Adoption of Renewable Energy Innovations in Rural Tanzania: An Innovation Systems Approach

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Abstract
Renewable energy innovations have in recent years attracted attention due to their potential as alternative sources of energy in rural areas. The current debate in sub-Saharan Africa not only focuses on the possibilities and limitations of renewable energy innovations to reach the poor, but it also centres on the contribution of these innovations in achieving sustainable development goals. In the current paper, I examine the role of intermediary organisations in the transfer and adoption of renewable energy innovations in rural areas. I employ an exploratory case-study approach to collect data from 15 intermediary organisations in Tanzania. Using an innovation systems approach, I argue that intermediary organisations may often be in a position to coordinate activities and create an enabling environment for transfer and adoption of renewable energy innovations. A more active involvement of intermediary organisations could transcend social and cultural barriers as well as transform attitudes of other actors towards renewable energy innovations. However, 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 all actors are also fully involved in the innovation process. While attempts to integrate an innovation systems approach into research and development in sub-Saharan Africa have consistently focused on agricultural innovations, renewable energy innovations remain under-researched.

Keywords: *innovation systems, renewable energy innovations, intermediary organisations*

Introduction

Energy plays an important role in the technological and industrial development of humankind. Herbert Spencer, one of the earliest social scientists to study the energy – society relationship, argued that energy is the driving force towards cultural and social change in societies. He suggested that variations in development levels depended very much on the amount of energy produced and consumed in those societies (Harper, 2016:102). 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. So far, scientific evidence has indicated that climate change is very probably, at least in part, a result of over-dependence on and unlimited utilization of fossil fuels in many countries (Uitto et al., 2017:31). Climate change and its consequences pose a profound challenge to both developed and developing countries.

The use of fossil fuels to meet human's energy demands has increased the emission of carbon dioxide into the atmosphere. Carbon dioxide and methane, which are considered the main

greenhouse gases, have surpassed their equilibrium levels, and as a result global temperatures are believed to be rising i.e. global warming. There are concerns that 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[1] (Elliott, 2003:4; IPCC, 2001:92). However, 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. Renewable energy sources such as wind, biomass, solar, geothermal and hydropower are widely seen as the best alternatives available so far (Sosa-Nunez and Atkins, 2016:92; Dauda, 2012:3). The latter have been widely recommended as the best options since they offer relatively clean and sustainable sources of power (IEA, 2017:50).

Like other 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 (Dauda, 2012:4). 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[2]. Therefore, a strategy that relies upon highly capital intensive combustion of fossil fuels may be neither economically nor environmentally sustainable for developing countries such as Tanzania.

Likewise, it is worth noting that the main challenge to the transition to greener, cleaner, and more equitable economic growth is for innovation to focus on the three dimensions[3] of

[1] Elliott (2003) argues that the environmental problems arising today are 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.

[2] Tanzanian government has recently revived its plans to build Stiegler's Gorge Hydropower dam. Research suggests that large hydropower dams could be sources of greenhouse gases. Empirical evidence from 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. On the other hand, small-scale hydro-electric power generation projects do not pose as large threats to the environment as do large scale hydropower projects which involve the construction of large dams (WCD, 2000:75; Miller, 2004:400).

[3] Three most significant dimensions of sustainable development include: the social dimension which 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 such as security, human rights, health, education and shelter. The economic dimension 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. The environmental dimension calls for 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.

sustainable development (Gjoksi, 2011:6; Rogers et al., 2008:58, Baker, 2006:38-45, Reed, 1996:36). Ecological modernization scholars, for example, 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. 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). Ecological modernization theory is among the most prominent 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 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). 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.). This paper seeks to answer the question as to whether or not intermediary organisations can facilitate the transfer and adoption of renewable energy innovations in rural Tanzania, especially in areas that are isolated from the national electricity grid. In particular, it seeks to provide some insights on the role that can be played by community-based organisations in an innovation system. 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.

Innovation and Sustainable Development

Innovation[5] is perceived to be the primary source of economic change or transformation in a country hence technological change is one of the determinants of economic development. However, in order to understand the whole process of technological and economic change, we must first focus on the processes taking place at the micro level and that should, in most cases, include the role played by the entrepreneur (Smith, 2009:1). Economic change 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

[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).

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

also takes into account its 'complex network of micro relationships'. It is in this context, therefore, 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 (Carlsson and Stankiewicz, 1991:93).

In order to achieve environmental sustainability, for example, we face the 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.). According to Baker (2006:7), 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 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 has for many years focused on the economic dimension of sustainable development, and as a result the social and environmental dimensions have, to a larger extent, been neglected. However, current environmental and societal pressures have led to 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" (Gjoksi, 2011:7).

While technological innovations may provide the means to achieve sustainable development, they could also be sources of uncertainties in the society. For example they may lead to pollution or other forms of environmental degradation. Thus, to avoid or minimize such uncertainties, it is important to promote the use of more environmentally friendly technologies, including renewable energy innovations[6]. The transfer and adoption of environmentally friendly technologies could play a key role in achieving the economic, social and environmental dimensions of sustainable development. To achieve sustainable development, it is also important to examine the connections and relationship between human society and the natural world in a holistic way. This sociological-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, 2001:19). This means the world's physical environment, ecosystems and human social systems are today interconnected and interdependent.

[6] 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. 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".

2. Theoretical Framework

Innovation systems, as a theoretical approach, is becoming increasingly recognised as an important holistic framework that may be used in understanding innovation processes in both developed as well as developing countries. 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 for improving economic growth and competitiveness in global markets (Hall et al. 2004:31; Hall et al., 2010; Markard and Truffer, 2008:597). 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 approach also recognises the importance of information flows; hence it encourages partnerships, alliances, coalitions, linkages, and other means of contacts among the actors in an innovation system[7] (Hekkert et al., 2011:5).

The emerging consensus in the field of innovation and technology is 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; Edquist, 2001:4). This means that the innovation and transfer of new technologies should be seen as a process that takes place within an innovation system (ibid.). The underlying 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). Actors in an innovation system do not often innovate in isolation, but rather through interaction with other actors. Such actors may include households, firms, farmer organisations, researchers, financial institutions and public organisations (World Bank, 2012:11).

The growing interest in this approach is also driven by claims that conventional economic models cannot fully explain 'innovation'. Conventional economic models view innovation as a linear process that is driven by research (Hall, 2005:614). These models tend to emphasize linear relationships between science and society. During the era of Green Revolution in the 1960s and 1970s, for example, researchers who worked in modern scientific establishments were regarded as producers of knowledge and information. In contrast, extension workers were seen as carriers of information who were to carry such information to the farmer as the ultimate adopter. Thus, conventional models have since treated science and technology as relatively independent of historical, social, political, cultural, and other institutional factors (Pant and Hambly-Odame; 2009:107). As a result, they have largely ignored factors such as local knowledge and practices, and how various actors in a locality interact in an innovation system (ibid.). The social structure of the system can facilitate or inhibit the adoption and transfer of new technologies (Rogers, 2003:15). 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. Compatibility, for example, is the degree to

[7] An innovation system is defined as networks of organisations that bring new products, new processes, and new forms of organisation into economic use. It is made of networks of actors and institutions that are willing to develop as well as diffuse and use innovations.

which potential adopters perceive an innovation as being consistent with their existing values, needs and past experiences in an innovation system.

Rogers is of the view that an innovation that does not alter the existing values and norms is more likely to be adopted by individuals. 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.). However, the innovation systems approach aims at 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 a complex interaction between actors and institutions (ibid.). 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, and so forth. However, in a broader definition which is 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). In innovation literature, 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). They also define organisations as formal structures with an explicit purpose, and which are consciously created (ibid.). The main task of these organisations is to promote the creation and dissemination of knowledge. Likewise, 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[8] (Edquist and Chaminade, 2006:109; Jacobsson and Bergek, 2004:818; Markard and Truffer, 2008:598).

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. Firms, for example, do not innovate in isolation, but rather tend to interact continuously with consumers and other stakeholders such as universities, suppliers, or other firms (ibid.). The 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 (Hekkert et al., 2007:414). 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 the activities that help or hinder innovation (ibid.).

[8] Organisations and institutions are regarded as the main components of the innovation systems (Edquist and Chaminade, 2006:111). 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 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 (Bergek, 2004:818). 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).

Therefore, an innovation system can be well analysed when both its components and the type of 'activities' taking place in the system are clearly understood (Edquist and Chaminade, 2006:112). 'Activities' are all those factors that influence the development and diffusion of innovations in an innovation system. Hence, the innovation processes within a respective innovation system are very much determined by the ongoing relations between its components and the 'activities' taking place (ibid.). 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). R&D in the energy sector, for example, has been successful in developed countries because governments collaborate with private firms (Edquist and Chaminade, 2006:119). It is also worth mentioning that the nature of R&D activities in developing countries sometimes is different 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).

Investment in R&D from private firms in Tanzania is still very low as most small and medium-sized enterprises do not fully engage in R&D activities (Piirainen et al., 2012:51). Although most R&D activities are still largely carried out by public research institutions and higher learning institutions, the macroeconomic reforms that were adopted in the country from the mid 1980s have encouraged various private research organisations which are now gradually engaging in R&D activities (Bastos and Rebois, 2011:36). In principle, the Ministry of Communication, Science and Technology has the overall responsibility of coordinating all R&D activities in the country. However, other government ministries, departments and agencies 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).

Cooperation between different actors is crucial for successful innovation. Intermediaries facilitate such cooperation in an innovation system because of their role in the technology transfer process (Klerkx and Leeuwis, 2008:849; Howells, 2006:716)[9]. Innovation intermediaries are organisations or bodies that act as agents or brokers in any aspect of the innovation process between two or more parties. Innovation intermediaries are sometimes also referred as 'innovation brokers'. These could be persons or organizations that, from a relatively impartial third-party position, purposefully catalyze innovation through bringing together actors and facilitating their interaction (Howells, 2006:720; Klerkx and Gildemacher,

[9] Intermediaries are "organizations that play a bridging role in the innovation system". Intermediary organisations are sometimes referred to in the literature as bridging institutions, third parties, superstructure organizations or innovation agents (Szogs et al., 2008:12; Metz et al., 2000:167).

2012:221). Thus, innovation intermediaries are perceived as independent third parties that serve the purpose of facilitating collaborative activities in an innovation system. As opposed to traditional extension and R&D, innovation brokering represents the institutionalization of the facilitation role, with a broad systematic, multi-actor innovation systems perspective to reduce barriers in the transfer and adoption of technologies (Klerkx and Gildemacher, 2012:221; Metz et al., 2000:167). Intermediary activities include, among others, the 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. Intermediary organisations identify, locate, and absorb knowledge that is relevant for the respective innovation system, and they help in adapting it to new applications even in other sectors or industries, and to transfer it to new users (Szogs et al., 2008:13; Howells, 2006:719).

In the current paper I apply an innovation systems approach because it is an approach that allows analysis of processes that in most cases are overlooked in the conventional linear approach to R&D. As argued above, innovation systems approach can be used to analyze actors' motives and behaviour as well as the institutions that shape such motives and behaviour. Its strength also lies in its ability to capture interactive, joint, and complementary processes of innovation together with the dynamics of institutional learning and change (Spielman, 2005:7).

However, the innovation systems approach has been criticized for its conceptual diffuseness, especially the use of its key terms such as 'institutions'. Critics also point to its unclear boundaries and lack of formal theory. The approach is yet to firmly establish itself as a formal theory in innovation literature. The innovation systems approach has been linked to the 'general systems theory' that is more widely applied in natural sciences than social sciences (Min and Christian, 2017: 209; Edquist and Chaminade, 2006:111).

Energy and rural development in Tanzania

A common understanding among rural development analysts is that, alleviating poverty should be one of the first steps towards achieving sustainable development goals. It is within this line of thinking, that Tanzania's ongoing poverty reduction initiatives have also included the expansion of energy investments to facilitate access to modern energy services in rural areas. An important development in the energy sector (at least in the past 10 years) is the establishment of an independent rural electrification agency known as Rural Energy Agency (REA), which was established in 2005 and became operational in 2007. REA supports rural energy programmes by mobilising, coordinating, and facilitating both private and public initiatives. However, the country still faces a huge challenge of providing energy access to the majority of the rural population as only 16.9 percent of the rural households were connected to electricity by 2016 (URT, 2017:40).

Over-dependence on firewood and charcoal as the main sources of energy for the rural population threatens the unique environmental and biodiversity values of the forests. Current energy problems in rural areas have accelerated environmental degradation as well as poverty. 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[10]. It is estimated that biomass energy sources account for more than 85 percent of the country's total energy consumption, and more than 90 percent of all the energy consumed by rural households in the country (Katunzi and Siebert, 2015:8; MEM, 2015; Kimambo and Mwakabuta, 2005:9). Biomass energy sources widely used in Tanzania include charcoal, firewood, and agricultural farm residues i.e. agricultural by-products and animal waste (ibid.). Thus, biomass remains an important energy source in rural Tanzania, where more than 75% of the country's total population still lives. The rural populations need energy for household use, agricultural activities and petty commercial activities for income generation (MEM, 2003:38; Kaale, 2005; IEA, 1998:51). However, traditional use of biomass energy sources encourages indoor pollution, which in turn leads to health problems. Previous studies on health effects from indoor pollution found a relationship between the time women and children spent near the fire and the incidence of moderate and acute severe respiratory infections (Barnes et al., 1994:122). Indoor air pollution was also classified as one of the most critical global environmental problems in the 1992 World Bank Development Report (WDR, 1992:17). Poor health may likely limit the involvement of the rural workforce in productive socio-economic activities, and as a result, constrain rural development in poor countries (Martinussen, 2004:300). Since firewood and charcoal will likely continue to be the dominant sources of energy for the rural poor in the foreseeable future, the country needs to invest in alternative energy sources. At the same time, in order to overcome indoor air pollution, there must be concerted initiatives to promote sustainable energy conversion technologies in the country.

As most of the rural population does not have access to the national grid electricity, electricity from sunlight could be an attractive alternative source of energy. This is because 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). 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. Additionally, solar thermal innovations such as solar cookers could also help rural households as they do not emit smoke which causes indoor pollution. Solar cookers can partly address firewood shortages as well as reduce deforestation rates in rural areas (ibid.).

Investment in renewable energy innovations such as improved cooking stoves, biomass plants, solar PV systems, solar cookers, solar water heaters, wind turbines and geothermal plants could increase rural energy access. This will encourage more rural households to engage in various income generating activities as well as protect the environment. Empirical evidence suggests that renewable energy innovations have the potential of reaching the majority of the rural population as opposed to conventional energy systems based on fossil fuels. Decentralized renewable energy systems based on solar photovoltaic systems or wind could diversify energy

[10] 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".

supply, facilitate socio-economic activities, and strengthen energy security in rural Tanzania. In turn, this would spearhead poverty alleviation efforts and improve rural livelihoods.

Methodology

In order to examine the role that could be played by intermediary organisations in the transfer and adoption of renewable energy innovations, I employ an exploratory case-study approach in collecting data from 15 intermediary organisations in rural Tanzania. The study was conducted from March 2015 to September 2015. Data were collected through semi-structured questionnaire surveys, in-depth interviews, and a review of secondary literature. Documents from the Registrar of NGOs were the main sources of information for a sampling frame. Using the sampling frame, intermediary organisations which directly or indirectly engage in activities that are associated with renewable energy innovations, environment, and natural resources conservation, climate change, and rural development were identified. Thus, intermediary organisations were ranked using the following criteria: experience with renewable energy innovations, operating area, and involvement in conservation activities. This was done so as to get a sample size of 15 intermediary organisations. Each criterion was given a score from which the aggregation to estimate a single index score was done. The index score was finally used to rank intermediary organisations in the order of their importance. With this approach, the total index score was 5 and the minimum was 1. An intermediary organisation with an index score of 3 and above was selected. The following intermediary organisations were selected: Mtwara Society Against Poverty (MSOAPO); Masasi Environmental Conservation and Agricultural Association (MECAA); Tanzania Domestic Biogas Programme (TDBP); Dodoma Biogas and Alternative Energies Organisation; Renewable Resources and Environmental Conservation Trust; Community Optional Renewable Resources and Environmental Conservation; Ileje Environmental Conservation Association; Environment Management and Economic Development Organization (EMEDO); Serengeti Development, Research and Environmental Conservation; Tanzania Traditional Energy Development Organization (TaTEDO); Tanzania Renewable Energy Association (TAREA); Sustainable Economic and Environmental Conservation Organization; Environmental and Agricultural Promotion and Services (EAPS); Mazingira Institute of Tanzania; and Mara Environment and Sustainable Development (MESUDO).

Employees level of education in selected intermediary organisations

Information was sought to establish whether respective intermediary organisations have employed adequate staff with relevant skills and knowledge about renewable energy innovations. Therefore, it was important to collect data on whether they have skilled staff to implement renewable energy programmes or related projects. Demographic characteristics such as education and gender were used as proxy variables as they are widely cited in literature as among the factors that may influence innovation processes in an innovation system. Information was collected from 163 employees. Out of these employees, 86 were male, while the remaining77 were female. The level of formal education attained by employees in these organisations was used as a proxy for their ability to effectively interpret and utilise the acquired knowledge about renewable energy innovations in an innovation system.

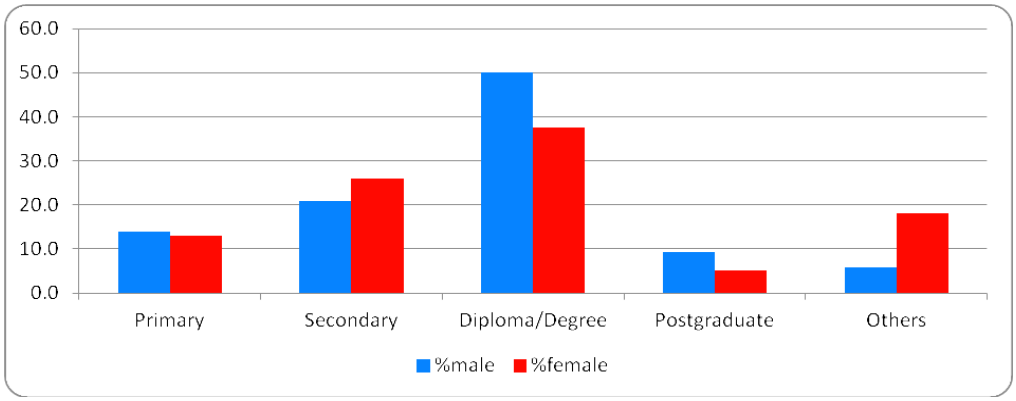

Figure 1: Employees education level by gender

As indicated in Figure 1, the education level variable was classified into 5 categories so as to have a fair distribution of employees in each category. About 14% of the male employees and 13% female employees had primary school education. Besides, 20.9% of the male employees, and 26% of female employees had secondary school education. It was also found that, 50% of male employees and 37.7% of female employees had reached a diploma or degree level. Those who had reached a postgraduate level were 9.3% male employees and 5.2% female employees. The remaining 5.8% of male employees and 18.2% of female employees had attended vocational training.

The level of education plays a wider role in strengthening the innovation capacity of the individuals in an innovation system. It is considered a critical element for communication, understanding, and assessing innovations in the interactive process that prevails within an innovation system (World Bank, 2012:108; Speilman et al., 2012:17). Thus, innovation must be perceived as a continuous learning process in which actors master and implement the design, production and marketing of goods and services[11] (Anandajayasekeram, 2011:17).

As argued above, education enhances the ability of actors in an innovation system to understand and eventually act on the information about an innovation i.e. new technology. Communication between actors is one of the most powerful forces for knowledge in an innovation system (World Bank, 2012:111). Individual actors, for example, can communicate easily with their peers, observe the techniques and skills used by others, and eventually adopt innovations that are perceived as being useful to them (ibid.). According to Hall (2006:12), a large part of innovation capacity constitutes patterns of trust between various actors and the habits and routines of these actors that relate to sharing information and learning in an innovation system[12].

[11] 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.).

[12] 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).

However, it appears that some of the employed technicians in these organisations do not have the necessary skills to install, repair, or provide right information about renewable energy innovations. This is partly due to the fact that some of the employees, especially those in lower positions, are still lacking adequate skills and technical knowledge on renewable energy innovations. One of the informants explained the challenges they face as follows:

"I am a 'solar technician', and I deal with clients from different areas in the District. You know, we install solar photovoltaic (PV) systems to their businesses or houses. Some of these systems would operate for months without problems. There are times when our clients complain about the solar panels, batteries, or inverters as not working properly. I would go and check the solar PV systems, but I would normally advise them to go to the solar equipment dealers in town as they are more qualified than us especially on maintenance and repair (IDI/MESUDO/Mara).

It is important to note that intermediary organisations whose employees are better trained and have the necessary skills are likely to play a very important role in building the capacity of other individuals (actors) to transmit, adopt, and use new products in an innovation system (Speilman et al., 2012:16; Rogers, 2003:288). Inadequate qualified personnel to deal with installation and maintenance of renewable energy innovations is still one of the main factors affecting the transfer and adoption of renewable energy innovations in the country. However, empirical evidence elsewhere suggests that 'locally' trained technicians in rural areas can play a pivotal role in the installation, operation and general maintenance of renewable energy innovations. 'Rural electronic workshops' in India can be among the successful examples whereby locally organised workshops have successfully recruited community technicians (also nicknamed 'barefoot solar engineers') who can easily assemble solar photovoltaic systems (Sharma, 2006). In that sense, the education level of the employees in these intermediary organisations can be a catalyst in shaping attitudes, beliefs, and habits of other actors in an innovation system. Innovation often requires extensive linkages with different knowledge sources and is an interactive process through which knowledge acquisition and learning take place. It needs effective co-ordination to allow the often fragmented actors who possess different assets, knowledge, and experience to take part in the innovation process (World Bank, 2006:16; OECD-FAO, 2012:27).

On the other hand, the innovation systems perspective calls for active engagement of both men and women in the innovation process. The roles that are performed by men and women in the selected intermediary organisations are important in influencing the transfer and adoption of renewable energy innovations in their area of operations. This was evident from one female informant:

"I was among a group of women who were training other women in villages. We trained them on how they could make improved cooking stoves using mud. Households started using the stoves for cooking, and they could repair or build new ones if they started cracking. We encouraged the households to use these stoves over the traditional three stone stoves. The

majority are happy with our innovation as they now use less firewood for cooking" (IDI/ MECAA /Masasi).

According to the World Bank (2012:12), "diversity, inclusion, and participatory approaches are critical to building the quality of the 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). As indicated in Figure 1, the percentage of female employees who have attained higher levels of education is lower in comparison with their counterparts. This does not necessarily imply that women involvement in the transfer and adoption of renewable innovations is constrained by their lack of skills. However, the empowerment of women through education is necessary, as their skills and networking capabilities can also play an integral role in the transfer and adoption of renewable energy innovations. Highly qualified women may secure technical and administrative roles, and therefore be in a better position to make decisions in their respective organisations.

Intermediary organizations and type of renewable energy innovations

Information was also collected on the type of renewable energy innovations that were being promoted by the selected intermediary organizations. All 15 selected intermediary organisations have experience in advocacy, and have been working on issues that are directly or indirectly related to renewable energy innovations. These innovations include solar energy, biogas, improved cooking stoves, wind energy, and hydropower (Figure 2).

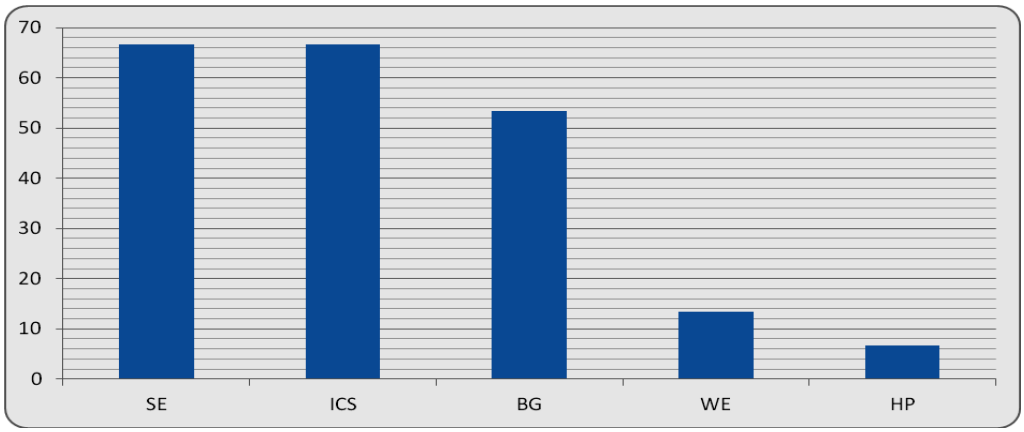

Figure 2: Percentage of intermediary organizations and renewable energy innovations

As shown in Figure 2 above, more than 65% of the selected intermediary organisations have experience in dealing with solar energy (SE) and improved cooking stoves (ICS) innovations. Biogas is the second most preferred renewable energy innovation, and more than 50% of the selected intermediary organisations are dealing with biogas technology. Comparatively, only 13% and 7% of the selected intermediary organisations are dealing with wind energy and hydropower technologies respectively. One of the identified barriers that hinder the transfer and adoption of renewable energy innovations is inadequate investment in R&D from both public and private organisations. Experience shows that, projects that involve large commercial and decentralized electricity generation from fossil fuels have largely been receiving support from both the government and development partners (Kimambo and Mwakabuta, 2005). Since little attention has been paid to renewable energy sources, this has slowed down the transfer and adoption of renewable energy innovations in the country. In the innovation literature, this is what is termed as a 'lock-in problem'. 'Lock-in' is a consequence of 'increasing returns[13]' to adoption or positive feedback (of incumbent technologies), which in turn prevents the adoption of the potentially sustainable alternative technologies (Negro, 2007:15; Hekkert et al., 2007:415; Foxon, 2002:2). This usually happens when the existing production system is overly dependent on a particular technology. As a result, it prevents the expansion of a new form of technology (i.e. innovation). 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. Renewable energy innovations have the potential of reaching a big 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.

Partnership and collaboration with other actors

It appears that the selected intermediary organisations have started to establish links with other actors in their respective areas. Although they use their own funds in their operations, some of these organisations have even managed to solicit funds from government and donors. There is strong collaboration especially between these intermediary organisations and donors (i.e. local

[13] 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 refer to a 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) refer 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.

and international donors) and most of the projects have been implemented with the financial and technical support from donors.

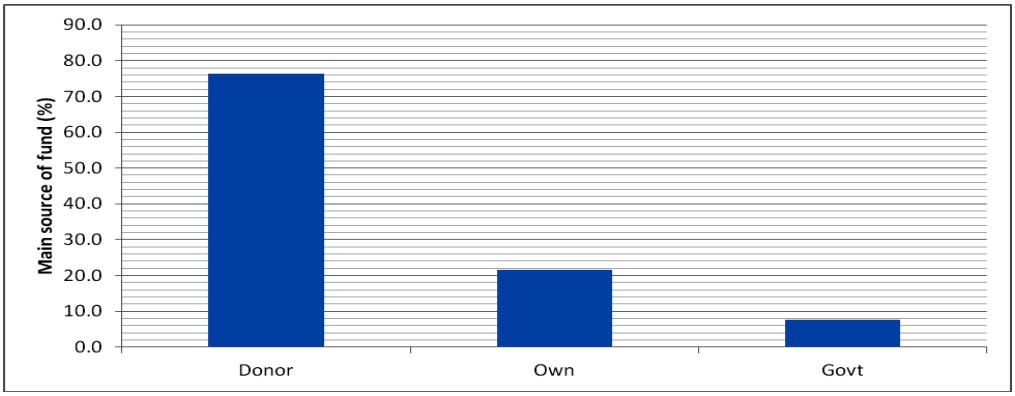

Figure 3: Sources of funding

As indicated in Figure 3, these organisations use either own funds, or funds provided by the government or donors. However, more than 70% of activities run by these intermediaries are financed through donor funds. Own generated funds contribute up to about 22%, and government support is less than 10%. This may, on the one hand, imply high dependence on donors and unsustainable source of funding if the donors pull out. On the other hand, however, this may imply that there is strong collaboration between the actors in an innovation system and such partnership is pivotal for innovation to take place. Therefore, the sustainability of these organisations largely depends on the continuous cooperation with other actors. Collaboration and partnership among actors may help in building the capacity of the local intermediary organisations. For example, actors such as UNDP not only provide funds to locally established intermediary organisations, but have in the past also provided technical support through training and demonstration projects on renewable energy innovations.

"Demonstrations are sometimes conducted in villages by the UNDP. In our organisation, we also work with technicians who were previously supported through training by donors. Together, we have been able to install solar photovoltaic systems in village dispensaries, health centres, and schools. I even wanted to have a solar photovoltaic system installed in my family house in the village as well. I am still saving money for it though. For the system to operate, it needs light bulbs, inverters, battery, solar panel etc. I realised that I could not afford buying all the equipment at a time" (IDI/EMEDO/Mwanza).

An innovation process must be perceived as one that involves interactive learning which is embedded in a series of relationships and institutional contexts that are likely to evolve over time (Hall, 2006:11). Innovation requires effective co-ordination to create room for fragmented stakeholders to take part in the innovation process. These stakeholders often have different assets, knowledge, and experience (OECD-FAO, 2012:27). Innovation process management implies enhancing alignment in heterogeneous networks, 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, building of trust, establishing working procedures, fostering learning, motivating, managing conflict and intellectual property management (Klerkx et al., 2009:11; World Bank, 2012:223).

Conclusions

In this paper I have employed an innovation systems approach to examine how interaction between actors in an innovation system can facilitate the transfer and adoption of renewable energy innovations. 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. I argue that the extent to which renewable energy innovations can successfully be transferred and adopted, especially in rural areas, and thereby contribute to rural development, would largely depend on whether or not all actors (i.e. government, private firms, households, community-based organisations, etc.) are also involved in the innovation process. However, intermediary organisations are often in a position to coordinate activities and create an enabling environment for the transfer and adoption of renewable energy innovations. Active involvement of intermediary organisations in the innovation process could transcend social and cultural barriers, as well as transform attitudes of rural actors towards renewable energy innovations. Intermediaries such as community-based organisations[14] may facilitate the involvement of rural actors in the planning and implementation of renewable energy initiatives. This emanates from the fact that actors in an innovation system are often more aware of, and responsive to the needs and concerns of other actors (i.e. resource-poor households) through intermediaries. Community-based organizations may exchange and share knowledge with members as well as with other stakeholders i.e. initiating multi-stakeholder platforms for renewable energy innovations. They may as well provide services such as marketing of an innovation as well as organizing funding i.e. outsourcing savings and credit schemes, and providing insurance to their members. This would increase prospects for rural communities' participation in the transfer and adoption of renewable energy innovations.

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 intermediary organisations has so far not been widely applied in understanding the transfer and adoption of renewable energy innovations in rural areas. The current paper attempts to fill that empirical void, at least for rural Tanzania specifically, and for sub-Saharan Africa more generally. There has been less research conducted on the roles that could be played by intermediary organisations 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, it contributes to innovation literature especially on a technology-

[14] In this case, community-based organisations may include: farmer organisations, faith-based organisations, women groups, youth groups, savings and credit groups etc. According to Klerkx et al., (2009:28), intermediaries or innovation brokers in developing countries include: national NGOs, international NGOs, international donor agents, farmer and industry organisations, research organisations or affiliates, government organisations etc.

specific innovation system by applying innovation systems approach to understand the connection between rural poverty, energy demands, and sustainable rural development.

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