study for longer hours and that Solar PVs are much more convenient and cleaner than kerosene.

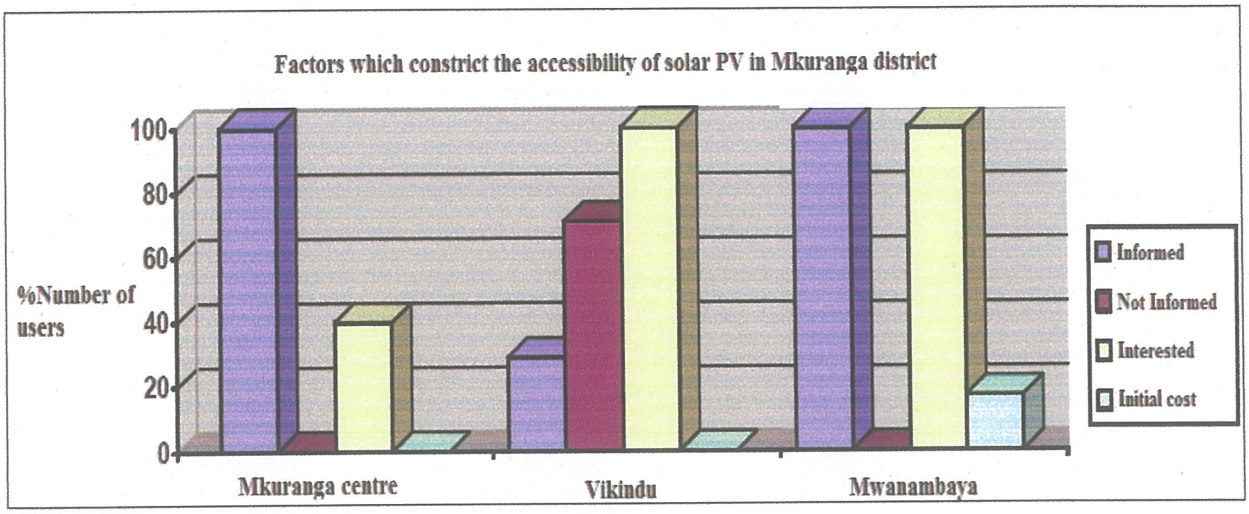
- The Solar PV (SHS) powers mobile phone chargers, thus villagers are able to use cell phones efficiently. They can use the cell phones to contact potential buyers of their local products in the city. This has expanded their customer base dramatically and has increased their earnings to a great extent thus improving their living standard.

- By powering radios, televisions and cell phone batteries, it has increased the knowledge base of the poor people thus giving them access to information on local and national event.

- Improvement in health: With the solar systems in place, women are not suffering from respiratory problems. Kerosene fumes tend to affect the eyes of the family members. During the time for winter it becomes so cold that windows are kept shut all the time, and the kerosene lamp emits so much carbon that not only do the eyes burn, but also respiratory problems develop. Women are affected much more severely than men since they stay at home for much longer hours.

4.5 Factors which constrict the accessibility of Solar PV system in Mkuranga

Figure 7: Shows factors which constrict the accessibility of Solar PV technology in Mkuranga district



Source: from the field by the reseacher, June 2012

Mkuranga centre

The results (Figure 7) indicate that 100% of the interviewed households in Mkuranga area have information on solar PV systems. The results have shown that most of the households got their information on media (i.e. radio). A small proportion of the households got their information from the various UNDP projects on Transformation of Rural PV Market. Having formal education and easy access to information is one of the reasons why most of the households in Mkuranga centre had information on the advantages of solar PV systems. This is contrary to the results from other villages which are far from Mkuranga centre where the majority of interviewed households were less informed about solar PV systems. The results indicate that only 40% of the sample households were interested in using solar PV. This is due to the fact that grid electricity meets most of the household energy needs in Mkuranga centre. However, the interviewed households have no information on the cost of solar PV systems (Figure 7). This can be the reason why the technology is not used. Studies have shown that energy choice of rural households are very much influenced by their income which means they are likely to avoid efficient devices or convenient carriers of energy due to high initial costs associated with the specific energy sources (UNDP, 1997). Despite the advantage of lower life cycle costs, solar PV systems in the study area may only be adopted by many households if initial costs of their installation will be competitive.

Vikindu

The study results in Vikindu (Figure 7) indicate that only 29% of the interviewed households have information on solar PV systems. The other 71% of the households have never heard of solar PV systems. At the same time, 100% of the households have no information regarding the initial costs of both technologies. However, the results indicate that 100% of the households would be interested in using Solar PV systems. This can be related to the slightly higher costs of petroleum fuels such as kerosene which is specifically used by many households for lighting purposes. Studies in Ghana have shown that inadequate information is one of the problems hindering the adoption of renewable energy technologies. It was learnt that the majority of the population had less knowledge on Solar photovoltaic (Makume, 1999)

Mwanambaya

The results (Figure 7) indicate that 100% of the sample households in Mwanambaya have information on solar PV and showed interest in acquiring solar PV systems. However, only 17% of the interviewed households had information on the initial costs of solar PV systems.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The result from this study (figure 5) indicate that 100% of interviewed households in Mkuranga district are using biomass fuel as source of energy for heating and cooking. Other sources of energy found were grid electricity, petroleum and other sources such as dry cells. Solar PV was found to be used only by 17% of interviewed household in Mkuranga district (figure 4). Solar PV was seen to be used as source of energy to power up appliances such as radio, tv, battery charging and lighting (figure 6). The reason behind such lower percentage of Solar PV usage was that some villages like Mkuranga centre was connected to grid electricity, and that most of their household energy needs are met by grid electricity. Another reason is lack of information on the cost of Solar PV systems and the technology it self. Solar PV systems have a potential for adoption by rural households in Tanzania. Thus the study concludes that solar PV systems can be useful in lighting and powering domestic electrical appliances in households living in the villages which are far from the grid electricity supply. The adoption of the technology will improve the living standards, reduce indoor pollution and slow down deforestation rate. In most cases, the technology is expensive for some poor rural households. Therefore, the extent of adoption of the technology will depend on the initial costs of acquiring them. However, the adoption of solar PV systems alone will not significantly improve the energy services in rural Tanzania. Other available renewable energy technologies such as improved wood fuel stoves and others should supplement solar PV systems if any meaningful long term rural development in Tanzania has to be achieved.

5.2 Recommendation

The study recommends the promotion of energy technologies which use less biomass fuels. Adoption of improved wood-fuel stoves, biogas and other RETs in rural Tanzania can reduce an excessive use of firewood and could help in conserving the environment. Although the adoption of improved wood-fuel stoves and other RETs is supposed be the household initiative, rural households should not be left to undertake this responsibility alone without government support, both technically and financially.

There should be provision of financial services. Provision of credit facilities in Mkuranga will be able to help many families in Mkuranga to adopt this technology; by lending money for installation

There should be an appropriate assistance to rural households; provision of loans to them at a subsidized interest rate, this will be a better strategy than a subsidy on the unit cost of $34. This is the opinion of those who sell product in the market. Paying a monthly installment of $3 would be far easier and implementable than expecting a lump sum payment.

There should be an access to after sales services: Purchasing power, however, is just one side of the coin. The other side has issues related to installation and maintenance services. Thus there should be a legitimate support and necessary infrastructure to maintain solar-powered equipment, this will contribute in to high penetration of the government sponsored solar lighting program

Government, NGOs and CBOs should encourage capacity building to the end users by training them on how to install and maintain the systems in villages, and also education on do's and don'ts of solar PV technology. That is, they should ensure villagers are very much explained what they should and what they should not do.

The govenment, NGOs and CBOs should Creat support systems for maintenance. One of the major bottlenecks generally encountered when new products are launched is the investment the company has to make towards ensuring that services for maintenance of the product are easily available to users. This holds true for the solar lighting system as well. The absence of adequate maintenance services is likely to affect the adoption of the systems.

Various stakeholders like the government, NGO's, CBO,s and others need to carry out more researches and investigations on dissemination, usage and innovations on various RETs to the community on Mkuranga district and whole Tanzania at large.

The government needs to create more employment opportunities in the village, this will encourage more youths to remain in the village instead of moving to urban areas in looking for high income generating activities. This can be solved through preparing youth service agents for maintenance in the village for various RETs.

Environmental education need to be provided to the people, this will increase people's awareness and understanding of the environmental resources hence they will start taking collective responsibility in conserving the environmental resources like land, soils, water and many others.

The study also recommends, there should be proximity of solar pv dealers to the people of Mkuranga since most of them are interested in purchasing the technology at an affordable rates which the dealer and the user will agree. Proximity will ensure easy access of information and equipment to the people. Thus it will encourage the purchasing power to shoot up.

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APPENDICES

APPENDIX A

QUESTIONNAIRE

Dear respondent, I am Bisarara S. Ayoub, a student of Environmental Management from Kampala International University (KIU), I am doing a research on "the role of solar PV system technology for sustainable energy use in Mkuranga district". This research is for academic purposes, only therefore I request you to help me in answering these questions and all the information obtained from you will be used with great confidentiality.

Questionnaire aimed at studying the role of solar PV system technology for sustainable energy use in Mkuranga, Tanzania.

INSTRUCTION

Please fill in the space provided or tick the correct answer for the multiple choice questions.

GENERAL HOUSEHOLD INFORMATION

1. Sex Female ☐ Male ☐
2. Age 15-25years ☐ 26-35years ☐ above 35 ☐
3. Marital status Single ☐ Married ☐
4. Occupation Employed ☐ Farmer ☐ Business ☐

   Any other, (specify)...
5. Educational level None ☐ Primary ☐ Secondary ☐ Tertiary ☐
6. Number of people in the household <5 ☐ 6-10 ☐ >11 ☐

SECTION A: AVAILABILITY AND AFFORDABILITY OF SOLAR PV SYSTEMS

1. Do you know what Solar Power technology means?

   a) Yes ☐ b) No ☐

2. If the answer is yes, what knowledge do you have about solar PV system?

   a) Power of the sun b) Sunlight energy c) The technology of converting sunlight energy into electricity d) any other…………………………………….

3. Do you use solar power technology?

   a) Yes ☐ b) No ☐

4. If yes, when did you start using Solar Power technology?

   …………………………………………………………………………………………

   …………………………………………………………………………………………

   …………………………………………………………………………………………

5. How did you come to know about Solar Power technology?

   a) Meetings/trainings b) Mass media c) Health workers d) Agricultural officers e) other means………………………..

6. Do you know where to get such technology?

   a) Yes ☐ b) No ☐

7. Are you interested in using Solar Power technology?

   a) Yes ☐ b) No ☐

8. If No, why are you not interested in using such technology option?

   …………………………………………………………………………………………

   …………………………………………………………………………………………

   …………………………………………………………………………………………

   …………………………………………………………………………………………

SECTION B: USES OF SOLAR PV SYSTEM TECHNOLOGY AND ITS ADVANTAGES OVER AVAILABLE ENERGY SOURCES

1. What forms of energy sources do you use in this community?

Types of energy sources	Where used	Satisfaction level	Remarks
Biomass fuels			
Grid electricity			
Petroleum			
Solar PV			

2. What do you use Solar PV for?

   a) Cooking ☐ b) Lighting ☐ c) Power appliance ☐ d) Others ☐

3. What are the advantages of using other energy sources apart from solar PV?

   ....

   ....

   ....

   ....

4. What are the advantages of using solar PV?

   ....

   ....

   ....

   ....

5. Do you think Solar Power technology is more reliable than other energy sources?

   a) Yes ☐ b) No ☐

6. If the answer is yes, please explain your answer

....
....
....
....

7. What is your view on the role of Solar PV systems technology for sustainable energy use?

....
....
....

SECTION C: FACTORS WHICH CONSTRICT THE ACCESSIBILITY OF SOLAR PV SYSTEM IN THE COMMUNITY

1. What NGOs are involved providing solar PV in your community

....
....
....

2. Is the government involved in extending this technology your community

   a) Yes ☐ b) No ☐

3. What is the government doing in relation to extension of Solar PV technology in this area?

....
....
....

4. Do you think it has done enough?

....
....
....

5. What is lacking

……

……

……

Thank you for your cooperation, may God bless you

APPENDIX B

AN INTERVIEW GUIDE ON THE ROLE OF SOLAR PV SYSTEM TECHNOLOGY FOR SUSTAINABLE ENERGY USE IN MKURANGA DISTRICT

Questions

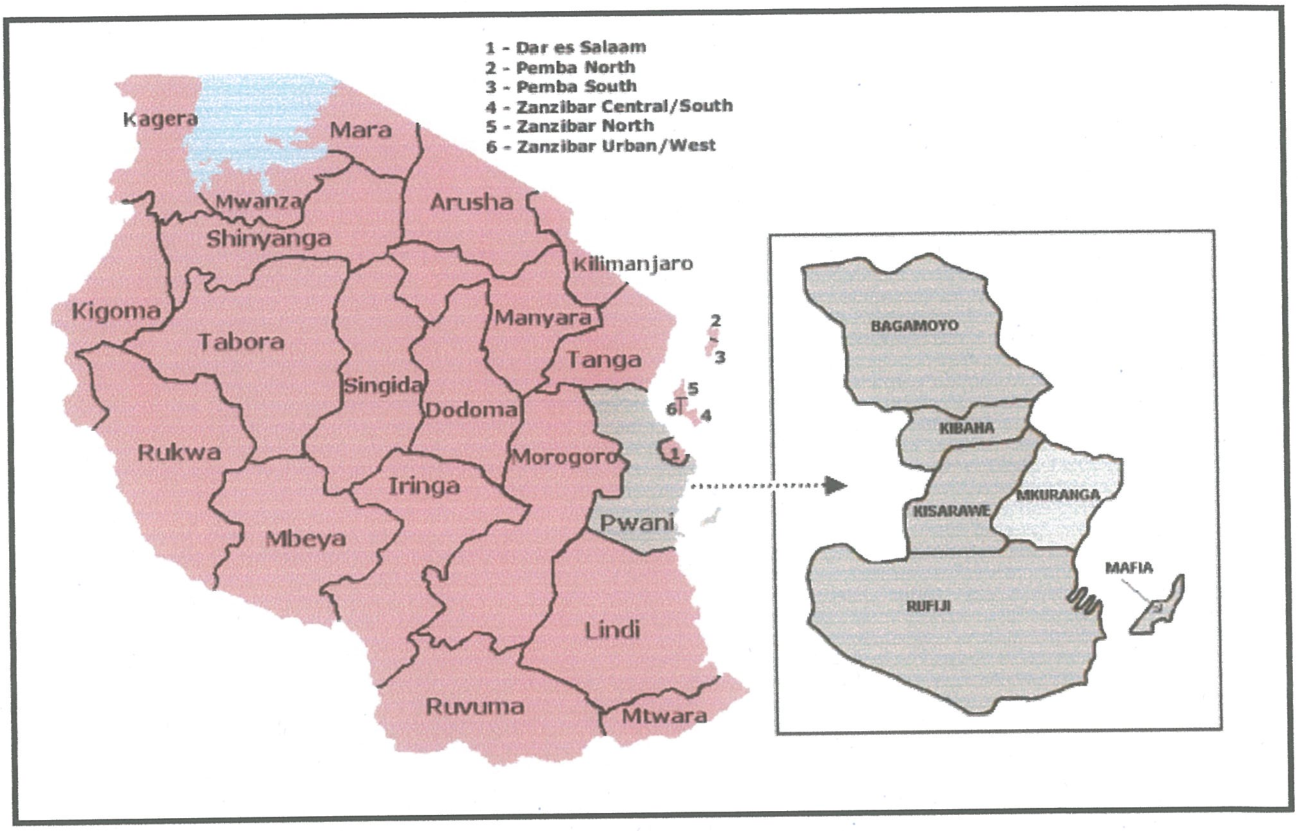
1. What is solar PV technology?
2. What are the major constituents of Solar PV technology?
3. How is the current market situation of Solar PV technology?
4. How is the information on Solar PV technology being disseminated to community members in the district?
5. With high initial costs of solar panel in hand, can the community members in the district afford this technology?
6. How is the government helping, in promoting such technology in the district?
7. What are the uses or applications of Solar PV technology in the district?
8. Which type of an application(s) or uses of Solar PV technology should be encouraged within the district?
9. What energy sources do the community members of Mkuranga have?
10. What is the use of each of the energy sources that you have mentioned above?
11. What are the advantages of using other energy sources apart from solar PV technology?
12. What are the benefits of using solar PV?
13. Which NGOs are involved providing Solar PV in your community?
14. Is the government involved in extending this technology in your community?
15. What is the government doing in relation to extension of solar PV technology in Mkuranga?

16. Do you think it has done enough?

17. What is lacking?

APPENDIX C

Figure 11: Map of Tanzania and of Mkuranga District



Source: Mkuranga Governance Baseline, 2006

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COLLEGE OF APPLIED SCIENCES & TECHNOLOGY (CAST)

Date: 29/05/2012

To : MKURANGA DISTRICT
PWANI (COAST) REGION
TANZANIA

This is to introduce to you **Mr/Ms BISARARA S. AYOUB Reg.** No **BEM/40343/91/DF** who is a bonafide student of Kampala International University. He/she is working on a research project entitled THE ROLE OF SOLAR PHOTOVOLTAIC (PV) SYSTEM TECHNOLOGY FOR SUSTAINABLE ENERGY USE

for partial fulfillment of the award of a Degree at KIU. I hereby request you in the name of Kampala International University to accord him/her all the necessary assistance he/she may require for this work.

I have the pleasure of thanking you in advance for your cooperation.

Yours sincerely,

29 JUN 2012

PP Dominic Byaugaba
Principal-College of Applied Sciences & Technology