Renewable energy in rural areas: the best path to sustainable development?

A case study in Rural Tanzania

By

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Declaration

I hereby declare that this thesis is my own work and that, to the best of my knowledge, it contains no material that substantially overlaps with that submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

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ABSTRACT

Renewable energy innovations based on wind power, solar energy, geothermal energy, and biomass energy are currently seen as offering a potential alternative to rural energy supply problems in rural Tanzania. However, such initiatives meet with some setbacks since renewable energy projects in Tanzania still face several challenges. Technical, social and economic barriers have constrained a speedy transfer and adoption of renewable energy innovations in most parts of rural Tanzania. This thesis therefore explores the roles that could be played by community-based organisations in facilitating the transfer and adoption of renewable energy innovations in rural areas. Community-based organisations (such as cooperative societies) can play a key role in innovation because they have the capacity to pool, aggregate, and disseminate knowledge and information to all actors in an innovation system. Cooperative societies are often positioned in both service networks and supply chains that allow them to coordinate activities and create an enabling environment for innovation. Thus, acting as innovation brokers, these organisations can utilise the available resources and existing social networks to facilitate the adoption of renewable energy technologies in rural Tanzania. This study was conducted in Magu district and employed an innovation systems approach in interpreting the main findings. The innovation systems approach stresses the importance of interactions among actors involved in technology development. It describes innovation as resulting from complex interaction between actors and institutions. The approach has provided insights into understanding the factors that facilitate or impede the transfer and adoption of renewable energy innovations in the study area. Despite the government initiatives to promote renewable energy innovations in Mwanza region, the study findings suggest that only a small percentage of households in the study area have adopted solar PV systems and improved cooking stoves. The thesis contributes to the innovation systems literature in two important ways: firstly, it explores the role that could be played by innovation brokers (intermediaries) in the transfer and adoption of renewable energy innovations. Secondly, it also applies systems thinking in identifying barriers in the transfer and adoption of renewable energy innovations, especially on 'a technology-specific innovation system'. Most importantly, systems thinking approach helps us to understand the connection between energy demands, poverty and sustainable development in rural Tanzania.

Key words: innovation systems, renewable energy innovations, systems thinking, sustainable development, solar photovoltaic systems, improved cooking stoves

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List of Acronyms and Abbreviations

AG&P	Artumas Group and Partners
CLDs	Causal Loop Diagrams
COET	College of Engineering and Technology
EWURA	Energy and Water Utilities Regulatory Authority
ECA	Economic Commission for Africa
EIB	European Investment Bank
GEF	Global Environment Facility
GHG	Greenhouse gases
GWh/yr	gigawatt-hour(s) per year
IDA	International Development Association
IEA	International Energy Agency
IMF	International Monetary Fund
IPPs	Independent Power Producers
IPTL	Independent Power Tanzania Limited
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt
kWh	kilowatt hour
KCPC	Kiwira Coal and Power Company Limited
MW	Megawatt(s)
MPEE	Ministry of Planning, Economy and Empowerment
MEM	Ministry of Energy and Minerals

OECD	Organisation for Economic Co-operation and Development
REA	Rural Energy Agency
REF	Rural Energy Fund
RETs	Renewable Energy Technologies
SACCOS	Savings and Credit Cooperatives
Sida	Swedish International Development Agency
TANESCO	Tanzania Electric Supply Company Limited
TANWAT	Tanganyika Wattle Company
TAZARA	Tanzania-Zambia Railway Authority
TPDC	Tanzania Petroleum Development Corporation
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
URT	United Republic of Tanzania
WCD	World Commission on Dams
WDR	World Development Report
WEC	World Energy Council
Wp	Watts-peak

Chapter 1: Introduction

1.0 Background

In this introductory chapter, I present the background to this study. I then state the aim and objectives of the study as well as the research questions that guide it. I have also provided some background information of the case study area by focusing on its history in order to give an overview of the geographical, institutional, historical and socio-cultural contexts of the study area, and thereby provide a snapshot of the factors that have been shaping innovation activities in the area. According to Baker (2006:7-8), promoting sustainable development is about steering social change and this is an on-going process, whose desirable characteristics change over time, across space and location and within different social, political, cultural and historical contexts. Experience shows that historical, institutional, social and political contexts may influence how rural communities respond to new challenges; hence such contexts may facilitate or undermine their ability to innovate (World Bank, 2006:31). Since development entails change, it is therefore helpful to consider such changes as processes of innovation.

Innovation systems as a concept is becoming increasingly recognised as an important holistic framework that may be used in understanding innovation processes in developed and developing countries (Hall et al. 2004). This renewed interest in an innovation systems approach has been necessitated by the need to incorporate poverty reduction and environmental sustainability in the current development agenda, basically as a strategy to improve economic growth and competitiveness in global markets (ibid.p.31). The importance of innovation systems as an approach inherently lies in its ability to show that the innovation process not only involves formal scientific research organisations, but it also involves other organisations as well as non-research activities. The concept also recognises the importance of information flows; hence it encourages partnerships, alliances, coalitions, linkages and other means of contacts among the actors in the innovation process (ibid.). In this thesis, I apply the concept of innovation systems as a means to explore the factors that facilitate or impede the transfer and adoption of new, low carbon energy technologies in rural Tanzania. In that way, I aim to contribute to the growing theoretical understanding of innovation systems by providing empirical evidence that may be used as a future reference in innovation and technology transfer studies. A literature search indicates that there is limited empirical evidence from rural areas of the developing countries about the local community involvement in innovation process, particularly when such processes are linked to the transfer and adoption of renewable energy innovations. In some cases, the existing empirical evidence from other countries around the world (as I will discuss later in this thesis) has been of little relevance or in some cases may not necessarily match specific rural settings in sub-Saharan Africa. The latter assertion is evident in most of the innovation literature. Hall (2007a:7), for example, argues that innovation processes "are usually very specific to a particular context", and as such each context may reflect its historical origins that are shaped by culture, politics, policies or power. Thus, adopting an innovation systems approach in this study will serve the purpose of accommodating such contexts. Through an innovation systems approach, I believe the study will be able to analyse the social, political, economic and cultural factors that influence the transfer and adoption of renewable energy innovations in rural Tanzania. The focus will be on the role of the 'rural intermediary organisations' in the innovation process and how these organisations can address innovation challenges in the renewable energy sector.

I argue that the transfer and adoption of renewable energy innovations in rural Tanzania is of central importance if the country is to achieve sustainable rural development. This emanates from the fact that energy has played an important role in the technological and industrial development of humankind. This can be traced way back from the earliest period of civilisation when the use of fire was discovered. Since that period, energy has been used in various forms to meet the human demands of many generations. Herbert Spencer, one of the earliest social scientists to study the energy – society relationship, argued that energy was the driving force towards cultural and social change in societies (Harper, 2004:238). He suggested that variations in development levels depended very much on the amount of energy produced and consumed in those societies (ibid.). It is against that background that energy has since been regarded as an engine for economic growth and development of many countries. Today's global technological and industrial advancement has been made possible by the exploitation of various energy sources. Notably, the current major energy sources in the world are fossil fuels such as coal, gas and oil, all of which are utilized on a large scale by comparison with other, alternative energy sources. Recent figures have shown that fossil fuels account for more than 80 percent of the total global energy supply (IEA, 2008:6). So far, scientific evidence has indicated that climate change is very probably, at least in part, a result of the over-dependence upon and unlimited utilization of fossil fuels in many countries[1] (IPCC, 2001a:92).

Similarly, the theoretical literature indicates that climate change and its consequences pose a profound challenge to both developed and developing countries. It is for that reason that the World Development Report on 'Development and the Environment' called for countries to initiate programmes that would facilitate both economic development and protection of the environment (WDR, 1992:2). It is also worth mentioning that there is a clear understanding among scientists, environmentalists, and policy makers that climate change may have disastrous consequences for the vulnerable rural poor living in developing countries (IPCC, 2001b:387). Although there are ongoing initiatives to utilize alternative clean sources of energy so as to minimise dependence on fossil fuels in developed countries, such initiatives are yet to be taken seriously by some countries in the developing world. It is evident, however, that growing global concerns about reliance upon fossil fuels as sources of energy and their repercussions on the environment have attracted a debate about other, alternative sources of energy. Thus renewable energy sources such as wind, biomass, solar, geothermal and hydropower have been widely recommended as the best options available so far. Research has shown that renewable energy may offer relatively clean and sustainable sources of power (Miller, 2004:381; Elliott, 2003:42). Like many developing countries, Tanzania is now experiencing rising energy costs due to over-reliance on imported fossil fuels. The country's dependence on imported fuels increases energy insecurity which in turn affects its economy. At the same time, the government still faces challenges on how to expand the existing fossil fuel-based grid systems across the country due to difficulties in attracting sufficient capital investment to explore and exploit available fossil fuels. The exploration and processing of natural gas, oil and even the construction of big hydroelectric dams not only require huge investment capital but may also cause environmental degradation. Therefore, a strategy that relies upon highly capital intensive combustion of fossil fuels may

[1] Climate change experts contend that the use of fossil fuels to meet our energy demands has increased carbon dioxide emissions into the atmosphere. Carbon dioxide and methane, which are considered to be the main greenhouse gases, have surpassed their equilibrium levels and as a result global temperatures are believed to be rising (i.e. global warming). If our current dependence on fossil fuels remains unchanged, we are bound to witness catastrophic and disastrous effects of climate change on human beings and the natural environment in the immediate future (IPCC, 2001a.). Elliott (2003:4) argues that the environmental problems arising today are the outcomes of how we use technology in terms of energy production and energy utilization. Elliott therefore suggests that climate change is a result of complex interrelations between economic and technological processes; and it is through such processes that the natural environment has been altered through the use of fossil fuels such as coal and oil (ibid.).

be neither economically nor environmentally sustainable for poorer developing countries such as Tanzania.

The latter point explains why many energy analysts perceive renewable energy innovations as having the potential to make a positive contribution to socio-economic development in sub-Saharan Africa and other parts of the developing world. Such an assumption derives both from current theoretical expectations of the renewable energy potential and the practical role of renewable energy innovations in socio economic development activities in rural areas[2] . In 2004, the International Energy Agency projected a rise of world primary energy demand by about 60% between 2004 and 2030. In this projection, it was anticipated that energy demand from developing countries would increase dramatically, and 85 percent of that demand increase will be met by the burning of fossil fuels (ibid.). This is because many countries have not yet taken steps to implement adequate energy policies which facilitate the use of renewable energy technologies (IEA, 2004b:370).

It is argued that most developing countries rely on the transfer of new technologies from technologically advanced countries. In such cases, national governments, international organisations, non-governmental organisations and other agents greatly contribute in the promotion and transfer of such technologies (Davies-Colley and Smith, 2012). As expected, Tanzania is no exception. The Ministry of Energy and Minerals began initiating projects on improved stoves since 1980s with assistance from international organisations (UNDP, 1998; Kaale, 2005). Since then, the Tanzania government and the private sector have made various initiatives to promote improved wood-fuel stoves in the country. Examples of international donor agencies that have financed the projects on improved stoves include the International Development Association which is under the World Bank. Local institutions and NGOs currently promoting sustainable use of biomass energy sources include the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC), Small Industry Development Organisation (SIDO), Miradi ya Gesi ya Samadi Dodoma (MIGESADO), Sokoine University of Agriculture (SUA) and Tanzania Traditional Energy Development and Environment Organization (TaTEDO). At the same time, the promotion of other renewable energy innovations such as solar energy technologies in the country is done by the government in collaboration with NGOs, private sector and other stakeholders. Ongoing initiatives to support the transfer of solar energy technologies in rural areas include: a

[2] Renewable energy has been defined as "energy that is derived from natural processes that are replenished constantly" (IEA, 2002:9; IEA, 2004a).

project on "Removing barriers on the transformation of the rural PV market in Tanzania currently being implemented in Mwanza region as a pilot programme supported by UNDP/GEF; Programme for facilitation of PV market development in rural Tanzania also currently being implemented and funded by Sida (Swedish International Development Cooperation Agency); and a solar irrigation pilot project in Bunda, Ulanga, Musoma (rural) and Ukerewe districts supported by UNDP/GEF small grants programme. The private sector involved include private companies such as UMEME JUA Tanzania Limited, RESCO Tanzania Limited, REX Investment Limited, BP Solar (BP Tanzania Limited), Chloride Exide Tanzania Limited, GESCO Tanzania Limited, Mona Mwanza Electrical and Solar, TROSS and ENSOL Tanzania Limited. The current main solar energy organisation in the country is TAREA (Tanzania Renewable Energy Association), formerly known as TASEA (Tanzania Solar Energy Association). According to Hall (2007b), the above organisations are seen as necessary partners in a wider process of change that may involve connecting rural communities into more competitive innovation practices. However, achieving such competitiveness in the country's renewable energy sector requires complete involvement of end-users as well as rural entrepreneurs in the innovation process. It is suggested, for example, that "innovation occurs within an interacting system of diverse actors" (Larsen et al., 2009:16). That is to say that innovation is a result of interaction and knowledge flows between research and entrepreneurial organisations in both public and private sectors (Hall et al., 2004:3). However, in the case of Tanzania, such interaction appears to be limited or sometimes completely lacking especially in the early stages of product innovation. This study aims to provide some insights into these interactions in a rural context, and therefore offers alternative means that could enhance innovation in rural communities.

Supporters of ecological modernization contend that successful transfer and adoption of renewable energy innovations will lead us to a win-win situation whereby such innovations will allow us to improve economic competitiveness and at the same time achieve environmental sustainability[3]. Ecological modernization theory is among the most prominent

[3] The main assumption under the ecological modernization theory is that "capitalism and production under market conditions are seen as part of the solution to many environmental problems" (Martinussen, 2004:155). In order to achieve environmental sustainability, we face a difficult task of implementing programmes that can bring into harmony the dynamics of economic systems with those of ecosystems (York, 2006:143). Among the challenges we face is to understand the dynamics of market economies, especially the consumption of natural resources in pursuit of economic development (ibid.). Despite the advancement of science and the use of more efficient technologies, experience shows that the consumption of natural resources has dramatically increased in the past two centuries (Polimeni and Polimeni, 2006:344). Since the natural environment provides the inputs to

theories in environmental sociology and social sciences[4] (York et al., 2009:140; Harper, 2008:28.). It originated from the work of the German social scientist, Joseph Huber, whose research showed that Germany and the Netherlands had begun to implement more strategic and preventive approaches in their bid to address environmental problems (Carter, 2001:211). Ecological modernization theorists argue, for example, that technological innovation and the use of market mechanisms would bring about efficiency and solve the current environmental problems (Giddens, 2009:195, Carter, 2001:211). In order to address these environmental problems, ecological modernization theory calls for transformation of social and institutional structures, including science and technology, markets and economic agents, nation-states, social movements and ecological ideologies (ibid.p.196). While ecological modernization calls for *science and technology* to be tailored towards the invention and delivery of sustainable technologies, it also insists on *markets and economic agents* to introduce incentives for environmentally benign outcomes (ibid.). The market is considered to be very important in the dissemination of ecological ideas and practices, with producers, financial institutions and consumers being also involved in the process (Carter, 2001:212). However, the above is possible with the helping hand of the *nation-states* which are supposed to shape market conditions that allow partnership and cooperation among the actors in the innovation process (ibid.). I therefore argue in this thesis that access to energy services especially from renewable energy innovations is of critical importance if we are to raise rural incomes, alleviate poverty as well as protect the environment. It must be noted that at present Tanzania relies heavily upon biomass for energy, although electricity supplies are rising quite rapidly from the present low level. Hydro provides a high proportion of current electricity supplies, but the potential for its expansion is limited and itself presents environmental problems. Although there are reserves of natural gas and coal that are presently under-exploited and often still unproven, were they to be developed, Tanzania's emissions of greenhouse gases would be greatly increased. Moreover, the geographical dispersion of the population, its consequent low density, especially in rural areas, and the absence of an extensive national electricity distribution grid suggest that, even if the centralised generation of electricity were greatly increased, its benefits would not be extended to the high proportion of the population

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economic production, increased consumption of natural resources and the destruction of ecosystems pose a threat to humanity.

[4] Ecological modernization also carries other names such as "eco-efficiency, clean production, industrial ecology, natural capitalism, restorative technology, the natural step, design for the environment and the next industrial revolution" (Harper, 2008:212).

who live in rural areas. Thus, both for broad environmental reasons and to accelerate rural development, there would appear to be great potential for renewable energy, and especially for distributed, small-scale rather than centralised generation of electricity by renewable means. Davies-Colley and Smith (2012), support this viewpoint by arguing that adopting sustainable technologies remains a key element in translating sustainability into practice. They insist that there is a need for transfer and implementation of 'small-scale appropriate environmental technologies' which may improve the livelihoods of the poor (ibid.). However, according to Hall (2006:11), that can only be achieved through partnering and other forms of alliances as well as networking which are among the key strategies in innovation. In that sense, community involvement (i.e. end-users involvement) plays an essential part in the successful transfer of renewable energy innovations in rural areas. I will therefore, later in this thesis analyse the importance of end-users involvement in the transfer and adoption of renewable energy innovations by focusing on the activities that are carried out by rural cooperative societies in the case study area. It must be understood that the innovation systems approach treats the end-users as an important part of the innovation process. This is due to the fact that end-users play a key role in matching the research agenda into local conditions as well as creating networks of partnership with governmental and non-governmental organisations (Poole and Buckley, 2006). I would therefore argue in this thesis that rural cooperative societies and other community based organisations could act as organs that unite end-users and as such could play a greater role in the transfer and adoption of renewable energy innovations in rural Tanzania.

1.1 Aim and objectives of the study

In an attempt to provide some perspectives on the challenges that face renewable energy projects in the country, the study will analyse the factors that influence innovation processes in rural areas. To be more precise, it will analyse the promotion of renewable energy innovations in rural areas and their contribution to sustainable development. I anticipate that the findings from this study will add knowledge to the existing literature on innovation and technology transfer, as well as providing insights into some factors that influence innovation in rural areas. The innovation systems approach is largely untested in the renewable energy sector. There is still very limited empirical evidence from the innovation literature about the contribution of rural community organisations in the transfer and adoption of renewable energy innovations. Therefore, this study also seeks to determine the extent to which local community organisations can contribute to the transfer and adoption of renewable energy innovations and how that could widen the available opportunities for the rural population to participate in socio-economic activities.

Although the application of an innovation systems approach in the transfer and adoption of innovations in rural areas appears to be diverse in the literature, it has so far not been widely applied in understanding the transfer and adoption of renewable energy innovations in rural areas, especially in the sub-Saharan African countries. I must reiterate that it is not only an affordable energy supply that is of critical importance to rural development but also clean and sustainable energy sources, which suggests the need for renewable energy innovations. As energy remains central to technological and industrial development, renewable energy innovations could influence the pace at which other innovations contribute to the transformation and improvement of rural livelihoods in the country. Most researchers and rural development experts would agree that poverty alleviation in rural areas should be the first step towards achieving sustainable development. However, this may only be possible if those involved in development projects fully recognise the central importance of energy in rural areas, and especially the role renewable energy innovations could play in the process of poverty alleviation. That is to say, we must conceive the transfer and adoption of renewable energy innovations as one of the basic factors that may determine the pace and success of poverty reduction initiatives in rural areas.

Although the importance of renewable energy technologies is widely recognised among scholars in the field of innovation and technology transfer, there are currently fewer studies about the roles that could be played by rural cooperative societies in the transfer and adoption of renewable energy innovations. What appears to be clear in the innovation literature is the suggestion that the technological innovation should blend with the local technological system as well as its social context in order for it to succeed (Fedrizzi et al. 2009), the main argument being that matching the new technology's characteristics to local needs can prove to be a decisive factor for successful transfer and adoption of new technologies (ibid.). I believe that the successful transfer and adoption of renewable energy innovations can be facilitated with some form of organisation at a local community level (i.e. through rural cooperative societies). I argue that the roles these organisations could play in the innovation process are more or less similar to what Howells (2006) refers as 'innovation intermediaries'. Howells has defined an innovation intermediary as "an organisation or body that acts [as] an agent or broker in any aspect of the innovation process between two or more parties". He notes that intermediary activities may include: helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator between bodies or organisations that are already collaborating; as well as seeking advice, funding and support for the innovation outcomes (ibid.p.720). Therefore, innovation intermediaries act as *innovation brokers*, whereby they facilitate the building of appropriate linkages in innovation systems as well as ensuring multi-stakeholder interaction in innovation (Klerkx et al., 2009:8). Literature suggests that the roles, performance and effects of innovation brokers for industrial sector have been widely researched in the developed countries and recently the focus has very much shifted to the agricultural sector (ibid.p.10). However, it appears that much of the current research has not focused on the roles of innovation intermediaries (innovation brokers) in the renewable energy sector, and this is particularly the case for the rural areas in sub-Saharan African countries.

1.2 The Research questions and hypotheses

As stated earlier, the government of Tanzania has recently stepped up efforts to increase the ratio of renewable energy technologies in rural areas. Renewable energy innovations based on wind power, solar energy, geothermal energy, and biomass energy are currently seen as offering a potential solution to rural energy supply problems in the country. However, such initiatives are met with some setbacks since renewable energy projects in Tanzania still face various challenges.

This thesis, will therefore attempt to answer the following two main research questions:

i) What social and/or demographic factors facilitate or impede the transfer and adoption of new, low-carbon energy technologies in rural Tanzania?

ii) What types of local organisations may promote renewable energy innovations in rural areas?

Experience shows that renewable energy projects in the country are mostly led by the government in collaboration with non-governmental organisations or donor countries. However, to encourage innovation processes in rural areas, innovation scholars emphasize the importance of involving all actors (stakeholders) in such initiatives[5]. It appears, however, that such involvement is to a large extent lacking. More importantly, what is interesting is that most renewable energy initiatives in Tanzania have mainly targeted providing energy services to individual rural households. This study will therefore test the following main hypothesis:

- Rural renewable energy initiatives will be more successful where they aim at providing energy access to individual households rather than small-scale rural industries.

1.3 Significance of the study

This study seeks to add more perspectives to the existing innovation literature, especially in understanding innovation processes in the rural setting. The study will analyse the roles that community based organisations can play in the transfer of renewable energy innovations in rural areas because these have not been adequately explored in the existing literature, despite their importance as potential contributors to the achievement of the government's energy objectives. Therefore, this study contributes to the body of scientific knowledge on the role of 'intermediaries' in the transfer and adoption of renewable energy innovations. It is common knowledge that the majority of the rural poor in sub-Saharan Africa are often marginalized and left out of innovation processes. Therefore, this study will offer some insights into the ways in which community based organisations could create an enabling environment for the rural poor to be involved in the innovation process by focusing on systematic approaches rather than conventional linear models of innovation processes. It is also envisaged that the study will help policy makers and planners in the rural energy sector.

[5] The stakeholders include the government, private sector, local communities, non-governmental organisations as well as end-users.

1.4 STUDY AREA

Geographical position, administrative organization and the population density

"All too often, studies on local innovation systems confine themselves to noting and grasping the importance of the capacity of regional actors, both public and private, to interact and to derive benefit from their interactions in an exclusively contemporary perspective, i.e. a brief and recent period. If we recognize that local innovation systems really do transform themselves and evolve and that the various elements within these systems operate in a complex and evolutionary process, then analysing them over a short historical period could end by at best arriving at a very partial understanding of their development trajectories and the dynamics that typify them. Only a long-term perspective, taking into account phases of growth and of subsequent decline, changes in trajectory and points of rupture can make it possible to ascertain the diachronic aspects that are essential in analysing systems" (Doloreux et al., 2007: 163-64).

The purpose of this section therefore is to explore the geographical, historical and socio-cultural contexts of the case study area. The historical context, for example, may give "an explanation of the origins and limitations of the attitudes and practices" that influence the ability of rural communities to innovate (World Bank, 2006:28). I believe that the latter have, for many years, continually shaped how innovation activities are carried out in the study area and may broaden our understanding of the current partnerships and linkages in the innovation process.

This study focuses on Magu District, which is geographically located in the north-western part of Mwanza Region. Mwanza Region lies along the southern shore of Lake Victoria in the northern part of Tanzania[6]. Magu is one of the eight administrative districts of Mwanza Region. Other districts found in Mwanza Region include Geita[7], Sengerema, Kwimba, Misungwi, Ukerewe, Ilemela and Nyamagana. Despite the poor road infrastructure within the district, it can be easily accessed using the available road networks. Magu was chosen as a case study area because of its historical background as well as being among the

[6] Tanzania is the largest of the three East African countries (i.e. Kenya, Uganda and Tanzania) covering an area of about 945,000 km^2. Its landscape is diverse and includes the Islands and coastal plains in the east, and the Great Rift Valley that crosses from north east Africa and cuts through the centre to the south of Tanzania along Lake Nyasa. The country has a tropical climate. Mount Kilimanjaro, the highest in Africa, the Ngorongoro Crater and the famous Serengeti national park are among the country's tourism attractions.

[7] Geita officially became one of the new regions in the country from March 2012

few districts which in the country have largely attracted a number of development projects but one that still faces energy supply challenges, poverty and environmental degradation.

Administratively, Magu district is divided into six divisions, which include Itumbili, Ndagalu, Sanjo, Kivukoni, Busega and Kahangara. Each division is subdivided into wards which are headed by ward executive officers (WEOs). The district has a total of 27 wards and 125 villages which are further subdivided into 778 hamlets (URT, 2008). It should be noted that amongst the notable administrative changes in the country after independence was the abolition of the then "hierarchy of tribal chiefs" left behind by the colonial administration. The aim was to utilise government and local institutions in mobilising people and organising support for development initiatives (Uchendu and Antony, 1974:1).

Magu district covers a total area of approximately 4,795 km^2. The dry land covers about 3,070 km^2 and a total of 1,725 km^2 is covered by water i.e. Lake Victoria (URT, 2008). About 236,300 hectares is said to be arable land, 144,000 hectares is pastoral land and 16,320 hectares are covered by forests. The 2002 population census indicated that the district had an estimated population of about 415,005 of whom 201,349 were males, and 213,656 were females. The revised figures by the time of second publication showed that the population was 416,113, of which males and females accounted for about 202,077 and 214,036 respectively. However, the current projections may show a slight population increase. There are more than 70,065 households in the district and the average household size is 5.9 persons (ibid.).

1.4.1 Historical background

Socio-economic Context and Organization of communities

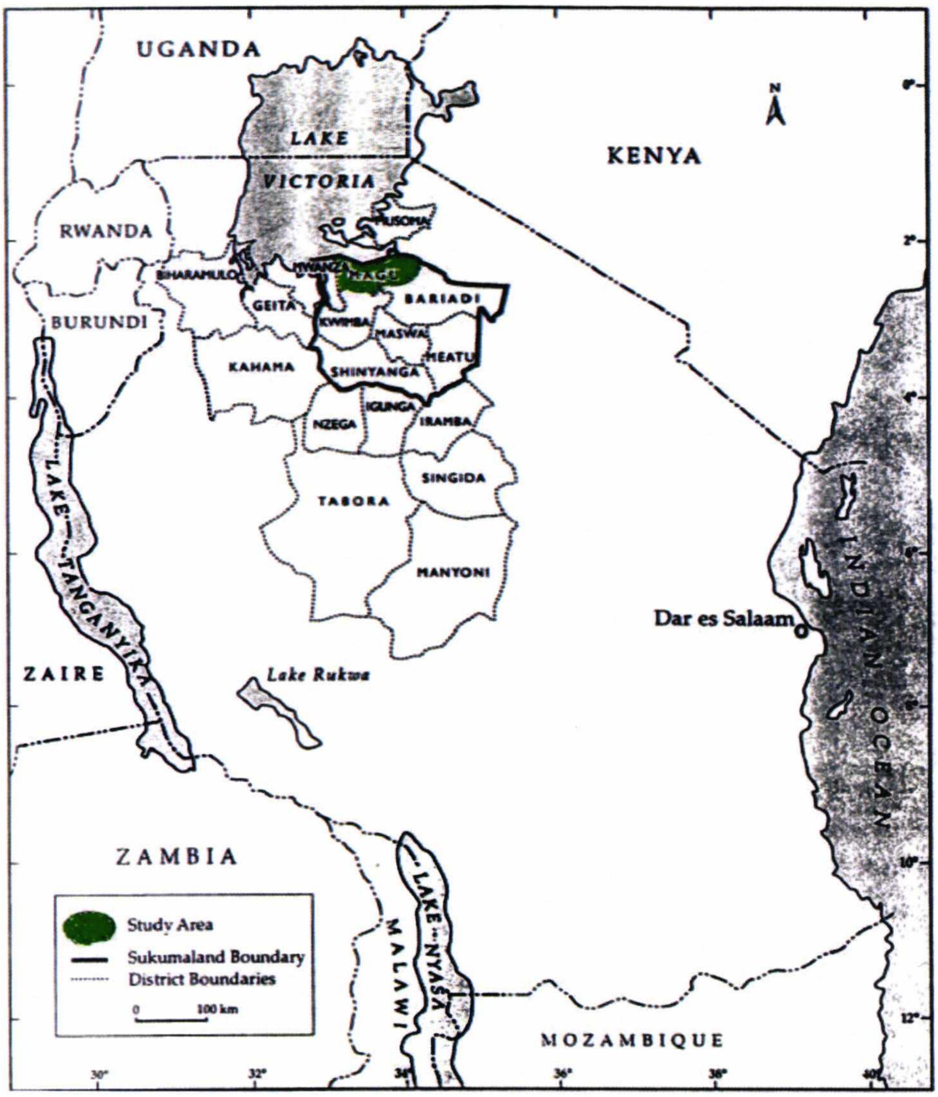
Magu district is part of what has long been referred by various scholars as the Sukumaland. Historical evidence suggests that people began to settle in Sukumaland as far back as the 16th century. As of the 19th century, Sukumaland was still made up of several chiefdoms (Meertens et al., 1996:204). Some of the well known areas that make up Sukumaland include: Ukerewe, Mwanza, Magu, Sengerema, Geita, Kwimba, Bariadi, Maswa, Meatu and Shinyanga and parts of Tabora. Burton, Speke and Stanley are some of the first of several European explorers who visited the Sukumaland in the 1860s and 1870s (Madulu, 1998:1; Birley, 1982:2). These explorers spoke about the wealth and peace found in the Sukumaland at the time, including the Sukuma tradition of livestock keeping (especially cattle) and their involvement in agricultural activities. Unfortunately, the area was plagued by a series of ecological disasters in the 1890s that negatively impacted the population. The area was first hit by 'Rinderpest', which affected many cattle. Reports suggest that the contagious viral disease in this area was believed to have been brought by European activities. It is estimated that about 90% of cattle died and this severely undermined the entire economic, social and political settings of the Sukumaland (Birley, 1982). This was followed by the outbreak of smallpox that claimed the lives of many people. The situation became even worse when people's feet were attacked by jigger fleas which in turn constrained their mobility and labour. As the population deserted the grassy plains of the Sukumaland, there was a regeneration of the bush which brought about tsetse flies. This resulted into other epidemics such as *trypanosomiasis* (also known as sleeping sickness) which infected people and animals. It is believed that by the 1920s, inhabited Sukumaland had been reduced to almost a quarter of its original size (ibid.).

German and later British colonial administrations tried to combat and contain the epidemics in the area. Both administrations moved people from infected areas and this led to the establishment of permanent population settlements. Although forced resettlement and villagisation was first thought by the colonial administration to be a temporary health measure (as a way to combat the outbreak of diseases), it was later to be seen as an easy way of building centres for education, medical care, water and other social services. This was also an opportunity for the colonial administration to impose major changes on the Sukuma agricultural system by regulating cattle, rotation systems and tillage. Settlements were also considered an easy target for cheap labour and a way to consolidate the colonial economy. According to some writers, forced resettlement programmes also marked a beginning of the Sukuma migration to other parts of the country[8]. When the British took over from the Germans after the First World War, they set up the first tsetse fly research centre so as to contain tsetse fly in the area. In the same period, they also encouraged cash crops such as cotton[9]. Tsetse control measures carried out in the 1920s are thought to have greatly contributed to massive clearing of forests which in turn removed the threat of trypanosomiasis. This period was to be accompanied by an increasing population which also contributed to forest clearing. Deforestation and overstocking led to soil erosion and the

[8] To date, the migratory nature of the Sukuma is thought to be mainly caused by population pressure, shortage of grazing land and environmental degradation.

[9] However, it is important to note that cotton was first introduced as a cash crop in the Sukumaland by German settlers in the early 1900s.

British colonial administration at the time, alarmed by the situation, started taking firm measures to address the problem in 1929. Demonstration plots were set up in the 1930s and the Sukuma were persuaded to adopt conservation measures. However, it is claimed that the majority of the people opposed the measures. The area then became identified as the "cultivation steppe" appearing as treeless and overgrazed; features that are still apparent and characteristic of most of the Sukumaland today (Madulu, 1998:2; Birley, 1982: 4, 7).



Map 1: Map showing the Sukumaland in Tanzania.

Source: Adapted from Charnley, 1997

After the Second World War, in 1947 the British launched an ambitious agricultural scheme. This was necessitated by a huge demand for raw materials in Europe after the war. Coined the Sukumaland Development Scheme, it aimed at serving the British Empire with much needed cotton, modernising agricultural practices and preventing soil erosion. In the 1950s and 1960s, cotton production increased and expanded dramatically in the Sukumaland because of the availability of the post war market i.e. high world prices, government propaganda, availability of high yielding cotton varieties and access to marketing channels i.e. cotton cooperatives (Charnley, 1997:606; Madulu, 1998:1; Meertens et al., 1996: 204; Birley, 1982:4). It was during this period that the administration also felt that it was important to enforce by legislation all soil conservation measures that were first promoted by voluntary means. The legislation required the Sukuma to practise tie-ridging, tree planting, contour banking (terracing), hedging and livestock reduction. This legislation in farming techniques was meant to encourage and sustain cotton production in the area. Some scholars, however, contend that such rules challenged the Sukuma's economic security and culture. Therefore, in some areas, these measures were met with widespread strong resistance from the locals although they were also successful in some cases[10] (Kjekshus, 1977:272). Meanwhile, Birley (1982) points out that we should also bear in mind that at the time there were few colonial administrators to enforce the measures or persuade the locals to have these measures adapted into the local culture and customs as initially planned (something that scholars consider to be essential in fostering innovation). It is therefore not surprising that the increase in cotton production in the 1950s was attributable to extensive rather than intensive farming techniques (Charnley, 1997:606). Furthermore, the population data indicate that between 1948 and 1967, the human population in the Sukumaland increased at a rate of 2.9% per annum. This rapid growth of population went hand in hand with an increasing demand for agricultural land i.e. land for cash crops, especially cotton and land for food crops. All these led to over-cultivation, reduced land available for fallows, overstocking and overgrazing (ibid.p.608).

1.4.2 Land Use and Cultural Background

The Sukuma are the main ethnic group in Magu since the district is also part of the Sukumaland. Previous studies indicate that prior to colonialism and during colonial administration, "the Sukuma were traditionally ruled by a political hierarchy of chiefs, sub-

[10] Macro approaches to studying social change can be a necessary starting point in understanding the source of environmental degradation in the case study area. However, social dynamics taking place at the micro level (in the same area) may have also contributed to the existing problem. According to Lélé (1991:618), such dynamics include social and cultural historical settings of the people in a specific locality.

chiefs, and village heads" (Uchendu and Anthony, 1974:8). In the past, there was no strong attachment between people and the villages (or pieces of land) they occupied in the 'Sukumaland'. Therefore, people could move their residence freely to other areas, provided that they were accepted and granted land by the representative of the chief. It should be understood that before the colonial invasion, land ownership was under the customary systems of the respective tribal communities. Therefore, the right to own land in Magu (Sukumaland) very much depended on customary systems of the Sukuma and chiefs had powers to allocate land on behalf of the community (Madulu, 1998:15). Uchendu and Anthony (1974:11) observed that the traditional ideas of the Sukuma on land rights were at the time rooted in the concept of residence. Residing in an area meant that one was qualified to be allocated land so as to make ends meet. As stated above, only the chief had full control and command of communal land; however village heads could also allocate land because of the powers bestowed on them by the Chief.

Both German and British colonial administrations introduced a dual system of land tenure. For example, the Germans declared all land to be crown land whereby the German governor became the custodian of all the land in the country, although the land rights of chiefs or clan heads of communities were still recognised and hence they were still allowed to allocate land in their respective areas. In general, the colonial administration recognised the existence of customary systems of land tenure, and customary systems of land tenure still exist in the country today. Nevertheless, as opposed to the colonial era, in the post-independence period, chiefs no longer had powers to allocate land. Instead, the new Villagisation Act gave the elected village leaders through village development committees (village councils) the mandate to administer land allocation in the villages. However, the colonial legislation governing land tenure systems was in a way kept. Similarly, the colonial legacy that recognised land as belonging to the state still exists. Therefore, all land in the country whether occupied or idle is still considered to be 'public' and individuals cannot own land. This implies that the state (through the president) is the sole owner of the land. Despite that fact, it is important to note that although land is owned by the state, individuals have legal right to use land provided that such land is put into productive use. The government grants the rights of use to individuals and, in circumstances where land ownership is under customary or local law, the local authority takes responsibility for allocating land. Unfortunately, during the implementation of the 'villagisation' policy, which aimed at promoting communal production, the existing customary land tenure systems were initially ignored (Uchendu and Anthony, 1974:8-12, 54; Meertens et al., 1996:204; ECA, 2004:35).

1.4.3 Current land ownership in the study area

The common way of individuals to acquire land is through inheritance. Therefore, in most cases this method of land acquisition greatly favours the eldest son in the family. However, it should also be understood that the eldest son is only given the custodian role in the absence of elders. The essence of this customary inheritance law is to protect original land holdings from future fragmentation. Similarly, customary land tenure system in the Sukumaland is meant to consolidate family ties and social solidarity in the society (ibid.). Indeed, social solidarity in the family was also noted by Burton et al. (2002:66) when defining the concept of household and its importance to anthropology and other disciplines. Burton argues that in most cases members of households share the same shelter and other basic human needs. And as such, these members may usually benefit from important resources in their household. This may include the status acquired "from the quality of their housing, the social ranking of their land or the prestige of other household members" (ibid.). It should be noted that customary land tenure systems in most sub-Saharan African countries allow the possession of land exclusively by households or individuals for the purpose of settlement (residence), farming or other socio-economic activities in the respective community (ECA, 2004:23). In this case, customary land tenure systems also include 'the commons' and that is land shared by various users for grazing, sources of water and activities such as firewood collection and charcoal burning (ibid.). Therefore, the majority of inhabitants in Magu District have in one way or another acquired land through inheritance. Interestingly, however, it seems that the customary land tenure system is gradually becoming weak due to various reasons. Amongst others, such reasons include the current rural market economy and population pressure[11] that has in turn led to the scarcity of land. These changes have created new ways of acquiring land whereby the majority of households and individuals are now made to purchase land. In other cases households are forced to rent land from others in order to conduct their farming activities. Although the old tradition of borrowing land from neighbours or close friends is still being practised between households, now it appears to be

[11] According to the World Bank (1989), population pressure in developing countries contributes to environmental degradation and that may constrain rural development. The Bank argues that because of poverty, the majority of poor people in developing countries might be forced to over-exploit the natural resources in their immediate environments.

slowly disappearing in the district due to the scarcity of suitable agricultural land. Borrowing of land has for long been a tradition among the Sukuma. For households or individuals, this tradition assures them of securing arable land for a variety of crops. Nevertheless, land borrowing and renting are usually short-term arrangements that are mostly limited to very few growing seasons. It should also be noted that in some cases such arrangements may also enhance unsustainable farming practices as respective households seek to maximize profits from the land rented or borrowed.

The Sukuma are predominantly patrilineal in nature, are agriculturalists and traditionally own cattle. Cattle ownership serves as a means for both economic and social prestige. For example, owning cattle is considered as a way to keep one's wealth and is thus considered as an investment to be sold in case of emergency. In the past it was also very common for cattle to be used in marriage exchange i.e. bride price. By the year 1875 cattle had already become a primary source of wealth among the Sukuma. In the Sukuma culture, owning land, cattle and having residence in a community signifies one's wealth and success (Birley, 1982:9; Madulu, 1998:16).

1.4.4 Agricultural activities

Magu district's economic base lies mainly on agriculture and livestock keeping. It is through agriculture that food and cash crops for both consumption and sale are produced in the district. It is estimated that about 90% of the population engages in farming and animal husbandry. Not only does the agricultural sector employ the majority of the population, but it also stands as a major source of income for the poor rural households whose income depends entirely on selling cash crops such as cotton. Although in the past cotton used to be a major export from this area and other parts of the Sukumaland, its production has been declining since the 1970s due to low world market prices, failure of the agricultural cooperatives and the introduction of structural adjustment programmes (liberalisation policies) in the country in the 1980s. Other main crops grown in Magu district include rice, maize, millet, groundnuts, sorghum, paddy, cassava, sweet potatoes etc. Vegetable crops such as beans and cowpeas are also grown in the area. Although some farmers use tractors or cattle (ox-ploughs) in their farming activities, the majority use a hand hoe with minimal use of modern agricultural inputs. Since the collapse of the co-operative organisations in Tanzania, it has become difficult for farmers to easily acquire agricultural inputs (Wamara, 2000:48; Madulu, 1998:27). In the past, the co-operatives used to distribute inputs to farmers at the village level on a credit basis. For example, records show that until the early 1990s, Nyanza Cooperative Union was still distributing mineral fertilisers, cereal seeds, cotton seeds and cotton insecticides to the village Primary Societies. However, the distribution was abandoned altogether from 1992 due to financial difficulties (Meertens and Lupeja, 1996:53). On the other hand, the private sector has not been able to establish as reliable an input distribution network as that of the co-operatives and as a result, farmers are forced to look for inputs from distant towns (Care Tanzania, 2004:5). It must be noted that the presence of cooperatives not only facilitated interaction between the major actors in agricultural sector but their activities also encouraged the adoption of agricultural innovations in the study area. However, with the collapse of these cooperatives, interaction between farmers, government and private sector in agriculture appear to be lacking at the moment, thus preventing the sharing of knowledge, which could eventually restrict their ability to innovate.

The above background information indicates that the current innovation practices in the case study area can be better analysed from the historical, cultural, social and gendered specificities of its population. My argument, here, is that innovation as a process within specific social dynamics in the communities would be better understood if we relate it with other aspects of the larger socio-economic realities and networks in the country. Therefore, to provide a balanced analysis and to avoid a crippled understanding of innovation practices in the area, we need to understand how structures at the macro level have been interacting with actors at the micro level (i.e. in the innovation process).

1.5 Structure of the study

This study is divided into seven chapters. Chapter 1 starts with the introductory background and gives an overview history of the case study area. The chapter summarises the study objectives and presents the main research questions. Chapter 2 examines the political and economic factors that have shaped the energy sector since independence. The chapter first discusses various development initiatives and policies in the country and the factors that led to the reforms in the energy sector. The chapter then discusses the country's key energy challenges arising from recurrent drought-related hydroelectric power crises and growing energy demand from the rural population. From there, it explores rural energy needs and various forms of energy sources that are available in the country. Chapter 3 provides a review of the literature on innovation and innovation systems, and discusses the analytical framework in which this study is based. The chapter begins with a review of the 'innovation systems' approach and discusses different types of innovation systems. This is important for this study because it is from there that the chapter broadens our understanding of innovation systems in the context of developing countries. Chapter 4 discusses the overall research design and methodology adopted in this study. In this chapter, I will discuss the research process, illuminating both my background and choices made during the course of this research; I will describe the methods I have used for data collection and transformation, and try to offer a basis which would better enable the reader to evaluate this study. Chapter 5 presents the survey findings and describes the socio-economic and demographic characteristics of the households in the study area. The chapter analyses the respondents' knowledge and perceptions about renewable energy innovations as well as their awareness about environmental problems and factors that may influence the adoption of renewable energy technologies in the study area. Chapter 6 concludes with a discussion of the main findings and reiterates the main arguments of the study. The chapter presents the limitations of this study hence the conclusions reached and also points out the contribution of this study to the body of knowledge (i.e. on the role of innovation brokers (intermediaries) in the transfer and adoption of renewable energy innovations).

Chapter 2: Energy in Tanzania

The chapter discusses the overall energy issues in the country. The first section in this chapter examines the political and economic factors that have shaped the development of the energy sector since independence. Thus, the chapter first discusses various development initiatives and policies in the country since independence and the factors that led to the reforms in the energy sector. The chapter then discusses the country's key energy challenges arising from recurrent drought-related hydroelectric power crises and growing energy demand from the rural population. From there, it explores rural energy needs and various forms of energy sources that are available in the country. It discusses current energy problems and why rural access to renewable energy is seen as an important step towards poverty alleviation. By doing so, the chapter also examines the potential of solar and biomass energy innovations in the country and why these innovations could play an important role in addressing the current energy problems in rural Tanzania.

2.1 Tanzania's Political Economic context

Tanzania still faces a huge challenge of providing access to energy to the majority of the rural population. This is in part due to poor investment and lack of innovative capabilities in the energy sector. Some scholars suggest that understanding the political economy and drivers of energy production and distribution can be an important step towards improving accessibility to modern energy[12]. This emanates from the fact that investment and innovation in the energy sector (i.e. all technology generation and promotional activities) take place in a historically defined political, economic and institutional context (Rehman et al., 2002; Anandajayasekeram, 2011). The above viewpoint is supported by Collinson (2003:9) who argues that the focus of political economy analysis is "on the distribution of power and wealth between different groups and individuals and on the processes that create, sustain and transform these relations over time". The following section, examines the political and economic factors that have shaped the development of the energy sector in the country since independence.

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[12] Political economy refers to "the interrelationships between social, political, and economic processes in society" (World Bank, 2006b:7). Drivers in this study refer to the factors that promote investment and innovation in the energy sector

The Period from 1961 to 1978

The country's social and economic structure inherited in the 1960s was very much influenced by the legacy left behind by colonial governments. At the time of independence industrial development was low and mass produced imports undermined the traditional production based on craft skills (Ewald, 2011:97). This was also coupled with low investment from foreign companies as these companies preferred investing in neighbouring Kenya because it had a relatively well established domestic market and infrastructure (ibid.). In short, Tanzania was characterised by extreme poverty before, during and after independence. It is against that background that since 1961, development strategies in Tanzania have consistently focused on combating poverty[13]. In 1967, the government tried to implement radical policies which involved extensive compulsory villagisation (Vijiji vya Ujamaa), nationalization (i.e. government ownership of major means of production), and price controls[14]. It is thought that by the early 1970s, the government had already controlled the large part of formal economic activity (Bigsten and Danielsson, 1999). On the other hand, by the mid-1970s, the majority of the rural population had moved to Ujamaa villages. This was part of the government strategy to promote cooperative agriculture. At the same time, the mid 1970s also saw the former peasant marketing cooperatives being replaced by the government marketing boards (ibid.). It must be noted that the peasant marketing cooperatives initially facilitated local community participation in economic activities (Kwayu, 2006). The cooperative societies, for example, were directly involved in the production, distribution of farm inputs, extension services and marketing of agricultural produce. Therefore, the 1976 transformation of 'cooperative societies' into 'cooperative unions' (under a national apex body), undermined the role of cooperative societies in the country (ibid.). This is important for this study because the transformation of cooperative societies had implications on the innovation activities in rural Tanzania, especially the involvement of end users in innovation processes[15].

The Period from 1977 to 1985

The relative achievements made in the economy were immediately thwarted in the late 1970s. The decline of the country's social and economic growth was partly due to

[13] Tanzania mainland (by then Tanganyika) gained its independence on 9th December, 1961

[14] This was implemented through the famous Arusha Declaration of 1967

[15] This would be further discussed in other chapters of this thesis

regional events such as the acrimonious break-up of the East African Community in 1977, the war with Uganda, severe droughts that hit the country as well as the world economic crisis[16] (Reed, 1996:110). All these led to a gloomy outlook of the country's economy in the 1980s and the country was listed as being the second poorest in the world by the United Nations.

The Period from 1986 to date

However, in the mid 1980s, macroeconomic reforms and structural adjustment programmes were widely adopted in an attempt to revive the country's economy (Reed, 1996:113). These measures were then being advocated by the International Monetary Fund (IMF) and the World Bank as appropriate means to address the structural weaknesses of African economies. By adopting development strategies from the IMF and World Bank, the country forfeited control over its domestic spending priorities. The conditions attached to the loans from these financial institutions obliged the country to spend less on development activities and other social services which had previously enjoyed support from the government. This meant that government could no longer subsidize agricultural inputs. Since the country's economy is heavily dependent on agriculture, this has resulted in intensive land clearance, and reduced agricultural outputs in rural areas (ibid. p.120). On the other hand, the country's population has been increasing over the years hence causing increased demand for energy, which has mostly been satisfied by combustion of biomass. The increasing number of the rural population causes increased demand for farming land and energy needs that have to be met by the country's remaining natural forests. This has, in turn, accelerated deforestation (Madulu, 2004:89).

Although Tanzania's population was estimated to be around 34.6 million in the national census conducted in 2002, other projections indicate the population to have gone up to more than 38 million (MPEE, 2007). The latest projections (i.e. 2012) indicate that the population might have gone well above 40 million[17]. It must also be noted that about 75 percent of the population still live in rural areas and the majority live below the poverty line. In the 1988 and 2002 censuses alone, the population is said to have increased from 29 to 39 inhabitants per square kilometre (Madulu, 2004:93). Although population density figures imply that the country is sparsely populated, there are variations between regions, and some areas have recorded very high population densities. For example, areas with high

[16] The former East African Community linked Tanzania with Uganda and Kenya

[17] Another national census was carried out in August, 2012. The Tanzania's population is now estimated to be around 44.9 million (see www.nbs.go.tz).

concentrations of population are those that have favourable lands for agriculture and business opportunities, viable geographical positions and better road infrastructure (ibid.). As a result, the natural resource base is increasingly coming under threat. The total forest area in the country was estimated in 1996 to cover about 33.55 million hectares (Monela et al. 1999:1); and it is argued that about 300,000 to 400,000 hectares of forest and bush land are cleared annually for farming activities in the country[18] (Reed, 1996:116; Madulu, 2004:89). Research studies carried out across Usambara Mountains suggest that nearly 70 percent of the rainforests have been cleared since the 1950s for agricultural activities while Kondoa, Iringa and Mufindi Districts are other examples of agricultural expansion in forested areas (ibid.). Energy needs and poor farming practices lead to a vicious circle whereby deforestation resulting from tree clearing increases land degradation (i.e. soil erosion) which reduces agricultural farm outputs and exacerbates poverty[19].

It is a common understanding among the rural development analysts that alleviating poverty should be the first step towards achieving sustainable development. However, over-dependence on firewood and charcoal as the main sources of energy for the rural and urban population also threatens the unique environmental and biodiversity values of the forests. Environmental degradation poses a serious threat which may erode the positive economic gains achieved so far through ongoing poverty reduction initiatives. The country's ongoing poverty reduction initiatives have since included the expansion of energy investments so as to facilitate access to modern energy services in rural areas. An important recent development in the energy sector is the establishment of an independent rural electrification agency. The Ministry of Energy and Minerals has established a Rural Energy Agency (REA) which became operational since 2007. REA is tasked to support the ongoing rural energy programmes by mobilising, coordinating and facilitating both private and public initiatives. However, the majority of the population in the country still do not have access to affordable modern energy services.

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[18] Other estimates indicate that the total annual deforestation rate is between 91,000 and 500,000 hectares (World Bank, 2010:1).

[19] Clark and Drimie (2002:5) define poverty as "the inability of individuals, households, or entire communities to command sufficient resources to satisfy a socially acceptable minimum standard of living".

Biomass remains the major source of energy in the country; the majority of the rural population rely entirely on biomass energy sources such as firewood, charcoal and agricultural residues to meet their daily energy needs[20].

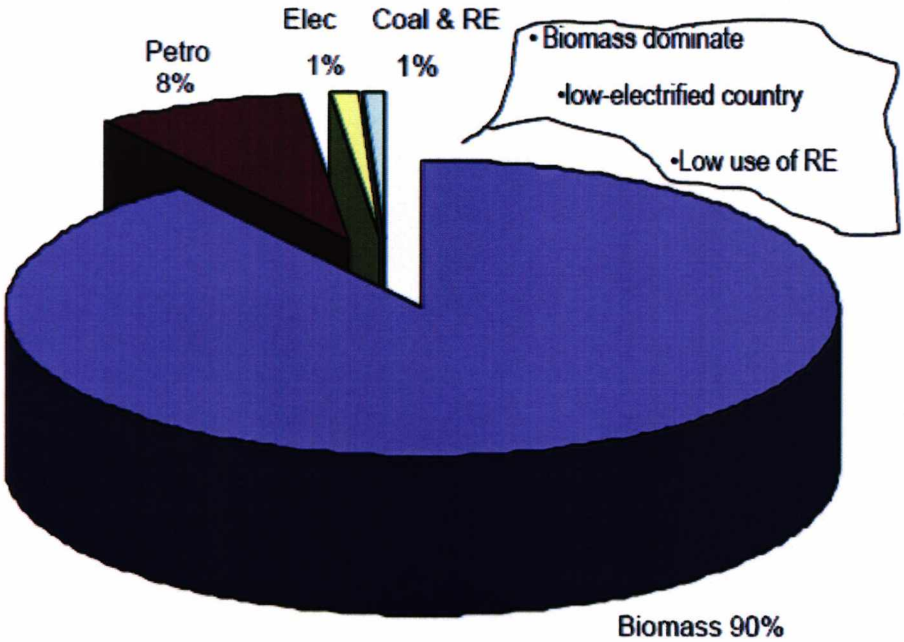

Figure 1: Total energy consumption in Tanzania in 2004

Source: Adapted from Kimambo and Mwakabuta (2005)

Figure 1 (above), shows the energy consumption pattern in the country by the end of 2004. It is estimated that biomass energy sources account for more than 90 percent of the country's total energy consumption and about 95 percent of all the energy consumed by rural households in the country (MEM, 2003:38; Kimambo and Mwakabuta, 2005:9). Imported petroleum products such as petrol and diesel account for about 8 percent of the total energy consumption. Grid electricity was estimated to account for only 1 percent of the energy used in the country by the end of 2004. Figures show that most of the grid connected households are found in urban areas; while in the countryside it was estimated that not more than 2 percent of the rural population was connected to the national grid until recently. However, other estimates indicate that by 2007 about 2.5 percent of the rural population was connected to the grid. At the same time, the figures released by the National Bureau of Statistics in 2007 indicated that the percentage of households connected to the grid in mainland Tanzania (both

[20] This is further discussed in section 2.2.4 of this chapter

urban and rural) had increased to 12.1 percent. The latest estimates, however, indicate that the percentage of households connected to the national grid has slightly increased in the past four years to about 14 percent to date. On the other hand, renewable energy sources such as solar, wind, geothermal, hydropower and biogas, which make up 1 percent of the total energy consumption remain the least utilised energy sources in the country so far (Kimambo and Mwakabuta, 2005:10; Mwihava and Mbise, 2003:6).

2.1.2 Energy sector reform

Among the noticeable impacts of the development policies of the mid 1960s and early 1970s was the excessive government intervention in the economy, which in turn led to government monopoly over the energy sector. As the state assumed a dominant role in the key sectors of the economy, there was a need to consolidate its power sector. Tanzania Electric Supply Company Limited (TANESCO) was established in 1964 under the Company Ordinance Act of 1931(UNECA, 2007). As the only public power utility, the company has since been responsible for generation, transmission, distribution and commercial services of electricity in the country[21] (ibid.p.18). Although TANESCO was effective and well functioning from the 1970s to the mid 1980s; the company's performance started plummeting towards the end of the 1980 and early 1990s (Gratwick et al., 2007:17; UNECA, 2007). In this period TANESCO experienced poor technical performance and became financially stretched. As a result, the company failed to sustain its operations and maintenance costs (ibid.). It must be noted however that economic reforms in mid 1980s and early 1990s encouraged private-sector involvement in most key sectors of the economy. As pointed out earlier, these reforms were intended to reduce the government's direct involvement in providing important services such as electricity. Therefore, the reforms in a way transformed the country's energy sector. There were, for example, changes in the country's 1992 energy policy so as to accommodate Independent Power Producers and these producers have since been allowed to own facilities to generate electricity (UNECA, 2007:18). However, Independent Power Producers (IPPs) can only generate and sell their electricity to TANESCO[22], which distributes electricity to the customers. Prior to the IPPs, about 80

[21] However, the Energy and Water Utilities Regulatory Authority (EWURA), which was established in 2001 (but became fully operational in 2006), is currently tasked with licensing, tariff review and monitoring performance and standards. Its main focus is on quality of service as well as safety measures on electricity use, water, petroleum and natural gas (EWURA, 2009).

[22] The state owned power utility which runs both the national grid and isolated electricity supply systems in Kagera, Kigoma, Rukwa, Ruvuma, Mtwara and Lindi regions (EWURA, 2009).

percent of electricity in the country was generated through hydropower plants which were under the supervision of the TANESCO (Gratwick et al., 2007:10). However, due to unreliable weather conditions in the country between 2002 and 2006, Independent Power Producers were able to generate about 60 percent of electricity mainly from thermal power plants (ibid.p.10). Persistent drought conditions have diminished the country's hydropower capacity and undermined the existing IPPs thermal capacity as both have failed to sufficiently meet the country's electricity demands (ibid.). Thus, hydropower[23] and thermal power plants are currently the two main sources of grid electricity in Tanzania, and hydropower is considered to be the most important source of commercial energy (Kimambo and Mwakabuta, 2005:19; Gratwick et al., 2007:10; EWURA, 2008). Examples of hydropower plants connected to the national grid include Kidatu, Kihansi, Mtera, Uwemba and Pangani system[24]. Thermal power generating plants which use diesel and natural gas include Ubungo Diesel plant, Songas Ubungo Power plant, Ubungo Gas turbines, and Independent Power Tanzania Limited (IPTL) all located in Dar es Salaam. Other plants are located in Mwanza, Mbeya, Tabora, Musoma, Dodoma, Sumbawanga and Bukoba including Kiwira Coal and Power Company Limited (KCPC) which is in Mbeya region (ibid.).

The country's hydropower potential is estimated to be between 4,500 MW and 4,700 MW (Mwihava and Mbise, 2003:1). The currently installed hydro-electric power generating capacity in the country is about 561 MW. Although, thermal power generating plants had the capacity to produce about 398 MW of electricity for the national grid, there are indications that the situation has improved in the past few years. The estimated country's electricity

[23] Hydropower is considered to be the World's largest developed renewable energy source as it accounts for about 87 percent of total energy generated from renewable energy sources in the world. Hydropower is considered to be a clean source of energy because it does not produce greenhouse gas emissions such as carbon dioxide or other pollutants and has been referred as one of the cleanest methods of generating electricity in the world (Harper, 2008:135; WEC, 2007:272-4). According to the World Energy Council, potential sites for hydropower generation can be found in almost 150 countries worldwide (WEC, 2004:14). However, the report by the World Commission on Dams (WCD) published in 2000 stated that hydropower dams are sources of greenhouse gases (WCD, 2000:75; Miller, 2004:400). Research carried out on all large dams and natural lakes in 'boreal' and tropical regions has indicated that reservoirs trap rotting vegetation which in turn emits greenhouse gases (GHG) such as carbon dioxide and methane (ibid.). It is also worth noting that there has been worldwide concern recently about both the social and environmental effects of constructing large dams for hydroelectric power. It is argued, for example, that the construction of large dams may lead to land degradation, destruction of forests and terrestrial plants, displacement of wildlife, and decrease in water quality. At the same time, change in land use may result in negative impacts upon communities living closer to large hydropower projects (ibid.). Notably, environmentalists have been recently campaigning for the World Bank and other development agencies to stop funding projects aiming at constructing new large scale hydropower plants (Miller, 2004:400).

[24] Pangani system includes Nyumba ya Mungu and Hale power plants. It is worth noting that Tanzania also imports a small amount of electricity from Zambia and Uganda (MEM, 2003:26)

generating capacity (hydro and thermal) is now estimated to have reached 1095 MW which includes 180 MW from emergency sources (EWURA, 2009; Kabaka and Gwang'ombe, 2007:2). Although most countries in Eastern and Southern Africa rely heavily on hydropower plants for their grid electricity supply, hydropower generation in Tanzania has often been affected by rampant drought and silting of dams which have caused severe power shortages (Mwihava, 2002; Karekezi and Kithyoma, 2003:12). Hydropower plants in the country were on the verge of shutting down in 2006 due to severe drought, and in 2011 there was widespread power rationing of up to more than ten hours a day in major towns.

2.1.3 Independent Power Producers

Prior to reforms, there were no independent power producers in the country. Recently, the IPPs are among the important players in the energy sector alongside TANESCO (the state owned utility). The main independent power producers include the Independent Power Tanzania Limited (IPTL) and Songas Limited. By the end of 2007, both IPTL and Songas Limited were contributing about one third of the country's electricity generating capacity. The construction of Independent Power Tanzania Limited was initially completed in 1998 and the company started producing electricity in 2002 hence becoming the first Independent Power Producer company to sell its electricity to the state power utility company-TANESCO (ibid.). IPTL is a diesel-fired plant with 100 MW of electricity generating capacity and is very much dependent on imported heavy fuel oil. There are ongoing negotiations to convert the diesel-fired plant into natural gas-fired plant in the near future in a bid to reduce the current higher operating costs (ibid.). Songas Limited with its electricity generating capacity of 180 MW started its operations in the country in July 2004. However, unlike IPTL which is diesel-fired plant, Songas is a natural gas-fired plant which receives its gas from Songo-Songo area, currently a main domestic source of natural gas in the country (ibid.). The Songas project was funded by the World Bank International Development Association (IDA), European Investment Bank (EIB), and Swedish International Development Cooperation Agency (Sida). The construction of the Songas project took more than ten years before the production finally began in 2004 (ibid.). In addition to IPTL and Songas Limited, Tanganyika Wattle Company (TANWAT) supplies about 2.5 MW of electricity to the mini-grid located in Njombe. TANWAT is a "wood-wasted fired" cogeneration power plant (UNECA, 2007:19; MEM, 2003:26). Other private companies have also expressed interest in generating electricity and selling it to the national grid. These include Kiwira Coal and Power Company Limited (KCPC), Artumas Tanzania (Jersey) Limited, Aggreko, and Symbion Power (ibid.).

According to Johansson and Goldemberg (2002:10), electricity market liberalisation coupled with technological innovation may accelerate access to electricity. However, it appears that the energy sector reforms in the country have not been accompanied by improved efficiency in the national grid and quality of service for customers in both rural and urban areas. For example, there is still limited expansion of electricity to isolated rural populations because of long distances and scattered settlements. At the same time, most of the independent power producers mentioned above have hardly invested in renewable energy technologies, partly due to lack of political will and commitment[25]. In order to avoid overreliance on big generation companies, there is a need to encourage small independent producers in the country (i.e. end-users and other stakeholders) to invest in renewable energy. It appears that the country's existing institutional framework in the energy sector largely favours big generation companies. As a result, most of the current 'big' IPPs have in a way locked TANESCO into buying the electricity they produce even when the state utility (TANESCO) itself can produce sufficient electricity on its own[26]. This has greatly weakened the financial capability of TANESCO and has dealt a huge blow to the country's energy sector. On the other hand, the government efforts to attract huge investment from IPPs have also sometimes been accompanied by allegations of corruption[27].

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[25] TANESCO still holds a monopoly on electricity distribution which may hinder the prospects of the independent producers (with huge capital) to invest in renewable energy as many still fear losses and therefore wish to be directly involved in the distribution process.

[26] For example, when the hydroelectric dams are able to produce electricity to their full capacity.

[27] For example, the Richmond controversy over the bidding process that led to the resignation of the then Prime Minister in 2008. His office was implicated in an energy deal corruption scandal whereby a contract was awarded to a US-based electric company, Richmond Development, in 2006. At the time the country was experiencing a power crisis because of a severe drought.

2.2 Energy sources in Tanzania

2.2.1 Small-scale hydropower systems

As pointed out above, the electrical energy sector in Tanzania is predominantly based on large-scale hydro. It also appears that reforms in the energy sector were initially aimed at improving electricity generation for the national grid rather than promoting decentralized energy systems. However, experience from other countries shows that grid extension in rural areas may be both technically and economically challenging as opposed to decentralized energy systems. Energy experts argue, for example, that small-scale decentralized hydropower systems have a potential to generate electricity for the majority of the rural poor in developing countries[28]. It is also thought that small-scale hydro-electric power generation projects do not pose as large a threat to the environment as do large scale hydropower projects which involve the construction of large dams (Miller, 2004:400). Experience also shows that small-scale hydropower projects can easily be built locally at a low cost and do not require large-scale civil engineering or high operating costs (WCD, 2000:180).

Potential sites for small-scale hydro-electric power generation in Tanzania are mostly located in the rift valley escarpments in the west, south west and north east of the country (Kabaka and Gwang'ombe, 2007:4). The country's mini-hydropower potential is estimated at 100 GWh/yr and by 2004; individuals and private organisations were producing about 32 GWh/yr from small hydropower systems (Gwang'ombe, 2004:3). Previous reports show that the Ministry of Energy and Minerals in collaboration with international organisations and external funding bodies were in the process of initiating small-scale hydropower projects in some regions in the country. These regions include Ruvuma, Rukwa, Arusha and Kigoma (Kaale, 2005:38; Kabaka and Gwang'ombe, 2007:4). It is envisaged that the completion of these projects will help the rural population by stimulating socio-economic activities in rural areas as well as addressing the shortage of biomass fuel in these regions (ibid.). In 2005, the Ministry of Energy and Minerals commissioned the Rural Electrification Master Plan feasibility study, which examined the technical, economic, social, and environmental aspects of supplying electricity to rural areas including the development of

[28] Electricity generated from small hydro-electric power systems in countries such as India has proved to be useful when exploited through decentralized grid systems (Sharma, 2006:586).

renewable energy systems (Kabaka and Gwang'ombe, 2007:5). Five areas (sites) were identified as having small-scale hydropower generation potential[29] (ibid.).

Project site	Location	Cost (USD/kW
Pinyinyi Hydropower potential	Ngorongoro District-Arusha	5500
Nzovwe Hydropower potential	Sumbawanga Rural-Rukwa	2700
Malagarasi (Igamba Falls Stage 2) potential	Kigoma Rural District	2900
Sunda Falls Hydropower potential	Tunduru District, Ruvuma	2800
Nakatuta Hydropower potential	Lower Nakatuta, Songea Rural District	3500

Table 1: Small Scale Hydro potentials appraised for Development in Rural Master Plan Study- 2005
Source: Kabaka and Gwang'ombe, 2007

Table 1 shows the identified potential sites for small-scale hydropower plants with their estimated installation costs per kilowatt. These sites have been appraised for development by TANESCO and assessment on other areas with hydropower potential in the country is still ongoing. About twelve regions in mainland Tanzania have been identified so far (ibid.). However, past experience suggests that implementation of such projects could take longer than anticipated or may not take place at all. It is suggested that local mini-grids utilising resources that are locally available could provide a cost- effective alternative for rural areas with high population density (Johansson and Goldemberg, 2002). Such systems can be easily managed and maintained by local organisations (ibid.).

2.2.2 Natural gas reserves in the country

Natural gas reserves in Tanzania are estimated to be around 45 billion cubic metres (MEM, 2003:32; Kaale, 2005:5). The confirmed natural gas deposits at Songo-Songo in Lindi region and Mnazi Bay in Mtwara are estimated to be about 30 and 15 billion cubic metres respectively (ibid.). Natural gas from Songo-Songo is supplied to Dar es Salaam through a pipeline and the gas is used for electricity generation in gas-fired power plants

[29] See Table 1 for details

(Gratwick et al., 2007:23; EWURA, 2008:27). The natural gas supplied from Songo-Songo, for example, is used by Songas natural gas-fired plant and Twiga Cement plant at Wazo Hill in Dar es Salaam (ibid.). Other companies involved in extraction of natural gas from Songo-Songo include: PanAfrican Tanzania, and Tanzania Petroleum Development Corporation (TPDC). Currently, the companies operating at Mnazi Bay are Artumas Group and Partners (AG&P) Gas Limited and Tanzania Petroleum Development Corporation (EWURA, 2008:26).

It is worth noting that investment in natural gas has recently increased worldwide[30]. The fact that many countries are now investing in natural gas is attributed to the claim that gas is both economically and environmentally viable in comparison with other fossil fuels (IEA, 2006:183; IEA, 2007:86). According to IEA (2007:86), the "gas-fired generating plants are very efficient at converting primary energy into electricity and are cheap to build, compared with coal-based and nuclear power technologies". In terms of greenhouse gas emissions, gas when burned emits less carbon dioxide than other conventional sources such as coal and oil (ibid.). However, it must also be noted that natural gas comprises about 50 to 90 percent methane by volume when it is underground (Miller, 2004:362), and methane is itself a potent greenhouse gas (IPCC, 2001a:87). Safe and efficient recovery of gas is therefore essential in order to avoid environmentally damaging leaks of methane into the atmosphere.

2.2.3 Coal

Although Tanzania's coal deposits are estimated to be around 1,200 million tonnes, only 304 million tonnes have so far been proven in Kiwira (Kaale, 2005:6). Kiwira Coal and Power Company Limited (KCPC) which is the only coal plant currently operating in the country has the capacity to generate about 6 MW of electricity (ibid.). The company is thought to have recently expressed interest to supply about 200 MW to the national grid.

[30] According to the International Energy Agency, proven world natural gas reserves were estimated to be around 180 trillion cubic metres by the end of 2005. Using the 2006 projections in which the annual rate production growth was 2 percent, the supply of natural gas from the world reserves was predicted to last for only about 40 years (IEA, 2006:114). About 56 percent of the proven global natural gas reserves are in Russia, Iran and Qatar (ibid.). However, there are concerns whether the projected percentage rates of increase in exports would be achievable in light of the recent financial crisis and world economic downturn. What is important to note, however, is that in recent years, the demand for natural gas has increased enormously in developing countries, and even more striking is the fact that Africa, the Middle East, and Asia (China in particular) are places where demand for natural gas has greatly increased in recent years (ibid.). It is also worth noting that North America and Europe are projected to remain as the main leading gas consumers and are likely to account for more than one-third of world consumption in the near future (IEA, 2007:85).

However, the company had to secure funds to finance a 135 km transmission line from Kiwira to Mbeya and lack of funds has since made it difficult for the company to initiate the project (Gratwick et al., 2007:16). Although the extracted coal has been mainly intended for electricity generation at Kiwira, it has also occasionally been utilized for thermal requirements in cement factories and textile industries in Mbeya, Iringa and Morogoro regions (Kaale, 2005:6; Gratwick et al., 2007:14).

Despite the fact that coal is an abundant fossil fuel[31], it has the highest environmental impacts when compared with other fossil fuels (Miller, 2004:363). Coal accounts for about 36 percent of the world's annual emissions and releases particles of toxic mercury during the burning process (ibid.). Research has also shown that coal releases thousands of times more radioactive particles into the atmosphere per unit when compared with a normally operating nuclear power plant (ibid.). At the same time, coal burning is said to be causing water pollution hence damaging the ecosystem and also costing human lives. Research has shown, for example, that in the United States of America alone, air-borne pollutants from coal burning have caused deaths to thousands of people with estimates ranging from 65,000 to 200,000 (ibid.p.364). At the same time, respiratory diseases have increased as a result of burning coal and more than 50,000 cases have been reported in United States (ibid.).

2.2.4 Biomass

Energy studies suggest that biomass is a primary source of energy to more than 2.4 billion people in most rural areas in developing countries (Karekezi et al., 2004:1; Harper, 2004:229). Recent projections have indicated that by 2020, there will be almost a simultaneous increase between biomass energy use and population growth rates. At the same

[31] Coal is one of the most abundant fossil fuels with proven reserves amounting to about 909 billion tonnes according to the figures collected by the end of 2005 (Miller, 2004:363; IEA,2006:125). China, the United States of America and India are currently the largest consumers of coal (ibid.). Recent concerns about future oil supply have led to renewed interest in coal as many countries seek to meet their energy demands. Energy experts argue that coal is used "*as an alternative feedstock for production of transport fuels and chemicals*" (IEA, 2006:128). The latest coal technologies can convert solid coal into gaseous or liquid fuels whereby the solid coal is converted into synthetic natural gas through a process known as "*coal gasification*" or can be turned into liquid fuels such as methanol or synthetic gasoline by "*coal liquefaction*" (Miller, 2004:364). Coal gasification is now widely used in production of chemicals and fertilizers; and China has been identified as having about 8,000 coal gasifiers operating to date (IEA, 2006:128). However, energy analysts do not expect coal gasification to play an important role as an energy source in the near future. This is due to the fact that coal gasification and gas burning produce more carbon dioxide emissions than burning coal itself or natural gas (Miller, 2004:365). It is also argued that the overall construction and operating costs of coal gasification are much higher than generating electricity from conventional coal (ibid.). Nevertheless, extraction, processing and transportation of coal is projected to increase in China, India, the United States of America, Australia, South Africa, Indonesia, and Colombia due to lowest operating costs in coal production (IEA, 2006:73).

time, the rural population relying on biomass energy in Africa is envisaged to increase by 27 percent before the year 2030 (ibid.).

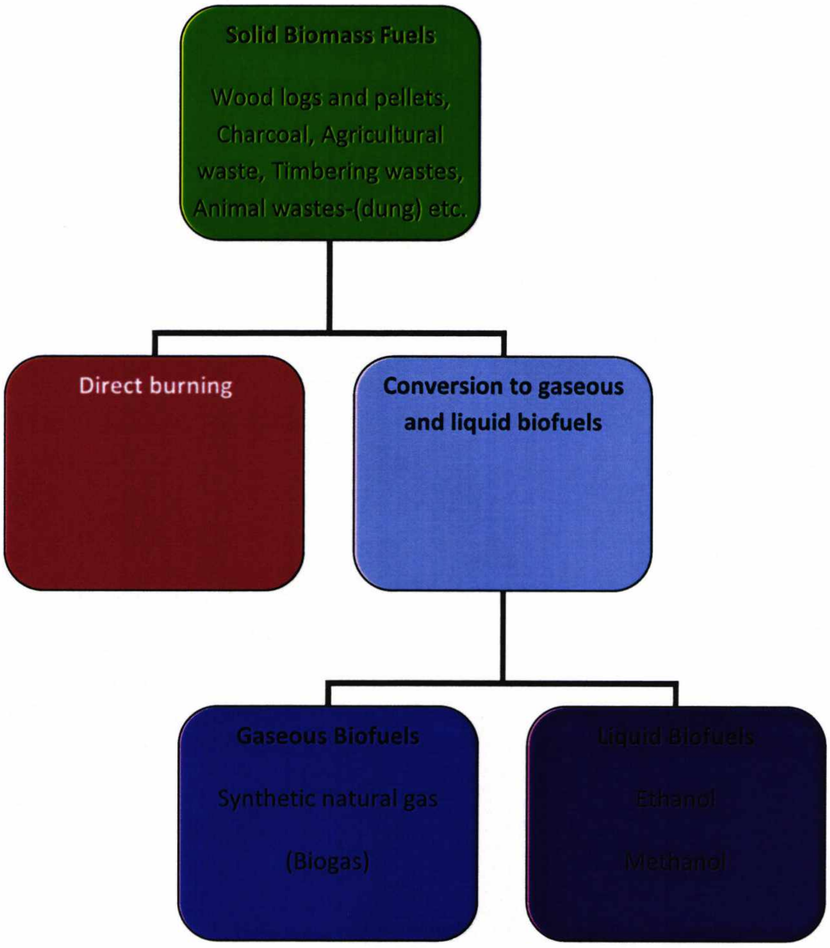


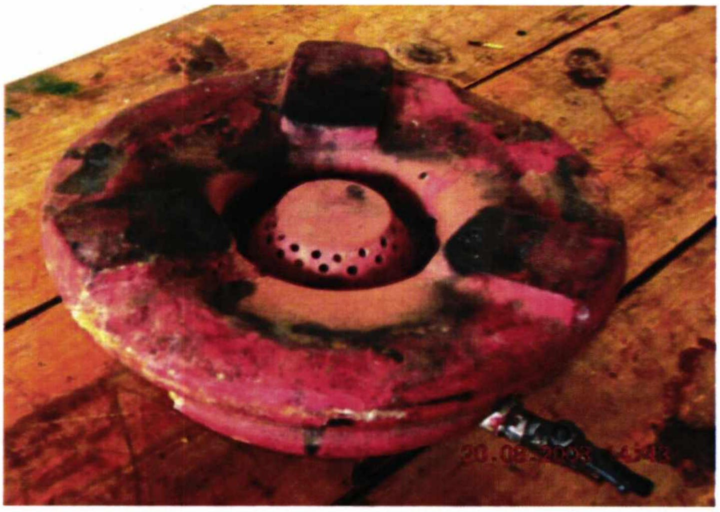
Figure 2: Principal types of biomass fuel

Source: Adapted from Miller, 2004

Biomass can be burned as a solid fuel or converted into gaseous or liquid biofuels as shown in Figure 2 above. Biomass can be used for heating, cooking, and generation of electricity[32]. In rural Tanzania, crop residues such as sugar cane residues, rice husks, cotton

[32] Energy researchers use various concepts when referring to **biomass**. For example biomass has been often referred as traditional fuels, biomass fuels (or biofuels), non-commercial energy etc. However, this study borrows the term used by the International Energy Agency (IEA), in which biomass has been referred as 'Combustible Renewables and Waste' (CRW). The term 'Combustible Renewables and Waste' includes all vegetable and animal matter used directly or converted to solid fuels, biomass-derived gaseous and liquid fuels, as well as industrial and municipal waste converted to energy(IEA, 1998:159).

stalks, coconut shells and animal manure such as cow dung are used as energy sources[33]. These biomass sources are either burned directly or sometimes are converted into biofuels. Bacteria and other chemical processes can convert some forms of biomass into either gaseous biofuels such as biogas or liquid biofuels[34] (Miller, 2004:404). Biogas is a renewable energy source which can be used for heating, cooking or as fuel for electricity generation in gas turbines or gas engine generators.



Locally built ceramic biogas stove (Source: COET)[35]

The solid residue (waste) produced from the digestion process after biogas is separated can be used as fertilizer on food crops (ibid.). However, anaerobic decomposition produces methane. Methane has been identified as a greenhouse gas; thus emitting more methane into the atmosphere could increase the risk of global warming. Thus, methane must be properly captured and used when an anaerobic digestion is applied. Although biogas digesters[36] have

[33] In Latin America, biomass energy is widely used in the industrial sector and Brazil is one of the best examples. In most cases, plant residues from sugarcane, sugar beets, sorghum and corn are processed to produce ethanol (Harper, 2004:254).

[34] Biogas refers to the gas produced from controlled biological decomposition of organic waste such as kitchen waste (e.g. potato peelings), food waste (e.g. rice leftovers, fruits, vegetables etc.), garden waste and agricultural waste (e.g. rice husks). Biogas can also be produced from animal manure in the absence of oxygen. Biogas can be upgraded and compressed into "biomethane" and used directly in natural gas vehicles or "added to the existing natural gas pipeline networks" (ENGVA, 2009: 6). Synthetic methane produced from sewage sludge has been used in buses in cities such as Berne in Switzerland (ibid.).

[35] A college of the University of Dar es Salaam

[36] In China, anaerobic bacteria is used in more than 6 million biogas digesters to convert plant and animal wastes into methane fuel for heating and cooking. Experience has shown that small-scale household biogas digesters and community anaerobic digesters which are fed with household organic waste and agricultural organic waste are widely used in rural China. The total cost of building a simple *biogas digester* was estimated

so far proved to be effective the challenge remains on how to control the quality of raw materials used in the production process such as organic waste (e.g. sorting plastic materials from kitchen waste). Previous experience has shown that raw materials with contamination could compromise the effectiveness of biogas digesters.

Biomass energy sources widely used in Tanzania include charcoal, firewood and agricultural farm residues i.e. agricultural by-products and animal waste. Biomass remains an important energy source in rural Tanzania where more than 75% of the country's total population still live. The rural population need energy for household use, agricultural activities and petty commercial activities for income generation (Kaale, 2005; IEA, 1998:51). Firewood which is mostly used for cooking and heating is the main source of energy for the rural population in the country (Mwihava, 2002; Monela et al., 1999). Although biomass energy[37] is predominantly used by the rural households for cooking and heating, it is also considered to be an important source of energy for traditional village-based local industries in most developing countries (IEA, 1998:158). Evidence also suggests that biomass energy plays an important role not only in the household sector but also in the economies across countries and regions worldwide. However, its importance varies greatly between developing and developed countries, mainly reflecting the differences in their level of economic development (ibid.). Statistical energy data show that the share of biomass in final energy consumption in industrialized countries is generally lower, while it is higher in countries with low per capita incomes. It is therefore not surprising that the share of biomass in final energy consumption in countries such as **Tanzania**, Democratic Republic of Congo, Nepal, Ethiopia and Mozambique exceeds 80%. The widely cited reason is that these countries are predominantly rural and heavily rely on subsistence agriculture (ibid.p.158).

The recommended supply of fuel wood (i.e. firewood and charcoal) which is considered to be sustainable in Tanzania is estimated to be about 19 million cubic metres per year (Madulu, 2004:89). However, the total consumption in the country had reached about 43 million cubic metres per annum as of 2004 (ibid.). According to the latest estimates, the total annual consumption of charcoal alone is about 1 million tons; and the required annual supply of wood to meet the charcoal demand is about 30 million cubic metres (World Bank, 2010:1). Recent

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to be about $50 in 2004 (ibid.). If such digesters (i.e. simple biogas digesters) were to be built in rural Tanzania and based on the current country economic situation, I would estimate that the cost could range between $50 and $100 which translates to between TZS 80,000 and TZS 165,000 respectively.

[37] Sweden serves as one of the best examples in Europe since the country uses biomass energy for domestic heating through advanced heating systems and district heating (Johansson et al., 2004).

studies conducted in rural Tanzania suggest that firewood and charcoal will continue to be the dominant sources of energy for the rural poor in the foreseeable future. Therefore, there is a need to invest in alternative energy sources. Evidence shows that there is a close link between people living under the poverty line and their overwhelming dependence on traditional biomass energy sources in the country. As stated earlier, the growing rural population has increased demand on energy sources. In turn, this has caused firewood shortages and in some cases agricultural farm residues are widely used in the most affected areas (Madulu, 2004). A number of regions in the country have been reported to have severe shortage of biomass energy sources and these include Dar es Salaam, Kagera, Kilimanjaro, Mara, Mwanza and Shinyanga (Kaale, 2005).

Studies have also shown that traditional use of biomass energy sources is still common within many rural families in the country (Kaale, 2005; Madulu, 2004; Dauda, 2005). Traditional use of biomass energy sources encourages indoor pollution. Health problems resulting from indoor pollution have been reported in some areas in sub-Saharan Africa. A study of health effects from indoor pollution that was conducted in Gambia found a relationship between the time children spent near the fire and the incidence of moderate and acute severe respiratory infections (Barnes et al., 1994:122). According to Karekezi (2002), indoor air pollution is among the factors contributing to acute respiratory infections and lung diseases in highland areas of sub- Saharan Africa. However, women and children are thought to be the most affected (ibid.). Indoor air pollution was classified as one of the most critical global environmental problems in the 1992 World Bank Development Report (WDR, 1992:17). On the other hand, it is also important to note that health problems can limit the involvement of the rural workforce in productive socio-economic activities. This could consequently constrain rural development in poor countries (Martinussen, 2004:300). Therefore, in order to overcome health problems related to indoor air pollution, concerted initiatives to promote sustainable energy conversion technologies in most developing countries are required (Miller, 2004:404). Grossman and Krueger (1991:6) contend that the choice of technology determines the extent to which the households control indoor pollution. They hypothesize that an increase in household income leads to an increase in expenditure on the purchase of environmentally friendly innovations. Experience has shown that, as incomes rise, households tend to switch from traditional fuels such as firewood and dung to modernised renewable energy innovations or commercial fuels such as kerosene, liquefied petroleum gas (LPG) and natural gas. As a result, these less polluting innovations tend to improve their indoor air quality (ibid.).

Stassen (2002) suggests that wood charcoal may reduce indoor pollution when used as a fuel for cooking as it emits less smoke than raw biomass such as firewood. However, Steenblick (2005:10) argues that charcoal contains 85% to 98% carbon and is derived from woody biomass. He claims, for example, that traditional charcoal processing which involves heating biomass in an earthen mound is considered to be less expensive but during the process a large amount of ground level air pollution is released. There have been attempts to increase efficiency in charcoal processing in recent years and this has involved the introduction of small scale metal or brick kilns (ibid.). Those behind these initiatives believe that the 'increased efficiency' in charcoal processing would reduce pressures on forest resources in most developing countries. Charcoal processing facilities are currently available in some countries around the world. In Europe for example, charcoal processing facilities can be found in countries such as France and Netherlands. In sub-Saharan Africa, such facilities are widely found in Ghana and South Africa (Stassen, 2002). Charcoal as a fuel source not only produces higher temperatures when used for cooking but also burns cleaner than wood and dried biomass (ibid.). A study on indoor pollution suggested that about three million premature deaths caused by respiratory illnesses could be avoided if the majority of households were to switch from raw biomass to charcoal (ibid.). According to Miller (2004), improved wood fuel stoves can greatly reduce indoor pollution. He argues that due to the high combustion efficiency of these stoves, households can also save on the amount of fuel used for cooking (ibid.).

Although charcoal is an important energy source in Tanzania, the charcoal sector has not received the necessary attention. According to the recent study by the World Bank, the charcoal sector in Tanzania is politically treated as "something unseen or unwanted" (World Bank, 2010:1). The study found that the charcoal sector is characterized by weak governance, unsatisfactory regulatory capacity as well as poor law enforcement capacity. The study concludes that "there is no comprehensive policy, strategy or legal framework in Tanzania addressing the charcoal sector" (ibid.p.16). A study conducted in Dar es Salaam (Tanzania), found that charcoal used in improved energy-efficient cooking stoves was the cheapest fuel source for the households (Foster, 2000:37). It is important to remember, however, that world-wide interest in adopting energy efficiency improved stoves in the world rose in 1970s as a result of the global oil crisis (Barnes et al., 1994:123). Hence, initiatives from governments, donors and NGOs to finance improved stoves projects came as a result of the rising oil prices, increasing deforestation and the threat of fuel-wood crisis as opposed to health problems (ibid.).

There is growing evidence that improved biomass energy technologies may encourage the development of income generating activities and job creation for the rural poor. At the same time, energy analysts believe the use of improved wood-fuel stoves with high-efficiency combustion techniques will encourage sustainable biomass harvesting practices. It should be understood, however, that both the government and private sector could also play an important role in disseminating and encouraging the use of improved biomass stoves in rural areas, especially those experiencing acute shortage of biomass fuels. Barnes et al. (1994) argues, for example, that involvement of the government and private sector led to successful projects on improved wood-fuel stoves in some countries. The installation of an estimated 120 million stoves in China under the Chinese National Improved Stove programme can be considered as one of the most successful initiatives ever taken by a government (Barnes et al., 1996).

Cogeneration technology and biofuel production

Although evidence shows that biomass energy use in most developing countries "is still in the form of direct combustion of unprocessed solid fuels", recent developments indicate that the amount of biomass used in large-scale industries and electricity generation is steadily increasing (IEA, 1998:159). Current technological advancement has made it possible for electricity to be produced from biomass energy conversion technologies. For example, Biomass energy sources such as bagasse from sugar industries, palm wood and rice can be used as fuel for cogeneration (Gwang'ombe, 2004). Cogeneration or combined heat and power (CHP) is referred as the simultaneous generation of electricity and heat using a single primary energy source such as liquefied petroleum gas (LPG) or natural gas. According to Miller (2004:384), in a cogeneration system, "two useful forms of energy such as steam [heat] and electricity are produced from the same fuel source". Studies show that for many years, cogeneration has been widely used in Western Europe. Cogeneration accounts for about 9 percent of the total electricity produced in the United States and its use is believed to be expanding in China (ibid.). The steam generated from this process can be used for industrial as well as domestic purposes. Cogeneration systems are believed to be environmentally friendly as they emit two-thirds less of carbon dioxide per unit of energy produced. Cogeneration systems also provide greater conversion efficiency of about 80 percent as opposed to conventional coal-fired boilers and nuclear power plants[38] (ibid.)

Tanzania has an estimated cogeneration potential of 315 GWh per year and the currently installed capacity is thought to be 35.825 MW (Gwang'ombe, 2004). Despite such potential, cogeneration technology has not been widely developed across the country[39]. Experience has shown that cogeneration in Tanzania is done in sugar factories, food processing plants, timber sawmills as well as pulp and paper mills (ibid.). However, researchers have predicted that currently operating wood- and bagasse-fuelled plants have the potential to generate electricity for the national grid in future. The existing biomass fuelled power plants in the country include Kilombero Sugar Plants (K1-K2), Mtibwa Sugar Estate, Tanganyika Planting Company, Kagera Sugar Company, Sao Hill Saw Mill, and Tanganyika Wattle Company (TANWAT). For example, TANWAT cogeneration plant with the installed capacity of 2.5 MW generates steam and electricity to run the tannin processing plant and supplies surplus electricity to the national grid. Previous study on cogeneration in the country indicated that the excess bagasse energy generating potential from current sugar factories is estimated at 99 GWh per year (ibid.).

[38] For example, Okeelanta Cogeneration Facility (OCF) is one of the largest bagasse and wood fired cogeneration power plants in the United States. The plant is located adjacent to the Florida Crystals Okeelanta Sugar Mill and Refinery in South Florida. Wood waste material for the plant comes from municipal solid waste, construction and recycling. With an estimated installed capacity of about 74 MW, the plant generates electricity which is sold into wholesale markets throughout a year (Wiltsee, 2000:130).

[39] Mauritius sugar sector is one of the best examples in Africa where development of cogeneration has significantly contributed to the country's power sector (Karekezi, et al., 2007). It is argued that due to the extensive use of cogeneration in Mauritius, the sugar industry has been able to meet its own electricity demands and at the same time selling excess electricity to the national grid. It is estimated that cogeneration produces about 40% of the electricity in Mauritius and as a result the country's dependence on imported oil has been reduced (ibid.). In Latin America, small - scale bagasse cogeneration projects have generated surplus electricity which is supplied to the national grid (UNFCCC, 2004). Examples include, the Cruz Alta Bagasse Cogeneration Project (CABCP) which is located at Cruz Alta sugar mill in Brazil. Deoband Bagasse based Co-generation-Power Project in India generates electricity for internal use and exports the surplus electricity to the Uttar Pradesh Power Corporation Limited (UPPCL) which is part of Northern regional grid (UNFCCC, 2004). This is a large – scale grid connected baggase based cogeneration power plant located in the complex at Deoband Village, Saharanpur District in Uttar Pradesh (ibid.). The plant serves as a highly replicable model to other sugar mills in India and has improved the transmission grid reliability as it relies on local renewable energy resources such as bagasse.

Biofuels

Interest in funding large biofuel projects in Africa is thought to have significantly increased in the past few years[40]. Biofuels can be used to substitute or supplement traditional fossil fuels used for transportation as well as domestic and industrial uses (ibid.). Although much of the investment has so far been done by private firms, donor countries are believed to be stepping up their efforts to support African countries which have incorporated biofuel policies in their development plans (ibid.). Optimists argue that biofuel production in African non-oil producer countries will help them to lower inflation rates in their economies. They argue, for example, that because these countries spend huge amount of foreign exchange to import oil, the introduction of biofuels as supplements would see them substantially reduce dependence on costly oil imports (Cotula et al., 2008: 10; Sulle and Nelson, 2009:7). On the other hand, it is also expected that biofuel production will accelerate the improvement of rural infrastructure, stimulate socioeconomic activities and may as well be a source of income for the rural population. They contend that profitable land use and energy supply from biofuels could encourage the expansion of other income generating opportunities in rural areas. This way, they argue, biofuels will protect the long-term interests of the rural poor (ibid.). Inadequate energy supply in rural areas, especially in poor developing countries, has also attracted the cultivation of biofuel crops as energy alternatives (ibid.p.33). Although biofuel production is mostly carried out by large-scale farmers, experience has shown that even small scale farmers are also involved in the production of biofuels, and in particular biofuel crops such as palm, coconut, jatropha, and sunflower[41] (Sulle and Nelson, 2009:7). In Mali, for example, small-scale jatropha cultivation to meet local energy demands (e.g. for

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[40] According to Sulle and Nelson (2009:7), biofuels can be broadly defined as liquid, solid or gaseous fuels that are predominantly or exclusively produced from biomass. Biofuels may include among others: biodiesel, ethanol, or purified biogas derived from crops, plant residues or wastes. Energy experts suggest that liquid ethanol and methanol produced from biomass could in future be used as substitutes to gasoline (petrol) and diesel fuel. **Ethanol** can be produced from sugar and grain crops such as sugarcane, sugar beets, sorghum, sunflowers and corn through fermentation and distillation processes (Miller, 2004:405). **Bioethanol** refers to "distilled liquid produced by fermenting sugars from sugar plants and cereal crops e.g. sugarcane, maize, sugar beet, cassava, wheat, sorghum", while **biodiesel** is usually produced from oily fruits (crops) such as rapeseed, sunflower, soya, castor, oil palm, coconut or jatropha (Cotula et al., 2008:8). In some cases, the generation of biofuels is done using simple manufacturing processes which could be therefore suitable for small scale projects in rural areas (ibid.p.10). Brazil and the US are currently leading in the production of bioethanol while Europe leads in the production of biodiesel by processing locally grown vegetable oil crops such as oilseed rape as well as imported crude palm oil from Indonesia and Malaysia which are the major producers of oil palm (ibid.p.11).

[41] Perennials are best suited crops for biomass energy when compared with food crops. However, agricultural food production in poor countries may become under threat if perennials are cultivated on a large scale as this could result into food shortages in rural areas (Miller, 2004:618).

rural electrification and vehicles) has been widely promoted by the government as well as development agents (Cotula et al., 2008:33). Other examples of small scale biofuel projects for rural energy generation which have involved farmers, governments and non-governmental organisations can be found in countries such as Mozambique, Ghana, Burkina Faso, Guinea and Senegal. On the other hand, South Africa, Ghana, Zimbabwe, Tanzania, Nigeria, Kenya and Cameroon are among the countries in Africa currently attracting huge investments in biofuel production (ibid.p.12, 34).

It is worth noting, however, that the growing interest in the production of biofuels in rural areas of sub-Saharan Africa has been very much influenced by the relatively low cost of land and labour. Nevertheless, the current expansion of biofuel production has stirred a debate among energy analysts and development experts. Critics of biofuel production are more concerned with the advantages and disadvantages of biofuels with respect to their impacts on the local and global economy as well as on society and the environment. The contentious issues surrounding the debate include the role of biofuels in climate change mitigation, the impact of biofuels on food production (i.e. food security) and other related social and environmental consequences, i.e. land redistribution in rural areas and the subsequent impact of biofuel crops on natural ecosystems (ibid.p.6, 22). Although, the recent rise of world food prices is not directly linked with biofuels production, critics argue that the competition between biofuels and food may lead to a significant increase of food prices in the near future. They suggest, for example, that the large-scale commercial biofuel production from crops such as maize, soya (soy), palm oil, and sugarcane will increase pressure on arable land and cause food shortages, which could in turn have a devastating impact on the poor and vulnerable groups in rural as well as urban areas in many developing countries (ibid.p.13). It also argued that the cultivation of some biofuel crops is very much dependent on water availability (i.e. due to the need for irrigation). Since water is increasingly becoming a scarce resource, the extraction of water by biofuel companies for irrigation may cause conflicts between investors and local communities over its competition with domestic consumption and its possible environmental damage (Sulle and Nelson, 2009:31). The allocation of massive areas of land for biofuel production in Mozambique, Tanzania, India and Colombia has raised concerns about land use and land access for the vulnerable rural poor (Cotula et al., 2008:35).

Although the biofuel industry in Tanzania is still in its infancy, by 2008 more than 37 biofuel companies had sought land in the country for biofuel production (Sulle and Nelson, 2009:15). These include among others: FELISA (oil palm), BioShape (jatropha), Sun Biofuel (jatropha), SEKAB BT (sugarcane), Donesta Ltd and Savannah Biofuels Ltd (jatropha), Kapunga Rice Project (rice/jatropha) etc. (ibid.p.16, 17).

Biofuels: Jatropha plants (Photos taken by Dr Louis Kasuga)

The growing interest in biofuel production from investors is partly driven by the government (via the Tanzania Investment Centre). The centre recommends biofuel production on the basis that it is technically feasible in the country due to the availability of huge hectares of undeveloped land suitable for biofuel crops (ibid.p.15). The current main biofuel crops in the country include oil palm and jatropha. Sugarcane is cultivated in the country, but although it is widely used to produce sugar, there has been an initiative in recent years to diversify its use (ibid.p.18). One of the successful biofuel pilot projects on rural electrification in Tanzania is the use of jatropha oil for domestic lighting and milling machines in Engaruka village, in Monduli district though its long-term viability is still questionable (ibid.p.22). However, some energy analysts have been critical of the large-scale biofuel production in developing countries because large-scale biofuel production is neither a convincing nor a viable alternative to the current use of oil (Miller, 2004:405).

2.2.5 Wind energy

The concept of wind turbines has existed for a very long time but it was until the middle of the 1970s when a large scale development of what is known as 'a new generation of wind turbines' began in most countries as a result of the 1973 energy crisis (WEC, 2004). However, the first commercial wind turbines are thought to have been deployed since the 1980s (GWEC, 2008). Similarly, small-scale wind turbines for generating electricity and pumping water have since been developed alongside large-scale power-generating wind turbines (WEC, 2004). In twenty years, wind plant size is believed to have increased from 50 kW rated power to the tune of more than 5 MW by the end 2003 (ibid.). Not only has there been an increase in installed capacity of wind turbines but also their efficiency and visual design have been improved to a greater extent (GWEC, 2008). Wind is regarded by energy experts as a widely distributed energy resource and its availability varies between regions[42]. Because of such variations, the potential of wind for electricity generation can sometimes be greater than the indicated annual mean wind speed (WEC, 2004). It is therefore recommended that both wind speed and wind speed frequency distribution be included in the estimation as that would in turn give accurate average amount of electricity the wind turbines can generate in a particular region (ibid.). Current evidence suggests that 'a new generation of wind turbines' can operate across a wide range of wind speeds, ranging from 3-4 metres per second (m/s) to nearly 25 m/s (GWEC, 2008). This is because most of the recent models of wind turbines can withstand the constant variations in the wind as they use 'pitch control' to change the angle of their blades. Thus, with current advancement in technology, wind turbines are able to effectively operate at a wide range of sites, including sites with low wind speeds (ibid.).

[42] Renewable energy marketing analysts suggest that the global market for wind energy grew faster in the past few years in comparison with other renewable energy sources (Harper, 2008; Aubrey et al., 2006). For example, between 2001 and 2007 about 70 Gigawatts of wind power generating capacity was installed worldwide (van Kooten and Timilsina, 2009). By 2001 wind turbines produced about 25,000 MW of electricity worldwide (Miller, 2004). However, such market potential for wind energy can be felt more in developed countries than in developing countries (especially those in sub-Saharan Africa like Tanzania). Africa is believed to account for only less than half a percent of globally installed wind power generating capacity despite the fact that it has good wind potential (UNEP, 2008a:103).The 2008 World Energy Outlook projections indicated that wind energy will only cover less than two percent of the world energy supply by the year 2030 (IEA, 2008). Wind energy contributes a significant portion to the national energy share in Germany, Spain, United Kingdom, USA, India, China and Denmark. These countries are seen as leaders for wind energy market (Miller, 2004; Sharma, 2006; UNEP, 2008a; Energy Policy Institute, 2008). It is also worth noting that 66 percent of the world's wind energy is currently produced in Europe (UNEP, 2008a). The European Union remains as one of the strongest markets for wind energy in the world. Wind power accounted for nearly 30 percent of new electricity generation installations among the European Union member countries between 2000 and 2007 (GWEC, 2008).

Only a few areas have been identified as having wind energy potential in Tanzania. These areas include the coastlines, the highland plateau of the Rift Valley and around the Great Lakes, i.e. Lakes Victoria and Tanganyika (Mwihava, 2002). The use of wind energy in the country is thought to have begun about three decades ago in some areas for limited purposes. By the early 1990s, most of the installed windmills in the country were still in use.

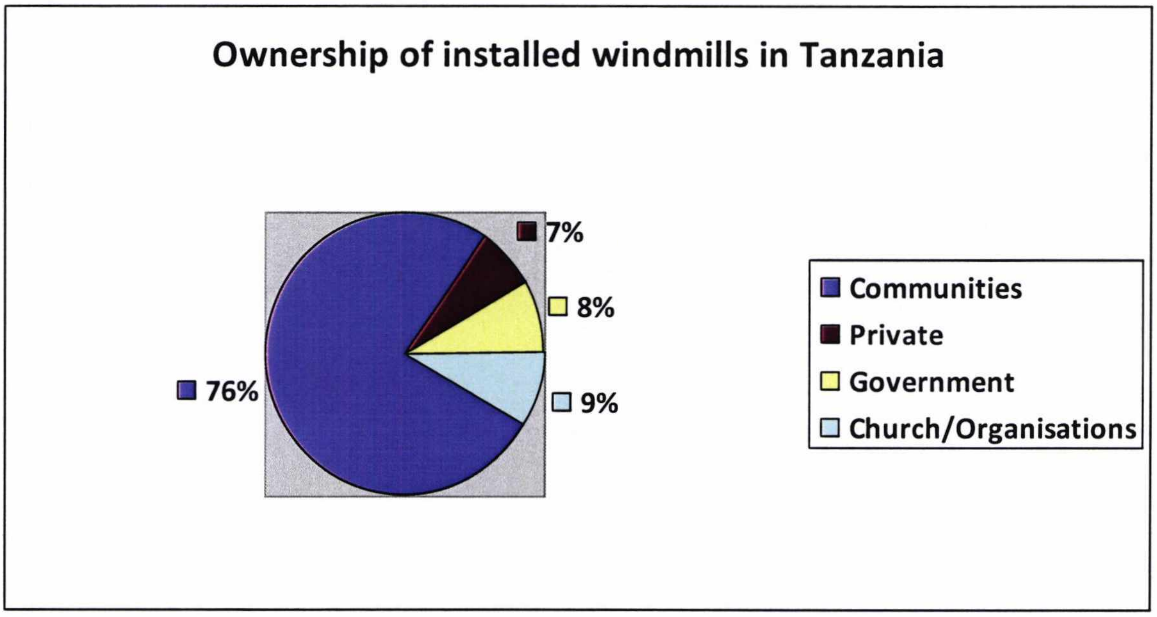

Figure 3: Ownership of installed windmills by various stakeholders in percentage[43]

Figure 3 shows the ownership of installed windmills (mainly for water pumping) whereby nearly 76% of them are believed to be owned by the communities, 9% by missionary organisations, 8% by the government and 7% are privately owned by individuals. It is estimated that more than 120 windmills for water pumping have been installed in the country (Mwihava and Mbise, 2003). Earlier attempts to generate electricity through wind failed because of several factors such as lack of adequate knowledge of the country's wind patterns and initial high investment costs[44]. In most cases wind energy has been used in water

[43] Adapted from Nzali and Mushi (2006)

[44] Siting of wind turbines (i.e. wind farms) has proved to be one of the main setbacks to the successful implementation of wind power projects. Wind turbines are normally sited in areas with convenient wind speeds and require appropriate landscape of which they can be located. In some cases, this may lead into conflicts between project planners and neighbouring communities. Experience from previous wind projects elsewhere suggests that construction and operation of wind farms have faced resistance from the local communities. This is due to issues such as visual impact, noise and sometimes what is viewed as the potential effects they may have on the landscape and ecosystem (GWEC, 2008). For example, wind turbines need to be tall so as to tap the wind effectively, and as a result this may cause the visual impact in the particular landscape. However, when compared with other huge energy projects such as nuclear, coal and gas power stations, wind farms are thought to "have relatively little visual impact" (ibid., p.30). Some studies have found that communities that live near the wind farms are satisfied with the projects as opposed to the way they felt when the projects were in their initial

pumping, i.e. for irrigation, livestock and domestic use in rural areas. However, there has been less investment in the installation of wind turbines for generating electricity (ibid.). Currently, there are attempts to install wind turbines for generating electricity in Singida region, although the project is still at its initial stages. According to Gwang'ombe (2004) the known installed wind turbines operating capacity for electricity generation in Tanzania by the year 2004 was estimated at 8.5 kW only. Technical barriers which include operation and maintenance of wind turbines are also said to be impeding investment in wind energy. Inadequate investment is backed by claims that wind turbines which generate electricity require more regular maintenance than solar PV systems when these two sources of energy are compared (Karekezi, 2002). It has been further argued that low wind speeds affect the efficiency of windmills in most areas in eastern and southern Africa[45] (ibid.).

Region	Estimated Wind Speeds (m/s)	Region	Estimated Wind Speeds (m/s)
Dodoma	4.8	**Pwani**	3.2
Mtwara	4.7	**Kigoma**	3.1
Mwanza	4.1	**Zanzibar**	3.1
Tabora	3.8	**Dar es Salaam/Mara**	3.0
Ruvuma	3.6	**Lindi**	2.6
Tanga	3.6	**Kagera**	2.2
Mbeya	3.5	**Iringa**	1.8
Arusha	3.2	**Kilimanjaro**	1.8
Pemba	3.2	**Morogoro**	0.9

Table 2: Wind Speed in Tanzania Regions. Adapted from Karekezi et al. (2005)

stages. Similarly, studies carried out in Scotland found that wind farms projects did not affect the tourism industry as tourism activities remained stable even after the wind turbines became operational (ibid.).

[45] In Africa, Morocco and Egypt are among the best examples where wind energy has been successfully developed. However, Egypt is the most successful country so far with a number of large wind farms which have been constructed at Zafarana (Aubrey et al., 2006; Karekezi et al., 2007; Harper, 2004). Egypt being located closer to the Gulf of Suez has an advantage in terms of wind regime with the average wind speeds reaching over 10m/s (GWEC, 2008). Egyptian wind energy generating capacity is also said to have increased in recent years as the wind power capacity reached 310 MW by the year 2007 from the previous 5 MW capacity recorded in 2001. From 2001 to 2007, about 305 MW of wind energy generating capacity has been installed at the Zafarana project along the Gulf of Suez (ibid.). Wind energy is also regarded to be one of the sectors with high potential for renewable energy generation in Morocco as the country enjoys an estimated 3,000 km coastline which has average wind speeds ranging from 7.5 to 11 m/s and (ibid.).

Table 2 shows the average wind speed from selected regions in Tanzania. It is argued that an average wind speed of 5m/s is required to generate electricity from wind turbines. However for wind pumps an average wind speed of more than 3m/s may be sufficient (Karekezi et al., 2005). With estimated average wind speeds as shown in Table 2, it is clear that unreliable wind speeds could be one of the factors that the government has long considered before taking initiatives to invest in wind energy. However, as discussed earlier, with modern wind turbines, it is possible to generate electricity even in the areas with low wind speeds (GWEC, 2008).

2.2.6 Geothermal energy

Geothermal energy is produced by natural heat which comes from rocks, hot water or steam and is usually emitted from the earth's crust (Miller, 2004). It can be used to produce electricity and heat buildings (ibid.). Africa is believed to have a generating potential of 9,000 MW of energy from geothermal energy sources[46]. However, it is thought that only about 127 MW of geothermal energy has been harnessed so far in Kenya and less than 2 MW in Ethiopia (Karekezi et al., 2007). The successful establishment of geothermal energy in Kenya came as a result of both public and private sector initiatives (Karekezi and Kithyoma, 2003). Although geothermal exploration has taken place in some countries in Africa, available evidence so far indicate that Tanzania, Kenya, Uganda and Ethiopia have great geothermal potential for grid- connected electrification (Karekezi et al., 2007). In Tanzania, however, financial and technical barriers are thought to have slowed down geothermal energy development. Geothermal explorations have been carried out in the country around Lake Natron, Lake Manyara, Rufiji and Mbeya region. The country's national energy policy supports the development of geothermal energy as one of the potential sources of electricity (Ministry of Energy and Minerals, 2003). It has been reported that the country is ready to back up private sector initiatives in geothermal energy development and earlier plans had suggested that the country has been considering developing small-scale geothermal plants for rural electrification using "mini-grid systems" in the near future (ibid.). Some energy analysts have suggested that due to the very successful geothermal development in Kenya, Tanzania

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[46] Geothermal sources produce electricity to about 22 countries, most of them being from developing countries (Miller, 2004). In sub-Saharan Africa, Kenya is said to be the first country to exploit its geothermal energy potential and plans to increase the geothermal capacity to about 504 MW by the year 2019 (Karekezi et al. 2007).

could learn from that experience to develop and promote its geothermal energy technology (Mwihava and Mbise, 2003).

Geothermal energy development in the rural areas may play a crucial role in the country's effort to alleviate poverty by stimulating the growth of small-scale industries. Processing of agricultural products can be easily done through the establishment of rural agro-processing industries which may improve the agricultural sector and crops market in the country. As a result rural households' incomes may be improved through income generating activities (ibid.). Electricity from geothermal plants may be also used in rural dispensaries, health centres, hospitals, schools, and water pumping for domestic household use and irrigation. Experience from neighbouring Kenya has shown that through geothermal energy development, companies such as KenGen and OrPower 4 Inc have managed to improve the livelihoods of the local Maasai communities in their areas. KenGen has also been involved in constructing schools, roads, health centres and provides telecommunication services in the area (ibid.). Past experience has also shown that geothermal energy is not very much affected by drought as compared to hydropower. For example, when Kenya was hit by severe drought in 1998-2000 which affected its hydropower plants, geothermal power plants salvaged the country by supplying the much needed electricity for the economy (ibid.).

2.2.7 Solar energy

Technological advancement has made it easier to harness energy from the sun. Thus, energy from the sun can now be used for various purposes. Solar photovoltaic (PV) cells can today trap and convert rays from the sun into electricity (Miller, 2004:398; Harper, 2008:139). A number of manufacturers of solar (PV) cells and modules now exist worldwide but the currently well-known manufacturing companies include: Sharp Electronics Corporation (Japan), Kyocera Solar, BP Solar Industries, Sanyo Electric Company, Suntech (China), First Solar (U.S), Yingli (China), Trina Solar (China), Canadian Solar, SunPower (U.S), Hanwha SolarOne (China), Renewable Energy Corporation (Norway), and SolarWorld (Germany)[47]. However, manufacturing of solar (PV) cells is complex and relatively costly because thin cells of pure crystalline silicon and strips of amorphous silicon are used in the process[48] (Steenblick, 2005:15). The production of solar cells is largely controlled by the microelectronics sector. This is due to the fact that the silicon wafers used in the

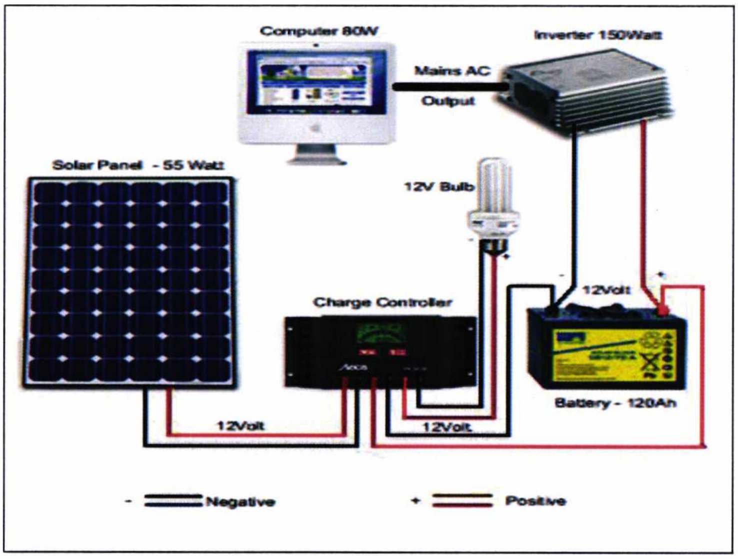
[47] See www.solarenergyexperts.co.uk

[48] This may however be changing because of the recent technological developments

manufacturing of solar cells are also predominantly used in microelectronics (Hekkert et al., 2007:416). In order to have more electrical output, the PV cells are normally assembled together in series to form PV modules also known as solar panels. This is done because the maximum output of power from the single PV cell is small and is estimated to be around 2 watts only (Steenblick, 2005:15). It should also be noted that solar panels may be manufactured in different forms such as PV roof tiles, PV glass units and the framed PV modules which are common in the market. According to Miller (2004:398), PV roof tiles also known as PV panel roof systems (solar cell roof shingles) can be used to generate electricity for a house or building. He argues that using traditional-looking PV roof tiles in buildings not only generates electricity but also saves the costs of buying ordinary roof materials for buildings (ibid.).

PV systems

A solar photovoltaic (PV) system generates electricity from solar radiation and is comprised of a PV array and other components such as DC-AC power inverters, electric cables, solar batteries and charge controllers (Miller, 2004:398). These are needed to store, control and distribute electricity produced by the array. Components required in a solar PV system depend on the operational and functional requirements of the specific system. Solar PV systems are classified into two main types: stand-alone systems and grid-connected (utility-interactive) systems (ibid.). Stand-alone PV systems are not designed to operate with the utility grid and most of such systems are comprised of PV panels, charge controllers, converters and batteries. In most cases, stand-alone PV systems are meant to supply specific electrical loads. They are installed in areas which are far from the grid or when connection to the grid is considered to be not economically viable. Once installed, the life span of the solar PV system is believed to range between 20 to 30 years (Miller, 2004:394; Steenblick, 2005).



A stand-alone PV system[49]

Experience shows that there have been ongoing efforts since the early 1980s to disseminate solar photovoltaic systems in Africa. Community-based solar photovoltaic (PV) systems for water pumping systems, communications, and vaccine refrigerators in rural clinics were among the successful pilot projects for most rural areas that had no access to electricity in developing countries (Krause and Nordström, 2004). The pilot projects raised awareness and as a result solar PV was recognized as a "reliable technology for rural development" (ibid.p.10). However, most of these earlier community solar PV systems projects were implemented in rural areas through grants from donor countries. Thus, there was less emphasis on local participation and long-term sustainable use of these systems (ibid.). The invention of solar home systems also helped to raise awareness and the need to promote solar PV technologies in rural areas. Countries which serve as examples where projects for promotion and dissemination of solar home systems[50] became successful are Indonesia, the Philippines, Sri Lanka, Vietnam, Colombia, Honduras, Jamaica, and the Dominican Republic (Krause and Nordström, 2004:8;Harper, 2004:257).

[49] Source: www.mysolarshop.co.uk

[50] Studies conducted in three East African countries – Kenya, Uganda and Tanzania – indicate that the high demand for cell phones by people in the rural areas could facilitate the adoption of solar home systems (Krause and Nordstrom, 2004).

Solar PV in Tanzania

Since the majority of the rural population do not have access to the national grid electricity, electricity from sunlight could be an attractive alternative as the country's average annual solar radiation levels range between 4.2- 5 kwh/m^2 per day, depending on seasonal variations in insolation levels (Kimambo and Mwakabuta, 2005). Average annual daily solar insolation in most African countries is estimated to range between 5 - 6 kwh/m^2 (Karekezi, 2002). Electricity from solar photovoltaic (PV) systems is gradually gaining recognition in Tanzania and has recently been used in water pumping, lighting, telecommunication, health centres, dispensaries, schools, refrigeration and powering electronic equipment such as radio and television (Mwihava, 2002; Kimambo and Mwakabuta, 2005). Previous survey data on solar energy estimated that solar PV with the capacity of about 600 kWp (kilowatt peak[51]) had been installed in Tanzania by the early 2000s. It was found that solar home systems at the time accounted for about 30 to 40 percent of the total installed capacity of solar PV in the country (Mwihava and Mbise, 2003). However, the main users of solar PV systems were the Tanzania-Zambia Railway Authority (TAZARA), the Tanzania Railways Corporation (TRC), mobile phone companies and missionary centres[52] (European Commission, 2005).

Installing a PV system at Ngasamo dispensary in Magu District (UNDP)

[51]The maximum power rating of the PV system

[52] For the purposes of this study I was unable to get updated data on installed solar PV capacity around the country.

Solar thermal systems

Water heating and food cooking can be done using "solar thermal systems". Solar thermal systems are designed in such a way that they "collect and transform radiant energy from the sun into high-temperature thermal energy (heat), which can be used directly or converted to electricity" (Miller, 2004:396).

Samples of cheap solar cookers made by TATEDO (Field trip photo)

Cheap solar cookers could help rural households in developing countries as they do not emit smoke which causes indoor pollution. Solar cookers could also play part in addressing firewood shortages as well reducing deforestation rate in rural areas (ibid.). Solar cooking and solar crop drying technologies are not very much used in Tanzania. However, water heating is believed to be the most proven and convenient way of using solar thermal system in the country (Mwihava and Mbise, 2003). Where electricity has been used to heat water for various applications in households, public services and industries in the country, this may be substituted or supplemented by the use of solar thermal systems (ibid.). However, evidence also suggests that awareness of solar thermal technology is lacking in Tanzania. The current available data indicate that there are only a few users of solar thermal systems in regions across the country. Best examples where solar thermal systems are actively used for water heating in Tanzania include: Bugando hospital in Mwanza region, Makiungu hospital in Singida region, Morogoro Hotel in Morogoro region and Hotel 77 in Arusha region (ibid.). Energy analysts suggest that if water heating in hotels, small scale industries and residential houses were to be done by using solar thermal systems, a significant amount of energy would be saved in the country (ibid.). Tanzania's energy statistics show that more than 600 solar heater systems were believed to have been installed and operating by 1999. However, the exact number of the solar heater systems still operating to date is unknown. At the same time, energy analysts in Tanzania suggest that solar thermal technology could be affordable and local expertise on the installation, operation and maintenance of the systems is currently available (ibid.).

Empirical evidence from other countries

Bangladesh

Rural electrification in Bangladesh has been under the Rural Electrification Board (REB) since 1977. Before REB started its operations, the responsibility to supply electricity in rural areas was under the Bangladesh Power Development Board of which most of its efforts were principally limited to urban areas (Yadoo and Cruickshank, 2010). Access to electricity has improved in rural Bangladesh since REB took over, and it is now regarded as one of the successful rural electrification programmes in developing countries (ibid.). For example, by the year 2009, about 28% of the rural population in Bangladesh were having access to electricity (Palit and Chaurey, 2011:268). The Rural Electrification Board has been working with rural communities to establish 'rural electric cooperatives' known as Palli Bidyuit Samity (PBS) and these cooperatives have played an important role in electrifying rural Bangladesh. Under the supervision of Rural Electrification Board (REB), these 'electric cooperatives' have so far constructed, managed and operated facilities as well as distributing electricity to rural consumers. Since the 'Palli Bidyuit Samity' cooperatives are connected to the grid, they get electricity in bulk from the Bangladesh Power Development Board. The electricity is subsequently distributed to the respective consumers. There are currently about 70 operating electric cooperatives in Bangladesh (Yadoo and Cruickshank, 2010; Palit and Chaurey, 2011:268). Nevertheless, rural households which are connected to the network are still fewer when compared to the total number of households in the country. This is mainly due to the high upfront costs of being connected to the electricity network. Performance targets such as revenue/km of line, collection efficiency and cost of service as well as system loss have also impeded the PBS to connect households in unviable rural areas (ibid.).

Nepal

Nepal has made significant progress in the past few years to electrify remote areas. The country began to involve communities in rural electrification programmes since 2003. This was mainly done to address system losses and poor revenue collection. Consumer associations in form of cooperatives have taken the responsibility of managing, maintaining and expanding the rural distribution of electricity (Palit and Chaurey, 2011). Communities are required to raise 20% of the investment cost to have their areas connected to the grid and 80% of the cost is covered by the government through the Nepal Electricity Authority (NEA). The Nepal Electricity Authority sells electricity in bulk to rural electric cooperatives which in turn distribute and collect revenue from rural households. About 230 electric cooperatives are known to be working with Nepal Electricity Authority (ibid.p.268).

USA

In the mid 1930s, about 90% of rural households did not have access to electricity in the United States (Yadoo and Cruickshank, 2010). However, the large part of rural USA was electrified in the 1930s, 1940s and 1950s through the formation of local electric cooperatives. Rural Electrification Administration (REA) was established in 1935 and within 13 years of its establishment, locally owned rural electric cooperatives were able to double the number of rural electric systems as well as triple the number of consumers. As a result, by 1953, more than 90% of the rural USA had been electrified. It is now estimated that about 930 rural electric cooperatives (864 distribution and 66 generation and transmission cooperatives) provide energy services to about 42 million people in 47 states and own assets worth billions of US dollars (ibid.).

Summary

Rural access to energy services is of paramount importance if Tanzania is to achieve its Millennium Development Goals. However, achieving these goals would also require the country to invest in renewable energy sources and technologies. Current energy problems in rural areas have accelerated environmental degradation as well as poverty. At the same time, the rural population has been denied access to quality social services such as health, water and education. This is, in part, because most of the facilities offering such services lack electricity. However, investment in renewable energy technologies such as improved cooking stoves, biomass plants, solar PV systems, solar cookers, solar water heaters, wind turbines and geothermal plants could increase rural access to affordable and clean energy. Investment in renewable energy will allow most rural households to be more productive as well as to engage in various income generating activities. For example, decentralised renewable energy systems appear to be more economical, sustainable and appropriate for rural areas than conventional centralised energy systems, which would require massive investment in a grid distribution network which itself would entail leakages as electricity was transported over long distances. Decentralised renewable energy systems can easily match into specific local needs as they could be developed even in very remote areas. Such systems could also be designed to match the available renewable energy sources or technologies in the targeted area. However, this is not to say that decentralised renewable energy systems should not be integrated into the centralised grid system, but rather that that should happen only when it appears that the move will be both economically viable and environmentally sound. Although small-scale decentralized hydropower systems have a potential to generate electricity and do not pose as large a threat to the environment as do large scale hydropower projects; such systems may not be appropriate in some geographic locations. Experience suggests that the best geographical locations for small-scale hydropower systems are those characterised with constant flow of water from rivers, streams etc. throughout the year. Since the country has in the past been hit by frequent droughts, small-scale hydropower systems may not be a viable option in most rural areas. On the other hand, low wind speeds affect the efficiency of windmills in most areas in the country hence investment in wind energy may not offer long-term solutions to rural energy problems. As discussed in this chapter, solar energy and biomass appear to be the most widespread renewable energy sources in the country. This study will therefore focus on solar PV systems and improved cooking stoves because they seem to offer the best alternative solution to rural electrification problems[53]. These renewable energy innovations have the potential to reach the majority of the rural population as opposed to conventional energy systems based on fossil fuels. Decentralized renewable energy options such as Solar PV systems could diversify energy supply, facilitate socio-economic activities and strengthen energy security in rural Tanzania. In turn, this would spearhead poverty alleviation efforts and improve rural livelihoods.

[53] However, solar Photovoltaics (PV) appear to have particularly great potential.

Chapter 3: Innovation and Sustainability

This chapter provides a review of the literature on innovation and discusses the analytical framework on which this study is based. The chapter begins with a review of the 'innovation systems' approach and discusses different types of innovation systems. This is important for this study because it is from there that this chapter seeks to broaden our understanding of innovation systems in the context of developing countries. It is important to note that while attempts to integrate an innovation systems approach into research and development in sub-Saharan Africa have consistently focused on the agricultural sector, the renewable energy sector has so far received limited attention. Therefore, in this chapter, I argue that although the roles, performance and effects of innovation brokers for industrial and agricultural sectors have been widely researched in both developed and developing countries, research on the roles of innovation brokers (intermediaries) in the renewable energy sector in rural areas of sub-Saharan Africa is still limited or lacking. By this argument, I share a widely held view in innovation studies that 'innovation does not occur in isolation'; rather it is a result of interaction between various actors. In this chapter, I also briefly discuss the relationships between innovation, and the concept of sustainable development. The last part of the chapter explores how systems thinking can broaden our understanding of the concept of sustainable development and innovation systems.

3.1 Innovation Systems approach

There is now a growing consensus in the field of innovation and technology that innovation processes and diffusion of technologies in a nation or region should not be studied as isolated phenomena, but rather as a part of a larger system (Johnson, 2001:2; Clark, 2002). That is, the innovation and transfer of new technologies should be treated as a process that takes place within an 'innovation system' (ibid.). The basic assumption under the innovation systems approach is that innovation and transfer of technology is a result of both an individual and collective act (Hekkert et al., 2007:415). Innovation Systems[54] as a new approach to study innovations has gained popularity in academic contexts and has been widely used "as a framework for innovation policy-making" in the past few years (Edquist, 2001:2). This popularity has been mainly driven by the failure of the conventional economic models to fully explain what innovation means. Conventional economic models view

[54] Sometimes referred as systems of innovation

innovation as a linear[55] process that is driven by research (Hall, 2005:614). This may also imply that conventional innovation models have since treated science and technology as "relatively independent of historical, social, political, cultural [or] other institutional factors", and therefore factors such as local knowledge and practices have been largely ignored (Pant and Hambly-Odame, 2009:107). Empirical evidence suggests that conventional economic models have so far failed to "offer convincing explanations of trends in innovation, growth and productivity [because, among other things], they present a somewhat static snapshot of technology performance which neglects how the various actors in a country interact in the innovation process" (OECD, 1997:9). Thus, the innovation systems approach has emerged with the aim of integrating different sources of knowledge and innovations so as to overcome these challenges. This approach stresses the importance of interactions among actors involved in technology development, seeing innovation as resulting from complex interaction between actors and institutions (ibid.). According to Edquist and Chaminade (2006:109), the innovation systems approach focuses not only on how systems operate but is also concerned with the subsequent complex interactions taking place between various organisations and institutions within the systems at different levels, regional, national etc. They argue, for example, that "firms do not innovate in isolation" but rather tend to interact continuously with consumers and other stakeholders such as universities, suppliers or other firms (ibid.p.109). This view is also supported by Hekkert et al. (2007:414) when they argue that the innovation systems approach is used to "analyse all societal subsystems, actors, and institutions contributing directly or indirectly to the emergence of [an] innovation" and subsequent activities which include the diffusion processes. It is important to note, however, that for the actors or agents in the system to be fully involved in innovation processes, they must understand well how a specific innovation system functions, knowing activities that help or hinder innovation (ibid.).

The reviewed literature suggests that until recently, researchers in innovation studies have categorised innovation systems into national, regional, sectoral and technological

[55] Pant and Hambly-Odame (2009:107) argue that conventional models emphasize "linear relationships between science and society". To support their viewpoint, they cite examples of the programmes that were advocated during the era of Green Revolution in the 1960s and 1970s. At the time, researchers working in modern scientific establishments were regarded as producers of knowledge and information while extension workers were seen as carriers of information who were to carry such information to the farmer as the ultimate adopter (ibid.).

innovation systems[56] (Edquist and Chaminade, 2006:110). Technological systems as an approach is very much confined to specific technologies and was first conceived by Thomas P. Hughes in 1983 (Johnson, 2001:7), although it was later developed by Bo Carlsson in the 1990s (Archibugi et al.,1999:528). Therefore it does not come as a surprise that in the literature, 'innovation systems' as a concept has, in most cases, been defined and applied differently by researchers from various social science disciplines. As Hall (2007b:5) puts it:

"One of the challenges of using this concept is that not only is there no well recognised innovation systems "approach", but also that there shouldn't be one either! Blueprints, best practices and tool kits are all an anathema to this perspective. Instead the innovation systems concept presents a set of principles that researchers, planners and entrepreneurs need to operationalise in their own contexts and in ways suited to their own goals".

One could therefore argue that the majority of these researchers are either influenced by their theoretical background guiding their research or by the characteristics of the system they are studying (Markard and Truffer, 2008:598). Thus, the following section (see 3.1.2), provides what I might term a general definition of the concept of 'innovation systems'[57].

3.1.2 Defining an innovation system

An innovation system is defined by Hall et al. (2010) as "networks of organisations or actors — together with the institutions and policies that affect their innovative behaviour and performance — that bring new products, new processes and new forms of organisation into economic use". According to Markard and Truffer (2008:597), an innovation system is "composed of networks of actors and institutions that develop, diffuse and use innovations". Edquist (2001:2) defines innovation systems as "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations[58]". It should be noted, however, that innovation systems as a concept was first introduced into publications by Christopher Freeman in 1987 when he coined the concept "national systems of innovation". Freeman was at the time describing the technological and industrial performance of Japan during the post-war era (Edquist and Chaminade, 2006:109;

[56] According to Clark et al. (2003:1847), national innovation system "can be described as the system or network of private and public sector organizations whose interactions produce, diffuse and use economically useful knowledge".

[57] "Innovation system is a concept that stresses that the flow of technologies and information among people, institutions and enterprises is central to any innovative process. It contains the web of interactions between all the actors needed in order to turn an idea into process, product or service in a market" (Smith, 2009:128).

[58] An innovation system has also been defined as "all institutions and economic structures that affect both rate and direction of technological change in society" (Hekkert et al., 2007:415).

Archibugi et al., 1999:528; Hall, 2005:614). By then, he defined the national system of innovation as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies" (Freeman, 1987:1).

A number of research papers and books on innovation systems have since been published, the major contributions including the work of Bengt-Åke Lundvall in 1992 followed by Richard R. Nelson in 1993 on 'national systems of innovation' (Edquist and Chaminade, 2006:109). However, these two major contributors to the innovation systems research have employed different approaches in studying national systems of innovation (ibid.). For example, Nelson has mainly focused on empirical case studies by primarily dealing with "the composition and characteristics of the national system of industrial research and development". Nelson also emphasizes institutional factors such as property rights for the firms investing in innovation and government policies influencing research and development (Carlsson and Stankiewicz, 1991:111-112). While Nelson appears to have focused more on empirical case studies, Lundvall is more theoretically oriented and his analysis is built upon in what is termed as "interactive learning" and "user-producer interactions" (Edquist and Chaminade, 2006:109). According to Lundvall, an innovation system is jointly defined by its two most important dimensions: 'the structure of production and the institutional set up' (ibid.). Thus, Lundvall's analytical framework explains the emergence and performance of an innovation system by looking at the social structure (i.e. actors, their relations, and institutions[59]) of the system in question (Hekkert et al., 2007:414). However, Nelson and other innovation researchers argue that the main sources of innovation are the organisations that support research and development. Such organisations (also referred as actors or agents) include among others: private firms, government agencies, non-governmental agencies, industrial research facilities, universities and associations (Markard and Truffer, 2008:598; Jacobsson and Bergek, 2004:817; Carlsson and Stankiewicz, 1991:112). The main task of these organisations is to "promote the creation and dissemination of knowledge" (Edquist and

[59] Institutions are defined widely in the innovation literature. In a more conventional definition or in a day to day common usage the concept is mostly used to refer to non-market, non profit organisations such as governments, public agencies, universities etc. However, in a broader definition widely used in disciplines such as sociology, institutions comprise "all forms of organisations, conventions and repeated and established behaviours which are not directly mediated through the market" (Dosi and Orsenigo, 1988:19). With regard to innovation studies, Edquist and Johnson have defined institutions as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups and organisations" (Edquist, 2001:5; Edquist and Chaminade, 2006:112). Therefore, it is from this definition that they also define organisations as "formal structures with an explicit purpose" and which are "consciously created" (ibid.). Describing institutions in what they have termed as the institutional infrastructure in the technological system, Carlsson and Stankiewicz (1991:109), refer to institutions as the normative structures that are meant to encourage stable societal interactions, prevent or mitigating conflicts and reducing social uncertainties.

Chaminade, 2006:109). On the other hand, institutions set the norms and rules that regulate interactions between actors (i.e. laws and regulations, use patterns, shared expectations, socio-cultural and technical norms) and therefore are important in influencing connectivity in the system[60] (Jacobsson and Bergek, 2004:818; Markard and Truffer, 2008:598). Lundvall, however, perceives organisations as being parts of a wider socio-economic system in which the success or failure of innovative activities is solely determined by political, cultural and economic factors[61] (Edquist and Chaminade, 2006:109).

Nevertheless, experience has shown that the organisational and institutional set up may vary considerably from one innovation system to another. For example, while empirical evidence suggests that research institutes and company based research departments have significantly played an outstanding role in research and development (R&D) in countries such as Japan, that may be not be the case in the United States and Sweden where universities have so far played a leading role in R&D. Similarly, although the available evidence suggests that independent public research institutes are weak in Sweden, such institutes are thought to be stronger in Germany (ibid.). On the other hand, institutions also differ across national systems of innovation (i.e. between countries). In some cases, for example, patent laws in the United States may not necessarily be applicable in the European Union.

One can therefore argue that the categorisation of systems of innovation into sectoral, national, regional and technological systems is very much influenced by the research interests and theoretical orientations of the respective researchers. And that explains why some researchers consider national, sectoral, regional and technological systems of innovation to be variants of a single generic innovation systems approach. These researchers do agree that in most cases, these systems of innovation coexist and complement each other (ibid.p.110-112). Carlsson and Stankiewicz (1991:111), for example, have defined a technological system as "a network of agents interacting in the economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology". To put this into context, they have also defined 'the institutional infrastructure' as "a set of institutional arrangements (...) which, directly or indirectly, support, stimulate and regulate the process of innovation and diffusion of technology" (ibid.p.109).

Technological systems are described as being multi-dimensional entities interacting with their internal and external environment, and for this reason they are perceived to

[60] It is also important to note, that most researchers in innovation studies consider both organisations and institutions as the main components of the innovation systems (Edquist and Chaminade, 2006:111).

[61] (i.e. political reasons, cultural influence as well as economic policies)

constitute among other things: dynamic knowledge, competence networks, clusters of firms and technologies within an industry, and institutional infrastructure (Leoncini, 1998: 76; Carlsson and Stankiewicz, 1991:111). According to Jacobsson and Bergek (2004:817-18), a technological system comprises a number of elements but they consider actors, networks and institutions to be the main constituent elements that make a technological system[62]. They argue, for example, that actors can significantly influence the development and transfer of new technology in the technological system. These actors include users, suppliers and organisations but a significant contribution is made by the key actors who are "technically, financially and/ or politically so powerful" known as "prime movers". In order to promote a new technology in the system, 'prime movers' would normally "undertake investments, raise awareness, provide legitimacy and diffuse the new technology" (Jacobsson and Johnson, 2000:636).

It is worth noting that most technological systems are found within the boundaries of the national state. It is argued, however, that in other situations, technological systems can be international or global, and in such cases, boundaries of technological systems very much depend on the technological and market requirements, agents' capabilities, and the extent at which the agents are interdependent. Although in terms of the systems perspective, both technological system and national systems of innovation are considered to be similar; the concept of technological system differs from that of national systems of innovation (Carlsson and Stankiewicz 1991:112; Carlsson, 1994:14). It is argued, for example, that whereas the technological system refers to "specific industrial areas", the national systems of innovation "refer to the national system in all areas as a whole". That is to say, that rather than being defined by national boundaries, technological systems are instead defined by ***technology*** and their boundaries are not necessarily confined within the national boundaries. Therefore, in some cases, these boundaries may differ from one techno-industrial area (technology area) to another implying that technological systems may be different from each other despite being located in one country (ibid.). According to Carlsson (1994:14), one crucial aspect which differentiates technological systems in the country is their inherent international connections

[62] While networks play an important role in the diffusion of information and knowledge about a new technology among individual actors hence shaping their perceptions and decisions; the function of institutions (as stated earlier), is to regulate interactions among the actors in the technological system and that may include influencing connectivity in the system and creating "the incentive structure or structure of demand" (ibid.p.818). Nevertheless, one should note that institutions are not static since their structure may change over time and such changes could shape the direction of economic change i.e. towards growth, stagnation, or decline (Leoncini, 1998:80).

i.e. the degree to which they are not confined within national boundaries. However, it is also important to note that technological systems are very much shaped by cultural, linguistic and other factors within national boundaries, and the interactions among various parts within the system are in a way dictated by all or some of these factors (ibid.). Finally, what differentiates technological systems from systems of national innovation is the emphasis of the former on microeconomic aspects of technology diffusion and utilization, especially the role played by economic competence, knowledge networks and development blocks (Carlsson and Stankiewicz 1991:112; Carlsson, 1994:14). While economic competence has been defined by Carlsson and Eliasson "as the ability to identify, expand and exploit business opportunities" (Carlsson, 1994:15); development blocks are referred as "synergistic clusters of firms and technologies within an industry or group of industries" (Carlsson and Stankiewicz 1991:111). According to Carlsson (1994:15), technological systems can only function properly if (amongst others) all relevant economic agents, users, suppliers and government agents have economic competence. Nevertheless, it is argued that although the concept of the national systems of innovation is different but it has much in common with the concept of technological systems, especially when the boundary of technological systems is defined in terms of the national institutional infrastructure (ibid.p.111).

A technological system approach, also termed "a technology-specific innovation system" approach, offers a broader insight into our enquiry especially when the researcher seeks to understand the competition between emerging technologies and incumbent technologies within or between the technological systems (Jacobsson and Bergek, 2004:817). A technological system is not only analysed in terms of its functions and its constituent components (ibid.p.819) but the analysis may also include the interactions taking place among the agents or actors in the system (Negro, 2007:17; Carlsson and Stankiewicz, 1991:111). Therefore, in analysing the technological system, one needs to first understand the boundaries of the system in question so as to identify the factors that promote or hinder its development i.e. "the generation, diffusion and utilisation of a new technology" (Jacobsson and Bergek, 2004:819). Due to the fact that technological innovation systems are 'technology-specific', the number of actors, networks and institutions (system's components) is relatively smaller than in a national system of innovation. This significantly reduces the complexity of mapping the system's dynamics and its performance i.e. mapping important activities that shape the direction of the system in question over time. And as noted earlier, these activities contribute to the overall goal of the technological system, which is to generate, diffuse and utilise (application of) a new technology (Alkemade et al., 2007:141; Negro, 2007:26). According to Leoncini (1998:91), "the technological system appears to be a useful tool especially because of the synthetic and precise way with which it is possible to describe its main components and their interactions: being more clearly defined at the theoretical level, it allows for more reliable and more compact empirical work".

The following section explores how investment in R&D activities in Tanzania has changed over time and discusses the role that could be played by innovation brokers and other actors in facilitating the innovation process in an innovation system.

3.1.3 R&D and the role of innovation brokers in the innovation process

The majority of researchers in innovation studies agree that the 'overall function' of an innovation system is to generate (i.e. develop), diffuse and utilise innovations[63] (Johnson, 2001:4; Markard and Truffer 2008:601). Edquist and Chaminade (2006:112) support this view by arguing that the innovation system can be well analysed when both its components and the type of "activities" taking place in the system are clearly understood. As stated earlier, an innovation system constitutes organisations and institutions; therefore, using a innovation systems as an analytical approach we focus on the complex interactions taking place between various organisations and institutions in the specific system (ibid.p.115). Edquist and Chaminade thus refer 'activities' (in this sense) as all "those factors that influence the development and diffusion of innovations". This implies that the innovation processes within a particular innovation system are very much determined by the ongoing relations between its components and the 'activities' taking place (ibid.p.112). One of the key activities in the innovation systems is the provision of knowledge inputs to the innovation processes through research and development (R&D). R&D plays an important part in the innovating process and acts as a source of both knowledge development and knowledge diffusion through the existing networks in the system i.e. 'learning by searching and learning by doing' (Alkemade et al., 2007:144; Hekkert et al., 2007:422-3). For example, R&D in the energy sector has been successful in developed countries because in most cases the governments collaborate with the private firms[64] (Edquist and Chaminade, 2006:119).

[63] In the innovation literature, functions refer to "the contribution of a component or a set of components to the overall function of the innovation system" (Bergek et al., 2008:409).

[64] Although fossil fuel as well as nuclear power-based technological systems have for long benefited from public funded R&D both in developed and developing countries; inadequate funding of R&D in renewable energy technologies, has hampered the growth of renewable energy industry (Jacobsson and Johnson, 2000:634;

However, for the case of Tanzania, which is the focus of this study, available evidence suggests that investment in R&D from private firms is still very low as most small and medium-sized enterprises do not fully engage in R&D activities (Piirainen et al., 2012:51). Critics cite lack of meaningful collaboration between the government and the private sector as the reason[65] (ibid.). It must be noted, however, that R&D activities in Tanzania started during the colonial period when the Germans established the first Central Veterinary Laboratory at Mpwapwa in Dodoma Region (Diyamett et al. 2010). When the British took over in 1919, they expanded the research base and initiated collaborative research programmes in East Africa. In 1948, the British established an 'East African High Commission' in which each of the member states was mandated with a specific research programme. Mainland Tanzania (then Tanganyika) dealt with research on malaria while Zanzibar was tasked with marine fisheries, Uganda focused on virology and Fresh water fisheries and Kenya did research on Forestry and Veterinary (ibid.). However, such initiatives were mainly meant to safeguard colonial interests. Colonial administrators had less interest in the development of industrial research because the industrial structures in these countries at the time did not require industrial R&D as most of these industries were labour intensive (ibid.). After independence in the early 1960s, health, food and livestock development in Tanzania did not change much as there was still no well-defined and focused science and technology policy. After the collapse of the East African Community in 1977, more research and development organizations were established in the country. Nevertheless, it appears that most of the R&D activities have since focused on the agricultural sector. For example, by 2010, public research organisations in the country were as follows: sixteen (16) in agricultural sector; six (6) in animal sciences and animal diseases; nine (9) in human health, nutrition and medical sciences; six (6) in natural resources; and seven (7) in the industrial sector[66] (MCST, 2010:4). Although most R&D activities are still largely carried out by public research institutions and higher learning institutions, the macroeconomic reforms that were

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Foxon, 2002:5). One should also note that the nature of R&D activities in developing countries sometimes differs from that of developed countries. This is mainly due to the fact that R&D in most developing countries is tailored towards absorption of technologies that are developed elsewhere rather than the development of their own innovations (Szogs et al., 2008:10).

[65] The Ministry of Communication, Science and Technology has the overall responsibility for coordinating all R&D activities in the country. However, other ministries are also mandated to oversee R&D activities in their respective areas of interest. Meanwhile, the National Commission for Science and Technology (COSTECH) advises the government on all matters that are linked to scientific research and technological development. COSTECH is also tasked with the coordination of research activities in the country (MCST, 2010:3; Bastos and Rebois, 2011:30).

[66] The latest data suggest that about 80 organisations are currently conducting R&D activities in various sectors in the country (ibid.).

adopted in the country from the mid 1980s have encouraged various private research organisations which now appear to be gradually participating in R&D activities (Bastos and Rebois, 2011:36). Examples of private R&D organisations that have emerged in recent years include: the Economic and Social Research Foundation (ESRF); the Tanzania Gender Networking Programme (TGNP); the Research for Poverty Alleviation (REPOA); the Society for Women and Aids in Africa- Tanzania (SWAAT); Ifakara Health Institute (IHI); the Tea Research Institute of Tanzania (TRIT); and the Tanzania Coffee Research Institute –TaCRI (MCST, 2010:4). However, it seems there are still significant challenges in promoting R&D activities in the country. Some of these challenges include insufficient funding of R&D activities in both public and private sectors, poor mechanisms for training and hiring researchers (i.e. capacity building), lack of a multidisciplinary approach to research and inadequate involvement of end-users and other stakeholders in R&D process as well as limited partnership between private and public sector institutions that are involved in research (MCST, 2010:6).

Most scholars in innovation studies suggest that cooperation between several different actors is key to successful innovation (Klerkx and Leeuwis, 2008:849). According to Howells (2006:716), "intermediaries" facilitate such cooperation in the innovation system because of their role in the technology transfer process[67]. The role of intermediaries in the innovation process was initially established in the field of diffusion and technology (ibid.). Earlier studies conducted by Torsten Hägerstrand and Everett M. Rogers found that "change agents had a powerful influence on the speed of diffusion and uptake of new products and services by household and firm adopters[68]" (ibid.). Thus, innovation intermediaries are perceived as independent third parties that serve the purpose of facilitating collaborative activities during the innovation process. As opposed to traditional extension and R&D, innovation brokering "represents the institutionalization of the facilitation role, with a broad systematic, multi-actor

[67] Intermediaries refers to "organizations that play a bridging role in the innovation system". Intermediary organisations are sometimes referred to in the literature as innovation intermediaries, innovation brokers, bridging institutions, third parties, superstructure organizations or innovation agents (Szogs et al., 2008:12; Metz et al., 2000:167). Howells (2006:720) has defined an innovation intermediary as "an organisation or body that acts [as] an agent or broker in any aspect of the innovation process between two or more parties". According to Klerkx and Gildemacher (2012:221) "innovation brokers are persons or organizations that, from a relatively impartial third-party position, purposefully catalyze innovation through bringing together actors and facilitating their interaction".

[68] As a geographer, Hägerstrand's main argument was based on the notion that the spread of an innovation across the landscape was the outcome of learning or communication process (Brown, 1981:18). Everett M. Rogers' diffusion of innovations theory describes the process in which an innovation is adopted in the social system. The theory focuses on issues such as awareness, knowledge, as well as attitude change to a new technology.

innovation systems perspective" (Klerkx and Gildemacher, 2012:221). According to Metz et al. (2000:167), technology intermediation reduces barriers to technology transfer. Some of the functions of technology intermediaries involve: information dissemination and communication, locating key sources of new knowledge as well as building linkages with the external sources of information[69] (ibid.). UNCTAD report clearly stipulates why channels of communication may spearhead the innovation process. According to this report, these channels can "build awareness of alternative technology energy sources" and "public policy regimes that can help or hinder transfer processes". This also includes establishing "incentive structures that permit co-operative arrangements among organisations that currently treat each other as rivals rather than as potential sources of new knowledge" (Clark, 2002:353-68).

I therefore argue, in this study, that the importance of these intermediary organisations has been mostly covered in studies that focus on Agricultural Innovation Systems as opposed to Renewable Energy Innovation Systems[70]. Most of the studies on agricultural innovation systems have focused on the ability of intermediary organisations to link actors of public, private and civil organisations, input suppliers, producers, transporters, traders, and international agri-food firms in an agricultural innovation system (Klerkx and Gildemacher, 2012:4). Empirical studies, for example, suggest that innovation brokers have played an important role in optimising interaction in Agricultural Innovation Systems as well as enhancing the innovation capacity of small farmers (Pérez et al., 2010). These findings support my earlier argument that although the literature has highlighted the role of intermediary organisations in facilitating cooperation between actors in the agricultural innovation systems, their role in the renewable energy innovation systems has not yet been sufficiently studied. This study aims to fill this gap by exploring how intermediary organisations in rural Tanzania can facilitate the transfer and adoption of renewable energy innovations. In particular, the study provides some insights on the role that can be played by rural cooperative societies and other local community-based organisations in the innovation

[69] This is what Howells (2006:719) terms as information scanning and gathering function, and the communication function. Intermediary activities include, among others: provision of information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator between bodies or organisations that are already collaborating; and seeking advice, funding and support for the innovation outcomes. "Intermediate organizations' main roles are to identify, locate and absorb knowledge that is relevant for the innovation system, to adapt it to new applications even in other sectors or industries and to transfer it to new users" (Szogs et al., 2008:13-14).

[70] See in *Int. J. Agricultural Resources, Governance and Ecology, Vol. 8, Nos. 5/6, 2009* "Strengthening agricultural innovation capacity: are innovation brokers the answer?" By Laurens Klerkx, Andy Hall and Cees Leeuwis

process. As will be later discussed in this study, a well-established co-operative society has the capability to serve several purposes in a community. It is argued that, among other things, a well-established co-operative society may utilise available resources and existing social networks to facilitate the transfer and adoption of renewable energy innovations. It is worth noting that, recent empirical studies suggest that innovation systems in countries such as Tanzania are characterised by weaker institutional frameworks and low levels of interaction between the main actors (Szogs et al., 2009:3). These studies indicate, for example, that the "Tanzanian National Systems of Innovation" is underdeveloped and characterised by weak linkages between various sectors in the national economy[71] (Mwamila and Diyamett 2011:172). The studies also suggest that even though the country's 'national systems of innovation' are still in their infancy (i.e. emerging), they have so far excluded users and other actors in the informal sector[72] (Piirainen et al., 2012:48). One important point to note, however, is that innovation systems in developing countries are in most cases seen as being heterogeneous, and this implies that every innovation system in each respective country is embedded in its unique socio-economic institutional context (Chaminade et al., 2010:2).

3.1.4 Weaknesses of innovation systems approach

Although this study has used an innovation systems approach as an analytical framework, it is important to note that the approach is yet to firmly establish itself as a formal theory in innovation studies. The innovation systems approach has been linked to the "general systems theory" that is more widely applied in natural sciences than social sciences (Edquist and Chaminade, 2006:111). However, at present, the main focus among innovation researchers does not rest on transforming the innovation systems approach into theory, but rather on maintaining its consistency and making it clearer to understand. It is believed that this will further strengthen its foundation and will assist researchers to generate hypotheses about relations between variables within innovation systems (ibid.).

Following the above discussion of the concept of 'innovation systems'; the following section summarises the arguments that link innovation, economic development and the

[71] See Burton L.M. Mwamila and Bitrina D. Diyamett (Tanzania: The Evolving Role of Universities in Economic Development) - Universities In Transition: The Changing Role and Challenges for Academic Institutions. Edited by Bo Göransson and Claes Brundenius

[72] It appears that activities in the current system follow a top-down approach in which bottom-up feedback mechanisms are lacking (ibid.).

concept of sustainable development[73]. The section first outlines how innovation and economic development are linked. Then it briefly explores the concept of sustainable development by introducing its three main dimensions. It is through the exploration of these dimensions that this section also establishes a base on which the connection between renewable energy innovations and sustainable development has been established throughout this study.

3.2 Innovation, Economic growth and Sustainable Development

It has long been argued that technological change is one of the determinants of economic development (Smith, 2009:1; Carlsson and Stankiewicz, 1991:93). However, some scholars argue that in order to understand the whole process of technological and economic change, we should first focus on the processes taking place at the micro level and that should, in most cases, include the role played by the entrepreneur (ibid.)[74]. Freeman (1988:330), for example, contends that although the 'technological gap' opened up by Britain during the industrial revolution can be attributed to the advancement in science and technology, and an increasing number of development blocks (i.e. a *cluster of innovations*) in the textile, iron and engineering industries, it also came about as a result of the improved ways of organizing production, combining invention with entrepreneurship, investment and marketing (ibid.). This leads Carlsson and Stankiewicz (1991:102) to suggest that economic growth at the macroeconomic level can be better understood if we study the interdependence between micro units and know how they are interlinked with other sectors of the economy. This line of thinking views the macro economy as constituting not only the sum of various micro units but also takes into account its "complex network of micro relationships". Thus, it is argued that firms and innovations alone cannot explain economic change in a society, and on that account they must be viewed as parts interacting with other parts of a larger system, assisted by the existing institutions (ibid.). It should be also noted that the main focus of most innovation studies is on the process in which "new technological forms are integrated into the economy" and the subsequent changes they bring into the structure of the economy (ibid.). For example, Metcalfe (1988:560) argues that economic or structural change as a result of the

[73] Rogers (2003:12) defines an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". In this study, the term innovation has been used to describe 'a new technology'.

[74] In this respect, the word 'micro' refers to firms, units within firms, or sometimes it refers to what is termed as development blocks i.e. clusters of firms and technologies (ibid.p.94).

successful transfer of a new technology may be analysed "from the macro development of an entire industry, to the micro level at which a new machine, or consumer good, is diffused to generate corresponding marginal changes in the behaviour of firms and individuals". Therefore, innovation is perceived to be the primary source of economic change or transformation in a country (Carlsson and Stankiewicz, 1991:95).

3.2.1 Defining the concept of Sustainable Development

There are suggestions that the main challenge to the transition to greener, cleaner and more equitable economic growth[75] is for innovation to focus on the three dimensions of sustainable development (Gjoksi, 2011). The preceding section suggests that innovation has for many years focused on the economic dimension of sustainable development, and as a result the social and environmental dimensions have for long been neglected. However, it appears that the current environmental and societal pressures have stimulated the rethinking of innovations in the context of sustainable development. This emanates from the fact that "the challenge for innovation does not rest solely on economic benefits and opportunities, but also in the societal changes induced by innovative capacity and the consequences of this for the environmental and social sustainability[76]" (ibid.p.7). Although technological innovations could help the rural areas to effectively respond to various challenges such as meeting energy needs, health problems, and natural resource management, most African governments have so far given little attention to environmentally friendly technologies, mainly due to market failure, inappropriate pricing, risks and lack of knowledge (Webersik and Wilson, 2009:408). However, innovative technologies for making more efficient use of energy must be encouraged if we are to improve the standards of living in sub-Saharan Africa. Although it is true that most activities relating to technological innovation in energy production and distribution are taking place in industrialized countries, there is an urgent need for developing countries to be also fully involved in the energy technological innovation process (Williams, 2001:50). This is especially important in sub-Saharan African countries if they are to achieve sustainable development.

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[75] Economic growth is a basic and necessary stage for rural development (Shepherd, 1998:90). This is due to the fact that increased rural incomes generate greater demand for goods and services; therefore rising household income is considered as a key to rural development (ibid.).

[76] Innovation could be in the form of technological innovation, organization, processes and management

But what is sustainable development? In the past few years, sustainable development has emerged as an important and contested concept in social science and other disciplines. Some scholars have argued, for example, that 'the term sustainable development' initially surfaced into public debates in the 1980s when it was first introduced by the IUCN[77]. The main aim at the time was to conserve and sustain ecological resources (Baker, 2006:18, Lélé, 1991). However, literature also suggests that sustainable development as a concept was for the first time recognised at the 1972 United Nations Conference on the Human Development in Stockholm, when members of the international community officially agreed that protecting the environment was one of the important components in the development agenda (Rogers et al., 2008:9; Carter, 2001:4).

Despite the fact that the concept may have surfaced in the 1970s and received international publicity from the 1980s, one could argue that the concept of sustainable development has been evolving for many years and its genesis could be traced way back to the eighteenth and nineteenth centuries[78] (Rogers et al., 2008:20; Baker, 2006:18). It was during this period, for example, when a British economist Thomas Malthus wrote his famous essay on population growth. Malthus argued that if the population growth was left unchecked it would surpass the food supply (i.e. lead to food shortage and deteriorating living standards), while referring to the growing population in the United States and what he termed as 'modern states of Europe' (Malthus, 1798:7). His argument was built upon the assumption that population always increases at a geometric rate while the food supply increases at an arithmetic rate (Rogers et al., 2008:20; Ekins, 2000:36; Malthus, 1798:6). Malthus wrote:

[77] International Union for the Conservation of Nature and Natural Resources

[78] Campaigns to protect the environment in western industrialised countries gained momentum in the 1950s and became more active in the 1960s and the early 1970s, amid growing concerns that industrial activities (in pursuit of economic development) were causing severe and negative impacts to the natural environment (Carter, 2001:4). Although people's concern about the relationship between environment and development could be traced back to the eighteenth century, the interest to protect the environment grew towards the end of the nineteenth century and the early twentieth century. It is at the same period when pressure groups such as the Sierra Club in the USA, the Royal Society for the Protection of Birds in the UK and Naturschutzbund Deutschland in Germany emerged (Carter, 2001:3, Rootes, 2007:15). This period also witnessed the publication of articles and books from environmental campaigners. This stirred international debate about the relationship between environment, development and population. Some of the well known writings from the campaigners which attracted the attention of the international community include the publication of "*Limits to Growth*" by Donella Meadows et al. in 1972 by the Club of Rome, *Silent Spring* in 1962 by an ecologist Rachel Carson (who wrote about the detrimental effects of the excessive use of chemical pesticides on plants and animals) and 'Tragedy of the Commons' in 1968 by Garret Hardin (Rogers et al., 2008:20, Carter, 2001:4, 41,164).

"We will suppose the means of subsistence in any country just equal to the easy support of its inhabitants. The constant effort towards population, which is found to act even in the most vicious societies, increases the number of people before the means of subsistence are increased. The food therefore which before supported seven millions must now be divided among seven millions and a half or eight millions. The poor consequently must live much worse, and many of them be reduced to severe distress" (Malthus, 1798:9).

Interestingly, it was during the nineteenth century that another British economist, William Stanley Jevons, was also concerned about the exhaustion of energy sources in Britain. In his book, The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal Mines, Jevons was worried about the depletion of British coal as that would have led to the collapse of British industry[79] (Ekins, 2000:38; Baker, 2006:18; Polimeni et al., 2008:7). However, Malthus, Jevons and other early scholars have since been criticised for underestimating the potential of science and technology to develop substitutes and/ or improve the efficient use of scarce resources (Ekins, 2000:39).

The concept of sustainable development attracted many analysts when it was further expanded to include social and economic dimensions of development by the World Commission on Environment and Development in its report published in 1987 (ibid.). The much publicized report, famously known as the Brundtland report, defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987: 54). The report explicitly stated that sustainable development encompasses three dimensions: social, economic and environmental sustainability (Rogers et al., 2008:42, Harper, 2004: 276, WCED, 1987). For the society to achieve sustainable development, all three dimensions need to be fully integrated and supported as they are "intimately interdependent" (Reed, 1996: 33).

3.2.3 Three important dimensions of Sustainable Development

The *social dimension of Sustainable Development* is derived from the perspective that all human beings should at least be able to have access to the basic requirements of quality of life which include security, human rights, health, education and shelter. To achieve social sustainability, the following conditions have to be met and these include: distributional

[79] See Appendix E: the debate about technological efficiency (in what has been termed as 'The Jevons' Paradox')

equity, social services, gender equity, population stabilization, as well as political accountability and participation (Rogers et al., 2008:58, Baker, 2006:38-45, Reed, 1996:36).

On the other hand, the *economic dimension of Sustainable Development* calls for economic growth that improves the living conditions of the people for the longest time possible, and not short-term economic policies that may lead to long term impoverishment. Economic analysts contend that in order to achieve economic sustainability, environmental effects are to be internalized in the production of goods and services with positive effects (benefits) being felt by all producers and consumers (ADB, 1997:55). Achieving economic sustainability requires governments, private producers and other stakeholders to "internalize the externalities[80]", and that is to include the social and environmental costs involved in the production and distribution of goods so as to realize the full cost of their products (Rogers et al., 2008:25, Reed, 1996:33,36). A good example of an externality is pollution resulting from technological innovations. Producers may operate at lower costs and make huge profits if pollution is not internalised in their costs of production. As a consequence, the impacts of pollution may lead to disastrous effects to the society as well as the natural environment (ibid.).

The *environmental dimension of Sustainable Development* calls for the sustainable use of our natural environment in a way that will not compromise the productivity of nature and / or cause harm to human beings in present or future generations. It calls upon the governments to implement the *precautionary principle* and make it an integral part of development initiatives so as to protect our natural environment (Reed, 1996:34). As one of the concepts in regulatory policies, the precautionary principle states that "lack of scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation[81]" (Carter, 2001:6). It is argued, for example, that governments should refrain from using technologies or implementing development projects when it appears that there might be a risk of serious and irreversible damage to natural environment and human health[82].

[80] Externality has been defined as "effects of an economic activity not included in the project statement from the point of view of the main project participants, and therefore not included in the financial costs and revenues that accrue to them" (ADB, 1997:198).

[81] Marxian analysts would trace the origins of environmental degradation as resulting from the process of using private capital to increase profit for the ruling capitalist class at the expense of the society's common interests. For example, Carter (2001:67) argues that "it is capitalism, characterised by the dominance of the competitive and dynamic market, the need to accumulate capital, the unbridled pursuit of profit, the use of destructive technologies and the hegemony of economic interests, which has created the contemporary ecological crisis".

[82] Even in circumstances when there is absence of scientific proof of such a risk or threat.

The aim of this section was to broaden our understanding and therefore making it easier for us to identify the connection between innovation and the concept of sustainable development. The section has briefly discussed the concept of sustainable development and how technological innovation is essential in fostering economic development. However, as pointed out above, while technological innovations may provide the means to achieve sustainable development, they could also be sources of uncertainties in the society[83]. Thus, to avoid or minimize such uncertainties, it is important to promote the use of more environmentally friendly technologies in rural areas such as renewable energy innovations. Environmentally friendly technologies could play a key role in achieving the economic, social and environmental dimensions of sustainable development. Although the majority of researchers and development experts agree on the need to incorporate environmental, social and economic goals if future development projects are to succeed, critics argue that sustainable development lacks conceptual clarity and this has caused misunderstanding of the concept[84] (Lélé, 1991:608; Reid, 1995: xv). According to Batie (1989), such misunderstanding has led to opposing theoretical interpretations of the concept from different schools of thought. For example, the concept of sustainable development requires governments to ensure that all people have access to "basic requirements of an acceptable quality of life" (Reed, 1996:33). Some scholars have argued that basic needs can be differently interpreted between various societies as these needs are sometimes socially and culturally determined (Baker, 2006:20). The main argument is that it is difficult to have the same definition of human basic needs as these can be treated differently across cultures. The critics also argue that the international community in an attempt to accommodate the definition of sustainable development tend to ignore social and cultural backgrounds of some societies so as validate the concept[85] (Redclift, 2000:2-3). However, some scholars argue that in most global cultures basic needs are similar and these needs include shelter, food, clean water, energy, health protection, security and freedom. However, critics argue that since the

[83] For example: pollution or other forms of environmental degradation from technological innovations.

[84] Although this section has focused on social, economic and environmental dimensions of sustainable development; Seghezzo (2009:547) has proposed other five dimensions of sustainability. He argues that "the conventional idea of sustainable development has a number of conceptual limitations and does not sufficiently capture some spatial, temporal and personal aspects" (ibid.p.551). Seghezzo argues that sustainability can be better understood in terms of 'Place', 'Permanence', and 'Persons'. "Place contains the three dimensions of space, Permanence is the fourth dimension of time and Persons category represents a fifth, human dimension" (ibid.p.539).

[85] Culture is considered as imperative to the way people interact with nature. It is through people's culture whereby one may be able to understand if their actions (i.e. socio-economic activities) are compatible with the concept of sustainable development.

'basic needs' change from one generation to another, it is unlikely that the needs for the present generation will be the same as those of future generations (Redclift, 2000:2). Others such as Reid (1995: xviii) have questioned whether it is useful to discuss sustainable development when the present generation does not know for sure what might be the needs of future generations. However, they raise an important question on whether sustainable development incorporates new features which may help solve our current problems which earlier models of development failed to address (ibid.).

On the other hand, Lélé (1991:613) has criticized the advocates of the concept for rejecting the notion that environmental conservation may constrain development or that development causes environmental degradation. While the concept of sustainable development calls for adequate provision of basic necessities (needs) such as food and shelter, but to acquire them one needs to utilize natural resources such as land and trees. This may cause loss in biodiversity and hence contradict the environmental dimension of sustainable development (ibid.). The concept of sustainable development has also been challenged for its weak characterization of the problems of poverty and environmental degradation, especially the mainstream perception that there is only a two-way link between poverty and environmental degradation i.e. poverty causes environmental degradation and vice versa (ibid.p.613). The main assumption underlying mainstream thinking is that poverty is the major cause of environmental degradation; hence development (i.e. alleviation of poverty) is necessary in order to achieve environmental sustainability.

3.3 Systems thinking and Sustainable Development

'Systems thinking' has on many occasions been used by researchers and policy planners to "*understand the connections and relations between seemingly isolated things*" within a system[86] (Haraldsson, 2004:4). "Systems thinking" is considered as one of the best ways to understand the root causes of the problems in the system (for example, the social system[87]). Therefore, it is through understanding the connections[88] between various parts of

[86] A system has been defined as a collection of multiple dependent variables (parts) that are connected to each other through causal relationships (Haraldsson, 2004:11; Harper, 2008:3). This is to say, that if one of the components (parts) of the system is altered in any way, the functioning nature of the system as whole changes (Proust, 2004:29; Haraldsson, 2004:11). Hall and Clark (2010:310) have defined a system as "an entity made up of interconnected elements, and has a boundary, which separates the inside from the environment". The interaction of components within the system and its dynamic behaviour can be better understood if we view a system as a whole i.e. treating all the components forming the system as being dependent on each other, and that altogether they make the system in question complete (Haraldsson, 2004:11).

[87] Various types of systems exist and these range from simple to complex systems. Examples may include ecological systems, social systems, biological systems or human-mechanical systems (McNamara, 2008;

the system that we may also be able to solve such problems within the system (Hjorth and Bagheri, 2006:74). 'Systems thinking' has won the hearts of many researchers around the world. For example, the 1990s witnessed changing trends among researchers as some shifted from single disciplinary research projects to multidisciplinary research and have since been using systems thinking as their methodological approach[89] (Bosch et al., 2007:218). Experts in the systems thinking field contend that in order to successfully implement policies, it is important that policy makers understand the issue at hand in terms of its connections to the system. According to Haraldsson (2004:13), the main principle of systems thinking is that the structure of the system determines its behaviour, i.e. development or failure[90]. Proust (2004:29) defines the structure of the system as the sum of "its network of causal relationships". The boundaries of the system are important in defining its structure. It is argued, therefore, that the solutions to problems are mostly found within the system itself, i.e. within the system boundaries. However, in some situations, we are compelled to expand our system boundaries so as to find solutions for the unresolved problems (Haraldsson, 2004:11). Within the system boundaries, components (or variables) of the system are considered as being very important in describing the system's behaviour (Proust, 2004:30; Rogers, 2003:25). Therefore, 'systems thinking' can be used as a conceptual approach in broadening our understanding of the concept of sustainable development, and its three dimensions (i.e. social, economic and environmental sustainability) as discussed earlier.

Haraldsson, 2004:11; Proust, 2004:29). Rogers (2003:23) defines a social system "as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. Members of a social system include individuals, informal groups, and organisations.

[88] In most cases, researchers use the causal loop diagrams (CLDs) to identify the relationships and feedback loops in the system (Hjorth and Bagheri, 2006:81; Haraldsson, 2004:5). Causal loop diagrams facilitate the process of understanding the source of the problem and at the same time suggesting what could be the likely solution in a more simplified way. CLDs have also proved to be useful in showing the characteristics of a system under study as well as describing its dynamic behaviour (ibid.).

[89] Sawyer (2003:1) argues that the history of systems thinking in sociology can be traced from Parsons' structural functionalism. However, he refers to structural functionalism as the first stage ("or wave") of the evolution of the systems thinking in sociology. This was followed by general systems theory of the 1960s and the complex dynamical systems in the 1990s (ibid.).

[90] According to Rogers (2003:25), the social structure of the system can facilitate or inhibit the adoption and transfer of new technologies in a social system. One aspect of social structure are norms, and these are used to define a range of behaviour that can be tolerated as well as serving as a standard for the behaviour of other members in the social system. Therefore, a system's norms can be a barrier to the transfer and adoption of new technologies (innovations) within the system. More importantly, norms operate at various levels such as a nation, a religious community, an organisation, or a local system such as a village (ibid.p.26).

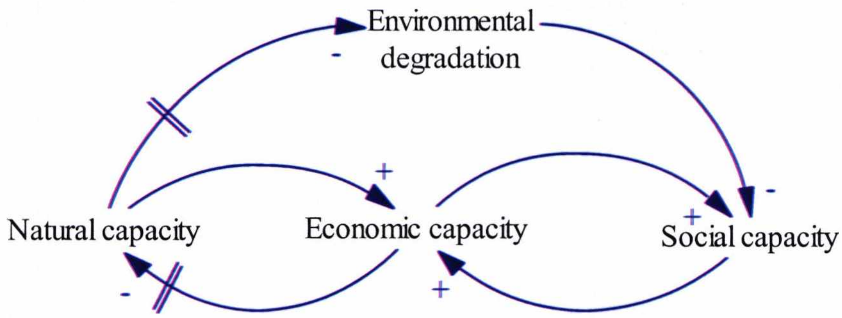

Figure 4: A Causal Loop Diagram showing the interaction between natural, economic and social sustainability[91] (Source: Adapted from Sverdrup and Svensson, 2004).

Figure 4 explains the relationships and feedbacks between the three dimensions of sustainable development (i.e. social, economic and environmental sustainability[92]). According to Sverdrup and Svensson (2004:144), natural sustainability "defines the maximum long-term use of a natural resource system as a source of raw material and energy and [its] capacity for destruction of waste and exploitation of living organisms". It means that the system's natural capability of self-reorganizing has to remain unchanged so that its natural biological diversity can be able to self-regenerate over time. To be sustainable, the population size of living creatures in the system must not exceed the system's capacity so as to avoid constraining its supply of available natural resources. For instance, human beings are considered to be an integral part of some of the ecosystems (i.e. the ones which they inhabit), and therefore it is very important to analyse their activities when contemplating the sustainability of the systems under study (ibid.p.147). The causal loop diagram above, (see figure 4) implies that the overuse of natural resources (i.e. natural capacity) as a result of economic activities would lead to negative feedbacks on the economy (i.e. economic capacity) as well as on society (i.e. social capacity) through environmental degradation and

[91] In the causal loop diagrams, variables (described as words) are connected by arrows (as shown in Figure 4) to illustrate the causal relationships between them in the system. In such diagrams, the arrow normally indicates causality between two variables. The causal relationships (connections) between the variables may be positive or negative. When two variables change in the same direction a positive (+) polarity or sign is used. For example, if the variable at the tail of the arrow increases, the variable at the arrow-head also increases. At the same time, if the variable at the tail of the arrow decreases, the variable at the arrow-head decreases. On the other hand, however, a negative (-) polarity is used when two variables change in opposite directions. That is, if the variable at the tail of the arrow increases, the variable at the arrow-head decreases and vice versa (Haraldsson, 2004:23). Arrows also represent time passing or "delays" in the system. A delay occurs when the anticipated action between two components in a system takes longer than other components in the same system. Such delays may be either shorter or longer depending on the varying circumstances within the system and "can range from seconds to days, centuries or millions of years" (ibid.p.30). Analysing the nature of delays in the system is considered to be very important because it helps the researchers to understand the behaviour of the system in question. The symbol // is usually used to indicate the delays within the system (ibid.p.30).

[92] For the purpose of this study, social capacity and economic capacity represent social and economic sustainability respectively while natural capacity represents environmental sustainability.

declining economy (ibid.p.146). On the other hand, "social sustainability defines the self-organizing stability systems of a social organization and its components. It defines the minimum requirement for system resilience, individual rights, limitations and duties for sustainability. It also defines necessary gradients and driving forces necessary for remaining stable, but still respecting individual integrity". Social sustainability is dependent on stability, support and protection, which are achieved through collective action. Evidence suggest that most of the countries that have faced, for example, problems resulting from environmental degradation, conflict in the use of resources and the appalling quality of life, appear not to have taken on board the information feedback from individuals about the redistribution of products, resources and wealth as well as the protection of personal integrity (ibid.p.148). Experience also shows that societies which prevent individuals from exercising their personal rights do not last longer because such systems are denied important mechanisms for relieving internal pressures and correcting errors. Personal integrity and respect should not be perceived as a peculiarity of western thinking, democracy or culture, but rather should be perceived as an important ingredient for the system's self social stabilization through social interaction (ibid.). Economic sustainability, however, is defined "in absolute value terms, derived from mass balance and economic feedback principles" (ibid.p.144). Sverdrup and Svensson (2004:149) argue, for example, that national economies can only be sustainable if they are balanced in the long-term. This means that any project carried out in the specific country must balance its anticipated profitability with the country's resources sustainability capacity. Any attempt to over-maximize the project's profitability in the short-term will ruin the system's resources base (ibid.) and so undermine its long-term sustainability and, ultimately, its survival.

3.3.1 Systems thinking and innovation systems

Using systems thinking, Hall and Clark (2010:311) have defined "an innovation system as both an economic and a knowledge system with flows of resources and information taking place among its component nodes and across its boundaries[93]". Thus, innovation systems are regarded as being evolutionary because they constantly receive new knowledge which shapes their behaviour (ibid.). As will be discussed throughout this study, in order to realise the full potential of rural renewable energy innovations in rural Tanzania, there is a need to address various social, economic and/or environmental barriers that affect the transfer

[93] According to Hall and Clark (2009), these resource flows comprise finance, materials and labour inputs while the knowledge flows include formal and tacit knowledge.

and adoption of the technologies in question. Research studies conducted in the country in recent years have identified a number of barriers that appear to hinder the transfer and adoption of renewable energy innovations. For example, one of the identified barriers is inadequate investment in R&D on renewable energy innovations from both public and private organisations. Projects involving large commercial and decentralized electricity generation from fossil fuels have however been receiving support from both the government and development partners (Kimambo and Mwakabuta, 2005). Since less attention has been paid to renewable energy sources, this has slowed down the transfer and adoption of renewable energy innovations in rural Tanzania. This is what is termed as a 'lock-in problem' in innovation literature[94]. Energy from fossil fuel sources serves as a good example of 'lock-in problems'. It is evident that the adoption and utilisation of energy from renewable energy sources such as solar or wind in most production systems is still inadequate due to the fact that such energy sources face stiff competition from the well-established existing technological systems based on fossil fuels (Edquist and Chaminade 2006:115). Technological systems based on fossil fuels are (in most cases) characterised by long periods of accumulated experience and therefore have benefited from evolutionary improvements, in terms of low operating costs, infrastructure, personnel skills, user knowledge, optimal institutional arrangements (i.e. social norms, regulations etc.) and vested interests, hence making them more efficient than their counterparts: emerging technological systems based on renewable energy sources (Hekkert, et al., 2007:415; Negro, 2007:15; Foxon, 2000:4). Therefore, technological systems based on fossil fuels seem to benefit from the comparative advantage they have over emerging renewable energy based technological systems[95]. Systems thinking as a conceptual approach could however be used to "explore opportunities

[94]'Lock-in' is a consequence of 'increasing returns' to adoption or positive feedback (of incumbent technologies), which in turn prevents the adoption of the potentially sustainable alternative technologies (Negro, 2007:15; Edquist and Chaminade, 2006:115; Hekkert et al., 2007:415; Jacobsson and Johnson, 2000:633; Foxon, 2002:2). This usually happens when the existing production system is overly dependent on a particular technology. As a result that prevents the expansion of a new form of technology (innovation). According to Foxon (2002:2), the term 'increasing returns' can be divided into four categories namely: scale economies, learning effects, adaptive expectations and network economies. Whereby scale economies refers to the situation in which unit production costs decline because an incumbent technology has strong establishment especially in terms of its infrastructure set up or fixed costs. As a result, firms may be reluctant to invest in alternative technologies. Learning effects (learning by doing) refers to the ability of incumbent technologies to improve the quality of products or reduce their cost because of the accumulated specialised skills and knowledge. Adaptive expectations refer to the increased confidence among users and producers as they become more certain of the quality, performance and the operating duration of the existing technology. While network or co-ordination effects refer to the advantages of which the agents or actors (i.e. firms, users, etc.) already have from the current technological system over a new technology.

[95] Foxon (2002:2) argues, for example, that "infrastructures develop based on the attributes of existing technologies, creating a barrier to the adoption of a more sustainable technology with different attributes".

to leverage technology deployments within existing and new energy infrastructure" (IEA, 2012[96]). In this context, systems thinking could assist researchers and policy makers to understand the problems associated with the transfer and adoption of energy technologies in a specific system. For example, 'systems thinking' as a mental model can help us understand the feedback mechanisms and the existing connections between energy needs, poverty and environmental degradation in rural Tanzania. At the same time, systems thinking can help to understand the interrelated factors that must be taken into account in order to solve any or all of these problems. As discussed in the previous chapters, experience in the country shows that it is very expensive and costly to have all rural areas connected to the national grid due to, among other reasons, the dispersed nature of most villages.

The causal loop diagram below (see figure 5) illustrates the current rural energy supply scenario in the country and how that has impacted the overall rural development. Evidence suggests that both the 'national grid based electricity systems' and 'decentralised mini-grid renewable energy systems' are not well established in rural Tanzania.

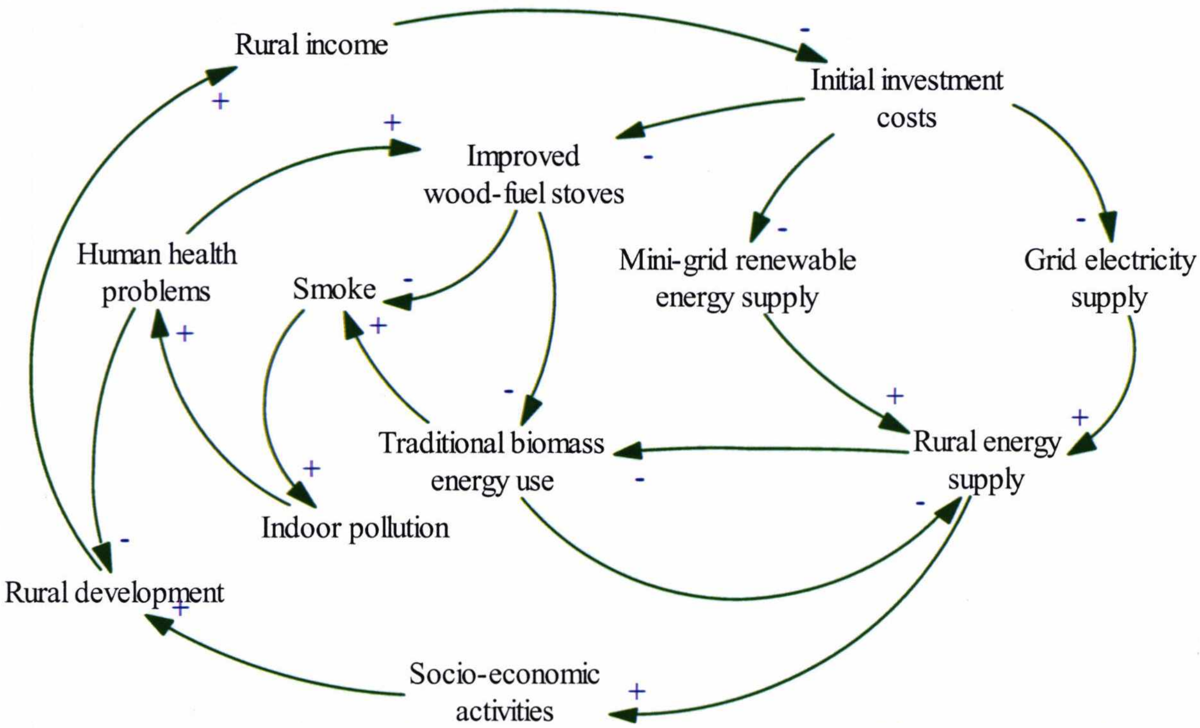

Figure 5: Dissemination of RETs in rural areas[97]

[96] Source: IEA 2012 fact sheet (Energy Systems-Tapping into synergies across sectors and applications)

[97] Adapted and modified from Dauda (2005)

Using systems thinking, the Causal Loop Diagram above illustrates how initial costs (as often claimed in energy studies) could either facilitate or hinder the transfer and adoption of renewable energy technologies in rural Tanzania. It shows that when initial costs to invest in renewable energy sources become higher, it is more likely that there will be less investment in mini-grid renewable energy systems in rural areas. The same scenario applies to grid electricity. From the causal loop diagram above, it may well be argued that the positive impact of an innovation into the social system is determined by its rate of adoption. As previously argued, higher initial capital to invest in the energy sources is one of the factors affecting rural electrification in the country. The failure to supply energy services in rural Tanzania may slow down socio-economic activities in these areas and that has implications for rural development. On the other hand, lower initial investment costs for either mini-grid renewable energy sources or grid electricity could boost rural energy supply. In turn, energy services in rural areas would stimulate socio-economic activities and rural development. The scenario above illustrates the importance of energy services for rural development. However, the successful implementation of rural energy projects and the role such projects could play in achieving sustainable development goals will very much depend on the rate at which specific technological energy systems are adopted in the country (i.e. fossil fuels-based technological systems or renewable energy-based technological systems). Hekkert et al. (2007:415), for example, suggest that technological change in a society is not necessarily very much influenced by simple competition between technologies; rather, technological change is largely dependent upon the competition between the existing innovation systems and emerging innovation systems. Therefore, renewable energy technologies have to compete with the current established fossil fuel based-technologies. It may well be argued that renewable energy systems would be successfully adopted in rural areas if they overcome the identified barriers. One possibility of overcoming such barriers is to integrate the environmental costs arising from fossil fuel-based technological systems into the market price so as to fully realise both the relative advantage and economic advantage of renewable energy sources (Negro, 2007:15-16). Some energy experts call for relatively lower taxes and import duties on renewable energy equipment to reduce the costs of such equipment. They anticipate that lower prices would encourage potential adopters in rural areas to adopt renewable energy technologies. Evidence shows that rural households in Tanzania use firewood, kerosene and charcoal as their major energy sources because they are relatively affordable. In most cases, the majority of the rural poor have not been willing or able to adopt renewable energy innovations such as solar PV systems because they are thought to be expensive. Ongoing government efforts to disseminate renewable energy technologies in rural areas have taken into consideration strategies aiming at addressing the affordability barrier. The recently established Rural Energy Fund is aiming at subsidising rural energy services and making energy services affordable to the rural population (Ministry of Energy and Minerals, 2003). Experience has also shown that the rural poor prefer lower initial costs of energy sources to lower long term costs (life-cycle costs), and as a result they tend to avoid efficient or convenient sources of energy due to the higher initial costs involved in acquiring or accessing such sources (Habtetsion and Tsighe, 2002). It is important to note, however, that the cost of renewable energy equipment may not be the only constraining factor. For example, a study on the adoption of solar systems conducted by Berkowitz and Haines (1980)[98] found that economic advantages alone are not the main reason for consumers to purchase solar systems since they also take into account other things such as reliability and safety. Rogers (2003:15), supports this view in what he describes as the "perceived attributes of innovations". Rogers contends that the rate at which innovations are adopted in the social system depends on the characteristics of an innovation in question and how such innovations are perceived by members of the social system. The perceived attributes of innovations include relative advantage, compatibility, complexity, trialability and observability as outlined below (ibid.).

Relative advantage: This has been described as the extent to which an end-user and other beneficiaries perceive an innovation in terms of economic benefits and social prestige, convenience and satisfaction. These factors are crucial for the rapid adoption of an innovation (ibid). It is therefore very important for adopters and other actors to perceive an innovation as being beneficial when they calculate the costs and time involved in their investment. The more advantageous the new technology is over the old technology, the more rapid its rate of transfer and adoption will be (ibid.). This happens as adopters perceive a new technology to be faster, cheaper, and more durable than the previous technology. A previous research study which sought to test the hypothesis on a gradual process of innovation adoption revealed that perceived advantages of energy-efficient innovations initially form the basis of decisions from the potential consumers or adopters (Karger and Bongartz, 2008). Barnes et al. (1996), also describe how households make their energy source choices based on factors such as

[98] As quoted in Karger and Bongartz (2008)

efficiency, cost, convenience and cleanliness. In such cases, for example, if renewable energy technologies prove to be efficient and economically viable, they are more likely to be adopted quickly than fossil fuel energy sources or technologies.

Compatibility: Rogers (2003:15) describes compatibility as the degree to which potential adopters perceive an innovation as being consistent with their existing values, needs and past experiences in the social system. According to Rogers, an innovation that does not alter the existing values and norms is more likely to be adopted by individuals in the social system. Although the energy choices of the rural poor might be very much influenced by their income, there are cases where cultural factors may also influence their decisions. Furthermore, Rogers (1995:11), argues that an individual's decision to adopt a new technology is a gradual process which sometimes may take time depending on the nature of the technology.

Trialability: Trialability is the degree to which an innovation is first experimented with on a limited basis before it can be widely adopted in a social system (ibid). It might be a necessary process for potential adopters before they make a decision to adopt an innovation. It is envisaged that demonstration projects on solar systems in rural Tanzania which are funded by UNDP and Sida in collaboration with the Ministry of Energy and Minerals would facilitate the rate of transfer and adoption of Solar PV innovations in the country. Experience has shown that potential adopters in rural areas have sometimes been discouraged from adopting new technologies because of their past negative experiences with sub-standard renewable energy equipment (Mwihava, 2002).

Observability*:* Observability refers to the situation whereby the results of an innovation may be easily visible to others in the social system. "The easier it is for the individuals to see the results of an innovation, the more likely they are to adopt" (Rogers, 2003:16). Recent initiatives in the country by telecommunication/mobile phone companies, health centres and schools to install solar photovoltaic (PV) systems may attract potential adopters in rural areas.

I therefore argue that it is through 'systems thinking' that we may be able to identify other factors that are inhibiting the transfer and adoption of renewable energy innovations in rural Tanzania. 'Systems thinking' serves as a useful approach in understanding both simple and complex systems (Bosch et al., 2007:218). As Harper (2008:10) argues, a systems perspective is not only fundamental to ecology (i.e. natural sciences), but it has also proven to be very useful in the social sciences. He contends, for example, that human beings as well as other species are connected with everything else in a system and therefore any human activity is likely to affect other parts of the system in question. Although, traditionally, many environmental issues have been "treated discretely as separate policy problems", that is slowly changing in recent years. This emanates from the fact that there has been an increasing tendency to examine the connections and relationship between human society and natural world in a holistic way. This environmental discourse (holism) holds that, "rather than examining individual issues in isolation, [the focus should be] on the interdependence of environmental, political, social and economic issues and the way in which they interact with each other" (Carter, 2001: 3-19). Harper (2008:36) also argues that "human causes of environmental change are themselves a complex system that not only produce changes in global ecosystems, but cause changes in each other through complex feedback mechanisms". That means the world's physical environment, ecosystems and human social systems are today interconnected and interdependent (ibid.p.37). This holistic perspective is also supported by Hjorth and Bagheri (2006:75) in their study about sustainable development, which implies that we can only have a better understanding of innovation systems, the current environmental issues and the concept of sustainable development if "systems thinking" is used as our methodological approach.

Summary

This chapter has reviewed the literature on innovation and technology transfer with the purpose of providing the analytical framework that has guided the discussions throughout this study. The chapter has explored the emergence of innovation systems as an approach and how this new approach to study innovations has gained popularity in academic contexts. Systems thinking and the innovation systems approach represent an alternative perspective towards achieving sustainable development. The chapter has also discussed the status of R&D activities in Tanzania and how that has been evolving since the colonial period. This includes the impact of macroeconomic reforms on R&D activities in the country. However, in this chapter, the particular attention is on the role of innovation brokers in facilitating the innovation process in the innovation system. I argue that although the importance of innovation brokers (intermediary organisations) has been mostly covered in studies that focus on Agricultural Innovation Systems, studies that cover the role of the intermediaries in renewable energy sector in sub-Saharan Africa are still lacking. Therefore, this study seeks to contribute both theoretically and in practice to our understanding of renewable energy innovations, especially the role of innovation brokers in facilitating innovation process within the rural context of developing countries. Also, using systems thinking, this chapter has presented the connections between innovation, social change and sustainable development.

Chapter 4: Methodology

This chapter discusses the overall research design and methodology used in this study. It is in this chapter where I discuss the research process, illuminating both my background and the choices made during the course of this research. Here I describe the qualitative as well as the quantitative methods that I have used for data collection and transformation, and try to offer a basis which would better enable the reader to have an insight into the thesis.

I should state from the beginning that the following section is not what could be termed a detailed discussion of the pros and cons of all the research methods that can be used by the field researcher. Rather, it is more an effort to reflect on the research process in general, and to be more specific, on my own role in this research process. To begin with, I will first provide some background information about myself as a researcher and my perspective on the research process. I admit that the latter may have influenced, in one way or another, how I have undertaken this research. I will then describe in detail the research methods I have used as this will show the reader not only what I have done during the fieldwork, but also why was it done.

In addition to environmental studies, I have a background in development studies – two disciplines that, I may argue, are connected and can hardly be separated, as they have both influenced the way I have conducted my research. Generally, I am much interested in the wider debate about development issues; thus I am convinced that the existing social systems are more or less influenced by what began in the enlightenment period. It was widely believed during the enlightenment period that the problems in society could be easily contained through technological transformation and the use of scientific knowledge. That belief is still held in most social systems today. Thus, it rarely comes as a surprise to me when I come across conflicting views about how best we could address the current environmental problems. It is important to note, however, that such views emanate from different schools of thought and as such you may, for example, find some scholars who publicly treat capitalism as the decisive model for change and solutions of the current environmental problems. As Ortner (1984:142) argues: "at the core of the model is the assumption that virtually everything we study has already been touched ("penetrated") by the capitalist world system, and that therefore much of what we see in our fieldwork and describe in our monographs must be understood as having been shaped in response to that system".

What makes it more interesting, however, is what I came across during the course of my fieldwork. On several occasions, the people I met in the study area asked about the purpose of my research and how their villages were going to benefit from my research findings! As a reminder, however, it is worth mentioning that the debate about the environment and development, and especially "the interrelationship between environmental protection and economic development" as elaborated by Martinussen (2004:147), has been a major inspiration for my study, though not so much in the way I chose the topic for my research, or all the theories used in this thesis, but more so for my views about the concept of sustainable development.

Doing research is like knitting a fabric of relations and processes. It is an encounter between the researcher and the 'world' that is being researched, whereby elements of class, education and gender are all brought together and connect with each other during the research process. This chapter, therefore, explains how I commenced my research and what has shaped my perspective about some issues I came across with during my fieldwork study. Upon reflecting about my fieldwork visit to the villages in Magu District where I have interviewed and conversed with villagers in different periods, I have had to trace my own methodological and epistemological understanding as an analyst of social reality. The first time I visited villages in the study area and interviewed people was in July, 2004. Although, the fieldwork conducted in 2004 was intended for another research study, the research topic studied is related to what has been covered in this study. That said, I will now discuss the research process as it happened, a reflexive experience in which I felt much as an observer interacting not only with people in rural areas but also with government officials, donor agencies, private sector and other stakeholders in renewable energy projects.

To answer the research questions and meet the set objectives, a number of methods were employed in this study. Investigations into the factors that may influence transfer and adoption of renewable energy innovations in rural areas were based primarily on questionnaire surveys, interviews, focus group discussions and a review of the secondary literature. As anticipated from the beginning of this study, the literature review also played an important role in contextualising this research within the social science perspectives.

4.1 Qualitative and quantitative approaches

As I have noted above, the methods of data collection and data analysis techniques employed in this study combine both qualitative and quantitative approaches. According to Hall et al. (2012:582), combining qualitative and quantitative methods not only helps in measuring impacts of an innovation in a social system but it also enables respective researchers "to understand and learn from institutional and process changes". Spielman (2005:33-4) supports this view by arguing that innovation systems approach (as applied in this study) relies on a diversity of rigorous qualitative and quantitative methods because such methodological diversity brings credibility and strength to the study of innovation systems. Spielman further argues that innovation literature is currently "characterised by a wide variety of systematic, replicable, and consistent tools of analysis, including in-depth social and economic histories; policy benchmarking, cross-country comparisons, and best practices; statistical and econometric analysis; systems and network analysis; and empirical applications of game theory [etc.]" Therefore, in this section not only that I discuss the ontological and epistemological foundations of qualitative and quantitative approaches in social science research but I also explain the strengths as well as the weaknesses of employing these two approaches in this study[99]. In my view, the ontological and epistemological considerations that a respective researcher holds about social reality frames the way the research is undertaken since that may influence his/her choice of methods in a specific study. Thus, it is from such an assumption that I consider my values and background in social science to have greatly influenced my choice of methods and theories I have used in the whole process of conducting my research and therefore this bias should be kept in mind when reading this thesis.

4.1.1 Quantitative Approach

Quantitative research is predominantly rooted in the epistemological position referred as **positivism** which "advocates the application of the methods of the natural sciences to the study of social reality" (Bryman, 2008:13). That is to say, this positivist paradigm advocates objectivity of the researcher and use of quantitative methods as the only valid scientific

[99] Blaikie (2000:8) defines ontological assumptions as "claims and assumptions that are made about the nature of social reality, claims about what exists, what is looks like, what units make it up and how these units interact with each other. In short ontological assumptions are concerned with what we believe constitutes social reality". On the other hand, epistemological assumptions refer to "the possible ways of gaining knowledge of social reality, whatever it is understood to be. In short, claims about how what is assumed to exist can be known" (ibid; Grix, 2004:63).

method in studying social phenomena. In most cases, positivism applies a 'deductive approach' in which theories are used to generate hypotheses that can be tested thereby allowing their verification or rejection (ibid.p.22). The epistemological assumption under the positivist paradigm is that we can only confirm or reject a theory through the discovery of 'real facts' i.e. collection and analysis of 'hard data'. Such epistemological position assumes that the world is composed of facts; therefore these facts tend to speak for themselves and can be reduced into concrete and measurable units (Gibbs, 2005:139). Quantitative research is thus conceived as a research strategy that tends to emphasize quantification in the collection and analysis of data. It is a research strategy that "uses techniques that apply more to numerical data" (Grix, 2004:117; Bryman, 2008:22). According to Grix (2004:117), quantitative research is characterised by three fundamental stages such as finding **variables** for concepts, operationalisation of variables in the study, and measurement of variables. Measurement allows researchers to describe differences between concepts. Thus, measurement "provides the basis for more precise estimates of the degree of relationship between concepts[100]" (Bryman, 2008:144). Variables or concepts developed by researchers are measured and converted into specific data-collection techniques (Grix, 2004:117). Such techniques include identification of general patterns and relationships among variables, testing theories and hypotheses, and prediction based on the findings. Numerical information resulting from such techniques can be conceived as the empirical representation of the concepts (ibid.). It should be noted, however, that while some statistical packages and models may require a researcher to have a high level of mathematical knowledge, packages such as SPSS (Statistical Package for Social Science) do much of the work of calculation. The most common types of research methods used in quantitative research include social surveys, analysis of official statistics, questionnaires, structured interview schedules, attitudinal scales, quasi-experiments and randomised control trials (Gibbs, 2005; Grix, 2004:118).

4.1.2 Limitations of Quantitative Research

One of the weaknesses of the quantitative approach has been its inability to measure 'quantitatively' some aspects of social reality i.e. behavioural phenomena. Quantitative research "relies heavily on concepts in the pursuit of measurable phenomena"; however critics argue that there are some aspects of social reality which cannot be measured by statistical techniques. According to critics, to be overly dependent on quantitative methods

[100] Bryman (2008:143) defines concepts as the building blocks of theory that represent the points around which social research is conducted.

can lead researchers into neglecting "the social and cultural context in which the variable being measured operates" (Grix, 2004:118). This emanates from the fact that the quantitative methodologies tend to ignore the complex economic, political, and social structures that act upon spatial patterns (Marshall, 2006). At the same time, Bryman (2008:159) argues that many quantitative research methods rely heavily on administering research instruments such as structured interviews and self-completion questionnaires to the subjects. In such cases, therefore, it may prove difficult for a researcher to know if survey respondents have prior knowledge to a question that is being asked. Critics also reject the claim that quantitative research is value free. According to these critics, it is not possible for a researcher to be fully detached from any type of social research or offer a value free analysis. This is because the researchers are "the sum of their accumulated knowledge" as they are part and parcel of the society. Hence their values, experiences and motives tend to inevitably influence their research (Marshall, 2006; Grix, 2004:117).

4.1.3 Qualitative Approach

On the other hand, qualitative research is grounded in what is termed the **interpretive** paradigm. Proponents of interpretivism advocate for "a more interpretive and contextual viewing of reality". They argue, for example, that "social phenomena are socially constructed, context influenced and reveal multiple interpretations" (ibid.p.139). Thus, qualitative research provides researchers with an opportunity to investigate and understand the meanings assigned to various events from the viewpoints of the participants in a respective social system. It "emphasizes words rather than quantification in the collection and analysis of data" (Bryman, 2008:22). In other words, qualitative research is construed as a research strategy that encourages giving meaning to textual data and spoken words (ibid.). According to Pope and Mays (2006:4), a qualitative research is "concerned with the meanings people attach to their experiences of social world and how they make sense of that world". As individuals we may sometimes differ in the way we interpret our experiences and this emanates from the fact that individual experiences are influenced by a complex process involving social, cultural or institutional factors. It is therefore argued that employing a qualitative approach enables researchers to interpret such conflicting and competing views about social reality. In other words, qualitative approach seeks to establish contact between the researcher and the researched as a means to discover social reality. Research methods used by interpretivists to collect data include interviews, observations, documents, audiovisual data etc. In some cases, numerical measurements can be involved although these methods do not heavily rely on such measurements (Grix, 2004:120; Gibbs, 2005:140).

4.1.4 Limitations of Qualitative Research

Critics argue that qualitative studies are usually small-scale, and therefore cannot be generalised beyond the case that is being investigated. It is argued that the inability to generalise from small samples puts into question the validity of the findings from qualitative research. Qualitative research is also criticised for its lack of objectivity, a scenario that could attract personal opinion rather than evidence to support the arguments. Critics argue that qualitative research is too impressionistic and subjective, implying that "the qualitative findings rely too much on the researcher's often unsystematic views about what is significant and important" (Bryman, 2008:391; Grix, 2004:121). Thus, critics tend to label qualitative research as being unscientific; and that it attracts bias and manipulation.

4.1.5 Combining quantitative and qualitative research methods

According to Bryman (2008:604), the idea that quantitative and qualitative research are separate paradigms and represent distinctive epistemological positions, has caused debate about combining quantitative and qualitative research methods. Such views tend to imply that the two research approaches cannot be combined because of their differences and distinctive epistemological positions. Hence, some scholars argue that "mixed methods research is not feasible or even desirable" (ibid.). Other writers, however, contend that while it is true that some research methods are clearly confined to either quantitative or qualitative analysis; most research methods can be used in both quantitative and qualitative research. Although these two approaches have distinctive epistemological underpinnings, these writers argue that the combination of the two approaches increases chances of attaining the best possible results from the research investigation (Grix, 2004:123). While an epistemological argument views quantitative and qualitative research as being incompatible, a technical version about the nature of quantitative and qualitative research views the two research strategies as being compatible. As opposed to the epistemological version, research methods are perceived as autonomous thus a research method from one research strategy is capable of being applied in another research strategy (Bryman, 2008:606). For example, as discussed later in this study, the measurement of households' perceptions and attitudes (i.e. towards renewable energy innovations), household characteristics etc. involved a combination of both qualitative and quantitative research. Although mixed methods research cannot be considered to be an approach that is universally applicable, it provides a better understanding of a social phenomenon than when only one research strategy is employed (ibid.). Some researchers in innovation studies argue that diversity in the choice of methods would serve to strengthen literature on innovation systems (Spielman, 2005:35). Some of these scholars, such as Hall et al. (2012:584), argue that a major step towards mixed methods would be realised if researchers in innovation studies "increase the use of rigorous quantitative methods in qualitative studies (quantitative analysis informed by qualitative insight) or the use of qualitative data in quantitative studies". As previously stated in chapter one, this study investigates the factors that influence innovation processes in rural Tanzania. As the study applies an innovation systems framework, I opted for the mixed methods research[101] mainly due to the varied nature of the data that was required as well as various sources from which such data had to be collected. The combination of qualitative and quantitative research was also meant to achieve the idea of 'triangulation[102]'. As earlier mentioned, since the study requires a wide choice of methods, using a single research strategy would have probably led to inadequate data and misinformation. However, through triangulation I was able to cross-check the study findings and as a result my confidence in the results was enhanced. Proponents of mixed research methods argue that the validity and credibility of the study findings increases when such results are cross-checked between the two research strategies (Bryman, 2008:611).

4.2 Data collection methods

4.2.1 Sample size and sampling process

The target population in this research was the households in all villages of Magu District. During the course of my visit to the chosen villages, I sought permission from the village leaders and hamlet leaders. I also used the opportunity to request the list of the names of household heads from the village leaders. However, the exercise was not as quickly done as I had earlier anticipated because most of the villages either did not have updated household records or lacked such records altogether. For example, on my arrival at one of the first chosen villages and having introduced myself to the village leaders, I requested the list of

[101] Combination of research methods from both quantitative and qualitative approaches

[102] According to Bryman (2008:607), triangulation "refers to the use of quantitative research to corroborate qualitative research findings or vice versa"

household heads and the leaders assured me of the accuracy of the list provided. On the contrary, however, during the course of my survey, I discovered errors in the recorded information on the list of household heads. The errors included misspelt names of household heads or inaccurate numbers of household members presently living in the household. Interestingly, in the process, I also noticed that some villages had lists of names from the households that had participated in various activities that had taken place in the respective villages, including, among others, health training programmes, small scale businesses, local elections, and tree planting. Nevertheless, I was later to realise that such lists did not necessarily include all households currently present in those villages. It should also be noted that the household members I am referring to in this study were those living and/ or depending directly on the household, and therefore married children were excluded.

The sample households for this study were selected on the basis of a probability sampling. This sampling strategy includes simple random sampling, systematic sampling, stratified sampling and cluster sampling (Blaxter et al., 2004:163; Blaikie, 2009:201; Kothari, 1990:15). This technique was applied because it has proved to be among the techniques that provide a fair representation of the population under study. The technique enables the researcher to ensure that the chosen participants are representative of the entire population, due to the fact that it allows each unit of the population to have an equal probability to be included in the selected sample (Bryman, 2004:90). Hence, for this study, a probability sampling procedure provided a strong possibility of an equal chance for each household to be represented in the sample to be studied. It was during the field visit that I conducted in 2008 (July - September) when it became obvious that it would have been an uphill task to create a sampling frame of all households in Magu District, since such an exercise could have been expensive and time consuming. With that in mind, I opted to use the lists of households from the 2002 population census and administrative records to compile the list of households in the villages in the hope that that would give me a reasonably accurate depiction or a snapshot of the population in the study area.

MAGU DISTRICT POPULATION DISTRIBUTION IN 2002

Ward	Type	Male	Female	Total	Number of Households	Average Household Size
1. Kisesa	Mixed	13,368	14,164	27,532	4,626	6.0
2. Bujashi	Rural	5,649	5,830	11,479	1,842	6.2
3. Lutale	Rural	9,214	8,947	18,161	2,919	6.2
4. Kongolo	Rural	6,116	6,056	12,172	2,148	5.7
5. Nyanguge	Mixed	4,698	5,263	9,961	1,803	5.5
6. Kitongo	Rural	5,128	5,279	10,407	1,885	5.5
7. Mwamanga	Rural	5,298	5,437	10,735	1,605	6.7
8. Kahangara	Rural	7,700	8,035	15,735	2,694	5.8
9. Nyigogo	Rural	8,490	8,866	17,356	2,845	6.1
10. Mwamabanza	Rural	3,021	3,086	6,107	934	6.5
11. Sukuma	Rural	7,222	7,666	14,888	2,529	5.9
12. Lubugu	Rural	5,764	6,234	11,998	2,013	6.0
13. Kiloleli	Rural	7,495	8,179	15,674	2,832	5.5
14. Mwamanyili	Rural	7,316	7,874	15,190	2,746	5.5
15. Shigala	Rural	5,071	5,600	10,671	1,793	6.0
16. Kabita	Rural	8,281	9,203	17,484	3,555	4.9
17. Kalemela	Mixed	12,215	13,172	25,387	4,760	5.3
18. Mkula	Rural	12,433	13,461	25,894	3,980	6.5
19. Igalukilo	Rural	5,344	5,922	11,266	1,819	6.2
20. Ngasamo	Rural	8,263	8,979	17,242	2,560	6.7
21. Malili	Rural	6,815	7,060	13,875	2,223	6.2
22. Badugu	Rural	5,173	5,521	10,694	1,596	6.7
23. Nyaluhande	Rural	3,736	3,974	7,710	1,248	6.2
24. Ng'haya	Rural	8,329	8,616	16,945	2,612	6.5
25. Nkungulu	Rural	9,433	10,111	19,544	3,049	6.4
26. Shishani	Rural	11,899	12,418	24,317	3,643	6.7
27. Magu Mjini	Urban	8,606	9,083	17,689	3,806	4.6
District Total		**202,077**	**214,036**	**416,113**	**70,065**	**5.9**

Table 3: Magu District population by Gender, Number of Households, and Average Household Size

Source: Tanzania National Bureau of Statistics (The United Republic of Tanzania, 2002 Population and Housing Census)

Table 3 above shows the household distribution as indicated in the 2002 population census for Magu District. As can be seen in the table, 23 wards are considered as 'rural', one ward as 'urban' and the remaining 3 wards as 'mixed implying they possess both 'urban' and 'rural' elements. However, the criteria of categorising these wards into 'urban' and 'mixed' categories could not be immediately established at the time, as all wards seemed to be predominantly rural except Magu Mjini. The number of households from the 2002 population and housing census (in some cases) was matched to the number of households in the list provided by village leaders. Therefore while conducting the field visits (household surveys), corrections were made to the list of households by adding new names of household heads and deleting those who were no longer living in the village. The selected villages were from the listed wards in which the population count and a total number of households in the district are shown in Table 3 above[103].

As it was also quite obvious that I could not survey all the villages in the study area, the villages were grouped into three clusters (cluster 1, 2 and 3) in line with Magu District administrative structure and on the basis of their geographical location and distance[104]. Magu District is divided into six divisions which make 27 wards with 125 villages. The first cluster comprised Sanjo and Kahangara divisions, the 2nd cluster Itumbili and Ndagalu divisions, and the 3rd cluster consisted of Busega and Kivukoni divisions. A random selection of villages was done in each of the three clusters, whereby 15 villages were chosen altogether. In this case, at least four villages were chosen from each cluster (i.e. Kongolo, Kahangara, Nyanguge and Nyamahanga from cluster 1; Sakaya, Mwamabanza, Kabila, Ndagalu, Jinjimili, and Mahaha from cluster 2; Ihale, Yitwimila 'B', Sanga, Mkula and Kijilishi from cluster 3). This was followed by a random selection of the sample households from the selected villages. At this stage, both stratified and systematic sampling techniques were used in picking the sample households to be included in the study.

The multi-stage cluster sampling procedure as explained above is supported by Bryman (2004:94) who argues that the technique may be very useful when used in a large district or an area with dispersed population since it allows an interviewer to cover a wider geographical area. Stratified sampling involves selecting groups of households (strata) according to specific criteria and then using simple random or systematic sampling in each of the selected subgroups (Bryman, 2004:92; Babbie, 2008:227). Stratified sampling was mainly used to identify employed household heads such as teachers and health workers. On the other hand, employing a systematic sampling technique in this type of probability sampling,

[103] See appendix D for the list of all villages and their corresponding population (number of households)
[104] See the map in annex 1

involves selecting every *k*th unit in a list for inclusion in the sample. For example, using a systematic sampling, a researcher may select every 15th household on the list or every 10th household on one side of a street (Babbie, 2008:224; Kothari, 1990:15). Although, I was compelled to do some random selection from time to time due to the nature of the villages in the study area, using these sampling procedures made it fairly easy to identify households to be included in the sample.

Village

Village		Frequency	Percent	Cumulative Percent
Valid	Kongolo	9	8.5	8.5
	Kahangara	8	7.5	16.0
	Nyanguge	9	8.5	24.5
	Nyamahanga	7	6.6	31.1
	Sakaya	5	4.7	35.8
	Mwamabanza	6	5.7	41.5
	Kabila	6	5.7	47.2
	Ndagalu	5	4.7	51.9
	Jinjimili	7	6.6	58.5
	Mahaha	7	6.6	65.1
	Ihale	8	7.5	72.6
	Yitwimila B	7	6.6	79.2
	Sanga	8	7.5	86.8
	Mkula	7	6.6	93.4
	Kijilishi	7	6.6	100.0
	Total	106	100.0	

Table 4: Sample household heads

As seen in Table 4 above, a sample size of 106 households was selected from 15 villages with probability proportional to the number of households in each of the selected wards. A cluster sampling strategy was also used in the process of drawing a sample in the villages that covered wider areas. Some of these villages lacked lists of households and were as well identified as either having higher population or scattered households. This process involved grouping the hamlets (also known as vitongoji) in terms of their geographical location in the village. It was therefore from these randomly selected hamlets that I also systematically picked the households to be included in the sample. This was done to avoid extra costs and save time as it would have been costly and probably time consuming to list all households in the village taking into account that many village administrative offices did not have accurate number of households. In some cases, heads of selected households could not be found during the course of the survey. However, that was not considered as a major hindrance as an additional household was systematically selected from the prepared list in the respective village.

It is, however, important to note that in this study, household heads have been referred to as 'the major decision makers' in the household irrespective of their gender (i.e. male or female headed households). Rural development analysts argue that accurate information about the households is imperative in policy formulation and for the governments to effectively design, implement and evaluate development projects. For example, in anthropology and other social science disciplines, households are considered as important locations for the study of families, gender, demography, human development, the economy, migration, urbanization and social hierarchy (Burton et al., 2002:65). Similarly, previous research studies in the country have indicated that the household is not only a main unit of production and consumption in the rural areas, but also a basic social unit that helps a researcher to collect the necessary data for analysis and has therefore been used as an analytical unit for this study.

4.2.2 Questionnaire

The collection of primary data at the household level (both qualitative and quantitative) was done through the use of questionnaire-based surveys. The questionnaires used in this study were first developed in the English language. However, the language used during the survey was Swahili (Kiswahili) since it is widely spoken and understood by the majority of the respondents in the study area. The main local language spoken in Magu is 'Kisukuma', reflecting the fact that the 'Sukuma' are the main ethnic group in the area. The questionnaire was in the form of an interview with structured questions (face to face interviews), one of the prominent techniques for data collection in social surveys (Bryman, 2004:109).

Babbie (2008:291) argues that face to face interviews, in some cases, may allow the interviewer to attain higher response rates as opposed to mailed self-completion questionnaires. This is because the presence of an interviewer not only minimizes the risk of respondents misunderstanding the questions but also because some respondents may feel uneasy about turning down the researcher's request for an interview (ibid.). According to Yin

(1994), questionnaire-based surveys are mostly used to survey group characteristics, experiences and attitudes of the respondents towards specific research issues. I therefore, used the questionnaire to collect information on rural household characteristics and source of income, household energy needs and problems associated with energy use, barriers limiting the adoption of renewable energy innovations, perceptions and attitudes towards renewable energy innovations, and the rural households' awareness about sustainable utilisation of natural resources.

In some cases, while conducting interviews, I noticed that some of the respondents seemed to provide what I can best term as 'polite conditioned responses': answers that were intended to please the interviewer. This was not the first time I encountered such a situation as the problem was also experienced in my first visit to the study area in 2004. The likely question that may come into someone's mind is: why would respondents give 'polite answers'? The immediate explanation, however, may lie in the social and natural problems facing Magu District that have attracted researchers from several disciplines to visit the area. It is important to note that a number of studies that include various aspects such as agriculture, natural resources management, health issues and socio-demographic structures have been carried out in Magu district. Due to the fact that various research studies have been conducted in the area, some respondents have accustomed themselves to providing polite responses that seem likely to please the interviewer or meet the interviewer's expectations. However, another and perhaps more general and valid explanation for polite responses could be traced to the cultural background and tradition of the Sukuma. Politeness to visitors/guests is characteristic of the Sukuma culture and this might also have influenced their 'polite responses'. In such circumstances, much of the information obtained could be biased and diverted from the reality on the ground. Therefore, in situations where respondents were perceived as providing 'polite conditioned responses', a series of probe questions were asked and this led to a rather longer interview session than initially anticipated.

The questionnaire survey was complemented by informal discussions with village leaders, agricultural extension workers, villagers and local businessmen. In some cases, some of the issues could be easily spotted by direct field observation. For example, if during the interview a respondent stated that he/she uses a solar photovoltaic panel or an improved cooking stove (majiko sanifu) as sources of energy in the household, I would request a respondent to show them to me after the interview. According to Yin (1994), a research strategy that involves a field visit, creates an opportunity for the researcher to directly observe the reality on the ground. Informal discussions and direct field observations were used as means of cross-checking some of the responses from the formal interviews and also getting detailed information relevant to the study. The aim of these discussions was also to elicit local views on the possibility of initiating community/village level renewable energy projects to support small scale rural industries and to gain a wide understanding of the social and economic context of the study area.

The questionnaire was divided into sections whereby each section was used to collect the required data[105]. Part **A** of the questionnaire included the background information such as age, occupation, sex and education of the household head (i.e. the main decision maker in the household). As previously argued by Burton et al. (2002:66), during the process of collecting the household census data, field researchers tend to record the age and gender of household members, their relationships and other individual attributes such as occupation, income, education, and religion. However, not all of the mentioned individual attributes are always deemed relevant; in general, researchers would include such attributes if they find them to be useful or necessary to their topics.

Part **B** of the questionnaire was meant to seek information about the rural households' knowledge and perceptions on renewable energy innovations. Part **C** of the questionnaire intended to evaluate what households perceive as necessary conditions that may facilitate the transfer and adoption of renewable energy innovations in the study area. Part **D** assessed household awareness on environmental problems. The questionnaire was designed before commencing my fieldwork. The review of secondary data played an important role in designing the draft questionnaire. However, I felt that it was not sufficient to determine the parameters of the questionnaire to be used in this study. Therefore, the research instrument was pre-tested in the villages near Mwanza town prior to the actual field visit. The pre-testing enabled some modifications to be made to the original questionnaire to suit the study area, and some questions were dropped or reorganised. The responses of respondents involved in the pre-testing exercise were not included in the actual study as their participation was intended for testing purposes only.

The first field visit was conducted from July to September, 2008, when 59 household heads were interviewed. This was followed by another visit from April-May 2010 in which I

[105] See Appendix B for the questionnaire

successfully interviewed 47 households. The majority of respondents were cooperative during the interviews. Each interview lasted an average of 20 minutes. In order to ensure that the information provided by respondents was accurately recorded, some interviews were audio-recorded. However, the audio-recording very much depended on the consent from the respective respondents and also how comfortable they felt with it. In situations where respondents seemed to be uncomfortable or felt threatened in any way, audio-recording was avoided. It should be noted, however, that the selected household heads were first informed of all important details about the survey. It was at that juncture that they were able to understand what would be their role in the whole survey process. At the same time, they were advised about their right to respond or refuse to answer the questions asked or even to quit the interview session. This was done on purpose so as to create a more relaxed atmosphere in which the respondents could answer the questions comfortably and with confidence. Interestingly, in one occasion, before I had a chance to introduce myself, I remembered having been referred to as a journalist by one of the respondents. The respondent went on to ask whether the interview was going to be aired on radio! On average, due to the dispersed nature of some households in the study area, 5 interviews were conducted per day.

4.2.3 Focus group discussions and secondary data

Focus group discussions complemented the questionnaire and were used to obtain opinions and views from participants. Participants were given a number of questions to discuss and my role was to probe and prompt views from them during the discussions. These group discussions were recorded and later transcribed so as to make sure that the viewpoints of the participants are correctly taken. On the other hand, informal discussions as well as direct field observations were used as means of cross-checking some of the responses from the formal interviews and also getting detailed information relevant to the study. Documentation and archival information from government reports, legislation and policy documents were also used as sources of information. Information relevant to the study was collected from government agencies, libraries, non-governmental organisations (NGOs) and other stakeholders. I had the opportunity to meet the government officials from the Ministry of Energy and Minerals, an official from the Lake Victoria Environmental Management Programme (LVEMP), and private dealers in renewable energy technologies. I managed to get evaluation reports from the UNDP/GEF project on solar PV in Mwanza and also had a discussion with the then National Project Coordinator for UNDP/GEF project on Transformation of the Rural Photovoltaic (PV) Market.

4.3 Data analysis techniques

The primary data collected from study area was summarized and categorised into variables so as to ease its presentation. The data was then coded and entered into PASW Statistics (Predictive Analytics Soft-Ware) version 18 for Windows (also known as SPSS i.e. Statistical Package for Social Science). Analysis of descriptive statistics for all variables was first carried out so as to identify entry errors. Descriptive and inferential statistics were then used to describe numerical characteristics of all variables, identify relationships between variables as well as providing information for carrying out further statistical analysis of data. This process involved univariate analysis, bivariate analysis and multivariate analysis. Bryman and Cramer (1994) have presented an important discussion about the various ways in which a social scientist may analyse and present information that relate to a single variable (univariate analysis) and/or information which connects two or more than two variables (i.e. bivariate analysis and multivariate analysis), including the researcher's ability to recognise the different forms that such variables could take. To illustrate their point, the authors suggest, for example, that "the social sciences are concerned with variables and with expressing and analysing the variation that variables exhibit" (ibid.p.64).

4.3.1 Univariate analysis

Bryman (2008:322) defines univariate analysis as "the analysis of one variable at a time". That means exploring one variable in a data set at a time which mostly involves describing and summarizing the main characteristics of some phenomenon in terms of distributions (Blaikie, 2004:29). Univariate analysis involves measurement of the main three characteristics of a single variable i.e. *central tendency, the distribution, and the dispersion.* The most three common measures of central tendency include the arithmetic mean, the median, and the mode.

The arithmetic mean

The arithmetic mean is calculated by adding up "the value of the variable for each case and dividing the sum by the number of cases" (de Vaus, 2004:220). The arithmetic mean is by far the most commonly used method of measuring central tendency and can only be suitable for interval/ratio variables. Although it has proved to be useful even in more powerful statistical techniques; critics point at its main limitation which lies in its vulnerability to extreme values. It is argued that the arithmetic mean can be distorted by very high or very low values which in turn can respectively inflate or deflate its magnitude. However, some experts have suggested that when variables are perceived as skewed or contain extreme values, the median could be used as one of the alternative options. This is due to the fact that the median tends to ignore the extremes of a distribution. Other alternative options for addressing extreme values may include transforming the distribution or excluding the outlier (Bryman and Cramer, 1994:82-84; de Vaus 2004:220-222).

The median

The median is the mid-point in a distribution of values which is obtained by ranking cases from low to high on the respective variable. It normally divides a distribution of values into two equal halves (i.e. parts) and can only be used for ordinal and interval variables (ibid.). The median is therefore considered as not being an appropriate measure for nominal-level data (Blaikie, 2004:69). Nominal (sometimes known as categorical) data are usually related to qualitative variables or attributes such as gender or ethnicity, "and are merely records of category membership, rather than true measurements" (Kinnear and Gray, 2010:2). However, ordinal data are records of quantitative variables which are ordered in the form of ranks; for example, respondents may be categorised into four categories such as highly skilled, fairly skilled, semi-skilled and unskilled (ibid.). Nevertheless, interval/ratio variables (also called scale or continuous data) are perceived to be the highest level of measurement when compared with the other two levels of measurement i.e. ordinal and nominal variables. This is because interval/ratio variables are inherently open to a wider variety of statistical tests and procedures. One notable example is when "an interval/ratio variable like age is grouped into categories - such as 20-29, 30-39, 40-49,50-59, and so on - it becomes an ordinal variable" (Bryman and Cramer, 1994:66). Interval/ratio variables include heights, weights, age etc.

The mode

The mode is one of the common three measures of central tendency, despite the fact that it is rarely used in most of the research reports. It is the value that occurs with the highest frequency in a distribution and is the only measure of central tendency that can be used at any measurement i.e. ordinal, nominal and interval/ratio variables. However, it is not considered as being suitable for measuring central tendency since it does not use all the values of a distribution and is highly dependent on the way categories of a variable are combined (de

Vaus 2004:219; Bryman and Cramer, 1994:85). For example, it cannot be easily interpreted when there is more than one mode in a distribution (ibid.).

Measures of dispersion:

Dispersion is used to describe the characteristics of a distribution by looking at how widely it is spread. In such case, the three most common measures of dispersion are the range, the variance and the standard deviation.

Range

Of these three measures, the range is believed to be the easiest to calculate and understand since it only requires a researcher to take the highest and lowest value in a distribution and to subtract the latter from the former. In its simplest definition, the range refers to the difference between the highest and lowest value in a distribution i.e. maximum and minimum. However, like the arithmetic mean (as discussed earlier), it can be easily distorted by extreme values in a distribution. When that happens, extreme values must be removed from a distribution in order to avoid distorting the range (Blaikie, 2004:77; Bryman and Cramer, 1994:85; de Vaus, 2004:223).

Variance

According to de Vaus (2004:224), the variance and standard deviation are commonly used in conjunction with the mean for interval variables. Variance is defined as a measure of the extent to which the values in a distribution vary or differ from the mean of the respective distribution. It is argued, for example, that the larger the variance is, the more the distribution would differ on average from the mean. This measure is usually provided by statistical packages such as SPSS and is widely used in parametric statistical tests. Parametric tests refer to tests of significance which assume that values in a distribution are normally distributed (Cramer and Howitt, 2004:178).

Standard Deviation

Bryman and Cramer (1994:87) suggest that the standard deviation is the most commonly used method of summarizing dispersion. This is because the method is useful in calculating the average amount of deviation from the mean i.e. the degree to which the values in a distribution differ from the arithmetic mean. The method also can use all of the values in a distribution. However, the standard deviation can also be distorted by extreme values, although the distortion may be less when compared with the range because its calculation is influenced by the number of cases. Despite that, the method is widely used in research reports and is recognised as the main measure of dispersion. Thus, for researchers, the standard deviation remains the first choice whenever a measure of dispersion is required. It is also important to note that in most cases (as mentioned earlier); the standard deviation can only be used to measure dispersion for interval variables (ibid.p.88).

In univariate analysis, the **distribution** refers to "the way in which characteristics (values) of a variable are distributed over the sample or population" (Cramer and Howitt, 2004:52). The distribution summarizes the frequency of individual values for a variable; and the commonly used way of describing a single variable is through the construction of a frequency distribution or frequency table (Bryman and Cramer, 1994:76). The frequency distribution informs the researcher of the number of cases in each category (ibid.). It is therefore worth noting that univariate analysis served the purpose of examining single variables from the data set used in this study, as will later be shown and discussed in the analysis chapter[106]. However, univariate analysis alone could not demonstrate the relationships between the single variables in the data. In order to establish whether such relationships exist, it was important to also use bivariate analysis.

4.3.2 Bivariate analysis and Multivariate analysis

Bivariate analysis involves "the simultaneous analysis of two variables" (Cramer and Howitt, 2004:16). Evidence from previous studies suggests that with bivariate analysis, most researchers have been able to establish the existence (or lack of) such connections (relationships) between two variables in their respective data set. In doing so, a researcher would either establish similarities or differences between the characteristics of categories of objects, events or people; or would be in a position to describe patterns or connections between such characteristics (Blaikie, 2004:29). According to Cramer and Howitt (2004:16), the inferential statistics which involve two variables include two-way chi-square, correlation, unrelated *t* test and ANOVA. On the other hand, multivariate analysis entails the examination of three or more variables at the same time (ibid.).

4.4 Strengths and limitations of case study research method

Case study research has proven particularly useful for studying innovation systems as well as evaluating various innovation projects. According to Bryman (2008:52), case study

[106] See Empirical results and Analysis

research "entails the detailed and intensive analysis of a single case", such as a community or organization. Case studies facilitate in-depth understanding of what is being studied, as "the emphasis tends to be upon an intensive examination of the setting" (ibid.p.53). In other words, a researcher employing a case study method closely examines the data within a specific context. Case studies frequently use a mixed methods research (i.e. a combination of both quantitative and qualitative approaches), although they are sometimes wrongly associated with qualitative research (ibid.).

However, critics have questioned the "external validity[107] or generalizability of the case study research" (Bryman, 2008:391). They argue that the scope of the findings of the case study research is restricted in focus; hence such findings are unrepresentative and cannot be generalized to other settings. Nevertheless, other authors argue that it is possible to generalise from case studies. Bryman, for example, argues that "the findings of qualitative research are to generalize to theory rather than to populations", implying that "it is the quality of the theoretical inferences that are made out of qualitative data that is crucial to the assessment of generalization" (ibid.p.392). On the other hand, I also believe by employing a mixed methods research in this study, some of these limitations were overcome.

Summary

This chapter has discussed how this study was undertaken and the challenges I encountered during the fieldwork. The chapter has focused on the overall research design and methodology used in this study. First, it discusses the ontological and epistemological considerations of both qualitative and quantitative research and explains the strengths and weaknesses of employing the two approaches in social science research. The chapter then describes the qualitative and the quantitative methods that have been used for data collection and transformation in this study i.e. it discusses different methods of data collection and why such methods were chosen for this particular study. This is followed by a discussion about the strengths and limitations of a case study research and why a case study method was chosen for this study.

[107] The ability to apply the results outside of the specific research context

Chapter 5: Empirical Results and Analysis

This chapter presents the survey findings and describes the socio-economic and demographic characteristics of the households in the study area. The chapter analyses the respondents' knowledge and perceptions about renewable energy innovations as well as their awareness about environmental problems and factors that may influence the adoption of renewable energy technologies in the study area. By applying an innovation systems perspective, the chapter also examines the importance of involving households in the innovation process and shows how such involvement may have wider implications for promoting renewable energy innovations in the case study area.

The chapter is divided into three sections, with some of the sections being further divided into subsections. The first section of this chapter is section 5.1 which discusses the socio-economic characteristics of the selected households in the study area. It analyses the importance of household characteristics as key determinants of household involvement in the innovation process and adoption of new technologies. This section is divided into the following subsections: 5.1.1; 5.1.2; 5.1.3; 5.1.4; and 5.1.5. Subsection 5.1.1 deals with sources of household income and occupation of the sample household heads. This is because income and occupation have a significant effect on household involvement in the innovation process as well as on the adoption and use of renewable energy innovations in the study area. Subsection 5.1.2 analyses education of the household heads in the study area. In this subsection, the level of formal education attained by household heads was used as a proxy for their ability to effectively interpret and utilise information about renewable energy innovations. Subsection 5.1.3, discusses the gender relationships within the households in the study area. In this subsection, I look at the roles that are performed by men and women in the study area and how these roles may influence the adoption of renewable energy innovations. Subsection 5.1.4 analyses the age of the sample household heads. Age of the household head is used as a proxy for experience in innovating and adoption of innovations (i.e. learning by doing). The age of the household head may therefore have either a positive or negative effect on adoption of renewable energy innovations as will be further discussed later. Subsection 5.1.5 analyses the household size. Household size may influence the household consumption of energy. Larger households not only are likely to have higher household energy consumption levels but are also thought to consume more from the common resources (i.e. forests). The next section in this chapter is section 5.2 which is divided into two subsections.

Subsection 5.2 analyses households participation in renewable energy initiatives and discusses the role that can be played by innovation brokers in facilitating the linkage between various actors in the study area. On the other hand subsection 5.2.1 discusses the importance of cooperative societies in enhancing rural innovation and how they may facilitate the adoption of renewable energy innovations in rural Tanzania. Section 5.3 summarises the major findings of this study.

5.1 Household Characteristics

In order to measure the socio-economic status of the households in the study area, I have opted to use proxy variables such as the age structure of the household heads, gender, education, primary occupation, income and household (family) size. Socio-economic characteristics of the households have been frequently cited in the literature as among the factors that influence the adoption of new technologies in rural areas. In these areas, household heads make decisions and distribute authority among household members. Therefore, this study initially assumed that socio-economic characteristics of the households in the study area partly influenced their decision making on consumption, savings, labour power[108] and their general involvement in the innovation process. A household in this study is defined as a group of people who share the same shelter, and other basic human needs such as meals (i.e. from the same pot), cultivate the same land and recognise the authority of the household head[109]. In the Sukuma tradition, household heads are the major decision makers in their homesteads and therefore were considered as the main sources of information[110]. By using a household as a unit of analysis, this study will broaden our understanding about the innovation process from the micro level. That is, the information collected from the households will play a major part in broadening our understanding about rural innovation and other innovation-related activities in Magu District.

[108] The ways in which labour is organised within the household could also be an important factor in determining how household members participate in the innovation process. For example, understanding the division of labour within the household is important when trying to introduce innovations such as 'improved cooking stoves' and solar PV systems.

[109] See chapter 1(section: 1.4.3). It must also be noted that the term 'household head' in this study refers to anyone who is considered as the final decision–maker in a respective household.

[110] However, additional information from other household members was in some cases also used to complement the information collected from the household head. This is due to the fact that the choices that are made or taken by members of the household are mostly driven by their determination to achieve the goals of the household as a whole.

5.1.1 Household income and Occupation of the household heads

Household income

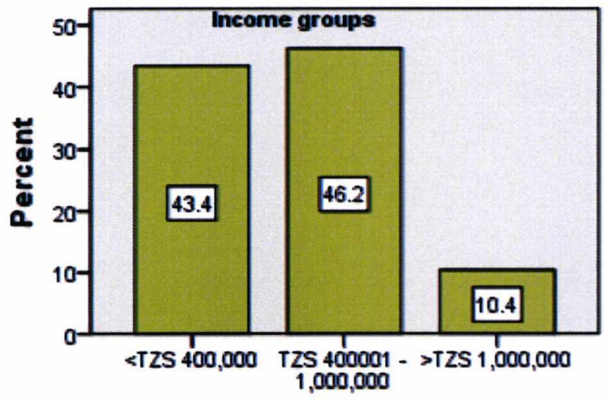

Figure 6: Distribution of income (sample households)

Figure 6: Distribution of household income

In this study, incomes of the sample households were categorised into three groups (see Figure 6). The first group comprised of (what I have termed) a low-income group with an average annual income not exceeding TZS (Tanzanian shillings[111]) 400,000 followed by the middle group with an average income of between TZS 400,001 to 1,000,000 while those in the upper income group have an average annual income of more than TZS 1,000,000. Figure 6 above, also shows the distribution of household incomes among the income group categories. The low-income group constitutes about 43.4% of the sample households while the middle group income makes about 46.2% of the sample. On the other hand, about 10.4% of the sample households make up the upper income group. Income categorization was done so as to get an overview of income distribution of households.

Annual income

N	Valid	106
	Missing	0
Mean		653,773.5849
Median		500,000.0000
Mode		400,000.00

Table 5.1: Mean annual household income

[111] When the surveys took place, 1 UK Pound Sterling was equivalent to about TZS 2,400 while 1 US Dollar equalled about TZS 1380. However, exchange rates for both Pound Sterling and US Dollar have risen since and currently stand at about TZS 2550 and TZS 1595 respectively.

Although the mean annual income for the interviewed household heads was TZS 653,774 (see Table 5.1), the median value was chosen instead. This was due to the fact that about 28% of the respondents reported incomes that were higher than the mean and one respondent reported the highest annual income of TZS 6,000,000. It is important to mention that having been in the study area before as a researcher, this didn't come as a surprise[112]. It was likely that I would encounter extreme values in a distribution because I was dealing with income data for a group of household heads, who not only have different sources of income but who may sometimes also not wish to mention their actual household income. The annual average household income was calculated by summing the estimated income earned by individual household members in each of the selected households. This included income from farm activities, income from non-farm activities and income from formal employment. But it must be noted that determining the exact income of each member of the household was very challenging, especially in the case of income from non-farm activities. On the other hand, income from farm activities could be easily estimated. This is because farm income in most households in the study area is administered by the household head. Income earned by members of the households who are in formal employment was also easy to record because they knew their exact salaries or wages. However, the whole process excluded other household members such as young children, school children and those unable to work such as the elderly and disabled.

Household income and adoption of energy innovations

Previous findings in most household energy surveys suggest that income is one of the major determinants of energy transition in the household[113] (Macht et al. 2007:5). If the cost of purchasing a solar PV system or making (building) an improved cooking stove is perceived as being higher than expected by the households, it would usually turn away the majority of the potential adopters as they cannot afford the required direct cash payment. In this study, for example, solar PV systems were found to be mostly adopted by households in the middle and, especially, the upper income groups (see Table 5.1.1 below):

[112] In case of extreme values in a distribution, the median is often used in preference to the arithmetic mean to avoid distortion of the study findings by a single outlying value.

[113] According to Mytelka et al. (2009:1750), energy transitions refer to "those processes that involve changes to 'new,' 'clean,' 'sustainable,' or 'energy-efficient' technologies and the formal and informal institutions required to support them". The general hypothesis in the 'energy transition ladder' is that household energy choice or preference is mostly influenced by household income. This perspective suggests that low income households depend on traditional fuel sources such as firewood or animal dung as their primary sources of domestic energy; however they tend to switch to alternative or more sophisticated sources of fuels once their incomes improve.

Income group categories * Energy for lighting? Cross-tabulation

			Energy for lighting?	
			Kerosene	Solar power
Income group categories	Low income group	Count	46	0
		Expected Count	43.8	2.2
		% within Income group categories	100.0%	.0%
	Middle income group	Count	47	2
		Expected Count	46.7	2.3
		% within Income group categories	95.9%	4.1%
	Upper income group	Count	8	3
		Expected Count	10.5	.5
		% within Income group categories	72.7%	27.3%

Table 5.1.1: A contingency table showing the association between income and energy source

Table 5.1.1 above indicates that there is some level of association between income and the source of energy used by households for domestic lighting purposes in the district[114]. The pattern of the frequencies in Table 5.1.1 is noticeably seen to support the predominant hypothesis (i.e. energy transition ladder) that household preference and choice of energy sources are largely influenced by income. The results from the contingency coefficient, phi coefficient and Cramér's V as indicated in Table 5.1.2 below confirmed the presence of association between two variables.

[114] There is at least a slight difference between the observed and expected cell counts (frequencies) in each of three income group categories, which suggests some kind of association with energy source. Although the observed and expected cell counts in Table 5.1.1 give some indication of association, this could only be confirmed by applying correlation coefficients such as **the contingency coefficient**, **phi coefficient** and **Cramér's V** to measure the strength of association between income group categories and domestic energy source for lighting. The above correlation coefficients are normally appropriate for measuring association in nominal data i.e. qualitative variables.

Symmetric Measures

		Value	Approx. Sig.	Exact Sig.
Nominal by Nominal	Phi	.373	.001	.004
	Cramer's V	.373	.001	.004
	Contingency Coefficient	.350	.001	.004
N of Valid Cases		106		

Table 5.1.2: The strength of association between income groups and energy source

As can be seen in **Table 5.1.2**, all correlation coefficient measures have indicated that there is association between income group categories and domestic energy source for lighting[115]. However, it is worth noting that most of the households in the study area still cannot afford the high initial costs of acquiring solar home systems. Empirical evidence from sub-Saharan Africa suggests that one of the main obstacles to the transfer and adoption of solar PV innovations (at least in the past few decades) has been the price in terms of megawatts per kWh and high costs involved in building the solar panel infrastructure (Harper, 2004:257). For instance, a 50 Wp (watts-peak) solar home system cost between $500 and $1000 which was (and is still) very expensive to most of the rural poor in developing countries (Krause and Nordström, 2004:9). Although the cost of solar panels have declined in the past few years, it is still likely that lower household income is limiting energy choices in the study area[116]. Most of the interviewed households perceived solar PV systems as being very expensive as was explained by one of the respondents:

"Demonstrations were conducted in our village. We now have electricity from the solar PV system that has been installed in our dispensary recently. I wanted to have a solar PV system installed in my house but could not afford the costs. I initially thought it was cheaper because when I first heard about solar energy on radio, they did not talk about the costs involved. When I saw the technicians from UNDP installing the solar PV system in our village dispensary, I told them of my desire to have a solar PV system in my house. However, they started asking about how many light bulbs I need in my house, what appliances I want to use etc. I then realised that I could not afford it and abandoned the idea."

[115] In this table, Cramér's V coefficient of .373 indicates a medium-strength association between two variables in accordance with Cohen's table for interpreting the effect size index. In his guidelines for interpreting the effect size index *w*, Cohen categorised the values into .1, .3, and .5 as small, medium and large effects respectively (Kinnear and Gray, 2010:413; Cohen, 1988:224). According to Cohen, a value less than .1 is considered trivial, while a value between .1 and .3 is a small effect. However, a value between .3 and .5 is a medium effect whereas a value of at least .5 is considered as a large effect (ibid.).

[116] It is worth noting that solar PV systems are considered to be cost effective over time and more importantly environmentally friendly when compared with non renewable conventional sources of energy (Miller, 2004).

Although lower household income partly constrains the adoption of renewable energy innovations such as solar PV systems in the study area; this does not appear to be the case with improved cooking stoves. A similar statistical procedure (cross-tabulation) was also performed to detect a pattern in the relationship between income and a type of stove used by households for cooking (see Table 5.1.3 in Appendix A). However, after examining the strength of relationship between income and the household adoption of stoves, it appears that in this case income does not influence their choice or preference for stoves. This is supported by correlation coefficient measures as shown in Table 5.1.4 below:

Symmetric Measures

		Value	Approx. Sig.	Exact Sig.
Nominal by Nominal	Phi	.204	.619	.611
	Cramer's V	.144	.619	.611
	Contingency Coefficient	.200	.619	.611
N of Valid Cases		106		

Table 5.1.4: The strength of association between income groups and household stove adoption

In Table 5.1.4 above, Cramér's V coefficient of .144 indicates a small-strength association between the two variables. The weak association between these two variables suggests that there are other factors than income in the district that affect household choice of energy source for cooking (these factors are further discussed in section 5.1.2 in this chapter).

Micro-credit institutions as a source of household income in the study area

What appears to be an important observation, however, is that most of the rural households in the district do not have access to credit institutions. This study found that since bank services are still very limited in Magu district, the majority of the households had little or no access to any form of credit from commercial banks or other lending institutions. These financial institutions hardly operate in off-grid villages. Even, worse is the fact that most low income households do not have collateral assets that might be used in securing loans other than their land; hence it is often difficult for them to get credit from the commercial banks because experience has shown that these banks find it difficult to recover their money in the event of a default by borrowers[117].

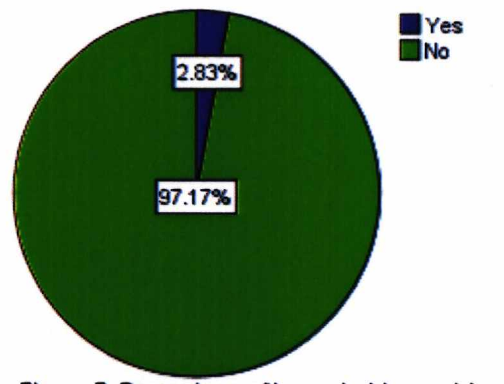

Figure 7: Percentage of households receiving loans from SACCOs

Figure 7: Household receiving loans

As shown in Figure 7, only 2.8% of the household heads admitted to have received credit from microfinance institutions. The loans are administered by the Savings and Credit Cooperative Societies (SACCOs) existing in some villages or ward centres in the district; for example Kabila SACCOs (known as Benki Kata Kabila)[118]. However, the study found that most of the loans received from the existing microfinance institutions were not directly linked with financing renewable energy technologies, with the exception of Magu Teachers' SACCOs, which helps teachers with loans to purchase and install solar PV systems[119]. As mentioned earlier, this is because some of the microcredit organisations in the district do not perceive installing solar PV systems as being a viable lending option. According to the World Bank (2006:47), such perception emanates from the fact that these "financial organisations usually are forgotten in the analysis, design and implementation of interventions that aim to

[117] Experience in the country has shown that most commercial banks are also not willing to offer long term loans to rural households at affordable interest rates due to the fact that most of these banks rely on customers' deposits in order to give out loans. For example, most local banks in the country charge interest rates ranging between 10% and 20% depending on the nature of the loan sought by the customer. Such interest rates may be higher for most individuals or households in rural as well as urban areas. Although in some cases the banks may have funds available for loans, they may still hesitate to invest in rural energy markets directly. This is because rural energy projects are perceived to be inherently risky and banks may not be willing to invest in projects that appear unlikely to offer immediate financial gains i.e. by a short payback period.

[118] Empirical evidence suggests that suggest that Savings and Credit Cooperatives or Credit Unions have greatly contributed to the development of rural finance in South Korea, Taiwan, and Kenya. SACCOs are mostly mutual membership organisations that involve pooling together voluntary savings and lending the same to the respective members (Bee, 2007:29; von Pischke et al., 1983).

[119] These loans are repaid through their monthly salaries by deducting the agreed amount on an instalment basis, and as a consequence the majority of rural dwellers who are not in formal employment are often left out.

strengthen innovation capacity". Thus, well-established local organisations may be used to administer loans and advise households on how to repay their loans. This will in turn enable households in the study area to opt for renewable energy equipment that matches their income and cash flow. A credit model for solar PV systems in **Box 1** represents an example of how these financial organisations may encourage rural households to adopt renewable energy innovations.

Box 1: Credit model for solar PV systems[120]

A consumer credit is referred as a short-term loan which enables the borrower to purchase goods (ISES, 2009). In this case, the customer secures a loan agreement with a financial institution to acquire a PV system from a solar energy company or dealer. There are two main categories under the credit model: these are dealer credit and instalment credit. With the dealer credit, the customer pays for the PV system through a credit directly given by the system provider (i.e. solar energy company) and the main parties involved are the customer and the supplier. The dealer credit system is thought to be popular in Sri Lanka and Indonesia and has contributed to wide scale adoption of PV systems in these countries. However, under instalment credit arrangements, the customer pays for the PV system on a credit received from the financial institution and channelled through the solar energy company (ibid.). Other subcategories which could fit into the credit model[121] include: hire purchase (salary withholding schemes), loans through savings and credit cooperatives (SACCOs) and subsidies to consumers (Krause and Nordström, 2004). Subsidies to renewable energy consumers are currently being offered in countries such as Germany and Japan. The World Bank project on 'Energy for Rural Transformation' also introduced pilot programmes on consumer subsidies in Uganda, Ethiopia and Mozambique (ibid.).

Innovation studies suggest that "provision of support services for innovating firms" is of central importance in strengthening innovation capacity within an innovation system[122] (Edquist and Chaminade, 2004:112). Despite past experience showing that rural credit financing schemes in sub-Saharan Africa could be risky and difficult to administer, recent trends suggest that rural consumers can do better with microcredit schemes especially when loans provided are invested in income-generating activities. Examples from India have confirmed that microcredit schemes have assisted most of the rural households in off-grid areas to acquire solar home systems (Sharma, 2006).

Although this study found that the majority of the interviewed household heads showed interest in using solar PV systems for lighting (see Table 5.1.5), what may still be

[120] See other delivery models that have been successful in other countries in Appendix A

[121] However, credit schemes may also be risky, expensive and difficult to administer in some areas (ibid.p.18).

[122] Provision of support services for innovating firms is described as one of the "key activities" in the innovation system. Edquist and Chaminade (2004:112) have defined 'key activities' in the innovation system as "those factors that influence the development and diffusion of innovations" (ibid.).They argue that there must be "financing of innovation processes and other activities that can facilitate commercialisation of knowledge and its adoption" (ibid.p.112).

unclear is whether using solar PV systems for domestic lighting is given a first priority by most households.

Are you interested in using solar electricity?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	98	92.5	92.5	92.5
	No	3	2.8	2.8	95.3
	Not applicable	4	3.8	3.8	99.1
	I am not sure	1	.9	.9	100.0
	Total	106	100.0	100.0	

Table 5.1.5: A percentage of households who are interested in PV systems

This emanates from the fact that the current socio-economic condition in the district leaves most households with a limited choice in terms of how to spend their hard-earned income[123]. Most households are faced with what could be perceived as pressing priorities, such as purchasing agricultural inputs, paying school fees for their children, and other related household needs that may be deemed to be more important than solar PV systems. According to Rogers (2003:15), although potential adopters would normally measure an innovation in economic terms, other factors such as social prestige, convenience, and satisfaction are also very important in the adoption decision process. Other scholars suggest that the intention to adopt, for example, a solar PV system can be influenced by *attitude and subjective norm*[124] (i.e. an individual attitude[125] towards an innovation as well as the influence exerted on an individual by peers in the social system – the opinions of others). Since the Sukuma are known for their fondness for keeping livestock, what may be of interest for future research is whether livestock keeping is prioritised over solar PV systems for lighting and vice versa (an issue that was not directly addressed in this study). My argument is that it is likely that buying more livestock is more preferred by the households than adopting solar PV systems due to either social prestige or economic reasons (i.e. the fact that livestock could be sold in

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[123] According to Jackson (2005, p.vi), "consumers make decisions by calculating the individual costs and benefits of different options and choosing the option that maximises their expected net benefits", and this is because their choices are bounded by limited resources.

[124] Subjective norm refers to the overall individual's perception of what relevant others (i.e. social pressures from important friends/allies) think of the individual on whether he should or should not perform the behaviour. In other words, it refers to the influence of the "socially agreed upon rules" in the social system on the individual's intentions to perform the behaviour (Ajzen and Fishbein, 1980:54-57; Ajzen, 1988, 1991, 2002; Fishbein, 1967; McKemey and Rehman, 2003; Kidwell and Jewell, 2003; Davis, 1986, 1989; Davis et al., 1989).

[125] The definition of attitude is sometimes contested. Olson and Zanna (1993:119), for example, argue that "there is no universally agreed upon definition" on attitude.

case of emergency) or possibly both. In the past, cattle ownership used to serve as a source of both economic and social prestige in the study area. Since initial costs to install a solar PV system are substantially higher in the study area, robust and effective rural financing credit schemes targeting renewable energy innovations are required. And as discussed earlier, it appears that at the moment only a small proportion of households in the district have managed to access the few available financing schemes. However, most of these schemes are not aimed at financing renewable energy innovations. Experiences from other countries suggest that microcredit schemes have played an important role in the transfer and adoption of solar home systems in rural areas. Loans available from these schemes have assisted poor rural households to acquire solar home systems. Small-scale businesses (also known as micro-enterprises) that result from adoption of renewable energy innovations may increase households' income and jobs in rural areas. There is growing evidence that decentralized small-scale energy systems could also greatly contribute in efforts to alleviate poverty in off-grid rural areas, especially if the systems are built upon renewable energy technologies.

Box 2: Solar Lamps (lanterns)
A recent initiative by a non-governmental organisation known as Solar Sister to disseminate solar lamps (lanterns) for lighting in Uganda and Rwanda has successfully helped rural households in these countries. It is claimed that households are more interested in solar lamps because they are perceived to be affordable, costing between $15 and $50. The main goal behind the idea of distributing affordable solar lamps, according to 'Solar Sister', is to empower rural women through solar energy (The Christian Science Monitor, 2011)[126]*. In 2008, a similar project (aimed at helping children) was also initiated in Tanzania by an organisation known as Solar Aid. The organisation claims to have sold more than 1,500 micro-solar units (lanterns) for lighting since then*[127]*. For the purpose of domestic lighting, similar solar lanterns could be an immediate option for the majority of households in Magu district for several reasons. First, as opposed to stand-alone solar PV systems, solar lanterns are portable and do not require installation; therefore they stand a chance to attract more households. Second, since most houses in the district are grass thatched and built with mud (using tree branches and straw) or mud-bricks, solar lanterns seemingly offer a better option than solar PV systems. However, this is not to say that solar PV systems are not suitable for permanent or non-permanent grass thatched houses which are found in many parts of the district. But that does not also dispute the fact that, in some cases, installing Solar PV systems may require a roof to be in a condition that could support the solar panels for a relatively longer period. This is because a PV system that is properly installed lasts between 20 to 30 years.*

Occupational distribution of the households

What became apparent is that households in the study area engage in both farm and non-farm activities in order to sustain their livelihoods. The occupational distribution of the

[126] For more information about Solar Sister, visit: http://www.solarsister.org/
[127] See: http://solar-aid.org/projects/all-projects/solar-for-children.html

household heads include farm activities, formal employment, and non-farm activities (i.e. small businesses such as owning a shop, kiosk or restaurant, carpentry, brick making and selling etc). It is important to note, however, that occupational choice in most rural settings such as Magu is often limited by comparison with that in urban areas.

Respondent's occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Formal employment	9	8.5	8.5	8.5
	Farm activities	55	51.9	51.9	60.4
	Non-farm activities	18	17.0	17.0	77.4
	Farm and non-farm activities	24	22.6	22.6	100.0
	Total	106	100.0	100.0	

Table 5.1.6: Occupational distribution of the sample household heads

Therefore, household income levels in the study area may be best understood by taking into account the above pattern of the occupational distribution among the sample households[128]. It is clear that Table 5.1.6 above illustrates the importance of agriculture in the district. As indicated in the table, about 51.9% of the sample household heads are involved in farming activities and 22.6% engage in both farm and non-farm activities. In this case, agriculture not only underscores its importance for households in the study area but it also serves as an engine for the country's rural economy. On the other hand, the study results show that about 17% of the household heads engage in only non-farm activities excluding formal employment, and most of the household heads that derive their income from both farm activities and non-farm activities come from 'low income and middle income groups' (See

[128] See Table 5.1.7 for association between occupation and income groups in Appendix A. The observed data on occupation and sources of income of the sample households (Tables 5.1.7**a** and 5.1.7**b** in Appendix A) is an indication that farm activities are of vital importance for the low and middle income groups. It also appears that those in formal employment earn more income; hence the majority are in the upper income group. I would assume this is because households with members who are formally employed are also likely be motivated to undertake either farm or non-farm activities so as to increase their income. This assumption takes into consideration the possibility that those in formal employment could use cash from their salaries to buy land and/or hire people from poor households to work in their farms. This scenario may also be true for households with sufficient land for farm activities who could as well hire people from poor households to work on their farms and use the income earned from crop sales to diversify their income sources i.e. engaging in non-farm activities. On the other hand, it is also more likely that some households that currently experience land problems and whose members are not in formal employment would mostly engage in non-farm activities including providing wage labour. It must be noted, however, that the survey questionnaire did not specifically collect information on land access or ownership by individual households.

Tables 5.1.7**a** and 5.1.7**b** in Appendix A). Interesting, however, is the low percentage of those who are formally employed by either public or private entities – they make up only about 8.5% of the sample households but account for the majority of all those households in the 'upper income group'. Lack of modern energy services has been cited by energy analysts as one of the factors that discourage more skilled workers (such as teachers, nurses, doctors, etc) from living in rural areas, and as a consequence that limits valuable services for the rural population (Modi et al., 2006:8). The majority of individuals from rural areas who attain the educational requirements or skills for professional jobs normally move out of villages to seek better opportunities in urban areas and that has implications for rural innovation.

The findings also reflect the trade-offs in the allocation of household resources such as labour. This arises when household members have to choose between farm activities and non-farm activities. It was also observed that since agriculture is a predominant activity in the study area, the majority of the household heads that are involved entirely in non-farm activities (excluding formal employment), are either landless or possess small portions of land which are not suitable for intensive agricultural activities. Research conducted by Reardon et al. (1998) on 'rural non-farm income in developing countries' found that decisions made by rural households regarding their involvement in non-farm activities generally depend on the following two main factors:

a) "The incentives offered, such as the relative profitability and risk of farm and RNF [rural non-farm] activities".

b) "The household's capacity (determined by education, income and assets and access to credit, etc.) to undertake such activities".

Thus, households are motivated to undertake rural non-farm activity due to either 'pull' factors such as better returns in non-farm activities as opposed to farm activities, or 'push' factors influenced by inadequate farm output as a result of events such as drought or land constraints (ibid). The 'pull' and 'push' factors can be best understood as risk coping strategies. For example, since poorer households do not have the ability to cope with negative shocks to their income, they are "more likely to diversify in favour of less risky income sources and activities" (ibid.). The study findings suggest that most of the households deriving their income from non-farm activities are in what I term the 'middle income group' category, implying that they have managed to invest in 'less risky income sources'. On the other hand, however, it appears that some households engaging in what I perceive to be less profitable non-farm activities were mostly in the 'low income group' category (See Table 5.1.9 in Appendix A). The majority in this latter category were found to be involved in non-farm activities such as repairing bicycles and radios, handicraft as well as selling locally brewed beer. By engaging in such activities, households in this group earn less income than their counterparts in other groups. It is also evident that since arable land is becoming increasingly scarce in the district, poor households are likely to continue exchanging their labour power for wages as well as engaging in non-farm activities. Previous empirical evidence gathered in other areas of Mwanza region (i.e. Kwimba District), indicate that the region is steadily becoming less agrarian due to long-term historical processes (as discussed in Chapter 1), coupled with "rural household diversification strategies" (Morris, 2002:45; Madulu, 1998:1). This view is supported by Bryceson (1999:4) who argues that most countries in sub-Saharan Africa are going through what she terms "de-agrarianisation"[129]. Therefore, it is more likely that some households in the study area have opted for non-farm activities as a strategy to cope with poor agricultural returns and persisting land pressure resulting from an increasing population. It appears that households in the study area are diversifying their economic activities mainly due to drought and other related risks associated with agriculture. Diversification increases their chance to earn extra income from non-farm activities. Diversification in this sense is described as the household involvement in other activities that may not necessarily be directly linked to farm activities. Diversification compels households to create new ideas or implement new techniques (as their coping strategy) and this eventually leads to some form of innovation. According to Layton and Rislund (2002:9), "the introduction of a new product, process or activity, on the farm represents an *innovation*, whether it is highly original or simply the local application of something that has already been tried and tested elsewhere". I therefore borrow from Heanue and Walsh (2007) the assertion that farm diversification is a form of innovative activity. What is evident is that diversification appears to have provided new opportunities for some of the households in the study area to earn extra income. Extra income can in future attract more households to engage in innovative activities and that may have positive influence upon households' decisions to adopt renewable energy innovations. Empirical evidence elsewhere suggests that when technological innovations are adopted widely, they tend to increase

[129] She defines de-agrarianisation "as a long term process of occupational adjustment, income-earning reorientation, social identification, and spatial relocation of rural dwellers away from strictly agricultural-based models of livelihood" (ibid.p.4).

farmers' incomes and allow poor households to engage in new income-generating activities[130].

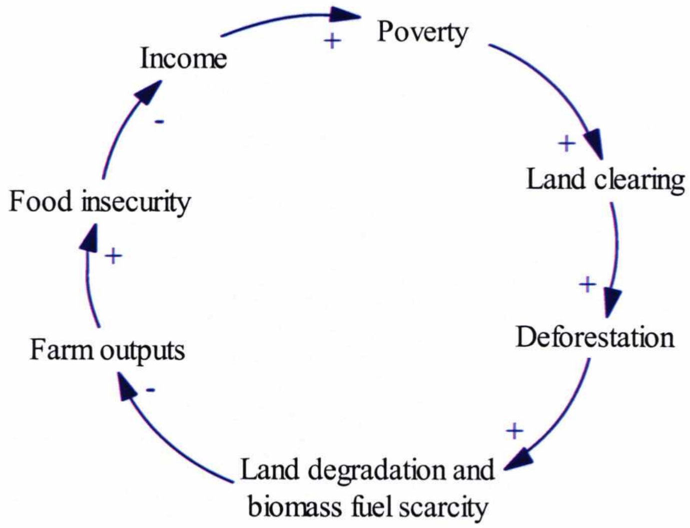
As pointed out earlier, the study found that important sources of household income in Magu District include farm activities, livestock keeping and non-farm activities such as business and wages. However, farming remains the main economic activity for most of the household heads and therefore this also means that their income primarily comes from farm activities. Sometimes there is an exchange of labour (i.e. for farming activities) between households based on social relationships, or an exchange of labour for food (or money to buy food) when villages experience food shortages[131]. Therefore, on other occasions, labour is exchanged for money (i.e. wage labour) in order to enable the poorer households to buy their basic domestic needs. In such circumstances poor households would normally work for wealthier families in the villages. Despite the traditional practice of free exchange of labour between households in Magu District, most households are no longer willing to offer free labour and instead prefer wage labour. This study, however, has not calculated the average number of household members from each of the surveyed households who are *actively involved* in farm activities or off-farm activities. At the same time, it is important to note that although children and the elderly are also members of a household, they are not infrequently used as sources of labour. Therefore, most school children are reported to be involved in household farm activities or off-farm activities often during the school holidays and weekends.

Although agriculture is still of central importance for the majority of rural households in Magu District, non-farm activities have been on the rise in the past few years due to declining agricultural outputs. The district is also currently experiencing a significant rise in environmental problems (primarily land degradation and deforestation) which have been exacerbated by human activities as well as periodic changes in climate. It is understood that prolonged land degradation has not only affected farm production but has also caused food insecurity in the district as well as reducing household income. Likewise, degradation of the remaining common property resources such as forests through land clearing and burning will further accelerate shortages of biomass fuels that serve the majority of rural households. It

[130] While innovation studies suggest that innovation plays an important role in creating jobs and generating income; experience also shows that it may be more difficult for limited-resource farmers to innovate because of the risks and investment required (World Bank, 2012:2; World Bank, 2009:258).

[131] Households have faced food shortages as well as financial hardship in the past due to drought and now are compelled to engage in a range of other economic activities as a risk coping strategy.

appears that an increase in rural household energy demands coupled with poor farming practices has led to what most scholars term as a 'downward spiral' or 'vicious circle.'



A Causal Loop Diagram showing a poverty vicious circle

As illustrated in a **Causal Loop Diagram** above, deforestation which results from tree clearing increases land degradation (i.e. soil erosion) as well as biomass fuel scarcity[132]. This in turn reduces agricultural farm outputs (production) hence exacerbating food insecurity and low income. As a consequence, this process only serves to accelerate poverty in the study area and eventually becomes a vicious circle.

The ngitiri system: an example of rural innovation in the study area

However, there are examples that illustrate how rural communities are capable of protecting and managing common property resources i.e. combating deforestation and firewood shortages[133]. This study found that for many years, the Sukuma have been involved in land conservation practices using a traditional resource management system known as 'ngitiri'(UNEP, 2008b:43; Madulu, 2005:13; Kamwenda, 2002:46). The ngitiri system is an example of local innovation in land management. Ngitiri is a Sukuma word that refers to a "fenced area". It is an indigenous silvo-pastoral system which emerged as a result of scarcity of grazing land and the Sukuma have since been using ngitiri system as a way of coping with dry seasons in Mwanza and Shinyanga regions. The system involves conserving grazing and

[132] According to Zein-Elabdin (1997:465), dependence on biomass as the main source of energy in Sub-Saharan Africa was one of the factors which contributed in the annual clearance of about three to four million hectares of land in the 1980s.

[133] It is suggested that rural communities with a fairly equal access to land (land tenure), agricultural inputs as well as markets, can protect and manage common property resources.

fodder lands (enclosures) by encouraging vegetation regeneration i.e. grasses, trees, shrubs etc. Under the ngitiri system, a piece of land remains under enclosure at the beginning of the rainy season and only becomes available for grazing at the peak of the dry season.

Cattle crossing the village centre on their way to grazing fields

Photo taken during the survey (2005)

Communities in these areas apply customary laws to protect and manage the ngitiri. Normally, the Sukuma would use the traditional guards locally known as 'sungusungu' as well as community assemblies (known as dagashida) to enforce the customary laws. The mentioned customary institutions are said to have played a significant role in the management of common property resources in the district. The ngitiri system is considered to be very effective in conserving biodiversity, preventing soil erosion and reclamation of degraded lands. It is also one of the traditional farming methods used in the Sukumaland to ensure food security (ibid.). Through the ngitiri system, an estimated 350,000 to 500,000 hectares of woodland were restored between 1986 and 2001 in Shinyanga region alone (Kamwenda, 2002:46). Traditionally, ngitiri are established on degraded land or near homesteads; these areas range from 0.2 to 20 hectares in the case of individual households while communal ngitiri could be as bigger as 50 hectares. The selection of a (ngitiri) site is largely influenced by the availability of land, proximity and ease of protection, and that is done by household heads or community leaders (ibid.p.47). The ngitiri constitute an ideal agro-forestry system that is capable of eliminating most of the fodder shortages, firewood scarcity, as well as soil degradation (Bekele-Tesemma, 2007:186). It is an important innovation for conserving the environment and thus may help improve the livelihoods of the poor households in the study area. The success of the ngitiri system is attributed to the fact that it is managed by rural households in these areas based on indigenous knowledge[134]. Experience also suggests that women in some villages have benefited from the ngitiri system because they are able to access firewood for domestic use within short distances (ibid.).

Photo taken in Yitwimila village during the dry season (2009)

However, availability of arable land in the study area remains a problem, and degradation of natural resources such as land and forests is still rampant due to various factors, such as increasing population pressure, climatic changes, or structural changes. The growing population, for example, has increased households' dependence on forest products such as firewood and charcoal, and consequently has contributed to deforestation[135]. This has in turn

[134] As an alternative solution to address rural energy needs, some energy analysts have proposed the establishment of afforestation schemes which can help restore degraded lands and at the same time serve as sources of biomass energy (Miller, 2004). Research suggests that agro-forestry (which involves planting of trees between crops on agricultural lands) coupled with proper forest management made a significant impact on alleviating firewood shortages in South Korea, Nepal, China and Senegal (Barnes et al., 1996). The Lacandon Maya Indians of Chiapas in Mexico could also serve as a good example as they are believed to be practising what is known as a multilayered system of agro-forestry whereby a total of about 75 crop species are grown on one hectare plots in every seven years. After seven years, they plant the crops into a new plot to allow the regeneration of soil in the latter plot (Miller, 2004:618). However, in countries experiencing rapid population growth and land shortages, afforestation should not be the only option to follow as afforestation alone cannot offer the lasting solution to rural energy needs.

[135] There are cases where households consider firewood and charcoal as alternative sources of income (i.e. they sell firewood and charcoal to nearby urban centres).

undermined large-scale application of the ngitiri system, hence threatening its very future existence in the district[136].

It is therefore important that we perceive current environmental problems in Magu District as inseparable from ongoing societal processes. Indeed, degradation of natural resources in the district could be well explained by the very dialectical relationship between households and nature (i.e. environment). In these societal processes, rational individuals or households would tend to utilise potential natural resources that are found within their vicinity to make a living. However, the outcome of such processes may not necessarily depend on how judiciously they are undertaken; rather it all depends on the social organisation structure of which they are part. For example, the poor or low income households in the study area are more likely to ignore or to avoid undertaking what they perceive as costly natural resource management practices, i.e. where such practices involve risks or uncertainties. The poor would normally seek to satisfy their pressing survival needs irrespective of whether their inappropriate use of natural resources threatens the environment and their future[137].

The World Bank argues that the best way to address the environmental problems in developing countries is to eradicate poverty by improving the livelihoods and production activities of the poor (Martinussen, 2004:152-3). It contends that when the causes of poverty are rooted out, the poor will be able to create a surplus from production activities. Its main argument is that, through increased production (i.e. economic growth), the relationship between growth in per capita income and protection of the natural resources is established[138]. The Bank therefore urges developing countries to pursue policies that promote income

[136] Traditional resource management system such as ngitiri can be further promoted in the district by empowering households through their own community-based organisations.
[137] This view is supported by Garret Hardin's explanation about resource degradation. Hardin's argument is that when scarce resources are shared in common and over-exploited (i.e. more than their capacities), such resources tend to be exhausted over time (Harper, 2004:322, Martinussen, 2004:158-9). To support his argument, Hardin cited a hypothetical example of a common parcel of land (pasture) that is shared by a larger number of herders. Hardin assumed that a rational herder would be attracted to add more livestock to his flock. If all herders were to make such rational economic decisions, then the pasture would be depleted. While the herder reaps the benefits in the short-term, the long-term damage to the land caused by overgrazing and the associated costs are shared by all herders. Experience suggests that in the past, local customary rules protected common resources from over-exploitation. However, the local customary rules in most developing countries have since failed due to the increasing population pressure and expansion of agricultural production (ibid.). At the same time, rural studies suggest that households in most rural areas rely on common resources such as forests for firewood collection and other forest products (Shepherd, 1998: 56).
[138] See Appendix E for a detailed discussion about the hypothesized relationship between Environmental Kuznets' curve and sustainable development

growth, poverty alleviation as well as environmental improvement by discouraging excessive use of fossil fuels and agricultural chemical inputs. However, critics point out that elimination of subsidies has always benefited the wealthier peasants in rural areas (ibid.). Empirical evidence from Tanzania shows that the removal of subsidies, as a result of structural adjustment programmes, increased fertiliser prices and encouraged the poor to clear more forests so as to expand their farming land (Reed, 1996:120). It is against such a background that Gray and Moseley (2005:10) have questioned the development experts' failure to sufficiently examine the connection between poverty and the environment. They argue that such weakness has led to the poor being inappropriately blamed for environmental problems they did not create (ibid.). Instead of blaming only the poor for environmental degradation, some scholars are calling upon development experts to include structural, technological and cultural factors as other causes of poverty and environmental degradation (Lélé, 1991:618).

5.1.2 Education level of household heads

Fostering education and the ability of rural households to innovate as well as to engage with other actors is crucial for rural development (OECD-FAO, 2012:32). However, most rural areas of the developing countries are characterised by low levels of general education and this is an obstacle to rural innovation. It is in that sense that education and training is required to provide rural households and rural small and medium enterprises with the skills, understanding and innovative capacity[139] (ibid.). In this study, the level of formal education attained by a household head was used as a proxy for his/her ability to effectively interpret and utilise the acquired information about renewable energy technologies more than others. Education increases the probability of households to be involved in the innovation process and was therefore expected in this study that more highly educated household heads would be the first adopters of renewable energy innovations[140]. The level of education influences the

[139] Household heads with better education are also likely to have more opportunities for formal employment in the rural sector as well as the knowledge that may allow them to gain access to financing schemes (or financial institutions for credit). Experience shows that educated household heads are more likely to understand and keep records of financial transactions; thereby increasing the likelihood of being trusted by creditors. That might empower the households financially and they could instead use the opportunity to invest in renewable energy technologies. It is also possible that in some cases, educated household heads may also attract other households in innovation activities.

[140] According to Davis et al. (2007:12), "formal education often has an indirect effect on innovation by enhancing the individual's ability to process information and by increasing his or her specialized knowledge". Rogers (2003:37) categorised the adopters of innovations on the basis of their level of "innovativeness" (i.e. how earlier an individual adopts a new technology). He argues that the first group of few individuals in a social

households' perceptions on how to adopt and integrate innovations into their household coping strategies. A study conducted by Weir and Knight (2000:6) shows that "years spent in formal education may affect the likely route to adopting an innovation and [may therefore be] the likely source of inspiration for innovating".

Respondent's education level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No formal education	9	8.5	8.5	8.5
	Primary School	72	67.9	67.9	76.4
	Secondary School	19	17.9	17.9	94.3
	High School	6	5.7	5.7	100.0
	Total	106	100.0	100.0	

Table 5.2: Education level of household heads

The education level variable was classified into 4 categories so as to have a fair distribution of household heads in each category (see Table 5.2). The results indicate that about 8.5% of the sample household heads had no formal education i.e. were unable to write and read. On the other hand, 67.9% of the household heads were educated to the primary school level. About 17.9% of respondents had secondary education while only 5.7% had attained high school education. As argued above, scholars in innovation studies suggest that education enhances the ability of potential adopters to respond, understand and eventually act on the information about a new technology (Rogers, 2003:288; Yapa and Mayfield, 1978). In that sense, the education level of the household heads may be a catalyst in shaping their attitudes, beliefs and habits, and that may in turn facilitate their involvement in innovation activities as they are likely be more willing to take risks (i.e. adopting new technologies). However, the decision to adopt renewable energy innovations must be understood within a context of an individual's rational evaluation about the advantages and disadvantages of the innovation in question based upon perceptions, values and attitudes. In this study, it was initially hypothesized that the education level of the household head influences the household decision to adopt solar PV systems or improved cooking stoves.

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system that shows interest in adopting a new technology must have ability to master a complex technical knowledge and have to be ready to take any risks associated with it.

Education * Energy for lighting: Cross-tabulation

Count

		Energy for lighting?		
		Kerosene	Solar power	Total
Education	No formal education	9	0	9
	Primary School	71	1	72
	Secondary School	18	1	19
	High School	3	3	6
Total		101	5	106

Table 5.2.1: Relationship between education level and energy source for lighting

The data in Table 5.2.1, indicate how the level of education of the household head is related to the energy source the household uses for domestic lighting. The study findings confirm the above hypothesis that household heads with a relatively high level of education are more likely to adopt renewable technologies as opposed to less educated household heads. The Pearson chi-square test of independence was used to test this hypothesis as shown in Table 5.2.2 below[141].

[141] Chi-square tests may be used to test the relationship between two categorical (i.e. qualitative) variables. However, chi-square tests results could be misleading if the scores in the table are related to any other score (Aron et al., 2008:376). For example, in this case, scores were based on the same household heads being tested more than once, i.e. scores for use of kerosene and solar power. In such cases, chi-square tests results would normally show that expected cell counts (frequencies) fall below the recommended levels as shown in Table 5.2.2; therefore can sometimes produce misleading *p*-values (Kinnear and Gray, 2010:426).

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	29.607[a]	3	.000	.001		
Likelihood Ratio	13.608	3	.003	.003		
Fisher's Exact Test	13.681			.002		
Linear-by-Linear Association	2.246[b]	1	.134	.102	.102	.032
N of Valid Cases	106					

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .28.

b. The standardized statistic is 1.499.

Table 5.2.2: Exact results for relationship between education level and energy source[142]

The study findings indeed suggest that households whose members had some form of education were found to be the 'first adopters' of renewable energy innovations in the study area. These study results are consistent with the widely held view that education plays a greater role in building the capacity of individuals (actors) to transmit, adapt and use new products in an innovation system (Speilman et al., 2012:16). Therefore, results in Tables 5.2.2 and 5.2.3 (in Appendix A) suggest that households in which their members are educated are more likely to be involved in the innovation process than households in which their members are less educated.

Sources of information

It is also worth noting that 'innovation' depends on the ability of the individuals and agents in an innovation system to gather information and use it creatively. According to

[142] Although the observed significance of the Pearson chi-square test (Asymptotic) **p-value < .05**, (see Table 5.2.2) I could not directly conclude that using solar power for lighting is related to the respondent's education level because 4 cells in the table have an expected frequency of less than 5, implying that the basic assumptions of calculating the asymptotic value for the significance level might have not been fulfilled. Therefore, exact results were instead chosen in which the exact **p-values** based on the Pearson chi-square test and Fisher's Exact Test above were significant at .001 and .002 respectively. The tests were used to confirm the relationship between the education level of the household head and a source of energy used for domestic lighting. Exact tests were used because they meet the statistical requirements of measuring association in such circumstances. These tests can be applied over skewed, unbalanced or sparse data as well as a small sample size (ibid.). However, in this case, the exact tests led to the same conclusion as the asymptotic test. Despite the fact that the p-values of these two tests were slightly different, they were all less than .05, thus confirming the relationship. To test the strength of such a relationship, correlation coefficient measures were applied as shown in Table 5.2.3 in Appendix A. Also see Table 5.2.4: The strength of association between the education level and source of energy in Appendix A.

Spielman et al. (2008:2), innovation agents may include the following: a) public sector entities such as national research organisations, agricultural extension and education services, institutes of higher learning etc. b) traders, brokers and other entrepreneurial individuals and their associations c) farmers organisations, cooperatives and cooperative unions d) nongovernmental organisations, professional associations and advocacy/lobby groups e) civil society organisations such as community or solidarity-based groups f) farmers, farm households, agricultural labourers and rural communities. Therefore, the ability to innovate is often related to collective action, coordination, and the exchange of knowledge among these diverse actors (World Bank, 2012:3).

Information appears to have played an important part for the households that have adopted solar PV systems and improved cooking stoves in the study area. Providing reliable information to the majority of rural households helps to clear up doubts over new technologies. According to Rogers (2003:205), one way of raising awareness and knowledge of a new technology among households is through communication channels[143], and these include interpersonal channels and mass media such as radio, television or newspapers.

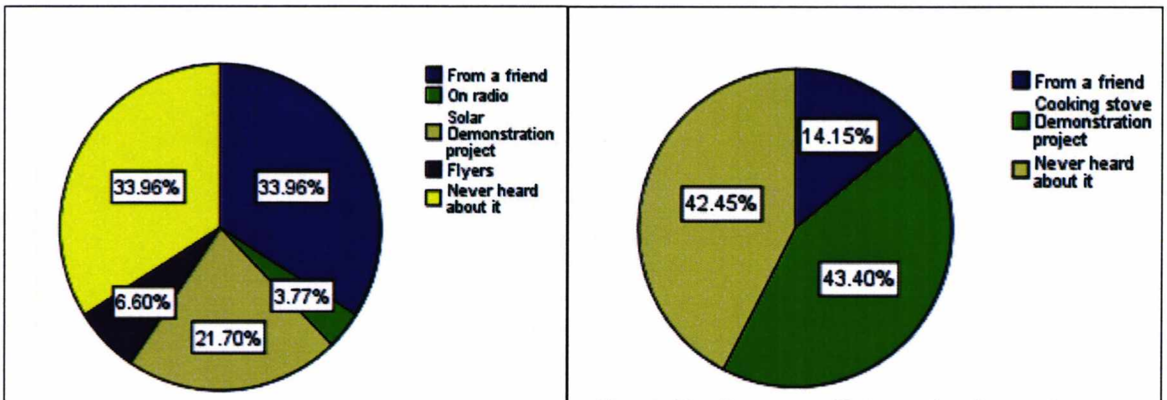

Figure 8a: Sources of information for Solar PV systems

Figure 8b: Sources of information for cookstoves

Figure 8a and Figure 8b: Sources of information about renewable energy innovations

[143] "A communication channel is the means by which messages get from one individual to another" (Rogers, 2003:18). Communication channels include 'mass media' (i.e. radio, newspapers and television), and 'interpersonal channels' which link two or more individuals who are related to one another in different ways. Mass media creates awareness of a new technology among the members whereas interpersonal communication between members in a social system encourages the widespread of a new technology and reduces uncertainties to the potential adopters. Interpersonal communication between individuals and the mass media play an important role in the transfer and adoption of a new technology since they both encourage knowledge sharing and experience among the potential adopters in a social system (ibid.).

As shown in Figures 8a and 8b, the study revealed that most household heads mentioned exchanging information among friends as well as demonstration projects as their primary sources of information. The study found that individual exchange of information (i.e. a friend to friend, neighbour to neighbour) was mostly mentioned as a source of information about solar PV systems. On the other hand, demonstration projects were widely seen as sources for information about improved cooking stoves by the majority of household heads. The study results also show that about 34% and 14.2% of the interviewed household heads heard about solar PV systems and improved cooking stoves from friends while 21.7% and 43.4% got the information from demonstration projects respectively. This clearly indicates that both demonstration projects and information by word of mouth (i.e. communication among individuals such as friends or neighbours) have greatly contributed in the exchange of information about renewable energy technologies in the study area. Similarly, it partly reflects the effectiveness of demonstration projects (**demonstration effect**) that have been implemented by the government, international donors and nongovernmental organisations in the district. It must be noted, however, that the focus of most of the demonstration projects has mainly been on a few selected households, health service centres or schools. This could be due to practicality concerns as well as financial difficulties that might arise if they were to cover every potential adopter in the district. It was also initially envisaged that when these projects reached the phase-out stage, the selected individuals, households, villages or representatives would continue to share their experiences with others in the area. However, it appears that those who received training in making, for example, improved cooking stoves have not trained others hence their skills have not been passed to other households in the district. The study found that some households that had adopted the improved cooking stoves in the past are no longer using them, mainly due to the fact that the stoves had cracked or broken. Below is the response from one of the respondents:

"A group of women visited our home and said they could build us an improved cooking stove if we paid them a small amount of money as a token. I think they mentioned an NGO called CARE or something as having trained them on how to build the stoves. My family used the stoves for about six months only and it started cracking. We stopped using it and continued to use our old stove (traditional three stone stove). My wife tried to repair the stove but it simply cracked again after few days. About six months had already passed and these women were not from this village, so we could not reach them for some advice".

Although the initial anticipation from the project was that low cost mud stoves would have been easily built by households after receiving training; that appears not to have been the case[144]. The few improved cooking stoves (known locally as Majiko Sanifu) that still exist in the study area, are made of locally obtained clay soil or bricks[145].

A low cost improved cooking stove made with mud (source:TaTEDO)

Users' comments indicate that most of these stoves were designed in a way that allowed two pots to be used simultaneously for cooking. Among those who used them, the stoves were also popular because they use only a small amount of firewood in comparison with traditional three stone stoves[146]. Inadequate training and expertise appears to have seriously undermined the transfer and adoption of improved cooking stoves in the district. The claim that the households lacked expertise needed to build or repair broken stoves suggests that they did not fully participate in the stove programme. The study found that the low cost mud stoves that were introduced in the district were abandoned mainly because of the durability problems, not being compatible with traditional household food preparation of the area as well as due to

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[144] Experience suggests that a low cost improved cooking stove does not require much technical knowledge to build and repair. It is worth noting, however, that the past negative experience from early projects on improved wood-fuel stoves in developing countries has shed some light on what can be done in stove projects today. According to Barnes et al. (1994), the following are some of the issues which need to be considered if a stove project was to be successfully implemented in rural areas: First, government or NGOs must initially find out if the intended local people (as actors) in the project area really need to save firewood. Second, projects should be implemented in areas where improved wood-fuel stoves are considered to be more effective than local traditional stoves. For example, because of their greater efficiency, it was initially anticipated that rural households would have preferred improved wood-fuel stoves to traditional three stone stoves. That did not materialise due to significant differences in cooking habits. A third and probably a most important factor is that stove projects are likely to be successful if improved wood-fuel stoves are locally made (i.e. involve local actors through local industries) and are available at affordable prices.

[145] Sometimes referred to as low cost mud stoves

[146] However, in most cases cooking food in households requires high heat intensity, and therefore, some households still prefer a three stone stove over a double hole cook-stove. This does not mean that such an improved cooking stove (double hole stove) does not produce high heat intensity; rather, it implies that there is lack of knowledge and awareness in selecting or making good stoves.

the fact that traditional three stone stoves are free and can easily be assembled[147]. Therefore, it was not surprising to find that some households that had adopted the low cost mud stoves were also still using traditional three stone stoves. They claimed, for example, that low cost mud stoves did not fulfil the cooking demands of households with large families. As opposed to traditional three stone stoves, cooking with improved stoves does not allow the households to freely use cooking pots of varying sizes since the cooking surface of these stoves (i.e. pot holes) is not flexible; thus, as a result they end up spending much of their time preparing meals for their families[148]. However, evidence suggests that a well built (made) improved stove does indeed save the time used in preparing household meals.

Box 3: Locally trained technicians
The observation from study area suggests that the shortage of qualified personnel to deal with installation and maintenance of renewable energy systems and equipment is still one of the main factors affecting the transfer and adoption of renewable energy innovations. Although the government does not have a sufficient number of qualified technicians for solar PV systems; empirical evidence in other countries suggests that trained local technicians in rural areas can play an important role in installing, operation and general maintenance of renewable energy equipment or systems if they are supported and involved in the innovation process from the beginning. 'Rural electronic workshops' in India are one of the successful examples. These workshops have successfully recruited local technicians whereby solar PV systems have been locally assembled (Sharma, 2006). Repair and maintenance of solar PV equipment and systems in rural India is now easily done by local technicians also nicknamed 'barefoot solar engineers' from these workshops (ibid.).

On the other hand, households also mentioned radio and flyers as their sources of information about renewable energy innovations in the study area. For example, about 3.8% and 6.6% of the household heads mentioned radio and flyers as their source of information about solar photovoltaic systems respectively. However, none of the interviewed household heads appeared to have heard about improved cooking stoves on radio. At the same time, the

[147] Empirical evidence elsewhere suggests that the durability of the improved cooking stoves that are made of a low temperature fired clay material when exposed to very high temperatures is between 3 to 6 months at most without an outside restraining device (USAID-undated,p.35) .

[148] Since the majority of the households collect free firewood from their farms or public bushy areas (i.e. common forest resources), the overall firewood consumption in the study area appears to be very much determined by firewood availability in a specific locality. This may influence the way household members perceive a new technology such as the improved cooking stove. As improved cooking stoves are meant to address firewood shortages (because they use less firewood), households in localities where firewood is easily available may not be keen to adopt them. In what has been referred as "*transformational effects*", technological improvements (i.e. technological efficiency) could, however, change consumers' preferences over time (Greening et al., 2000:391). The popularity of the traditional three stone stove among the locals in the district is inherent in its features as it is very common for the users, for example, to use cooking pots of varying sizes while cooking on it. A traditional three stone cooking stove normally supports one pot and can also easily use various fuel sources such as firewood, agricultural residues, twigs or cow dung. However, experience from practical laboratory tests as well as field studies has shown that traditional three stone stoves use more firewood and consequently generate more smoke than improved cooking stoves.

study results also show that about 34% and 42.5% of the household heads have never heard of solar PV systems or improved cooking stoves respectively as indicated in Figures 8a and 8b. Interesting, however, was an observation that the radio has the potential to reach the majority of households irrespective of their location in the district. The geographical nature and the current poor road networks connecting some individual households and some villages in the district make it harder for actors in the renewable energy sector to effectively communicate face to face with each other. In such environments, radio automatically plays an important role. For example, radio campaigns appear to have played an important role in disseminating renewable energy information in the study area. This is due to the fact that the radio can easily reach a larger proportion of the population in the district. However, I do not necessarily imply that every household in district has or can afford a radio. Therefore, other communication channels should also equally be given priority. It is worth noting that in most cases information that originates from radio is transmitted onward by word of mouth. In this sense, word of mouth is regarded as a regular and important source of information for the majority of rural households. Experience also shows that many people in the study area (as was the case in most of Sukumaland in the past) are known for their fondness of radio, so I would presume that even households with lower incomes could still own a radio or have access to one from the neighbour. Also, as mentioned earlier, it should be noted that most households live in un-electrified areas and the majority cannot afford the costs of using generators to watch television. Very striking, however, was the fact that, though some of the interviewed household heads had mentioned the radio as their source of information, some were quick to state their preference for direct (i.e. face to face) exchange of information. They claimed, for example, that direct personal contacts would have allowed them to get additional information or even technical support about solar photovoltaic systems and improved cooking stoves. Farmer-to-farmer communication is one of the most powerful forces for **education** within the informal system (World Bank, 2012:111). This is because these farmers communicate easily with their peers, observe the techniques and skills used by others, and eventually adopt innovations that are perceived as being useful in an innovation system (ibid.). This view is also supported by Hall (2006:12), who argues that "a large element of innovation capacity relates to patterns of trust between actors and the habits and routines of actors that relate to sharing information and learning". Capacity as a concept in the innovation systems perspective can be conceptualised in terms of the different actors, skills and resources that are needed to allow innovation to take place on a continuous basis

(Hall et al., 2007:10). Hence, capacity is defined as "the context specific range of scientific and other skills and information held by individuals and organisations and the practices and routines (institutions), patterns of interaction and policies needed to create and put knowledge into productive use in response to an evolving set of challenges and opportunities"[149] (ibid.p.11).

Box 4: A case study of rural Sweden
In his study, Hägerstrand (1970) also found that information sharing among members of various households was very crucial for dissemination of innovations among households who were neighbours – in what has been termed the ***neighbourhood effect.*** *He argued that the communication process facilitates the spread of an innovation. Interpersonal communication (i.e. sharing of information between members of the social system) is a fundamental push factor for the dissemination of an innovation (ibid.). He recognised the importance of personal contacts as a way of passing information about innovations in question. He claimed that such information could come from the mass media or existing adopters in the form of messages (Brown, 1981:19). In Hägerstrand's view, the individual's decision to adopt an innovation is based on information received as the result of face to face interactions with other adopters (ibid.). Hägerstrand suggests that geographical distance between members of a social system constrains interaction among them and as a result denying the potential adopters a chance to meet with other existing adopters thus inhibiting the innovation process. Due to the fact that a high proportion of personal contacts were local at the time he conducted his research, this meant that the spread of information was spatially constrained (Hägerstrand, 1967; Golledge and Stimson, 1997; Miller, 2003; Yu and Shaw, 2007). That also implied that the further the potential adopters lived from the early adopters, the less likely that they were to get information they needed before deciding to adopt an innovation (Brown, 1981; Hedström, 1994; Wolfe, 1999).*

In that sense, it appears that radio alone will not be a sufficient source of information for households in the study area. Therefore, the findings clearly indicate that Magu district needs communication channels that would be able to support each other in transmitting information. This is very crucial if such communication channels were to reach a wider audience and effectively raise awareness about renewable energy technologies in the district.

Household awareness of renewable energy innovations

In order to determine household awareness of renewable energy technologies, household heads were asked if they had heard about solar photovoltaic electricity or improved cooking stoves[150]. Awareness about solar photovoltaic systems and improved

[149] Mytelka et al. (2009:1750) define capacity as the ability of individuals, organizations, societies, and communities to make choices, perform functions, solve problems, and set and achieve their objectives.

[150] According to Rogers (2003:169), *awareness-knowledge* is considered as a very first important step in the adoption decision making process. In what Rogers termed as "a model of the innovation-decision process", he contends that there are five stages in which an individual goes through before adopting a new technology (ibid.). These stages involve knowledge, persuasion, decision, implementation and confirmation. The first stage in the innovation-decision process is for an individual to gain initial knowledge about an innovation. In this stage, a

cooking stoves is a first significant step for these technologies to be widely adopted by rural households in Magu District. The study assumes that household awareness may provide a general overview of how households are actively involved in the innovation process (i.e. their involvement in the planning stages as well as the implementation of renewable energy projects in the study area). For example, it is assumed that household heads with 'awareness-knowledge' about solar photovoltaic systems and improved cooking stoves are more likely to adopt these technologies than those who do not. Some 66% of the sample household heads were found to be aware of solar photovoltaic systems and about 57.5% have heard of improved cooking stoves. However, about 34% and 42.5% respectively of the household heads said they had not heard of solar PV systems or improved cooking stoves (see Figure 8c and 8d).

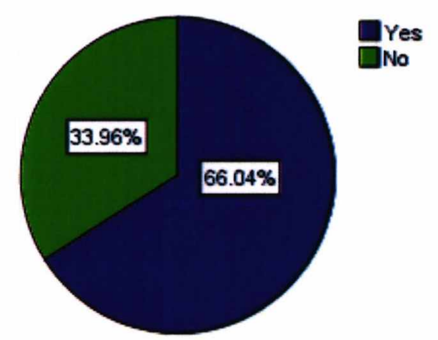

Figure 8c: Awareness about Solar electricity

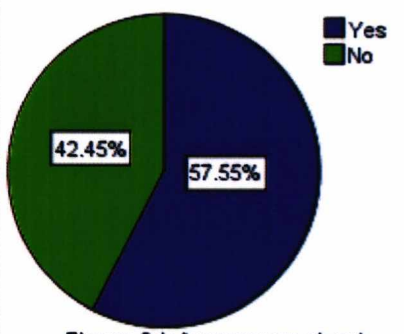

Figure 8d: Awareness about cookstoves

Figure 8c and Figure 8d: Household awareness about renewable energy innovations

The government in collaboration with donors and other actors have in recent years been supporting initiatives to raise awareness of solar photovoltaic energy and improved cooking stoves in Magu District. Thus, from the beginning, this study had assumed that the majority

consumer gains the **knowledge** by being exposed to an innovation and gaining an understanding of how it functions (ibid.). This **knowledge** is further categorised into three types: *awareness-knowledge* (information to an individual that a new technology actually exists), *how-to knowledge* (information to use a new technology properly) and *principles-knowledge* (functioning principles of a new technology so as to avoid misusing it). Thus, awareness-knowledge motivates an individual to seek the second and third types of knowledge as described above. However, Rogers also argues that an individual with *awareness-knowledge* and *how-to knowledge* may adopt a new technology without necessarily requiring *principles-knowledge*. At the persuasion stage of the model, an individual forms a favourable or unfavourable attitude towards a new technology after being aware of it. At the decision stage, however, an individual engages in activities that may influence his/her choice to adopt or reject a new technology. The implementation stage involves an innovation being put into use and evaluated for its usefulness by an individual before the confirmation stage. At the confirmation stage, an individual may decide to reverse or continue with his/her decision to use an innovation (ibid.p.173-189).

of households in the district would be aware of solar photovoltaic electricity and improved cooking stoves because of those initiatives. However, it appears that awareness about solar PV systems and improved cooking stoves in the district does not necessarily translate into how they are adopted by households. In this study, for example, a one-way ANOVA was used to determine if awareness of improved cooking stoves had a significant effect on kind of stoves that are used by households (see Table 5.2.5).

ANOVA

Type of stove usage rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15.084	1	15.084	.134	.715
Within Groups	11738.925	104	112.874		
Total	11754.009	105			

Table 5.2.5: The one way ANOVA summary table

In this case, the independent factor (variable) was household awareness of improved cooking stoves and the dependent variable was the usage rate of a respective type of stove[151]. As indicated in the one-way ANOVA summary table, the findings suggest that there is no significant difference between the groups ($p = .715$); thus awareness has no significant effect on the kind of cooking stove being used by households: $F\ (1,104) = .134$, $p > .05$ (see Table 5.2.5 above). At the same time, although over 60% of the interviewed household heads indicated they are aware of solar PV systems, only 4.7% were found to be using PV systems as shown in Figure 8e below.

[151] The mean difference between household heads who had heard of improved cooking stoves and those who had not, was statistically non-significant (see Table 5.2.6 and 5.2.7 in Appendix A).

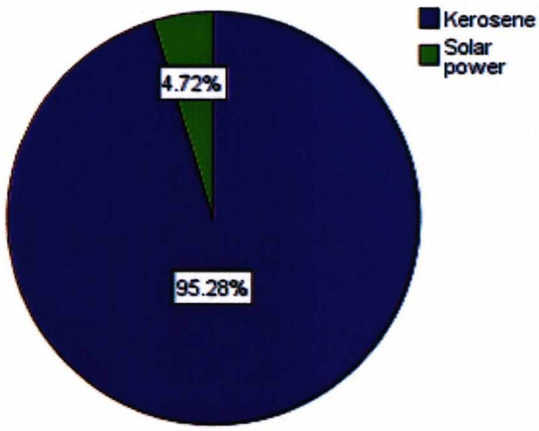

Figure 8e: Household energy sources for lighting

Figure 8e: Household energy sources for lighting

As seen in Figure 8e, kerosene remains the main energy source for lighting in most households, with the exception of a small number of households in Magu Mjini and other small centres located along the national grid. About 95.3% of the interviewed household heads in this study mentioned kerosene as their main energy source for lighting in their homes[152]. As noted earlier, Magu District is still predominantly rural and households are scattered across villages which are very far from the grid. The dispersed nature of households in most villages poses a great challenge for the provision of modern energy services such as electricity. The geographical location of villages across the district not only determines their accessibility to grid electricity but may also have some implications in terms of access to important resources such as water and forest products (i.e. firewood). This implies that household members (almost always women) in some villages are compelled to walk long distances in search of firewood or to fetch water and that may in a way affect their involvement in other productive activities. Although the study shows that the majority of households still depend on kerosene for lighting, it was equally observed that energy use for some of the interviewed households was gradually changing towards alternative energy sources i.e. solar PV electricity. The study findings suggest that a small proportion of the households were using solar PV systems for lighting purposes. However, it is also important to note that while households use kerosene wick lamps for lighting, the brightness from these lamps is very low and therefore in most cases does not fulfil all household lighting

[152] The study results remind us of the need for solar innovations in what might be generally considered to be remote and isolated rural areas in the country.

requirements. Energy studies suggest that a kerosene wick lamp can provide about 11 lm (lumens[153]) which is very low when compared with approximately 1,300 lm that come from a 100 Watt incandescent light bulb (Practical Action, 2010).

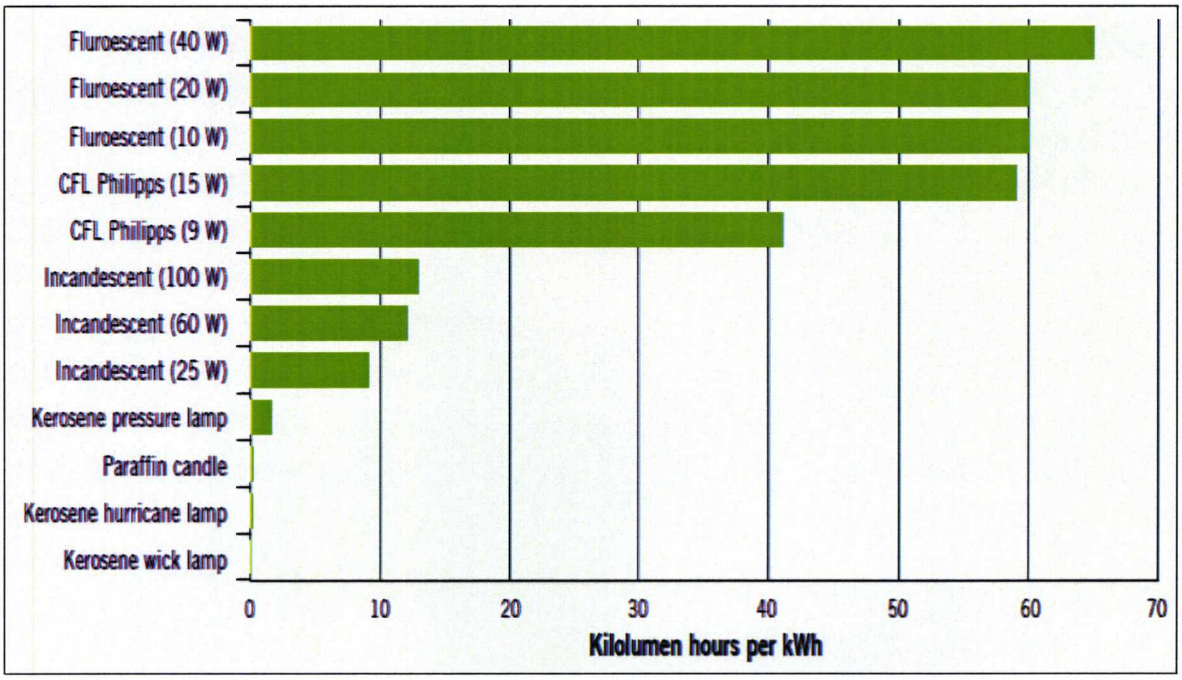

Figure 8f: Efficiency of lighting fuels (Adapted from Practical Action, 2010)

Some energy experts recommend approximately 300 lm as an appropriate illumination level required in a household. It is obvious that kerosene wick lamps or related appliances do not provide adequate light as recommended by experts (see Figure 8f). Thus, kerosene wick lamps are regarded as inefficient energy appliances for household lighting (ibid.p.3). The absence of efficient energy appliances for lighting may significantly affect the socio-economic activities of rural households. For example, it was observed in this study that the use of solar PV systems for lighting has not only improved services in health centres that have benefited from a UNDP solar PV demonstration project but has also increased studying hours in secondary (boarding) schools that were involved in the demonstration project. It must be noted, however, that most of the health centres and schools in the district do not have access to electricity, and that scenario applies to the majority of primary and secondary schools in rural Tanzania. The importance of energy services in rural areas has been equally documented by Modi et al. (2006:24) in their study on 'Energy and the Millennium

[153] A lumen is a measurement unit for brightness.

Development Goals'. They found that the deterioration of education and other social services in rural areas was partly due to lack of 'modern energy services' because well qualified teachers and other professionals shied away from working in those areas as they found it challenging to work in environments that lack access to modern energy services. Thus, modern energy services serve as a pull factor for well qualified personnel in rural areas[154].

Occupation * Energy for lighting? Cross-tabulation

Count

		Energy for lighting?		Total
		Kerosene	Solar power	
Occupation	Petty traders	16	2	18
	Field agricultural officers	2	0	2
	Teachers	2	3	5
	Health workers	2	0	2
	Farmers	79	0	79
Total		101	5	106

Table 5.2.8: Occupation of household head and the energy source for lighting

As shown in Table 5.2.8 above, this study found that solar PV systems were to a large extent adopted by households whose heads had permanent employment or are engaged in non-farm activities i.e. teachers and businessmen. Due to the nature of their activities, teachers and businessmen may (in some cases) require electricity for relatively more hours than other groups. For example, more lighting hours during the night may be of vital importance for teachers and other groups involved in non-farm activities. This could as well be attributed to other factors such as education levels, access to information and/or financial institutions, or having more disposable income than other villagers.

Commercial marketing vs. Social marketing of renewable energy innovations

As indicated earlier in this section, the majority of the interviewed household heads appear to have (what might be termed) 'basic education'. This may not be surprising, since education levels tend to be dismally low in most rural areas of sub-Saharan Africa (World Bank, 2012:108). Also as mentioned earlier, basic education is still considered as a critical element for communication, understanding, and assessing innovations in the interactive

[154] Experience from Brazil has shown that rural electrification is closely related with rural socio-economic development and has greatly reduced the "rural - urban migration" (UNDP, 2005).

process that prevails within an innovation system[155] (ibid.). This is due to the fact that 'innovation' is perceived as a continuous learning process in which actors master and implement the design, production and marketing of goods and services[156] (Anandajayasekeram, 2011:17). Marketing of innovations is among the key activities in the innovation system[157]. However, it appears that poor marketing of renewable energy innovations has constrained the adoption of solar PV systems and improved cooking stoves in the study area. This study found that poor and un-coordinated marketing system encourages dishonest petty traders and unqualified technicians to informally sell and install sub-standard solar PV equipment for the households in the district. Some households that had adopted solar PV systems complained of their systems not working properly and that some systems stopped functioning after being used for only a few days. As one respondent explained:

"I met a 'solar technician' at Masanza Kona who said he could sell to me a solar panel, a battery and an inverter as well as install a solar PV system at my house. We agreed on the total costs of buying the solar equipment and installation. However, after the installation, it only worked for a few weeks and that was it. I went to see the technician again and complained about it. He checked the system but could not make it work again. He advised me to buy a new battery. I could not afford spending extra money to buy another battery".

The above implies that first time adopters may be discouraged from adopting solar PV systems and that could also turn away other households (i.e. potential adopters) in the district. Renewable energy equipment must be of good quality in order to effectively function and produce sufficient amount of energy (electricity). On the other hand, customers and local suppliers must also be educated and provided with information on how they can detect low quality or defective renewable energy equipment before they are installed or put into use. However, avoiding defective and low quality equipment may only be possible if households (as actors) are fully involved in the planning and implementation of renewable energy projects in the study area. Thus, the recently established Rural Energy Agency needs to collaborate with rural households and other actors so as to ensure the quality of renewable energy equipment in the district.

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[155] According to Speilman et al. (2012:17), level of education plays a wider role in strengthening the innovation capacity of the individuals in an innovation system.

[156] Innovation does not exclusively take place through research but rather it often occurs after the combination of different types of information. Innovation may be driven by market, policy, or practical opportunities and conditions (ibid.).

[157] It calls for "formation of new product markets; and articulation of quality requirements emanating from the demand side with regard to new products" (Edquist and Chaminade, 2006:114). The government may offer its support in creating markets for innovations by establishing "technical standards and public innovation procurement" (ibid.).

The quality requirement for new products (innovations) in the market is considered to be crucial for the development of a product in the innovation system (Edquist and Chaminade 2006:121). Quality requirements emanate from interactive learning between innovating firms and customers and through government actions. The government, for example, may impose regulations on issues such as health and safety, the environment or technical standards (ibid.). Therefore, a well organised formal marketing of renewable energy innovations involving all actors is required if genuine equipment is to successfully reach rural households in the district. However, the seemingly obvious trend in the study area is that there is much emphasis on commercial marketing rather than social marketing of renewable energy innovations. Experience suggests that in most cases commercial marketing is inherently profit motivated and mostly aims at selling 'products and services' to consumers while social marketing may go beyond 'to promote social beneficial causes and behaviours' (Evans, 2008:182). Social marketing influences behavioural changes as well as transfer and adoption of innovations in the innovation system (Rogers, 2003:84). The core strength of the social marketing approach is based on its application of commercial marketing strategies and behavioural change theories to effect "the adoption of innovations that can improve health, raise literacy levels, and extend life expectancy" (ibid.). The approach applies commercial marketing strategies and draws knowledge from other social science disciplines to influence individual behavioural change in a social system[158]. The social marketing approach has been applied to several behavioural change campaigns such as energy conservation, safer driving, smoking prevention and tobacco control, and has been successfully used, for example, to encourage the adoption of oral contraceptive pills as well as condoms in developing countries (Rogers, 2003:85; Stern, 2000). One of the objectives for UNDP/GEF project on Transformation of Rural Photovoltaic (PV) Market in Magu district was to reduce the incidences of respiratory diseases and eye problems resulting from prolonged exposure to indoor pollution. However, observations from the area suggest that there has been more of

[158] According to Kotler and Zaltman (1971:5), "social marketing is the design, implementation, and control of programmes calculated to influence the acceptability of social ideas and involving considerations of product planning, pricing, communication, distribution, and marketing research". Social marketing is also described as "a social-change management technology involving the design, implementation, and control of programs aimed at increasing the acceptability of a social idea or practice in one or more groups of target adopters" (Kotler and Roberto, 1989:24). This definition was further broadened by Andreasen (1994:110) who defines social marketing as "the adaptation of commercial marketing technologies to programmes designed to influence the voluntary behaviour of target audiences to improve their personal welfare and that of the society of which they are a part".

commercial marketing of solar PV systems than raising awareness of the effects of indoor pollution. For example, the following respondent had this to say:

"I heard about solar energy when I visited a friend in Bugatu village. I was told that solar energy can be used in powering radios and TVs but cannot be used for cooking. Then something came to my mind, if I cannot use solar energy (from PV systems) to cook food, why should I incur all those expenses and costs they are talking about, just to have a solar PV system! Why not investing my money into something else which is profitable?!"

As pointed out earlier, the response from the above respondent suggests that there has been more of commercial marketing of solar PV systems than social marketing. This may be due to the fact that the private sector has played a leading role in the whole process of implementing the UNDP/GEF project in the study area as well as the neighbouring regions (Kimambo, 2009:12). It therefore implies that other actors (such as households) were either left out or marginalized and only assumed a role of 'recipients of a new technology'. However, the innovation systems approach calls for multi-actor involvement in the innovation process since that facilitates the transfer and adoption of innovations in question. A study conducted in Mexico found that leaving out the end users and putting them on the demand side only helped to undermine the adoption of solar PV systems in rural areas (Chambouleyron, 1996).

The study suggested that end-user involvement in the innovation process is of paramount importance because it is his/her attitude that determines the success or failure of the respective solar PV programme (ibid.). Chambouleyron argues, for example, that the user "is not an object but the one who defines the uses to be given to solar electricity and must understand the very special characteristics of the [solar] PV power" (ibid.p.390). That also means that the user must be able to operate and maintain the solar PV system (ibid.). End-user involvement (participation) may be of central importance, for instance, in the modification of an innovation itself. Modification leads to appropriate changes that suit the requirements of would be adopters as well as adapting a new technology to a specific physical environment. Chaurey and Kandpal (2010), suggest, for example, that some solar projects initiated by GEF (Global Environment Facility) have succeeded because the projects have involved users in the planning and implementation stages. User involvement or consultation in designing the renewable energy projects may also address other core issues such as the initial costs of installing a solar PV system for a poor household.

5.1.3 Gender of the household heads

The innovation systems perspective calls for active engagement of both men and women in the innovation process. In this subsection, I look at the roles that are performed by men and women in the study area and how these roles may influence the adoption of renewable energy innovations. According to the World Bank (2012:12), "diversity, inclusion, and participatory approaches are critical to building the quality of social capital needed for resilient and sustainable innovation systems". Thus, innovation "involves not only new actors but also new roles and many relationships that can sustain knowledge generation and learning" (World Bank, 2009:260). Since most of the households in the study area are traditionally dominated by males, it is obvious that men have a bigger influence on the household decisions to adopt renewable innovations because they are the ones who decide about which energy equipment can be purchased. As the traditional power structure in Magu district favours men as the main decision makers in most households and because men are not directly involved in cooking meals, it is more likely that innovations such as improved cooking stoves may not be among the energy equipment that attract their attention and may therefore be given less priority[159]. Therefore, gender relationships within the household and especially the position of women, can be an important factor in negotiating and reaching decisions on whether to adopt renewable energy innovations. In situations where women may be willing to adopt improved cooking stoves; men who in most cases control cash and make final decisions, may perceive the adoption of improved cooking stoves as being of secondary importance[160].

[159] Energy studies suggest that adoption of improved wood-fuel stoves can greatly address a growing demand for biomass energy in rural areas (Karekezi et al., 2004). The adoption of these stoves could as well play a significant role in sustaining socio-economic development in rural communities i.e. through time saving, reducing indoor pollution and deforestation.

[160] Some scholars argue that in order to have a successful cook-stove programme, "the whole cooking system needs to be considered through integrated approaches that work simultaneously with technology innovation, creative financing and market development, and the monitoring of actual health and environmental benefits" (Masera et al., 2005:25). Such programmes must involve women because they can correctly address users' priorities and preferences (ibid.). Innovation studies suggest that women are also critical actors in an innovation system (World Bank, 2009:259).

Women and children walk long distances to collect firewood **(Field trip: Magu in 2005)**

Men's decisions may therefore ultimately restrict the involvement of women in the innovation process across the district. As mentioned earlier, the traditional power structure and control of productive resources in the Sukuma society favours men as opposed to women. These observations only confirm the typical traditional dominance of male-headed households common in patriarchal societies. It was observed, for example, that most men in the study area posses more power and access to land, money and even control of the household labour force. They generally own most of the household assets and have control over other household members. Men have a bigger influence on household decisions, and it is in that context that their decisions are considered very important in understanding the transfer and adoption of renewable energy innovations in the district. According to the World Bank (2009:277), "the best practices for improving women's involvement in innovation processes are those that promote equity through representation and participation".

Gender of Respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	91	85.8	85.8	85.8
	Female	15	14.2	14.2	100.0
	Total	106	100.0	100.0	

Table 5.3: Gender distribution of household heads

Table 5.3 above shows the gender distribution of household heads in the study area. As indicated in Table 5.3, about 85.8% of the interviewed household heads were men and 14.2% were women. It must be noted that in the Sukuma culture, women and young girls are responsible for all kitchen matters such as cooking, fetching water as well as collecting firewood[161]. Since the majority of men do not get directly involved in the kitchen activities, they may therefore not be interested in the innovations that are associated with kitchen matters such as cook-stoves. A research conducted by UNDP suggests that a woman in rural Tanzania spends about 700 hours per year collecting firewood (Modi et al., 2006; Gaye, 2007:8; Practical Action, 2010:70).

An example of a traditional three stone stove (Source: Fieldwork, August 2008)

Although gender may influence adoption decisions, it must also be recognized that in some cases making the final decision about adopting an innovation may vary from one household to another, mainly due to internal organization and flexibility of the respective households. Innovation studies suggest that if "innovation capabilities, physical assets, and power are not distributed equally, the best-endowed actors [stand to] benefit the most from emerging

[161] It is also worth mentioning, that this study did not collect comprehensive data on all cooking practices of the sample households; hence health related problems emanating from indoor pollution were not thoroughly investigated. However, some of the respondents mentioned the social and health problems encountered by elderly women; after being exposed to smoke from the traditional three stone stoves, their eyes turn red. This has not only affected their health but these elderly women have also been subjected to harassment since they are accused of being witches because of their red eyes. There is a prevailing superstitious belief among the Sukuma that red eyes is a signal of being a witch, especially if you happen to be an elderly woman. As a consequence, in the past, a number of attacks have been carried out against innocent elderly women who have been linked with witchcraft, and in some cases they have been savagely murdered. The adoption of improved cooking stoves and solar power for lighting not only would reduce incidents of red-eyed elderly women in the study area but would also spare women and children from indoor pollution. For example, local NGOs in India trained women to design, build and install more than 300,000 smokeless wood stoves called '*chulhas*' (Miller, 2004: 620). As a result 'chulhas' have since greatly contributed in reducing deforestation and respiratory health diseases in some parts of rural India. At the same time, widespread adoption of 'chulhas' has improved living conditions of more than one million women (ibid.)

opportunities" (World Bank, 2012:29). What is obvious, however, is that if women in the study area continue to be marginalized, most households will miss the opportunity to participate in various development initiatives (and that may in turn affect even 'the best-endowed actors' as stated above). Thus, the empowerment of women is necessary, as their skills and networking capabilities are likely to play an integral role in the transfer and adoption of improved cooking stoves in the district.

As discussed earlier in this section, the gender of the household head was hypothesized to be a variable partly influencing the household decision to adopt solar PV systems and improved cooking stoves in Magu District. However, further empirical data was needed in order to develop some plausible explanations concerning the possible relationship between gender and adoption of renewable energy innovations in the district. It is on the basis of the foregoing assumption that this study also sought to establish if there is association between gender of the household head and awareness of solar PV systems and improved cooking stoves.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.003[a]	1	.956		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.003	1	.956		
Fisher's Exact Test				1.000	.602
Linear-by-Linear Association	.003	1	.956		
N of Valid Cases	106				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.09.

b. Computed only for a 2x2 table

Table 5.3.1: Test results for association between gender and awareness of PV systems

The chi-square (x^2) (as indicated in Table 5.3.1) was initially used to test if there is any association between gender of the household head and awareness on solar PV systems[162]. As

[162] The chi-square test is normally used to ascertain if there is association between two qualitative (categorical) variables (Kinnear and Gray, 2010:414). Using a contingency table (cross tabulation) it was easy to compare a bivariate distribution, making it possible to check if there is an association between the variables (ibid.). The chi-square value was obtained after "calculating the differences between the actual and expected values for each cell in the table" with the help of statistical software (Bryman, 2008:334). The value was automatically calculated by a Predictive Analytics SoftWare (PASW Statistics 18) at the significance level of $p < 0.05$.

indicated in Table 5.3.1 above, the chi-square value was 0.003. Thus, results for the chi-square test for association showed no statistical significance, indicating weak association between gender and awareness on solar PV systems at a confidence level of 95%: that is $x^2(1) = 0.003$; $p > 0.05$. This therefore indicates that awareness of solar PV systems is randomly distributed between male and female household heads, implying that awareness is not associated with gender.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.043[a]	1	.836		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.043	1	.835		
Fisher's Exact Test				1.000	.534
Linear-by-Linear Association	.043	1	.836		
N of Valid Cases	106				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.37.

b. Computed only for a 2x2 table

Table 5.3.2: Test for association between gender and awareness of improved cook-stoves

The chi-square test was again used to explore the association between gender and awareness of improved cooking stoves. The chi-square test results (see Table 5.3.2 above) for association between sex of the household head and awareness of improved cooking stoves were also not significant at the confidence level of 95%; that is $x^2(1) = 0.043$; $p > 0.05$, indicating that there is no association between the two variables. Results of chi-square tests reveal that awareness of both solar PV systems and improved cooking stoves is randomly distributed among the household heads. Although it was initially expected that male household heads in the study area would have been more aware of solar PV systems than improved cooking stoves and vice versa, these findings suggest that awareness levels do not significantly differ between male and female household heads.

The study findings above are very important in understanding the involvement of households in transfer and adoption of renewable energy innovations in the district. The findings suggest that even if women in respective households prefer to adopt renewable energy innovations,

According to Kinnear and Gray (2010:24), results of a statistical test can only be considered to show significance if the p-value is less than the significance level.

they lack resources and the authority to make final decisions. In that sense, women in the study area are likely, for example, to be deprived of efficient innovations such as improved cooking stoves or solar PV systems because men control most of the resources, have the authority to make final decisions and are as well not directly involved in most of the domestic chores. For example, the scarcity of firewood in the study area increases the burden on women as they are left with little time to participate in innovation activities and other decision-making processes at the community or village level. As a result, this constrains women's ability to benefit from or learn about new technologies, thus limiting their opportunities to utilise renewable energy innovations.

5.1.4 Age of household heads

As shown in Table 5.4, the household heads in this study were categorised into 5 age groups. Household heads who were not more than 19 years old were only about 1.9% of all the interviewed household heads. Those aged between 20 and 29 years made up about 17% of the sample. Household heads aged between 30 and 39 years, 40 and 49 years and those who were 50 years and above, represented 36.8%, 25.5% and 18.9% of the sample population respectively.

Age categories

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<19	2	1.9	1.9	1.9
	20 - 29	18	17.0	17.0	18.9
	30 - 39	39	36.8	36.8	55.7
	40 - 49	27	25.5	25.5	81.1
	>50	20	18.9	18.9	100.0
	Total	106	100.0	100.0	

Table 5.4: Age categories distribution of household heads

The overall mean age of the household heads was 39.06, ranging from 19 to 65. Because of such an age range, we cannot confidently claim that this overall mean age is representative of the sample size. To address that, I have used the Median. Hence, the median age for the household heads was 38 (see Table 5.4.1 in Appendix A). The standard deviation was 10.352, which implies that a larger proportion of the interviewed household heads were aged between 29 and 49 years.

Age categories * Gender of Respondent Cross tabulation

Count

		Gender of Respondent		Total
		Male	Female	
Age categories	<19	2	0	2
	20 - 29	17	1	18
	30 - 39	32	7	39
	40 - 49	23	4	27
	>50	17	3	20
Total		91	15	106

Table 5.4.2: Age of household heads by gender

Interestingly, as shown in Table 5.4.2, it appears that almost all of the interviewed female household heads were aged above 30 years as opposed to male-headed households. This could be explained by the fact that most female household heads who were interviewed were either widows or were divorced; hence the observed age difference between female and male household heads. Age may influence the overall participation of the household head in both farm and non-farm activities. For example, while younger household heads may want to try new technologies, the older household heads may be reluctant to make changes because of their past experience. On the other hand, however, older household heads might have already established reliable contacts and accumulated wealth over time, hence making them less averse to the risks entailed if they adopt new technologies. Due to the current energy problems in the district, this study initially hypothesized that all the age categories of household heads would be ready to adopt renewable energy innovations. To test this, I performed a cross-tabulation between age and energy source for lighting (see Table 5.4.3a below).

Age categories * Energy for lighting? Cross-tabulation

Count

		Energy for lighting?		Total
		Kerosene	Solar power	
Age categories	<19	2	0	2
	20 - 29	18	0	18
	30 - 39	36	3	39
	40 - 49	25	2	27
	>50	20	0	20
Total		101	5	106

Table 5.4.3a: Relationship between age and energy source for lighting

Contrary to what was initially expected, the cross-tabulation revealed that only middle-aged groups (30-39 and 40-49) had adopted solar PV systems. The explanation for this could perhaps be attributed to household income as the adopters in these groups appear to belong to households whose annual incomes exceed TZS 400,000 (middle and upper income groups. And as noted earlier, this could also be due to the fact that household heads in these age groups are still very active and have established themselves over years, which makes it easier for them to secure loans from financial institutions; or they might have accumulated adequate capital to spend. Results from further cross-tabulation also appear to suggest that some of the household heads in these age groups (30-39 and 40-49) were petty traders, teachers or extension officers (see Table 5.4.3**b** in Appendix A) and this may partly explain why this group adopted solar PV systems. After further cross-tabulating age groups with income, the results demonstrated that there is a weak association (small effect) between age groups and income; and there appears to be no association at all between the 30-39 age group and income above TZS 1,000,000 (See appendix A: Tables 5.4.4; 5.4.5 for a contingency table and symmetric measures). On the other hand, the test of strength of association between age and adoption of solar PV systems was also weak (see Table 5.4.6 below).

Symmetric Measures

		Value	Approx. Sig.	Exact Sig.
Nominal by Nominal	Phi	.173	.528	.450
	Cramer's V	.173	.528	.450
	Contingency Coefficient	.171	.528	.450
N of Valid Cases		106		

Table 5.4.6: Strength of association between age and adoption of solar PV systems

The Cramér's V coefficient was .173, indicating a small effect, but this reflects the fact that both the youngest and oldest household heads were non-adopters as shown in Table 5.4.6 above.

5.1.5 Household Size

The household average size of the sample households is 6.16, slightly higher than the 5.9 average of Magu District indicated in the 2002 population census (see Table 5.5 in Appendix A). A one- sample T-Test was used to compare the 2002 population census household size with the household average size from the sample households.

One-Sample Test

	Test Value = 5.9					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Number of household members	1.241	105	.218	.260	-.16	.68

Table 5.5.1: Results of a One Sample T-Test for household size

The results from a one-sample T-Test, indicate that the difference is statistically non-significant, $t\ (105) = 1.241$, $p > .05$ (see Table 5.5.1). It was also observed that the average household size of 6.16 is similar to that in other districts in Mwanza region. The 2002 population census, for example, indicates that household sizes in Ukerewe, Kwimba, Sengerema, Geita[163] and Misungwi districts were 6.2, 6.2, 6.1, 6.0 and 6.3 respectively. The total number of members in the household not only gives a snapshot of the potential labour

[163] Became a region in 2012

available to the household but may also indicate the level of dependence in the household. It is obvious that as the number of household members increases, so does the cost of living. Therefore, household size may positively or negatively depict the income of the household heads in the study area. As the majority of households depend on fewer resources that are available in the district, small or large household size may determine the dependency ratio and income of a particular household. For example, households with the most dependent members (i.e. children and the elderly) are more likely to be overstretched with the household expenses than their counterparts. It is also worth mentioning that the majority of rural households in the study area depend on forest products such as firewood for their domestic energy needs as well as land for agriculture. Therefore, this study assumes that the bigger the household size, the more the household consumption of energy for cooking and lighting, hence a greater incentive to adopt improved cooking stoves or solar power systems[164]. Larger households not only are likely to have higher household energy consumption levels but are also thought to consume more from the common resources (i.e. forests). Increased demand for firewood from the commons would only increase firewood scarcity and as a consequence cause further deterioration of the environment and household living standards in the district. Evidence suggests that biomass energy sources play an important role in the country's energy balance whereby cooking with biomass energy sources is still a common practice in rural and urban areas. This study found that most of the households in the study area still heavily depend on biomass energy sources for their daily domestic energy requirements such as cooking. For example, the study found that most of the households in Magu still use traditional three stone stoves for cooking despite the deliberate efforts (from government and other actors) to promote improved cooking stoves in the district (see Figure 9 below).

[164] However, that might also not be the case since the households may not be able to save enough money to invest in technologies such as solar PV systems.

Figure 9: Types of stoves used in the study area

As shown in Figure 9 above, about 89.6% of the interviewed households were found to be using traditional three stone wood-fuel stoves; while only 6.6% and 3.8% were using improved wood-fuel stoves and charcoal stoves respectively. Most of the cook-stoves that are used by households in the district are inefficient; and cooking still heavily relies on firewood. Despite the fact that some of the sample households were found to use multiple sources of energy, the majority still use firewood and charcoal as their main energy sources for cooking and heating, with only a small proportion of the sample found to be also using kerosene and cow dung as supplements[165]. In some cases firewood is also used for local beer brewing, fish smoking and brick-burning.

[165] Previous studies suggest that Kivukoni, Busega, Itumbili and Sanjo divisions are areas where agricultural farm residues and animal dung are mostly used to supplement other sources of energy for cooking (URT, 1997).

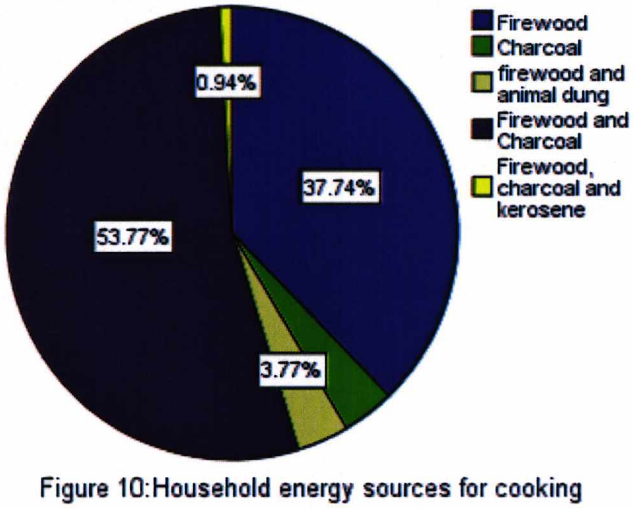

Figure 10: Household energy sources for cooking

About 99% of households use biomass energy sources for water heating and cooking (see Figure 10). Thus, firewood remains a major energy source accounting for a large percentage of the total energy consumed in most households in the study area. It is important to note that a household's preference on energy sources for cooking largely depends on the availability of the energy sources in question. For example, although scarcity of firewood has forced poor households to use agricultural crop residues from cotton and maize, while others have resorted to supplementing firewood with cow dung, these energy sources remain at the bottom of the fuel ladder among the households in the study area. However, during the course of this study it was found that agricultural crop residues and cow dung are only used by a significantly smaller proportion of the sample households. It was also observed that crop residues burn quickly and therefore households in the study area perceive them as unreliable energy sources as opposed to firewood and charcoal. As indicated in (Figure 10), about 1% of the interviewed household heads said they were also using kerosene for cooking. While on one hand that could be an indication of an increasing shortage of biomass fuels, on the other hand it could be an indication of improvement in household income and hence changes in energy source preference. However, it is important to also note that in most cases poorer rural households in the study area cannot afford cooking with conventional energy sources such as kerosene in periods of firewood scarcity. Though kerosene used to be subsidised by the government and is considerably cleaner than biomass fuels, it is still regarded as being more expensive than traditional biomass fuels by the majority of rural households[166]. Thus, it may be equally argued that household energy choice or preference in the study area is to a great extent determined by its availability and the ability of households to afford the cost of the energy source in question. It appears that rural households' dependence on biomass energy sources has not gone down although the district is currently facing an acute shortage of forest resources. Further clearance of land for agricultural activities and excessive utilisation of existing forest products would only accelerate the current energy problems and this was clearly evident during the fieldwork[167]. The study, for example, explored household heads' awareness of environmental problems in their respective villages. Respondents were asked to comment on what they thought about deforestation, causes of deforestation and what could be the possible solutions to the problem. Interestingly, about 99% of the interviewed household heads were able to identify what they perceived as being the major causes of deforestation in their areas (see Figure 11 below).

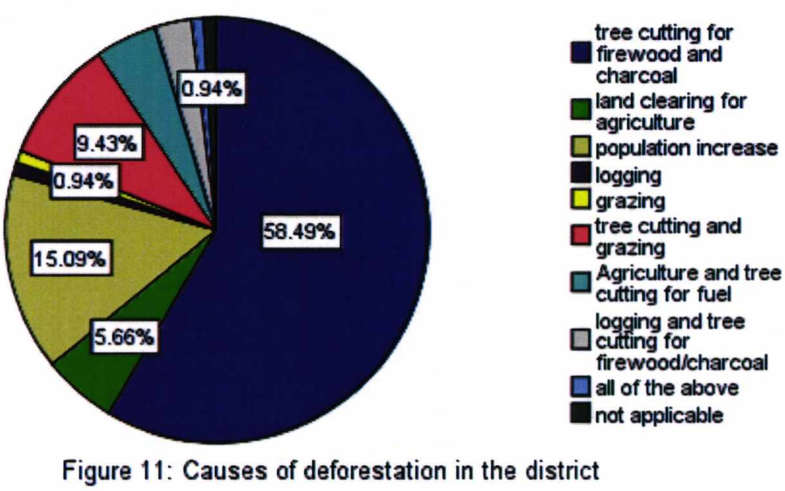

Figure 11: Causes of deforestation in Magu District

The majority of the household heads mentioned tree cutting (for firewood or charcoal), land clearing for agriculture, population increase, and logging as the major causes of deforestation in their areas (see Figure 11). It must be noted that the rural population has dramatically grown in recent years and that has increased demand for biomass energy sources. According

[166] The government has recently increased the price of kerosene and that has meant it has even become more expensive for the poor rural households.

[167] It is important to note, however, that firewood consumption varies considerably among individual villages across the district due to significant ecological changes that have taken place in the area over the years.

to Madulu (2004:89), the increasing rural population causes increased demand for farming land and energy needs that have to be met by the available natural forests. This has, in turn, accelerated deforestation in rural areas (ibid.). The above households' perceptions about the environmental problems illustrate the challenges that face households in Magu District. The current environmental problems are constraining the efforts to achieve sustainable development. Thus, more needs to be done if such efforts were to become successful. That would mean among other things, encouraging sustainable use of available natural resources as well as improving energy efficiency by adopting renewable energy technologies such as solar PV systems and improved cooking stoves. However, this is not to say that adopting renewable energy technologies would automatically end environmental degradation in the district and other rural areas in the country. On the contrary, socio-economic development coupled with advancement in technology in rural areas may also generate 'new' environmental problems[168] (i.e. environmental problems that have not previously been experienced in those areas). Empirical evidence, for example, appear to suggest that while it is true that most of the poor countries use less efficient technologies in their production activities (i.e. using more resources to produce less products and thus causing more pollution), these countries consume the least amounts of resources in per capita terms (York et al., 2009:137). Research findings from the study conducted in China, India, Japan and the United States indicate that the more their economies expanded, the more they intensified the exploitation of their natural resources. Therefore, the improvements in efficiency did not reduce but rather increased their consumption of natural resources. They therefore argue that their findings contrast with the *ecological modernization* theory's main assumptions that regard technological improvements and production efficiency as being the key solutions to the current environmental problems (ibid.).

5.2 Households' participation in renewable energy initiatives in the study area

Participation of households in renewable energy initiatives is essential for enhancing innovation. The analysis of the data suggests that households in the study area were not ***fully*** involved in the early stages of planning these renewable energy projects. What is evident, however, is that the efforts to involve households only gained momentum in the

[168] See Appendix D for detailed discussion about Jevons' Paradox. In the paradox, some scholars have disputed the assertion that technological improvements lead to decreased energy consumption. They contend, instead, that technological efficiency drives up the demand for natural resources and energy use hence technological efficiency would not necessarily save the environment from damage (York et al., 2009:137; Polimeni et al., 2008:2; Harper, 2008:24).

implementation stages of the projects in question. For example, a survey on UNDP/GEF project (on transformation of rural PV market), found that households in the study area were not aware of the strategic key players or stakeholders in the solar PV market, i.e. suppliers and technicians. These households were also not aware of the opportunities for income generation resulting from the adoption of solar PV systems (Kimambo, 2009:16). Thus, there is a need to involve households in renewable energy projects because their participation in planning these projects is part of the learning process. This is because "innovation process is viewed as one involving interactive learning, embedded in series of relationships and institutional contexts that (through learning) evolve over time" (Hall, 2006:11). According to the World Bank (2006:16), "innovation is an interactive process through which knowledge acquisition and learning take place" [and] this process often requires quite extensive linkages with different knowledge sources". It is suggested, for example, that generation and exchange of technical knowledge are not the only prerequisites for innovation. Rather, it is argued that other factors such as organisational capacity, policy, infrastructure, funding, markets as well as linkages among heterogeneous actors also need to be taken into account for innovation to occur (Kilelu et al., 2011:9). However, "innovation needs effective co-ordination to allow the often fragmented stakeholders with different assets, knowledge, and experience to participate in the innovation process" (OECD-FAO, 2012:27). Actors in an innovation system do not often innovate in isolation but rather through interaction with other actors (World Bank, 2012:11). Such actors may include households, firms, farmer organisations, researchers, financial institutions and public organisations (ibid.). This study, therefore, argues that innovation brokers (i.e. intermediary organisations) may facilitate the linkage between various actors in the study area. This may in turn encourage involvement of the households in planning and implementing future renewable energy initiatives.

Box 5: Successful examples of innovation brokers

Experience shows that innovation brokers have played an important role in agricultural innovation systems in developing countries. For example, according to Klerkx et al. (2009:27), national NGOs have brought together several actors in the Kenyan agricultural sector and that has facilitated the transition to organic agriculture in export horticulture production. Also Pachamama Raymi is the farmer network broker which has enabled the sharing of indigenous knowledge in Bolivia (ibid.). International Development Enterprises which is an international NGO has served as an example in managing packing technology and low cost irrigation pump innovations in India and Bangladesh. Other examples include the evolution of the Andhra Pradesh Netherlands Biotechnology Programme into a self-financed broker of research and development projects whereby biotechnology was used to address smallholder agriculture. The creation of the National Agricultural Advisory Services (NAADS) in Uganda also helped farmers to hire and train private service providers who assisted with technology and marketing support (ibid.). Farmer associations in India played an important role in the transmission of knowledge about vanilla production technology among farmers, negotiating prices with traders, and determining quality standards (World Bank, 2006:45).

It is suggested, for example, that through innovation brokers, actors in an innovation system are often more aware of and responsive to the needs and concerns of other actors, especially resource-poor households (World Bank, 2012:11). Without innovation brokers to address social and resource imbalances, prospects for the rural poor to participate in innovation processes are likely to remain limited (ibid.p.12). Although innovation brokerage comprises several functions; these functions can be summarised into three main generic functions which include: demand articulation (analyzing the context and articulating demand), network composition (composing networks), and innovation process management i.e. facilitating interaction[169] (World Bank, 2012:222-3; Klerkx et al., 2009:11).

5.2.1 Rural cooperative societies as innovation brokers

The ILO (International Labour Organization) defines a cooperative as "an autonomous association of persons united voluntarily to meet their common economic, social and cultural

[169] Demand articulation: "articulating innovation needs and visions and corresponding demands in terms of technology, knowledge, funding and policy, achieved through problem diagnosis and foresight exercises" (Klerkx et al., 2009:11). Innovation scholars suggest that "the participatory assessment of problems and opportunities through quick system diagnosis identifies promising entry points (in terms of prospective markets), supportive policy, and constraining factors to be overcome. The analysis provides information to stipulate a shared vision and articulate demands for technology, knowledge, funding and other resources" (World Bank, 2012:222). Network composition refers to facilitation of linkages amongst relevant actors through scanning, scoping, filtering and matchmaking of possible cooperation partners that have complementary resources such as knowledge, technology, and funding (Klerkx et al., 2009:11; World Bank, 2012:223). Innovation process management implies enhancing alignment in heterogeneous networks that are constituted by actors with different institutional reference frames which relate to norms, values, incentives and reward systems. Since the actors involved in coalitions come from different backgrounds; coalition building requires continuous translation between actors, the building of trust, establishing working procedures, fostering learning, motivating, managing conflict and intellectual property management (ibid.).

needs and aspirations through a jointly owned and democratically controlled enterprise[170]". Cooperative societies were first established in Tanzania in 1925 (Bee, 2007:74; Ministry of Agriculture and Cooperatives, 1997:2). Coffee producers in Kilimanjaro region formed what became known as the Kilimanjaro Native Planters Association (KNPA) which was later transformed into the Kilimanjaro Native Co-operative Union (KNCU). The British colonial government issued the first Co-operative Ordinance in 1932. The aim was to promote production and marketing of cash crops in different regions. Therefore, it is not surprising that co-operative societies were first established in areas where cash crops such as coffee, tobacco and cotton were being grown. These areas included Kilimanjaro, Kagera, Arusha, Ruvuma and parts of the Sukumaland. Cooperative societies served as channels through which credit institutions could reach households in rural Tanzania. They were involved in purchasing of farm inputs (i.e. seeds, fertilizers, farm equipment) as well as harvesting and marketing of farm outputs (ibid.). Before the country got its independence in 1961, cooperatives were formed from the members' own initiatives (Ministry of Agriculture and Cooperatives, 1997). The government mainly focussed on provision of information, sensitization, education and training, as well as inspection and supervision. "Cooperatives maintained their autonomy and practised the principle of self help" (ibid. p.2). However, after independence, the government became actively involved in the establishment and running of cooperative societies. As a consequence, cooperatives became increasingly integrated with the government objectives hence members' interests and aspirations were gradually undermined. As time passed, these cooperatives became increasingly dependent on the government. By mid 1970s, they were under active control of the government and as a result lacked international standards of what constitutes a cooperative society[171] (ibid.p.3). In order

[170] See ILO R193-Promotion of Cooperatives Recommendation, 2002 (No.193). Also according to Poliquit (2006:22), a cooperative refers to "a voluntary, democratically controlled association of people with the specific purpose of conducting some kind of business".

[171] Cooperative Principles include: 1. Voluntary and Open membership: co-operatives are voluntary organisations, open to all persons able to use their services and willing to accept the responsibilities of membership, without gender, social, racial, political, or religious discrimination 2. Democratic member control: co-operatives are democratic organisations controlled by their members, who actively participate in setting their policies and making decisions 3. Member economic participation: members contribute equitably to, and democratically control, the capital of their cooperative 4. Autonomy and independence: co-operatives are autonomous, self-help organisations controlled by their members 5. Education, training and information: co-operatives provide education and training to their members, elected representatives, managers, and employees so they can contribute effectively to the development of their co-operatives 6. Cooperation among co-operatives: co-operatives serve their members most effectively and strengthen the co-operative movement by working together through local, national, regional and international structures 7. Concern for community: while focusing on member needs, co-operatives work for sustainable development of their communities through policies

to control and regulate cooperative activities, the government introduced two legislations: the Co-operative Societies Act of 1968 which replaced the earlier Co-operative Societies' Ordinance of 1932 and the Unified Co-operative Services Act of 1968. Through the Co-operative Societies Act, the Registrar of Co-operatives could now control, supervise, audit, register, and dissolve co-operatives. Co-operatives were therefore required to operate within the government boundaries which meant they were now directly controlled by the state (Bee, 2007:90). Eventually, the government disbanded co-operatives in 1976 (ibid.). Membership to newly formed cooperatives then became compulsory and these cooperatives became de facto part of the state structures, directly receiving government support (Wennink and Heemskerk, 2005:33). However, under the influence of structural adjustment and economic liberalisation, most of the cooperatives later became inefficient and collapsed. Interestingly, some of these cooperatives have somehow survived and are currently engaged in reforms to become genuine membership-based organizations that comply with cooperative principles (ibid.). According to Wennink and Heemskerk (2005:38), farmers' organizations such as cooperative societies can fulfil several roles in an innovation system. These roles include: "voicing the problems and needs of farmers in directing knowledge-for innovation services (e.g. research, extension and training)". The authors argue that "commodity-based producers' organizations with their own financial resources are in a position to organize and/or outsource some of these services themselves, while community-based organizations may, to some extent, offer such services on a more voluntary basis". Cooperative societies are also tasked with "organizing the exchange and sharing of knowledge among members, as well as with other stakeholders (e.g. initiating multi-stakeholder platforms)"[172]. Experience suggests that through their economic roles, farmers' organisations are often well-informed about markets, which helps them define the overall direction and thrust of innovation (ibid.). They also provide economic services such as input supply and product marketing as well as organizing financial services (e.g. outsourcing savings and credit schemes, and providing insurance) to their members, which facilitates investments and mitigates associated risks (ibid.). Cooperative societies can also be involved in coordinating the services provided to their members by establishing functional relationships between different farmers' organisations

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accepted by their members (International Co-operative Alliance, 1995; Ministry of Agriculture and Cooperatives, 1997:3).

[172] The range of knowledge and information sources for farmers' organisations is wider than that of public research centres and extension organisations (Wennink and Heemskerk, 2005:40). Farmers' links with different actors widen the knowledge scope and provide information on market access, safety norms, environmental regulations etc. These may in turn facilitate innovation (ibid.).

(i.e. bridging) and by linking with other actors that operate within the sector. At the same time, they contribute to "community-oriented social services (e.g. education and health) for their members and infrastructure development (e.g. rural roads, storage and processing facilities) that facilitate stronger members' and non-members' entrepreneurial capacities". Cooperative societies also represent farmers and participate in policy and decision-making processes that create conditions and institutions that foster innovation (ibid.). Experience has shown that farmers' organisations provide important social capital that facilitates the adoption of technological innovations (ibid.p.93).

Box 6: MVIWATA – a farmers' organisation in Tanzania

MVIWATA (Mtandao wa Vikundi vya Wakulima Tanzania) is a national network of farmers' groups in Tanzania. MVIWATA was established in 1993 as a new representative network of farmers' groups, representing about 60000 farming households in Morogoro, Iringa, Tanga, Mbeya and Dodoma regions. Through its local networks, MVIWATA is strongly involved in Agricultural research and development and has initiated a farmer-to-farmer knowledge exchange for innovation as well as contracting agricultural services. Sokoine University of Agriculture (SUA) spearheaded the establishment of MVIWATA. The organisation was formally registered in 1995 and its mission is to link farmers' groups and local networks of such groups together into a sound and strong national farmers' organisation capable of ensuring representation and advocacy of their interests in decision-making processes. MVIWATA is represented at the village level and small-scale farmers can become members and hold positions in the organisation. MVIWATA collects and disseminates practical and technical information through formal and informal networks within its structure. The organisation plays an important role in rural innovation and links up with all actors (both local and international). It is recognised by farmers and other stakeholders as being a credible, independent, and democratic organisation with elected representatives. MVIWATA adopts a bottom up participatory approach in which farmers fully participate in designing and implementing innovative technologies for enhancing agricultural productivity. It encourages farmers to work together on various development initiatives thereby strengthening local farmers' groups and networks. The organisation also emphasizes formal research to improve indigenous knowledge i.e. integrating farmers' indigenous technical knowledge in new technologies. MVIWATA has facilitated the adoption of agricultural innovations such as the replacement of conventional cultivation systems that involved frequent ploughing and tillage to 'conservation agriculture'; and farmers have adopted rainwater harvesting techniques and agro-forestry in drought-prone regions such as Dodoma. MVIWATA members now realize the importance of working as a group to improve their socio-economic conditions. Farmers in areas covered by MVIWATA can now initiate their own development projects and take responsibility for implementation, monitoring and evaluation. **Source: Wennink and Heemskerk (2005).**

I therefore argue that there is a need to revive cooperative societies in Magu district if we want to address the current energy problems and other rural development challenges. Although other organisations[173] such as government agencies, NGOs, and private enterprises

[173] According to Klerkx et al. (2009:28), innovation brokers in developing countries include: national NGOs, international NGOs, international donor agents, farmer and industry organisations, research organisations or affiliates, government organisations, etc.

may also act as innovation brokers in the district; farmers' organisations such as cooperative societies are likely to play a key role in innovation because they have the capacity to pool, aggregate, and disseminate knowledge and information (Wennink et al., 2007:12). Cooperative societies are often positioned in both service networks and supply chains that allow them to coordinate activities and create an enabling environment for innovation (ibid.). My main argument here is that if cooperative societies were to be revived, they could as well play an important role in facilitating the adoption of renewable energy innovations in the study area[174]. I argue that a well-established cooperative society is capable of serving several purposes in the district. Since socio-economic activities in the study area (as is the case in most rural areas) are interconnected in one way or another; cooperative societies should not be limited to fewer activities such as providing agricultural inputs and buying agricultural crops. Instead, cooperative societies can utilise the available resources and existing social networks to facilitate the adoption of renewable energy technologies (equipment) such as solar cookers, solar lanterns, improved cooking stoves as well as solar PV systems. Reviving cooperative societies in the district would not only widen households' access to information and training but would as well pave a way for any credit arrangements and may serve as market centres for renewable energy equipment. Before co-operatives were disbanded by the government in 1976, they had succeeded in organising and managing rural credit (Bee, 2007:99). The Nyanza Cooperative Union, for example, was among the regional cooperative unions which operated in the study area for decades. Nyanza Cooperative Union provided reliable market for cotton which is the main cash crop in the study area. The collapse of the Nyanza Cooperative Union affected the production of cotton because it used to be a reliable market for households. Therefore, rural cooperative societies (as innovation brokers) may facilitate the involvement of households in the planning and implementation of renewable energy initiatives in the district. There have been concerted efforts by individuals in communities to revive the cooperative societies in the form of credit unions, i.e. SACCOs as earlier discussed in this chapter. However, in most rural areas, these credit unions have been successful only when they recruit members who are formally employed in government or

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[174] With the collapse of co-operative societies, households in the district no longer have easy access to agricultural inputs on a credit basis as was the case in the past. Before market liberalisation, however, it was common for the households to be supplied with agricultural inputs from the co-operative societies at an appropriate time (Care Tanzania, 2004:5). This study found, for example, that before the collapse of these societies, inputs were provided on credit just a few months (sometimes weeks) before the respective farming seasons began; after the harvest, co-operative societies would deduct the amount of money equivalent to the value of the inputs provided.

private institutions because with such members they (credit unions) are assured of loan repayments. The few existing credit unions require their members to repay their debts monthly and that is done by directly deducting repayments from their monthly salaries. Below is an example from the study area:

Box 7: Magu Teachers' SACCOs

The Magu Teachers' SACCOs was established in 1993. A group of teachers organised themselves to raise funds and then distribute the funds among members after a certain period. Magu Teachers' SACCOs was officially registered on 17th August, 1994. Its registration number is MZR. 860. Initially, each member was required to contribute about 2,000 (Tanzanian shillings) every month. The money collected from monthly contributions were then shared by members annually (at the end of the year).However, in 1997, after being advised by the registrar of cooperative societies, Magu Teachers' SACCOs started mobilising savings and providing loans to its members. At the time of its official registration in 1994, Magu Teachers' SACCOs had 14 members. By 2009, it had about 810 active members. It must be noted that Magu Teachers' SACCOs initially targeted teachers who were working under the office of district director. However, in 2007, other employees of the office of district director were also allowed to join as members, but the SACCOs retained its name (i.e. Magu Teachers' SACCOs).The Magu Teachers' SACCOs has the following core objectives: creating a savings culture for its members; receiving and securing the savings from its members; sourcing for funds so as to build the capacity to offer loans to its members; training its members on how to utilise borrowing opportunities and providing cooperative education to its members. By 2009, Magu Teachers' SACCOs had a capital of about 284,000, 000 (Tanzanian Shillings). The SACCOs receives financial support in form of loans from various financial institutions. For example, from 1999 to 2009, it received loans from Muungano wa SACCOs, SELF, CRDB Bank and UNDP. Magu Teachers' SACCOs has reported a remarkable repayment rate of the loans received. It has managed to repay 100% of the loans within a specified period of time. The success in repaying its loans is attributed to its members paying their loans on time. Magu Teachers' SACCOs can easily collect all the loans because the repayment instalments are deducted directly from the members' salaries. Names of members who have qualified for loans are submitted to the Treasurer in the Ministry of Finance and the deductions are effected and then deposited directly to the account (i.e. the Magu Teachers' SACCOs).

Source: UNDP/GEF (Transformation of Rural Photovoltaic (PV) market in Tanzania project

But the majority of people in Magu District are either unemployed or in informal employment; therefore this type of credit union may not serve the interests of various groups in the district. It appears that Savings and Credit Cooperatives alone may not be able to meet the expectations of many households in the district, unless such schemes are incorporated and run by well organised and functioning rural cooperative societies or other local organisations which include all actors. It is therefore against this background that this study calls for the transformation of former rural agricultural cooperative societies in the district. If transformed, these cooperative societies would be able to serve as innovation brokers and may facilitate various innovation activities in the district. It is anticipated that these cooperative societies will be able to mobilise savings from various member groups, i.e. those involved in farming activities or non-farm activities. More importantly, very well established cooperative societies are more likely to qualify for larger loans from financial institutions. Such loans could be invested in common facilities that are intended to serve all community members. That may, among other things, include installation of small scale off-grid renewable energy systems for social services such as water pumping, schools, health centres as well as serving rural industry, for example food processing factories and cotton ginneries.

5.3 Summary of the main findings

The chapter analysed the social and demographic factors that influence household adoption of renewable energy innovations in Magu District. Despite initiatives from both government and non-government organisations to promote renewable energy innovations in the study area, only a small percentage of households appear to have adopted solar PV systems and improved cooking stoves. The study found, for example, that only 4.7% and 6.6 % of the interviewed households had adopted solar PV systems and improved cooking stoves respectively. The majority of the households in the district still use kerosene for lighting and traditional three stone wood-fuel stoves for cooking. The findings suggest that income serves as an important factor for adoption of solar PV systems in the district. This study found that solar PV systems were to a large extent adopted by households whose heads had permanent employment or are engaged in non-farm activities i.e. teachers and businessmen (petty traders). This could be attributed to several factors such as having more disposable income than other villagers, access to financial institutions or nature of their economic activities.

Although households in the study area engage in both farm and non-farm activities; the study found that some of the household heads are opting for non-farm activities as a strategy to cope with poor agricultural returns and land pressure resulting from an increasing population. However, the findings suggest that the majority of the households in the study area had no access to any form of credit from commercial banks or other lending institutions. Due to the fact that the available micro-credit institutions operate under risky conditions, household heads who are permanently employed were more likely to have access to loans from micro-credit institutions. Formal employment and petty trading appear to be the main non-farm income earning activities in the study area. Non-farm activities (through diversification) appear to be providing new opportunities for households to earn extra income. This may likely attract more households to engage in non-farm activities. That could foster innovation by having positive influence upon households' decisions to adopt renewable energy innovations.

On the other hand, despite the fact that the right of women to have equal access and control over resources within the households is central to rural innovation; the study found that decision-making over household income and resources is generally in the hands of the male household heads. It was also observed that while both men and women are involved in farm and non-farm activities; women appear to carry out the bulk of domestic chores. Although the gender division of labour within the households may be a strategy to meet household needs, the nature of division of labour in the study area may restrict the involvement of women in the innovation process. Domestic chores such as cooking and collecting firewood are among the factors that may be limiting women's participation in the innovation process. This is due to the fact that these women sometimes do not fully participate in certain economic activities at the community level.

Although income appears to have been a significant factor for adoption of solar PV systems in the district; other factors such as education and occupation appear to have also influenced the adoption of renewable energy innovations. The study found, for example, that solar PV systems were also adopted by household heads with a relatively higher level of education and whose ages were between 30 to 49 years. Some of the household heads in this age category (i.e. 30 to 49 years) were teachers, petty traders or extension officers. However, the study findings suggest that there was no association between age group and income. At the same time, there was also no association between age and adoption of solar PV systems. Information played a part for the households that have adopted renewable energy innovations. Most household heads mentioned exchanging information among friends as well as demonstration projects as their primary sources of information. The study found that individual exchange of information (i.e. between neighbours or friends) was a major source of information about solar PV systems for the majority of the households in the study area.

On the other hand, the analysis of the study findings suggests that households in the study area are not being fully involved in the planning, implementation and monitoring of renewable energy projects. This therefore calls for innovation brokers (i.e. community-based organisations) that may facilitate the involvement of households in the planning and implementation of renewable energy initiatives in the district. There are various community-based organisations that exist in the study area. These include: farmer organisations, faith-based organisations, women groups, youth groups, saving and credit groups etc. Although there have been concerted efforts by individual groups to revive the cooperative societies in the form of credit unions (i.e. SACCOs); these credit unions have been successful only when they recruit members who are formally employed. Therefore, Savings and Credit Cooperatives alone may not be able to meet the expectations of many households in the district, unless such schemes are incorporated and run by strong and well organised community-based organisations that can serve as 'intermediaries' (i.e. innovation brokers).

Chapter 6: Conclusions

The main focus of this thesis has been to explore the factors that facilitate or impede the transfer of renewable energy innovations in rural Tanzania. This study sought to broaden the perspectives beyond the existing innovation literature, especially in understanding innovation processes in the rural setting. I have employed the 'innovation systems' approach as the main analytical framework but also took on board other conceptual, theoretical and analytical perspectives on innovations. I have sought to answer the following questions:

i) What social and/or demographic factors facilitate or impede the transfer and adoption of new, low-carbon energy technologies in rural Tanzania?

ii) What types of local organisations may promote renewable energy innovations in rural areas?

To answer the above questions and meet the set objectives, a number of methods have been employed in this study. As discussed in chapter 4, investigations into the factors that may influence the adoption of renewable energy innovations in rural areas were based primarily on questionnaire surveys, interviews, focus group discussions and a review of the secondary literature. This study also sought to test the following main hypothesis:

Main hypothesis:

- Rural renewable energy initiatives will be more successful where they aim at providing energy access to individual households rather than small-scale rural industries.

The main hypothesis above was tested by reference to the empirical findings, review of government energy policy documents as well as theoretical assumptions that guided this study. It appears, however, that the study findings do not support the above hypothesis. Although the government and other actors (i.e. private dealers, non-government organisations) have in recent years tried to promote solar PV systems across the district, it was found that only 4.7% of the interviewed households had adopted solar PV systems. The majority of the households in the district still use kerosene for lighting and heavily rely on traditional three stone wood-fuel stoves for cooking. The findings suggest that income is an important factor determining the adoption or non-adoption of solar PV systems in the district, because solar PV systems were to a large extent adopted by households whose heads had permanent employment or were engaged in non-farm activities, i.e. teachers and petty traders[175]. What I found interesting, however, was that the UNDP solar PV demonstration project in the district has largely focused on promoting solar PV systems by installing the systems in selected health centres and secondary schools. This is meant to attract households to also install PV systems in their homes. Although this might have attracted potential adopters, it has basically not addressed the cost issue and other social-cultural barriers[176]. It was observed, for example, that some households in the district still prefer traditional grass-thatched houses[177] as well as keeping a large number of livestock. Keeping large flocks of animals not only serves as an important source of wealth and social prestige for these households but it also serves as a means to protect households against food insecurity in times of poor harvests. In such situations, for a large portion of households in the study area livestock keeping may therefore be seen as being socially, culturally or economically more important than installing solar PV systems, because to raise the money to install solar PV would entail selling livestock, the only source of capital which most rural people possess. It was also observed that due to traditional male dominance in the study area, household decisions over resource allocation and income are very much influenced by men. This has significant implications for rural innovation since women are denied their right to have equal access and control over resources within the households. While both men and women are involved in farm and non-farm activities, women appear to carry out the bulk of domestic chores. Although the gender division of labour within the households may be a strategy to meet household needs, such strategy may constrain women's participation in innovative activities at the community level. For example, because women do most of the cooking, they might be presumed to have an interest in improved cooking stoves and/ or provision of electricity by solar PV. But they are not involved in decision-making, so their perspectives are in most cases left out.

On the other hand, my findings suggest that active rural community participation is to a large extent lacking in most of the renewable energy projects that have been initiated by the Tanzanian government in collaboration with non-governmental organisations or donor

[175] As mentioned earlier, this could be attributed to various factors such as having more disposable income than other villagers, education levels and their eligibility for loans from financial institutions. Despite the fact that non-farm employment has increasingly become important in recent years, the majority of the households in the district still rely on farming activities as their main source of income.

[176] It appears that social, cultural and economic factors are influencing households' perceptions (i.e. in terms of decision making and prioritisation of household needs).

[177] Poorly constructed traditional grass-thatched houses are not considered suitable for the installation of solar PV systems.

countries in the study area. Demonstration projects, for example, have not focused on assisting groups or community-based organisations to run small-scale industries[178]. Demonstration projects that have been carried out in Magu District are what Rogers (2003) categorises as '*exemplary demonstrations*'. This implies that such demonstration projects are meant to attract potential adopters into adopting solar PV systems and/or improved cooking stoves. However, it is presumed that these demonstrations will attract more rural households if they promote small-scale rural industries rather than focusing on individual households. Rural industries could create more opportunities for rural households to be involved in innovative activities and their success will be easily shared, felt and seen by the majority in the community. Small-scale industries will not only facilitate rural socio-economic development but will also be a catalyst towards rural innovation. Moreover, in an industrial setting, investment in solar PV could be seen as an input cost in a process designed to generate an economic surplus rather than as a relatively expensive element of enhanced consumption, as it might be seen in a household setting.

Rural participation in renewable energy projects

The innovation literature has often emphasized the importance of involving rural actors in planning and implementation of rural development projects. My findings, reported in chapter 5, suggest that the extent to which renewable energy innovations can successfully be adopted in rural areas, and thereby contribute to rural development, would largely depend on whether rural actors (i.e. households, community-based organisations etc.) are also fully involved in the process of planning and implementation of respective rural energy projects. Active involvement of local actors in the innovation process (in an industrial setting) could help to transcend social and cultural barriers as well as transform attitudes of rural households towards renewable energy innovations. This therefore calls for innovation brokers (i.e. community-based organisations) who may facilitate the involvement of households in the planning and implementation of renewable energy initiatives in the district. Although there have been concerted efforts by individual groups to revive the cooperative societies in the form of credit unions (i.e. Savings and Credit Cooperatives – SACCOs), these credit unions have been successful only when they recruit members who are formally employed. Therefore, SACCOs alone may not be able to meet the expectations of many households in the district,

[178] According to Rogers (2003:389), demonstrations usually serve two functions which are inherently different in nature. He cites, for example, that *experimental demonstrations* are intended to "evaluate the effectiveness of an innovation under field conditions", while what he terms as *exemplary demonstrations* are meant to "facilitate diffusion of the innovation to other units" (ibid.).

unless such schemes are incorporated and run by strong and well-organised community-based organisations that can serve as 'intermediaries' (i.e. innovation brokers) in the transfer and adoption of renewable energy innovations. As argued in chapter 5, community-based organisations such as rural cooperative societies can serve as innovation brokers and therefore facilitate various innovation activities in the district. Cooperative societies in the district are likely to play a key role in innovation because they have the capacity to pool, aggregate, and disseminate knowledge and information to the majority of rural actors. Literature suggests that cooperative societies are often positioned in both service networks and supply chains that allow them to coordinate activities and create an enabling environment for innovation. What appears to be even more important, however, is that well-established community-based organisations are capable of serving several purposes in the district. Cooperative societies can utilise the available resources and existing social networks to facilitate the adoption of renewable energy technologies (equipment) such as solar cookers, solar lanterns, improved cooking stoves as well as solar PV systems.

Renewable energy and rural development

Since the 1960s, development strategies in Tanzania have consistently focused on alleviating poverty and eliminating social and economic inequalities amongst its population. However, it appears that ineffective policies coupled with the high demand of the growing population for basic social services, as well as global economic crises, have more or less constrained most of the government initiatives to alleviate poverty. One of the main assumptions that informed my study was that renewable energy technologies can facilitate sustainable rural development, and that to achieve that goal, rural energy supply initiatives should focus on tapping the available renewable energy sources and technologies. This also calls for the government to limit its overreliance on conventional sources of energy. What is clear, however, is that Tanzania still heavily relies on hydropower and thermal power plants and it is unlikely that rural areas will be connected to the national grid in the near future. Before that happens, immediate and appropriate measures need to be taken to supply energy in these areas. Without such measures, there will not only be negative impacts on the country's rural economy and population but also upon the country's precious natural forests. To achieve sustainable development goals, energy supply strategies must be integrated into other rural development strategies. This is because energy is a cross-cutting issue that has a potential to facilitate development in other rural sectors such as agriculture, health, education, and the development of local industry. The energy sector should therefore not be treated as an isolated or independent entity; rather, it must be considered as a key sector that unifies all other sectors in the country. That way, rural energy projects would not only play a greater role in alleviating poverty but would also create more opportunities for the rural poor. However, successful promotion of renewable energy innovations in rural areas requires close cooperation between the government and other main actors at all levels. For example, an important step would be for the government to improve its regulatory capacity because weak regulatory measures have led to widespread marketing and distribution of low quality (substandard) or counterfeit renewable energy equipment in rural areas. Poor and un-coordinated marketing encourages dishonest petty traders and unqualified technicians to informally sell and install sub-standard solar PV equipment. As discussed in the previous chapter, the quality requirement for new products (innovations) in the market plays a significant part for the development of a product in an innovation system. However, it is worth mentioning that such requirements emanate from interactive learning between the main actors and through government actions.

6.2 Limitations of the study

This section presents the limitations of this study and hence the conclusions reached above. First, it is important to note that the systematic fieldwork investigations that were conducted in Magu District found rather fewer adopters of solar PV systems or/and improved cooking stoves than was anticipated. Thus, the study conclusions reached above and which are based upon the empirical evidence from the study area, are correspondingly limited and tentative. That suggests the need for further research in the form of a much larger subsequent investigation. And since the adoption of renewable energy technologies in rural Tanzania may remain limited for the foreseeable future, there is a need for a sampling design that deliberately oversamples adopters in order to have a larger sub-sample for comparison with that of non-adopters. Although socio-economic and demographic characteristics of households provided background information about adopters and non-adopters, very little was known about them in the beginning; there was no systematically collected data about the adopters of solar PV systems or/and improved cooking stoves available in Magu district. Without such basic information, it proved difficult to identify who were adopters and non-adopters of renewable energy technologies in the case study area, and so demonstrably representative samples of adopters and non-adopters could not be selected. Studying representative samples of two different populations (i.e. adopters and non-adopters) would provide insights into how households make adoption decisions. As previously discussed, decisions to adopt a new technology can take time; therefore it also requires more time to study both adopters and potential adopters in order to illuminate the process of decision-making and the impacts of adopting new technologies upon the adopters. Therefore, future research may, for example, seek to understand the extent to which solar PV systems or improved stoves have improved incomes or living conditions of the rural adopters. The above limitations notwithstanding, this study provides important insights into challenges facing renewable energy projects in the country and the issues that will have to be addressed in order to improve the situation. Finally, the study could be extended to other parts of rural Tanzania in order to compare the findings in different rural social settings.

6.3 The study's contribution to knowledge

Although the application of an innovation systems approach in the transfer and adoption of innovations in rural areas appears to be diverse in the literature, the concept of innovation brokers (intermediaries) has so far not been widely applied in understanding the transfer and adoption of renewable energy innovations in rural areas. This study attempts to fill that empirical void, at least for rural Tanzania but, perhaps, by implication, for sub-Saharan Africa more generally. There has been less research conducted on the roles that could be played by community-based organisations such as rural cooperative societies in the transfer and adoption of renewable energy innovations, except for a few related studies that have mainly focused on the agricultural sector as opposed to the renewable energy sector. Therefore, this study contributes to the body of scientific knowledge on the role of innovation brokers (intermediaries) in the transfer and adoption of renewable energy innovations because it proposes ways in which community-based organisations could create an enabling environment for the rural poor to be involved in the innovation process. I have argued that the successful transfer and adoption of renewable energy innovations can be facilitated through community-based organisations such as rural cooperative societies. The roles these organisations could play in the innovation process are more or less similar to what Howells (2006) refers to as 'innovation intermediaries', which he defined as "an organisation or body that acts [as] an agent or broker in any aspect of the innovation process between two or more parties". Howells notes that intermediary activities may include: helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator between bodies or organisations that are already collaborating; as well as seeking advice, funding and support for the innovation outcomes (Howells 2006, p.720). Therefore, innovation intermediaries act as *innovation brokers*, whereby they facilitate the building of appropriate linkages in innovation systems as well as ensuring multi-stakeholder interaction in innovation (Klerkx et al., 2009:8).

This study contributes to the innovation systems literature because although the roles, performance and effects of innovation brokers have been widely covered in industrial and agricultural sectors, little of the previous research has focused on the roles of innovation brokers (intermediaries) in the renewable energy sector, particularly in the case of the rural areas in sub-Saharan African countries. This study has shown, for example, how Magu Teachers' SACCO has successfully served teachers in the district but has not been able to assist the majority of households who do not qualify to be members (see Box 7 in chapter 5). However, as also discussed in chapter 5, unified and well organised rural cooperative societies may serve the interests of various groups (i.e. actors) in the district. Rural cooperatives (as innovation brokers) may facilitate the involvement of rural households and other actors in the planning and implementation of renewable energy initiatives by encouraging collaborative activities during the innovation process. Experience suggests that cooperative societies are also capable of organizing the exchange and sharing of knowledge among their members, and hence may define the overall direction and thrust of innovation. Acting as innovation brokers (intermediaries), cooperative societies may be able to locate key sources of new knowledge, as well as build linkages with the external sources of information. Since generation and exchange of knowledge are not the only prerequisites for innovation, cooperative societies may also provide other services such as product marketing, infrastructure development as well as organise financial services, i.e. outsourcing and credit schemes. Cooperative societies can also facilitate members' participation in policy and decision making processes[179].

Most importantly, this is the first investigation in rural Tanzania into the relevance of cooperatives societies (as innovation brokers) in facilitating the transfer and adoption of renewable energy innovations. The study contributes to innovation systems literature by broadening our understanding about the role that could be played by cooperative societies in

[179] According to Kilelu et al. (2011:9), factors such as organisational capacity, policy, infrastructure, funding, markets as well as linkages among heterogeneous actors are important for innovation to occur.

rural areas of sub-Saharan Africa. Rather than focusing on conventional linear models of innovation processes, this study has employed systematic approaches in analysing and understanding the factors that may facilitate or impede the transfer and adoption of renewable energy innovations in rural Tanzania. I argue that since socio-economic activities in most rural areas are interconnected in one way or another, cooperative societies should not be limited to a few activities such as providing agricultural inputs and buying agricultural crops. Instead, cooperative societies can also utilise the available resources and existing social networks to facilitate the transfer and adoption of renewable energy innovations in rural areas. The study findings contribute to the emerging literature on the role that could be played by innovation brokers (intermediaries) in an innovation system (see for example, Kilelu, Klerkx and Hall, 2011; Klerkx and Gildemacher, 2012; Klerkx and Leeuwis, 2008; Howells, 2006). As discussed in chapter 3 (see section 3.1.3), the 'Tanzanian National Systems of Innovation' is underdeveloped and characterised by weak linkages between various sectors in the national economy. Evidence also suggests that the country's 'national systems of innovation', though still in their infancy (i.e. they are still emerging), have so far excluded users and other actors in the informal sector. Therefore, rural cooperative societies can play an innovation brokering role by facilitating interaction between actors in the 'Tanzanian National Systems of Innovation'. This view is supported by Howells (2006:716), who argues that "intermediaries" facilitate cooperation in the innovation system because of their role in the technology transfer process.

The study also contributes to innovation literature especially on "a technology-specific innovation system" as discussed in chapter 3, section 3.1.2 (see Jacobsson and Bergek, 2004:817; Negro, 2007:17; Carlsson and Stankiewicz, 1991:111). The study does so (in chapter 3, section 3.3) by applying the systems thinking approach to understand the connection between rural energy demands, innovation systems and sustainable development in rural Tanzania. As discussed in chapter 2 and 3, technological systems based on fossil fuels seem to benefit from the comparative advantage they have over emerging renewable energy based technological systems. For example, the Tanzania Electric Supply Company Limited (TANESCO), which was established in 1964, has largely been responsible for generation, transmission, distribution and commercial services of electricity in the country and therefore has a comparative advantage over other independent power companies (see section 2.1.2 and 2.1.3 in chapter 2). Decentralised renewable energy systems have not received much support despite the fact that they appear to be more economical, sustainable and appropriate for rural Tanzania than conventional centralised energy systems, which require massive investment in a grid distribution network. This is known as a 'lock-in problem' in innovation literature (see Negro, 2007:15; Edquist and Chaminade, 2006:115; Hekkert et al., 2007:415; Jacobsson and Johnson, 2000:633; Foxon, 2002:2). The lock-in problem reinforces the argument, made by Edquist and Chaminade (2006:115), that the adoption and utilisation of renewable energy sources such as solar in most production systems is still inadequate because of the competition from the well-established existing technological systems based on fossil fuels. This appears to be the case even in those rural parts of Tanzania that are remote from, and are unlikely soon to be connected to any electricity distribution grid. Thus, in order to analyse the current technological system (i.e. the energy system) in Tanzania, we need to first understand the boundaries of the system in question so as to identify the factors that promote or hinder its development. That would therefore require us to apply a systems thinking approach. By applying systems thinking, we may explore opportunities to leverage technology deployments within existing and new energy infrastructure in rural Tanzania. In this context, systems thinking could assist us to understand the problems associated with the transfer and adoption of renewable energy technologies in remote areas (see for example, Figure 5: dissemination of renewable energy technologies in rural areas - chapter 3). It is through 'systems thinking' that we may be able to understand the feedback mechanisms and the existing connections between energy needs, poverty, environmental degradation and sustainable development in rural Tanzania.

Appendix A

Chapter 5: Section 5.1.1

		What kind of stove do you use for cooking?		
		local traditional wood-fuel stove	Improved wood-fuel cooking stove	both 1 and 2
Income group categories	Low income group	43	1	1
	Middle income group	44	2	1
	Upper income group	8	1	1
Total		95	4	3

Table 5.1.3: Relationship between income group categories and household stove adoption[180]

Delivery models (See Box 1 in section 5.1.1)

Various energy delivery models have in the past few years been tried in rural areas. However, the widely recommended Rural Energy Supply Models (RESuM) for renewable energy projects in developing countries include: cash delivery model, credit model, leasing model and service model (Krause and Nordström, 2004; ISES, 2009). Governments, business (private dealers), and financing institutions can use these models to disseminate renewable energy technologies in rural areas (ISES, 2009). A brief description of the models with examples from countries where they have been applied and proved to be successful is given below:

Cash delivery model

Using a cash delivery model, a customer may own a solar PV system through cash purchase. Cash purchase has been referred as "the payment of money amounting to the purchase price in exchange for merchandise" (ISES, 2009). Ownership of the PV system is transferred to the customer after the full payment. Although there may be various categories under the cash delivery model; the most common models which are widely applied in rural areas (especially on solar PV systems) include cash & carry, cash sales and modular cash purchase (Krause and Nordström, 2004; ISES, 2009). The cash delivery model has been

[180] The difference between the observed and expected cell counts is minimal in each of the three categories.

successful in countries such as Botswana, Kenya, Uganda, South Africa, Zimbabwe and China (ibid.).

Cash and carry category requires the customer to make one time full payment. The customer is also responsible for PV system installation arrangements (i.e. looking for technicians to do the installation). A solar project carried out in Zimbabwe serves as a good example for *cash and carry* category. The company under the name "Solar Energy Supplies" through its established stores managed to sell DIY (Do It Yourself) PV kits to rural households in Zimbabwe on cash and carry basis. PV light system kits of different size were sold and the model proved to be economically viable for the rural households (ISES, 2009). On the other hand, ***cash sales*** agreements require the PV company (i.e. dealer or supplier) to do the complete installation of the system and in such cases cash payment could be done on two instalments e.g. before and after the installation (ibid.). In China, Gansu PV Company which started its operations in 1994 is one of the successful examples for the *cash sales model.* The company manufactures, installs and also does servicing of Solar Home Systems (SHS) including small portable solar lighting systems. It is believed that the company sells more than one thousand PV systems annually on cash sale basis. The customers are required to pay at least half of the agreed price before the system is installed (ibid.).

However, for the ***modular cash purchase***, the customer purchases individual components of the PV system over time until the entire list of the components needed for the whole PV system is completed. For example, depending on the availability of the cash, the customer may buy a solar panel in the beginning and later on add the remaining components needed for the PV system to be fully installed (Krause and Nordström, 2004). In sub-Saharan Africa, modular cash purchase system has been widely used in countries such as Kenya, Uganda, Tanzania, Zimbabwe and Mozambique. For example, by the end of 1995, the consumers in Kenya alone were able to purchase more than twenty thousand solar panels per year through modular cash purchase system (ibid.).

The cash and carry model is thought to be suitable for the majority of the rural households since the consumer (buyer) is responsible for installation and maintenance of the PV system. In some cases, the supplier may also give a user manual and a limited guarantee to the buyer (ISES, 2009). The main advantage of the cash and carry model is that the financial risk is minimized as a buyer can only own the product after making all the payments. The main disadvantage, however, is that the majority of the rural population might not afford the PV systems under the *cash and carry* model. In Tanzania, for example, experience has shown that rural households and individuals with high income have so far benefited from solar PV projects (Kimambo and Mwakabuta, 2005). Nevertheless, experience has also shown that high income earners in rural areas play an important role in the transfer and adoption of renewable energy innovations as they are always among the first group of adopters (early adopters) who demonstrate the benefits of these technologies to others (Rogers, 2003; Krause and Nordström, 2004).

Leasing model

Leasing in the context of rural energy supply has been referred as an arrangement in which the owner (supplier) of a PV system allows the customer to use the PV system for a specified period of time, in return for payment of a regular leasing fee. Under this model, the customer may be able to own the PV system at the end of the leasing period. However, unlike other models, the supplier owns the PV system and the system could be uninstalled by the supplier if the customer does not fulfil leasing conditions i.e. paying the leasing fee on time (ISES, 2009).

Service delivery model

The service delivery model is similar to a leasing model since the service provider (supplier) offers the service (i.e. PV system) to the customer in which regular service fee is paid in every specified period (e.g. on monthly basis). Service may be provided by both public and private suppliers. In some cases, prices of the services could be subsidised by the government. For example, in areas not connected to the grid electricity the service provider could be the village or community owned 'decentralised small scale power systems'. The main difference between a *service model* and *leasing model* is that the customer cannot own the PV system even after using the service for years. There are two categories under this model which are "**fee for service**" and "**energy service**". With 'fee for service', the customer pays a supplier a regular service fee for the use of electricity. In this category, the supplier "guarantees the functioning of the system excluding the electric appliances". On the other hand, 'energy service' category is almost similar as *fee for service,* but the main difference is that in this category, the supplier "guarantees the functioning of the whole system including the appliances" (ISES,2009).

Income group categories * Respondent's occupation Cross-tabulation

Count

		Respondent's occupation				Total
		Formal employment	Farm activities	Non-farm activities	Farm and non-farm activities	
Income group categories	Low income group	0	28	8	10	46
	Middle income group	2	24	9	14	49
	Upper income group	7	3	1	0	11
Total		9	55	18	24	106

Table 5.1.7a: The association between occupation and income group categories (see section: 5.1.1). This table is also connected with Table 5.1.7b in Appendix A

Income group categories * Respondent's occupation Cross-tabulation

			Respondent's occupation				
			Formal employment	Farm activities	Non-farm activities	Farm and non-farm activities	Total
Income group categories	Low income group	Count	0	28	8	10	46
		Expected Count	3.9	23.9	7.8	10.4	46.0
		% within Income group categories	.0%	60.9%	17.4%	21.7%	100.0%
	Middle income group	Count	2	24	9	14	49
		Expected Count	4.2	25.4	8.3	11.1	49.0
		% within Income group categories	4.1%	49.0%	18.4%	28.6%	100.0%
	Upper income group	Count	7	3	1	0	11
		Expected Count	.9	5.7	1.9	2.5	11.0
		% within Income group categories	63.6%	27.3%	9.1%	.0%	100.0%

(Table 5.1.7b)

Table 5.1.7a and 5.1.7b show occupational distribution of the household heads in relation to the income group categories. Cross-tabulation was carried out to determine if there was a relationship between occupation and income group categories. According to Rose and Sullivan (1998:123), a bivariate cross-tabulation is a table of joint frequencies for two variables classified into categories and is sometimes also referred as a contingency table. Cross-tabulation is most frequently used in examining the existence, nature and strength of relationships between variables (ibid.). This statistical method provides an excellent means of inspecting a bivariate distribution in order to ascertain the presence or absence of an **association** between two qualitative variables (Kinnear and Gray, 2010:414; Bryman and Cramer, 1994:153). "Two variables are said to be **associated** if the values of one variable vary or change together with the values of the other variable" (Blaikie, 2004:89). An example of such case is when "respondents' positions on one variable are [found to be] consistent with their positions on another variable" (ibid.). The most widely used correlation coefficients for measuring association between nominal variables include **Cramér's V**, the phi coefficient and the contingency coefficient. On the other hand, **Spearman's rank-order correlation** is used to measure relationship between ordinal variables while **Pearson's correlation** is used to examine relationship between interval and ratio-scaled variables (Diamantopoulos and Schlegelmilch, 1997:199; Blaikie, 2004:97). And unlike the Pearson correlation (**Pearson r**) which can assume negative values, the contingency coefficient, phi coefficient and Cramér's V assess the relationship between two variables using an index that ranges from 0 to 1. In such cases, a value of zero usually indicates little or no association whereby the closer the number is to 1, the greater the association between the two variables. Hence, a value of 1 indicates a perfect association or relationship between the variables (Kinnear and Gray, 2010:416; Blaikie, 2004:97; de Vaus, 2004:35).

Sometimes, the choice of the appropriate statistic depends on the nature of the contingency table. For example in a two by two contingency table, each variable has two categories i.e. in both rows and columns. However, "some statistics such as the **phi coefficient,** cannot achieve the full range of variation from 0 to 1 when the number of columns is not equal to the number of rows" (ibid.).

Symmetric Measures

		Value	Approx. Sig.	Exact Sig.
Nominal by Nominal	Phi	.688	.000	.000
	Cramer's V	.487	.000	.000
	Contingency Coefficient	.567	.000	.000
N of Valid Cases		106		

Table 5.1.8: The strength of association between occupation and income group categories

Thus, as indicated in Table 5.1.8, the correlation coefficient that has been used to measure the strength of association between occupation and income group categories is **Cramér's V**[181]. This is because in Table 5.1.8 both variables have more than two categories i.e. the number of rows and the number of columns is greater than two. In this case, Cramér's V test coefficient value (effect size) for association between these two variables is .487 and

[181] It must also be noted that the calculations that are provided in the tables, test the null hypothesis of independence i.e. whether the variables are independent of each other. At the same time, it is worth noting that, in this study a significance level of .05 was adopted, and all tests were two tailed.

that indicates a medium-strength association if we apply Cohen's table for interpreting the 'effect size index *w*'. However, if we interpret Cramér's V coefficient value in Table 5.1.8 using Rea and Parker (1997:191) conventions for describing the magnitude of association in contingency tables, .487 indicates a relatively strong association[182].

Income group categories *Income generating activities: Cross-tabulation

Count

		Income generating activities							Total
		small shop	carpentry	brick making	selling fish	Other	None	cafe	
Income group categories	Low income	1	0	1	1	15	28	0	46
	Middle income	6	2	1	1	11	26	2	49
	Upper income	0	0	0	0	0	10	1	11
Total		7	2	2	2	26	64	3	106

Table 5.1.9: Association between income group categories and non-farm activities (see section 5.1.1 in chapter 5)

Chapter 5: Section 5.1.2

Symmetric Measures

		Value	Approx. Sig.	Exact Sig.
Nominal by Nominal	Phi	.528	.000	.001
	Cramer's V	.528	.000	.001
	Contingency Coefficient	.467	.000	.001
N of Valid Cases		106		

Table 5.2.3: The strength of association between the education level and energy source (see section 5.1.2 in chapter 5)

182 According to Rea and Parker (1997:191), when the value of phi coefficient or Cramér's V is between .00 and under .10 that implies negligible association, .10 and under .20 indicates weak association, .20 and under .40 indicates moderate association, .40 and under .60 implies relatively strong association, .60 and under .80 indicates strong association, while .80 to 1.00 indicates very strong association.

Respondent's education level * Energy for lighting? Cross-tabulation

			Energy for lighting?	
			Kerosene	Solar power
Respondent's education level	Primary School	Count	71	1
		Expected Count	68.6	3.4
		% within Respondent's education level	98.6%	1.4%
	Secondary School	Count	18	1
		Expected Count	18.1	.9
		% within Respondent's education level	94.7%	5.3%
	High School	Count	3	3
		Expected Count	5.7	.3
		% within Respondent's education level	50.0%	50.0%
	No formal education	Count	9	0
		Expected Count	8.6	.4
		% within Respondent's education level	100.0%	.0%

Table 5.2.4: The strength of association between the education level and source of energy –refer to Table 5.2.3 above (also see section 5.1.2)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Yes	61	52.54	10.552	1.351	49.84	55.24
No	45	51.78	10.721	1.598	48.56	55.00
Total	106	52.22	10.580	1.028	50.18	54.25

Table 5.2.6: Descriptive statistics on awareness (see section 5.1.2)

Test of Homogeneity of Variances

Type of stove usage rate

Levene Statistic	df1	df2	Sig.
.314	1	104	.576

Table 5.2.7: Levene's test for homogeneity of variance (see section 5.1.2)

Levene's test was used to determine whether the variances between the groups are significantly different. Table 5.2.7 shows that variances between the groups are not significantly different since the significance value is greater than .05. Therefore, the Levene's test does not violate the ANOVA assumption (null hypothesis) that the groups have approximately equal variance (homogeneity of variance) upon the dependent variable (Kinnear and Gray, 2010:182).

Chapter 5: Section 5.1.4

Statistics

Age

N	Valid	106
	Missing	0
Mean		39.06
Median		38.00
Mode		37[a]
Std. Deviation		10.352
Minimum		19
Maximum		65

a. Multiple modes exist. The smallest value is shown

Table 5.4.1: Measures of central tendency and dispersion (see section 5.1.4 in chapter 5)

Age categories * Occupation Cross-tabulation

Count

		Occupation					
		Petty traders	Field agricultural officers	Teachers	Health workers	Farmers	Total
Age categories	<19	1	0	0	0	1	2
	20 - 29	2	0	0	1	15	18
	30 - 39	10	1	2	0	26	39
	40 - 49	4	1	3	1	18	27
	>50	1	0	0	0	19	20
Total		18	2	5	2	79	106

Table 5.4.3b: Age groups and occupation (see section 5.1.4 in chapter 5)

Age categories * Income groups Cross-tabulation

			Income groups			Total
			<TZS 400,000	TZS 400001 - 1,000,000	>TZS 1,000,000	
Age categories	<19	Count	2	0	0	2
		Expected Count	.9	.9	.2	2.0
		% within Age categories	100.0%	.0%	.0%	100.0%
	20 - 29	Count	12	5	1	18
		Expected Count	7.8	8.3	1.9	18.0
		% within Age categories	66.7%	27.8%	5.6%	100.0%
	30 - 39	Count	14	21	4	39
		Expected Count	16.9	18.0	4.0	39.0
		% within Age categories	35.9%	53.8%	10.3%	100.0%
	40 - 49	Count	9	14	4	27
		Expected Count	11.7	12.5	2.8	27.0
		% within Age categories	33.3%	51.9%	14.8%	100.0%
	>50	Count	9	9	2	20
		Expected Count	8.7	9.2	2.1	20.0
		% within Age categories	45.0%	45.0%	10.0%	100.0%
Total		Count	46	49	11	106
		Expected Count	46.0	49.0	11.0	106.0
		% within Age categories	43.4%	46.2%	10.4%	100.0%

Table 5.4.4: see explanations in Table 5.4.3 in chapter 5: section 5.1.4

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.290	.348
	Cramer's V	.205	.348
	Contingency Coefficient	.279	.348
N of Valid Cases		106	

Table 5.4.5: The strength of association between age groups and income (refer to Table 5.4.3 in chapter 5: section 5.1.4)

Chapter 5: Section 5.1.5

Number of household members

N	Valid	106
	Missing	0
Mean		6.16
Median		6.00
Mode		6
Std. Deviation		2.161
Minimum		3
Maximum		16
Sum		653

Table 5.5: Measures of central tendency and dispersion for household size (see section 5.1.5 in Chapter 5)

Appendix B

QUESTIONNAIRE FORM

Renewable energy in rural areas: the best path to sustainable development?

Part A; Personal information

Name of interviewee...

Village/District...

Age...…

Gender...…

Education..…

Family size..

Occupation

- **Formal employment; Yes□, No□, Position** held..

- Farmer
- Other activities

Monthly income....................

Date ………..................... (Date when the interview was conducted)

Part B: Knowledge and perceptions on Renewable Energy Technologies

What kinds of energy do you currently use in your household?

- 1...
- 2...
- 3...
- 4...

What kinds of energy do you use in your household for the following:-

1. Cooking...
2. Lighting...
3. Water heating..

What are your current energy sources for other activities besides your household?

- 1...
- 2...
- 3...

What are your current energy sources for activities such as:-

1. Irrigation (i.e. water pumping)...
2. Crop drying...

Do you experience any problems with your current energy sources?

- YES ( )
- NO ( )

If the answer is YES or NO; why

- 1...
- 2...
- 3...
- 4...

Are you involved in any income generating activity in the village?

- YES ( )
- NO ( )

If YES; what kind of income generating activities?

- 1...
- 2...
- 3...

Do you require or use energy in your activities?

- YES ( )
- NO ( )

If the answer is YES; what are the energy sources?

- 1…………………………………………………………………………………
- 2…………………………………………………………………………………
- 3…………………………………………………………………………………
- 4…………………………………………………………………………………

Do you experience any problems with the current energy sources?

- YES ( )
- NO ( )

If the answer is YES; what are the problems?

- 1…………………………………………………………………………………
- 2…………………………………………………………………………………
- 3…………………………………………………………………………………

Have you heard of solar electricity before?

- YES ( )
- NO ( )

If YES, where did you hear about it?

- 1…………………………………………………………………………………
- 2…………………………………………………………………………………
- 3…………………………………………………………………………………

Have you heard of energy saving cooking stoves (majiko sanifu) before?

- YES ( )
- NO ( )

If YES; where did you hear about them?

- 1…………………………………………………………………………………
- 2…………………………………………………………………………………
- 3…………………………………………………………………………………

Are you interested in using solar electricity?

- YES ( )
- NO ( )

If you are interested in using solar electricity, what is stopping you from doing so?

- 1……………………………………………………………………………..
- 2……………………………………………………………………………..
- 3……………………………………………………………………………..

What kind of stove do you use for cooking?

- 1……………………………………………………………………………..
- 2……………………………………………………………………………..
- 3……………………………………………………………………………..

Are you interested in using energy saving cooking stoves (majiko sanifu)?

- YES ( )
- NO ( )

If you are interested in using an energy saving cooking stove, what is stopping you from doing so?

- 1……………………………………………………………………………..
- 2……………………………………………………………………………..
- 3……………………………………………………………………………..

Do other people in the village use solar energy?

- YES ( )
- NO ( )

Do other people in the village use energy saving stoves?

- YES ( )
- NO ( )

PART C: Necessary conditions for adoption of RETs

What conditions do you think would enable you to adopt solar energy systems?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3…………………………………………………………………………………..

What conditions would enable you to adopt energy saving cooking stoves?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3…………………………………………………………………………………..

PART D: Environmental Awareness

Think back to what it was like 5 years ago. Would you say that trees in the natural forest around your village have increased or decreased?

- Increased ( )
- Decreased ( )

What are your views about deforestation?

a) Not a problem ( )
b) Is a problem ( )
c) Is not a problem at least in this village ( )
d) I don't know ( )

If deforestation is a problem in this village, what do you think are the major causes?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3…………………………………………………………………………………..

If deforestation is a problem in this village, what do you think are the solutions to prevent or reduce deforestation?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3…………………………………………………………………………………..

PART E: Financial Schemes

Have you heard of any savings & credit scheme in your area?

- YES ( )
- NO ( )

Do you get credit from any financial institution?

- YES ( )
- NO ( )

Is it easy to get credit from the financial institution?

- YES ( )
- NO ( )

If YES or NO; why is that so?

- 1...
- 2...
- 3...

Semi-structured Questionnaires for village leaders/groups

What are the main economic activities of the village?

....

....

....

What are the average earnings from each of these activities?

....

....

....

What are the main sources of energy for the village?

....

....

....

Where do the villagers obtain fuel-wood?

....

....

Do you think deforestation is the problem in this village?

- YES ( )
- NO ( )

If YES; why is that so and what are the solutions?

- 1..
- 2..
- 3..

If NO, why not?

....

....

Do you think villagers can adopt improved energy saving stoves?

- YES ( )
- NO ( )

If YES or NO; why is that so?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3……………………………………………………………………………..

Do you think the village could be electrified through decentralized renewable energy sources such as solar energy systems?

- YES ( )
- NO ( )

If YES or NO; why is that so?

- 1…………………………………………………………………………………..
- 2…………………………………………………………………………………..
- 3…………………………………………………………………………………..

Does the village have plans for the collective use of renewable energy technologies?

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

Appendix C

Kisesa Ward

Village name	Population
Ihayabuyaga	2,929
Kitumba	4,104
Isangijo	1,963
Welamasonga	3,429
Igekemaja	2,507
Kisesa	2,362
Kisesa (Urban Area)	10,179
Total	**27,473**

Bujashi Ward

Village name	Population
Matale	3,119
Sese	2,476
Ihushi	5,860
Total	**11,455**

Lutale Ward

Village name	Population
Lutale	3,735
Itandula	2,415
Langi	2,349
Kayenze	9,604
Total	**18,103**

Kongolo Ward

Village name	Population
Kongolo	4,470
Chabula	4,752
Nyashigwe	1,753
Bugando	1,184
Total	**12,159**

Nyanguge Ward

Village name	Population
Matela	1,894
Muda	2,814
Nyanguge	2,163
Mantare	895
Majengo	905
Bugohe	1,245
Total	**9,916**

Kitongo Sima Ward

Village name	Population
Kigangama	3,715
Kitongo Sima	2,021
Lugeye	4,625
Total	**10,361**

Mwamanga Ward

Village name	Population
Malilika	779
Misambo	2,167
Kisesa 'B'	3,148
Mwamanga	2,603
Inolelo	2,016
Total	**10,713**

Kahangara Ward

Village name	Population
Nyamahanga	2,271
Bundilya	2,830
Ijinga	2,195
Bugabu	1,871
Kahangara	4,065
Shinembo	2,447
Total	**15,679**

Nyigogo Ward

Village name	Population
Yichobela	3,388
Nyashimba	2,189
Ilungu	3,406
Kipeja	3,521
Sagani	2,922
Kinango	1,879
Total	**17,305**

Mwamabanza Ward

Village name	Population
Mwamabanza	1,925
Salong'we	1,680
Mwalinha	2,489
Total	**6,094**

Sukuma Ward

Village name	Population
Buhumbi	4,665
Kitongo	4,009
Lumeji	2,822
Nyang'hanga	3,339
Total	**14,835**

Lubugu Ward

Village name	Population
Sakaya	3,931
Lubugu	1,287
Bubinza	3,810
Nsolla	2,938
Total	**11,966**

Kiloleli Ward

Village name	Population
Ijutu	2,959
Ihale	2,755
Yitwimila 'B'	4,157
Ilumya	3,041
Yitwimila	2,709
Total	**15,621**

Mwamanyili Ward

Village name	Population
Mwamanyili	1,830
Mwanangi	3,044
Mwagulanja	2,853
Bulima	5,910
Milambi	1,525
Total	**15,162**

Shigala Ward

Village name	Population
Nyamatembe	2,287
Shigala	3,884
Ihayabuyaga	3,016
Lwangwe	1,465
Total	**10,652**

Kabita Ward

Village name	Population
Bukabile	2,526
Nyakaboja	2,815
Kabita	2,898
Nyamikoma	7,047
Shimanilwe	2,156
Total	**17,442**

Kalemela Ward

Village name	Population
Mayega	2,359
Chamugasa	5,927
Bushigwamhala	1,756
Lamadi	4,446
Lamadi (Urban Area)	7,991
Lukungu	2,826
Total	**25,305**

Nyaluhande Ward

Village name	Population
Mwamkala	2,647
Nyaluhande	2,954
Mwagindi	2,087
Total	**7,688**

Mkula Ward

Village name	Population
Mkula	5,531
Ng'wanhale	1,661
Chabutwa	2,800
Mwasamba	3,187
Mwangika	1,404
Lutubiga	2,949
Mwakiloba	2,624
Kijilishi	5,697
Total	**25,853**

Igalukilo Ward

Village name	Population
Mwamjulila	1,344
Malangale	1,154
Lunala	1,082
Mwamagigisi	5,273
Nyangili	2,395
Total	**11,248**

Ngasamo Ward

Village name	Population
Sanga	4,384
Ngasamo	2,788
Ng'wang'henge	3,805
Imalamate	2,988
Jisesa	3,224
Total	**17,189**

Malili Ward

Village name	Population
Mwamgoba	1,587
Gininiga	4,199
Malili	1,631
Mwamigongwa	3,333
Ngunga	2,052
Nyangoko	1,041
Total	**13,843**

Badugu Ward

Village name	Population
Mwaniga	1,800
Manala	1,534
Badugu	4,575
Busami	2,737
Total	**10,646**

Ng'haya Ward

Village name	Population
Ng'haya	4,395
Mwabulenga	3,158
Salama	1,855
Bugatu	4,251
Chandulu	3,258
Total	**16,917**

Nkungulu Ward

Village name	Population
Igombe	3,467
Ndagalu	3,348
Kabila	4,954
Kayenze 'B'	2,244
Ng'washepi	1,994
Nhobola	3,484
Total	**19,491**

Shishani Ward

Village name	Population
Isolo	4,195
Jinjimili	2,853
Shishani	3,581
Kabale	2,919
Nyasato	3,044
Mahaha	7,659
Total	**24,251**

Magu Mjini Ward

Village name	Population
Wambiza	838
Bank	1,651
National	1,433
Nyanguge	1,915
Ibidanja	2,283
Isandula 'A'	1,945
Isandula 'B'	1,054
Nyigogo	1,294
Nyalikungu 'A'	742
Uhayani	578
Itumbili	762
Unyamwezini	852
Ndagalu	539
Magengeni	301
Mashineni	342
Mwabasabi	559
Unyamwezini Inst. Pop	550
Total	**17,638**

Source: Tanzania National Bureau of Statistics (The United Republic of Tanzania, 2002 Population and Housing Census)

Appendix D

The debate on technological efficiency (The Jevons' Paradox)

Sustainable development dilemmas

The 1970s oil crisis rejuvenated the debate on whether an improvement in technological energy efficiency increases energy consumption or rather leads to energy saving (Polimeni et al., 2008:79). As pointed out in this thesis, the literature suggests that improvement in energy use efficiency is considered by energy analysts as an ideal policy instrument in supporting global efforts to reduce greenhouse gases emissions (such as carbon dioxide) into the atmosphere. However, critics argue that improvement in energy efficiency encourages individuals or firms to use more energy and this causes demand for energy to rise (ibid.). This view was shared by William Stanley Jevons, the British economist who was the first to hypothesize this idea in 1865. In what has come to be known as Jevons' Paradox, it is hypothesized that "energy efficiency improvements will increase rather than reduce energy consumption" (Sorrell, 2009:1456). The main assumption under the paradox is that more 'efficient technological improvements' would lead to more consumption of natural resources. If such an assumption were to be proved right, then it would have profound implications for sustainable development and climate change issues. This would imply that efforts by the international community to invest in energy efficient innovations would not only be counter-productive but would also fail to reduce greenhouse gas emissions.

Jevons' arguments

Jevons developed his ideas while referring to the nineteenth century unrestrained mining of coal and its use in Britain, especially the use of coal in steam engines and smelting. During this period, Jevons was concerned that Britain was about to lose its world economic superiority due to what he saw as an impending depletion of its coal reserves (York et al., 2009:137; Sorrell, 2009:1458; Polimeni et al., 2008:7). It was at this time period when Jevons disagreed with those who thought increasing consumption of coal was 'not' a result of improvement in technological energy efficiency. He illustrated his arguments by giving examples of the possible increasing trends of future consumption of coal. He claimed for example, that more efficient steam engines would increase the consumption of coal and at the same time would accelerate extra usage of coal in other economic activities. Jevons argued that improvement in technological energy efficiency (i.e. the improved means of consuming coal) would increase the consumption of coal because it would become easier to extract and use coal. He further argued that improved coal efficiency would increase investment profits and open up the new inventions which use coal. As production costs decline because of improvements in energy efficiency, both demand and consumption of coal increases. Therefore, the rising demand for coal would eventually lead to the exhaustion of the existing coal reserves, resulting into what is now known as the 'Jevons' paradox' (Polimeni et al., 2008:87; Polimeni and Polimeni, 2006:345). To prove its applicability, researchers have tried to establish whether the Jevons' hypothesis is logically coherent and if there is any empirical evidence to support his claims (Sorrell, 2009:1456). According to Polimeni et al. (2008:87), the Jevons' Paradox not only applies to demand for coal and other fossil fuels resources but may be also applied to other resources. They claim, for example, that the development of more energy-efficient automobiles was coupled with an increase in leisure driving from car owners in the United States. Despite the records showing that the driving distance has increased dramatically due to automobile efficiency, it is now understood that car consumers in the US prefer owning four-wheel-drives as well as heavier vehicles (ibid.). It is further argued that the expansion of roads has failed to address traffic congestion as once anticipated but rather it has attracted more use of cars. The paradox enthusiasts have cited other examples such as the improved efficiency of food production. They claim, for example, that the improvement in food production efficiency per hectare in the past fifty years has not stopped famine and hunger since the global population has kept growing. They also refer to improved energy efficient appliances used in households such as refrigerators. It is suggested, for example, that the technological improvement has made it possible for manufacturers to produce more energy efficient refrigerators for household consumers than before, and that has led to an increased demand for bigger refrigerators (Polimeni and Polimeni, 2006:345). Recent report from the US government indicates a significant increase of energy use in residential sector, partly due to households' higher incomes which allow them to purchase more electrical appliances (EIA, 2009:12). Although the market for household energy appliances has been growing for years, evidence suggests that the market has substantially expanded in recent years due to the availability of energy efficient appliances (ibid.).

Rebound effect?

As argued above, the Jevons' paradox has been tested by a number of researchers in recent years so as to establish the empirical evidence in support of Jevons' arguments. Most of these researchers have used "the rebound effect" as their theoretical premise since Jevons'

Paradox is sometimes referred by energy economists as 'the rebound effect', 'take back' or 'backfire' (Polimeni et al., 2008:142, Roy, 2000:433). The rebound effect refers to an increased consumption of energy as a result of energy efficiency improvements of an energy equipment or appliance. The term is often used by energy economists to describe the resultant effect on consumer behaviours[183] due to the declining energy costs arising from increased energy efficiency (Sorrell, 2007:2). For example, by purchasing fuel-efficient cars, owners may be attracted to drive longer distances than usual. Also, a firm with more energy efficient machines and facilities gets more profits which may lead to more investments and hence a further expansion of the firm. This in turn leads to an increased consumption of energy and reduces the anticipated energy savings (ibid.p.19). According to Sorrell (2007:1) and Greening et al. (2000:390), this is termed as the **direct rebound effect** and was first introduced in the 1980s by Daniel Khazzoom who was examining the micro-level consumer behaviours. On the other hand, in what is termed as **indirect rebound** effect, it is assumed that the energy that would have been saved as a result of using energy efficiency equipment is offset by an increased consumption of energy in other energy consuming activities or equipment. Although research suggests that the rebound effects at the micro-level behaviours have been found to be insignificant or moderate, the opposite could prove to be true when we add the total consumption and investment by consumers and government. This scenario represents what is known among energy economists as the 'economy-wide rebound effect' (Sorrell, 2007:57).

Empirical evidence – the rebound effect

In his study, Zein-Elabdin (1997:465) found that the ability of improved stoves to significantly reduce the fuel-wood consumption could be deterred by the rebound effect especially through an increased consumption of fuel-wood (ibid.p.466). He suggested that the increased consumption of fuel-wood is attributed to either the gains in real income resulting from the use of more efficient stoves (income effects) or the falling fuel-wood prices due to initial decrease of fuel-wood demand sometimes referred as price effects (ibid.p.471). In the

[183] Models of consumer behaviour have been widely applied across diverse disciplines and they have been predominant in disciplines such as economics, psychology and sociology (Darnton, 2008a). The basic foundation of the rational choice model, for example, is believed to have originated from the economic theory of consumer preference. The economic theory of consumer preferences has about four key elements which include: the consumer's available income, the price of goods on the market, the consumer's tastes or preferences, and the assumption that consumers maximise utility (Jackson, 2005:30). Consumers with limited income and a specific range of goods to choose from, will do it in a way that maximises their subjective expected utility. Subjective expected utility is referred as consumer's level of satisfaction, happiness or personal benefit (Darnton, 2008b).

study carried out in Sudan, Zein-Elabdin estimated charcoal demand and supply elasticities to figure out the rebound effects from improved cooking stoves. His findings indicated that charcoal markets in Sudan at the time he conducted his research were characterized by low elasticities, and that 42 per cent of fuel efficiency gains (savings) could be easily lost because of large price adjustments. He argued that "low elasticities place more of the burden of market adjustment on prices than on quantities" (ibid.p.465, Polimeni et al., 2008:142). Zein-Elabdin (1997:473) therefore concluded that improved stoves would be most effective in areas with low demand elasticities as that would encourage households to climb the energy ladder.

Another example is a study that was conducted by Reinhard Haas and Lee Schipper on residential energy demand in OECD countries to determine the rebound effects after the energy prices plummeted following a period of high energy prices (Polimeni et al., 2008:142; Haas and Schipper, 1998:421). Their findings indicated that energy demand did not rebound as anticipated when energy prices declined. They attributed that to the "irreversible efficiency improvements" as a main causal factor for the slight increase in energy demand. They therefore concluded that, in order to interpret past and future household energy demand, there is a need to understand the irreversible improvements in technical efficiency as that may serve as an important factor in the analysis (ibid.). A study conducted in India by Joyashree Roy found that 'efficiency improvements' contribute to large rebound effects. Roy focussed on the effect of technical efficiency gains on energy use in three sectors which included: industry, transport and efficient lighting programme for rural households (Polimeni et al., 2008:142; Roy, 2000:434).

On the other hand, Sorrell (2007:38) found that empirical evidence supporting the direct rebound effect for automotive transport and household space heating is relatively significant in developed countries. However, he states that there is less evidence for direct rebound effects for other consumer energy services. Experience suggests that empirical evidence describing the existence of rebound effects as a result of energy efficiency improvements in developing countries is very weak due to the fact that only very few studies have been conducted. However, theoretical projections appear to suggest that direct rebound effects would be larger in developing countries than developed countries. This is attributed to the estimated 1.6 billion households in developing countries currently not having access to electricity. Similarly, about 2.5 billion people rely upon biomass as their main energy source for cooking (ibid.p.87-88).

Although the rebound effect hypothesis has recently attracted energy researchers and stirred a debate among policy makers on the whole idea of promoting energy efficiency innovations; for the majority of development analysts, policies that encourage energy efficiency improvements are crucial if sustainable development is to become a reality.

Appendix E

Environmental Kuznets' curve and sustainable development

Neo-classical economists have used the Environmental Kuznets' curve to substantiate their hypothesis about the relationship between economic growth and environmental degradation. The Kuznets' curve hypothesis was first developed in 1955 by Simon Kuznets who suggested that there was a link between economic growth and income inequality. According to Kuznets, this relationship could be explained in a form of an inverted-U curve (Harper, 2008:212, Kuznets, 1955:3). He suggested, for example, that in early stages of development, poor societies are mostly characterised with a higher level of income equality. However, this is followed by growing income inequality as a result of industrialisation. He then argues that during the post industrial era, there are changes in income distribution as income equality appears in these societies again (Gray and Moseley, 2005:12, He, 2007:6). Proponents of Environmental Kuznets' Curve and development experts who favour economic growth have adapted Kuznets' hypothesis by making comparison between poor countries, middle income countries and rich countries. They argue that patterns of income inequality and income growth as described by Kuznets are more or less similar to the patterns of economic growth and environmental degradation (i.e. pollution) experienced in most countries worldwide. The advocates (of the Environmental Kuznets' curve) consider environmental degradation as only a temporary and an unavoidable phenomenon in pursuit of economic development. They argue that countries will be able to address environmental damage by implementing necessary pollution abatement technologies (He, 2007:4). They suggest, for example, that countries with poor economies have low levels of pollution while the middle income countries experience higher levels of environmental degradation (i.e. are most polluted). The rich countries, on the other hand, are thought to have low levels of pollution because of the availability of technological innovations and limited production activities which have helped to bring down the pollution levels. These assumptions led to what is now termed as the Environmental Kuznets' curve, a copycat of the original Kuznets' curve on economic growth and income inequality (Frankel, 2009:8, Panayotou, 2000:12).The Environmental Kuznets' curve hypothesis has attracted the attention of some development experts since the early 1990s. Grossman and Krueger (1991:1), for example, used this economic model to observe the relationship between per capita income and environmental quality when investigating the potential impacts of North American Free Trade Agreement (NAFTA) on Mexico and in the border region. Environmentalists were concerned that liberalization of trade and direct investment flows from United States could exacerbate the already worsening environmental conditions (i.e. rising pollution levels) in Mexico and neighbouring areas (ibid.).

The proponents of the Environmental Kuznets' curve contend that during the early stages of economic development when countries are characterised with low levels of income per capita, economic growth leads to huge environmental degradation. For example, intensification of agriculture, extraction of minerals, industrialization and other related factors lead to massive environmental degradation. However, at an intermediate level of income of about $5,000 or so[184], as the country's economy grows beyond a certain limit, air pollution peaks up and then falls with higher income levels until it levels off (Grossman and Krueger, 1991:17). At the same time, further economic growth, would lead to growth of income per capita and more improved environmental conditions in the country (Frankel, 2009:8, Rogers et al., 2008:176, Panayotou, 2000:13). The main assumption is that at higher levels of economic growth, countries are characterised by higher levels of environmental awareness, enforcement of environmental regulations, advanced technology and sophisticated industrial activities which lead into a steady decline of environmental degradation. In their study, Grossman and Krueger found the relationship between higher income per capita and low levels of pollution when they measured local pollution in a cross section of countries. In their investigation, they found that economic growth accelerated the reduction of pollution levels (i.e. improvements in environmental quality) especially when a country's income per capita was estimated to go beyond the range of about $4000 to $5000 (Grossman and Krueger, 1991:19). In support of the above empirical evidence, proponents of the Environmental Kuznets' curve have also claimed that the air in major cities of most industrialized countries today is less polluted as compared to the 1950s (Frankel, 2009:9). This could be a reference to cities like London which experienced worsening air pollution (i.e. London Smog) in the early 1950s.

Researchers have also used the Environmental Kuznets' curve to study deforestation rates and argue that the rate of deforestation initially increases at the early stages of economic growth and eventually decreases when the income per capita grows. They contend that the rise in incomes is usually coupled with reforestation activities in an attempt to remedy the environmental damage caused by deforestation. For example, the percentage of forested land

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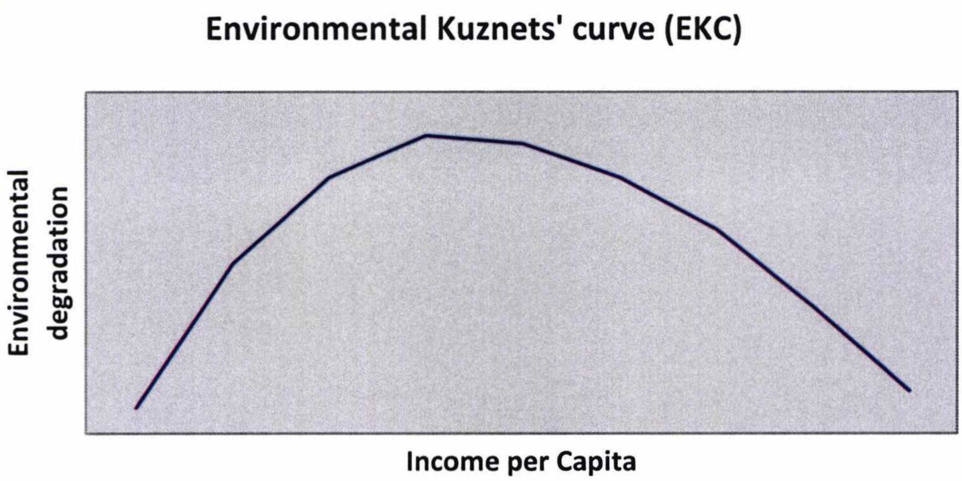
[184] measured in 1985 United States dollars

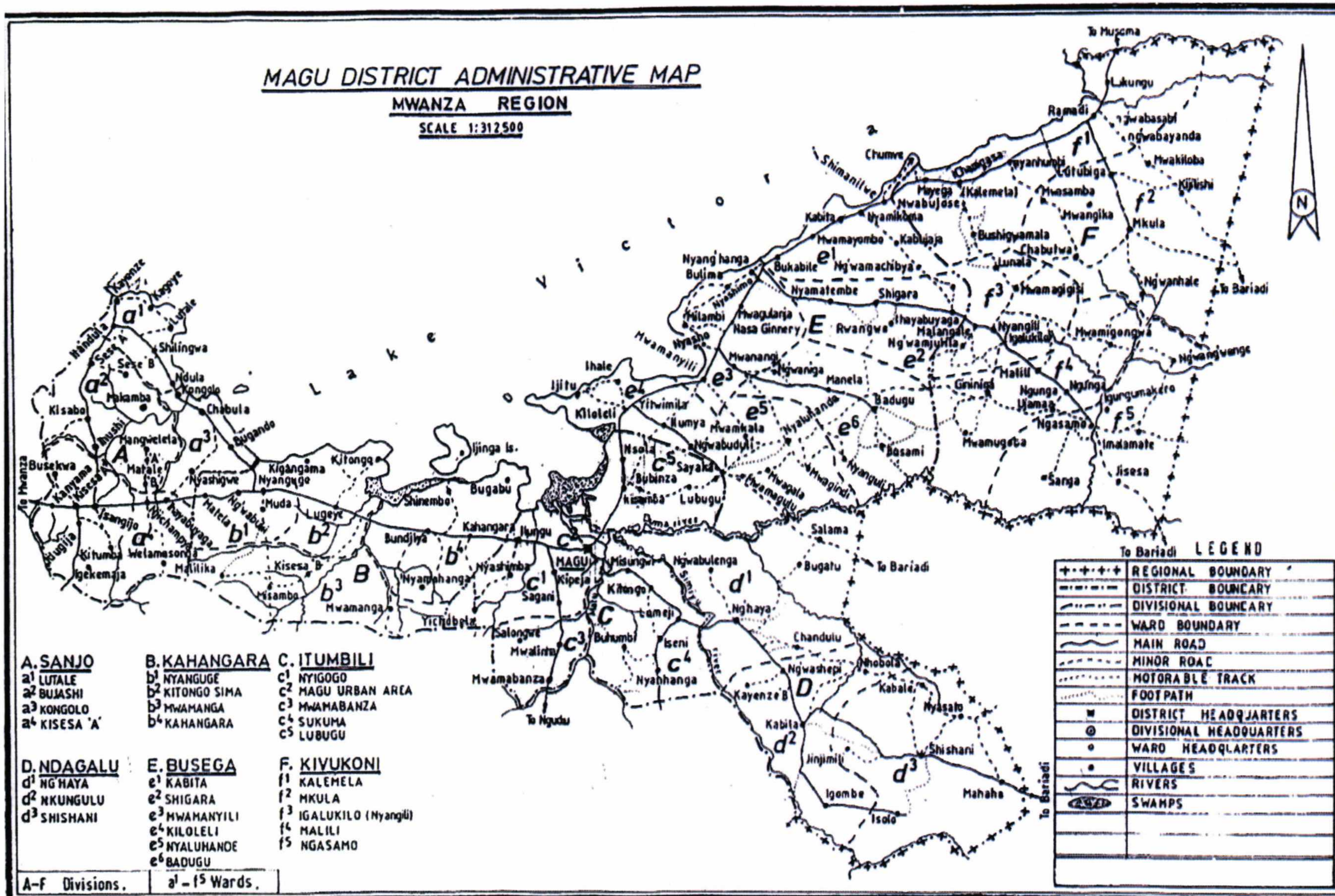
in the United States is thought to have risen in the twentieth century despite the fact that it was massively reduced in the eighteenth century and first half of the nineteenth century (ibid.). In his study, Panayotou found, for example, that the rate of deforestation conforms to the Environmental Kuznets' curve hypothesis and that deforestation is now very high in tropical and very densely populated parts of the world. However, research findings from Shafik and Bandyopadhyay appear to suggest that there is a very weak connection between the rise in income per capita and deforestation rate (Panayotou, 2000:12-13).



EKC curve on the relationship between economic growth and pollution

As stated earlier, the logic in the EKC curve above is that in pre-industrial and agrarian economies, the levels of per capita income tend to be lower and most economic activities are characterised by subsistence farming. As these economies begin to advance as a result of industrialization, environmental degradation increases. This is due to the increasing use of natural resources coupled with the use of less efficient and dirty technologies (innovations) which cause pollution. However, as the economy grows further, especially during the post-industrial stage, interest to use cleaner technologies and improvement in environmental quality leads to significant decline of environmental degradation.

Nonetheless, critics point out that the proponents of the Environmental Kuznets' curve have ignored the fact that industrialized countries tend to relocate their polluting industries into developing countries. The rich industrialized countries are blamed for spinning off pollution-intensive products to developing countries through trade or direct investment (Panayatou, 2000:16). According to this perspective, the inverted-U curve is a result of trade liberalization whereby multinational corporations relocate in developing countries because of the cheaper operating costs and enabling environments for investment. Critics argue, for example, that pollution reduction in industrialized countries is always counterbalanced by increasing pollution levels in developing countries since environmental regulations in most developing countries are less severe. Because of less strict environmental standards (as compared with the developed countries), many resource-depleting and polluting firms are attracted to invest in developing countries (He, 2007:7; Martinussen, 2004:155; Grossman and Krueger, 1991:13). Baker (2006:32) cites Japan as an example of an industrialized country which smelts its aluminium elsewhere and also uses the end products of forest resources from other countries while exercising restrictions on the use of its home forest resources. However, some researchers have disputed such claims and contend that there is less evidence to prove that patterns of trade or the location of investment are greatly influenced by differences in environmental regulations between countries (Grossman and Krueger, 1991:21-22). They argue, instead, that most multinational corporations are attracted to invest in developing countries because of cheap labour and market access. It is also argued that open economies attract investment in developing countries. It is thus hypothesized by some scholars that the more open the country's economy is, the cleaner the technology it uses in the production process. From their point of view, openness encourages technological and managerial innovation; hence this could also encourage innovations which are crucial both to the environment and economic development. Their main argument is that openness and competition are catalysts for investment in new and more efficient technology, therefore investment from multinational corporations would always be coupled with technology that match the higher environmental standards of their country of origin.


MAGU DISTRICT ADMINISTRATIVE MAP
MWANZA REGION
SCALE 1:312500
Lake Victoria
MAGU
A. SANJO
a1 LUTALE
a2 BUJASHI
a3 KONGOLO
a4 KISESA 'A'
B. KAHANGARA
b1 NYANGUGE
b2 KITONGO SIMA
b3 MWAMANGA
b4 KAHANGARA
C. ITUMBILI
c1 NYIGOGO
c2 MAGU URBAN AREA
c3 MWAMABANZA
c4 SUKUMA
c5 LUBUGU
D. NDAGALU
d1 NG'HAYA
d2 NKUNGULU
d3 SHISHANI
E. BUSEGA
e1 KABITA
e2 SHIGARA
e3 MWAMANYILI
e4 KILOLELI
e5 NYALUHANDE
e6 BADUGU
F. KIVUKONI
f1 KALEMELA
f2 MKULA
f3 IGALUKILO (Nyangili)
f4 MALILI
f5 NGASAMO
A-F Divisions.
a1 - f5 Wards.
LEGEND
REGIONAL BOUNDARY
DISTRICT BOUNDARY
DIVISIONAL BOUNDARY
WARD BOUNDARY
MAIN ROAD
MINOR ROAD
MOTORABLE TRACK
FOOTPATH
DISTRICT HEADQUARTERS
DIVISIONAL HEADQUARTERS
WARD HEADQUARTERS
VILLAGES
RIVERS
SWAMPS
To Musoma
To Bariadi
To Mwanza
To Ngudu
N

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