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Full Length Research Paper

A Model for Sustainable Adoption of Solar Photovoltaic Technology in Tanzania

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ABSTRACT

The aim of the study was to develop a sustainable model for enhancement of the solar PV technology adoption in Tanzania. The model was developed based on the identified barriers that hinder the adoption of solar PV technology and adopted the best strategies from successful projects. Further, the drivers and activities were developed based on selected best strategies from successful projects. The identified barriers to the adoption of solar PV technology, which are grouped into five associated categories and their significances, are lack of access to finance (32%), non-enforcement of policy and regulation (31%), technical (18%), lack of awareness (9%) and social (10%). The analysis of information and data that was obtained from the project reports shows that there are challenges on lack of awareness on solar PV technology and non-enforcement of quality standards. However, major barriers are high price of solar PV systems and lack of access to finance. A model for adoption of solar PV technology in Tanzania was developed and tested by validating it with a successfully implemented solar PV project in Tanzania. During the validation, thirteen (13) out of twenty-one (21) activities of the UNDP/MEM Solar PV Project demonstrated the moderate compliance with the model prescription by 62%. The UNDP/MEM Solar PV project developed a financing mechanism but it was not sustainable due to low application of sustainable adoptions strategies. The mechanism was not opening opportunities for new users to adopt the solar PV technology or maintain the existing ones. Recommended future studies include application of the developed adoption model for Solar PV by using data from other solar PV projects for sensitivity analysis of identified barriers and best strategies.

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INTRODUCTION

Solar energy has been traditionally used for a long time in various applications such as drying of various items such as clothes, food products, agricultural produce and evaporating seawater to extract salt. Today, solar energy is being utilized in various modern energy applications at various levels. On a small scale, it is used at household level to power appliances such as watches, calculators, small radios, televisions, computers, lights, cookers, and water heaters. On a medium scale, uses include solar thermal water heating, drying, electricity supply in institutions, water pumping for irrigation, and refrigeration for vaccine storage in health facilities. At community level, it is used for water pumping and purification, and for rural electrification. On industrial scale, solar energy is used for process heat, desalination, drying, power generation, municipal water heating, telecommunication and transportation (Karekezi and Ranja, 1997; Ahammed and Taufiq, 2008; Sharma et al., 2015).

Tanzania is situated in what is commonly known as the "solar belt" countries of the world i.e., countries with 2800-3500 hours of sunshine per year and global radiation of 4-7 kWh/m^2/day. Many parts of Sub-Saharan Africa receive a daily solar radiation of between 4 kWh/m^2/day and 6 kWh/m^2/day (REEEP/UNIDO, 2011). The average solar flux in some parts of the country based on 24 hours can be as high as 300 W/m^2 or more. With such high levels of solar energy resource, Tanzania is naturally a suitable country for application of solar energy as a viable alternative to conventional energy sources. The energy from the sun can reduce the consumption of fossil fuels, thus reducing pollution of the atmosphere (COSTECH, 2006).

Adequate and reliable power supply is essential for any country. Tanzania has very low levels of electricity consumption per capita of less than 100 kWh (i.e., 92 kWh) per capita per annum. This compares unfavorably to the world's average consumption of 2000 kWh per capita per annum, and average consumption in developing countries in Sub-Saharan Africa of 552 kWh per capita annum (World Bank, 2010). Only about 32.8% of the Tanzania mainland households are electrified with any form of electricity (NBS, 2017). Among the electrified households; rural and urban households connected to grid electricity were 34.5 and 96.4% respectively (NBS, 2017). Some section of the population obtain access through stand-alone solar PV and small hydro mini grids operated by local non-governmental organizations (NGOs) including faith-based organizations (World Bank, 2010).

The key constraints of using solar energy technologies include the requirement for sophisticated manufacturing processes, which are available only in few developed countries; the high initial capital cost; the long payback periods; and the skillset and instrumentation required for installation and maintenance of these technologies. This is a great hindrance that intensify the importance of developing skilled experts in the region's energy sector. As a result, there has been shortage of trained technicians to design and install solar systems (Kihedu and Kimambo, 2006). The utilization of solar energy technology in Tanzania has been slow due to some barriers. These are grouped into five major categories, namely standards and norms, market, awareness and human resource, industry and finance (Kimambo, 2009). This paper presents a model that addresses challenges hindering the adoption of solar PV technologies and proposes ways of overcoming the challenges. In addition, a framework is presented that gives the proper direction and strategies for enhancing the adoption process of solar PV technology.

METHODS AND MATERIALS

The study was designed and carried out to build on previous initiatives on solar PV projects that were implemented at Sumbawanga District in Rukwa Region of the United Republic of Tanzania. Relevant data was extracted from reports of these projects and from reports of stakeholders, which include Rural Energy Agency (REA) and the Ministry of Energy (MoE) as indicated by UCB (2012), UCB (2014) and UCB (2015)

Research Design

The research adopted a descriptive design. According to Kothari (1985), descriptive design allows the researcher to describe records, analyze, and report conditions that exist or existed. The research study used both qualitative and quantitative approaches. The data was collected in order to study factors affecting adoption of solar energy technology and investigate the efforts taken by the government and the stakeholders to enhance the adoption of solar PV technology in various projects in Tanzania.

Selection of Studied Projects

The study targeted the following projects:

Sustainable Solar Market Packages 1 (SSMP 1), which was implemented in Sumbawanga district as reported by UCB (2012), UCB (2014) and UCB (2015).

(a) Sida/MEM Solar PV Project, which was implemented in various regions in Tanzania.

(b) UNDP/MEM Solar PV Project, which was implemented in Mwanza region.

Data Collection Methods

The methods of collecting primary and secondary data differ, since primary data is to be originally collected while in case of secondary data the nature of data collection is merely that of compilation (Kothari, 2004).

In this study, the secondary data collection methods were used. Data were extracted from reports of solar PV projects that have been implemented in Tanzania (UCB, 2012; USB, 2013, USB, 2014, USB, 2015). Other information was obtained from journals, papers and books.

Data Analysis

The quantitative data analysis included the identification, examination and interpretation of collected information and determining how the information could help to answer the research questions at hand. The data obtained were presented and analyzed using Microsoft Excel sheets. In addition, Vensim software was used to develop User risk free model, Loan in form of equipment model and a Sustainable solar PV financial model.

RESULTS AND DISCUSSION

Figure 1 shows the challenges hindering the adoption of solar PV technologies, which are categorized in five major groups. These are; lack of awareness, lack of training on technical aspects, lack of accountability, poor policy and regulations and lack of access to finance. The government and stakeholders in renewable energy sector have made a lot of efforts to create awareness to the public on solar PV technology, through various programmes and projects. The analysis that was carried out in this study has revealed that the barriers associated to awareness have contributed 9% of all categories of barriers being studied. This shows that significant efforts had been made on creating awareness. The barriers associated with the technical aspects, which include limited number of trained staff (trainers and technicians) contributed 18% of all categories of barriers. Standards and codes of practice are in place but there is lack of facilities and equipment to test the quality of solar PV products.

On the social challenges' category, the projects faced vandalism and theft incidents and there were no legal actions that were taken against those who were suspected of the offenses. This suggests that there was lack of accountability among local leaders. This category contributed to 10% of all barriers. The barriers associated with policies and regulation contributed to 31%, while barriers due to lack of access to finance contributed 32% of all barrier categories. These high percentage contributions mean that more effort is needed on these two areas of policy and regulation and access to finance.

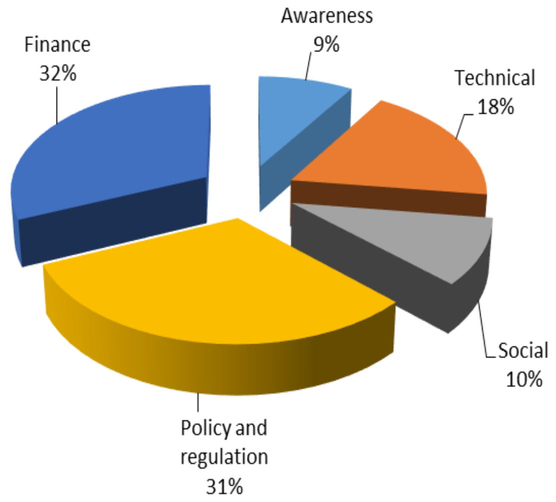

Figure 1: Typical contribution of barriers on the solar PV projects

The government and stakeholders have to put more efforts on implementing policies that will create attractive environment for the private sector to venture into solar PV projects. They should also create innovative financing mechanisms. These results indicate that the financial barrier contributes most significantly, including to the difficulty to implement on awareness creation, technical training and payment for security of systems. Further, policy and regulation were found to be important instruments as they influence almost all barriers. This means that they could be the root causes of all the other barriers. Policy and regulations affect much the price of solar PV systems. If the policies that are in place are not effective, they can have a negative effect on the access to finance by most of potential users and investors, who depend on loans from financial institutions and grants from government and development partners to cover upfront costs of the PV systems. The high cost of PV systems has contributed much to failure of many systems or solar PV projects because beneficiaries could not afford high replacement costs of PV systems or components, when need arose, similarly to the cases of theft and vandalism.

Framework Model to Enhance Adoption of Solar PV Technology

Figure 2 shows a framework model, which explains the steps to be taken by the government, project planners and private sector in order to achieve sustainable adoption of solar PV technology. The model addresses four aspects, which are barriers, strategies, drivers and activities. The model is divided into blocking mechanism that is barrier's part and driving mechanism that are strategies, drivers and activities. The blocking mechanism in the model is illustrated by arrows pointing in opposite direction to where the driving mechanism is pointing. The driving mechanism supports the adoption of solar PV technology. Basically, the model was developed based on the identified barriers that hinder the adoption of solar PV technology.

Barriers Hindering the Adoption of Solar PV Technology

Adoption of solar PV technology faces many challenges ranging from lack of awareness, technical issues, social issues, inadequate supportive policy and regulations, and lack of access to finance. These challenges are not unique to developing countries only. Lately, the relevance of regulatory barriers, and the importance of risk mitigation in general, has been recognized in the academic literature (Gross *et al.*, 2010; Komendantova *et al.*, 2010). Regulatory barriers include administrative hurdles like strict environmental regulations and long, bureaucratic and non-transparent authorization and permitting procedures (Beck *et al.*, 2004; Haas *et al.*, 2004; and Mitchell *et al.*, 2006).

The barriers associated with awareness include limited awareness of, and experience with PV technology and 12 VDC appliances (energy is a low priority area among users compared to the other needs); inadequate business knowledge and capacity for distribution and sale of 12 VDC appliances and PV systems; limited technical knowledge of proper sizing, installation, operation and maintenance; low awareness on sub-standard solar PV products; and low awareness on availability of standards and codes of practice (Kimambo, 2009).

Technical knowledge and limited infrastructure is a group of challenges that include limited technical and business knowledge and skills of technicians and dealers of solar PV systems and appliances. Therefore, they provide poor services to users and customers. The other issues are shortage of trained personnel (Raymond *et al*., 2014); lack of standards and codes enforcement, which leads to importation of poor-quality products; and lack of database and inventory for solar PV technology (Kimambo, 2009). The barriers associated with social issues is another group of barriers which include unaccountability of project managers and Local Government Officers (LGOs) on projects, vandalism and theft of PV systems, bureaucratic and non-transparent authorization and permitting procedures. Many solar PV projects, especially those that are publically owned and/or run have failed mainly due to lack of accountability on the part of the managers of the projects and local leaders. Law enforcement makes leaders more accountable and responsible of their duties.

Policy and regulations are one of the major determinants of price and availability of solar PV products in the market. If these are not effective, the price of products will be high and unaffordable, therefore contributing to high upfront cost of PV systems. The challenges associated with this are lack of effective policy implementation, high cost of solar PV systems, lack of established dealer network because of high cost of solar PV products and high cost of doing business.

Promoting competition to reduce energy costs continues to be the major energy market policy driver. Access to finance plays a big role in the success of many projects especially those that involve solar PV technology. The barriers associated with financing are the difficult access to finance by both users and dealers, and low purchasing power of the intended end users of the technology.

Strategies to Enhance Adoption of Solar PV Technology

These are the driving mechanisms in the conceptual framework developed in this study as depicted in Figure 2, which should overcome the barriers for successful adoption of solar PV technology to happen. The strategies are divided into five parts namely Awareness creation, Building competence, Legitimacy creation, Effective policies and regulations and Innovative financing mechanism. These are elaborated hereafter.

Awareness Programmes on Solar PV Technology

Projects and stakeholders should plan to conduct awareness events on solar PV technology in areas where the technology is going to be disseminated. Awareness programmes include demonstrations, radio and television programmes and distribution of promotional materials. These events cover the intended end users of solar PV technology, dealers and technicians who supply and provide technical services, decision makers and financiers.

Building Competence of Institutions

This part is made up of the following two main components which are described hereafter.

Technical Knowledge Strengthening

This component consists of short-term and long-term training measures. The long-term measures are to build the capacity of Vocational Training Centre (VTC), Technical Colleges (TC) and Universities to offer technical training on solar PV technology to students attending the institutions i.e., mainstreaming of solar PV technology training in the curricular of VTC, TC and Universities in order to impart such knowledge and skills to the students.

The short-term measures are provision of solar PV technical training to already practicing artisans, technicians and engineers so that they could immediately be deployed in providing services on solar PV technology. The intervention can include training on technical and business management. The aim is to create solar PV technicians and dealers, who will supply solar PV systems and provide services in the targeted zone. Poor technical services to end users bring bad image not only on technical personnel, but also of the technology as a whole.

Standards and Codes of Practices

Poor quality of solar PV systems and components in the market is a big challenge to the adoption of the technology. In order to get good products, the government in collaboration with the private sector and other stakeholders has to develop a quality control mechanism including standards, codes of practices and laboratory facilities, which are capable of testing and certifying these products. The codes have to cover issues such as sizing, installation and maintenance of solar PV systems and training of various actors such as technicians and users of the systems.

Legitimacy Creation

The social associated challenge is another group of barriers. The barriers associated with this include unaccountability of LGOs on public projects, vandalism and theft of PV systems, bureaucratic and non-transparent authorization on procurement procedures (Beck *et al.*, 2004; Haas *et al.*, 2004; Mitchell *et al.*, 2006 and Raymond *et al.*, 2014). Otherwise, this study recommends that laws and regulations should make users and beneficiaries of solar PV projects accountable and responsible on security of solar PV systems.

Effective Policies

Policies and regulations play an important role in the development of any country. Effective policies play important role, like creating a conducive environment for the private sector (including NGOs), financial institutions and donor ventures to implement solar PV technology dissemination projects.

Effective policies as a strategy play a big role in enhancing the adoption of solar PV technology, as this will determine the affordability (price), accessibility and availability of solar PV systems and components in the market. So, this will affect much the growth of the PV market.

New regulations in the energy sector in Tanzania allow Independent Power Producers (IPP) to enter into electricity generation, transmission and distribution business. The energy pricing policies like tax incentives and subsides for different solar PV products and services should be reviewed to promote solar PV electricity in rural areas (MEM, 2015). Value Added Tax (VAT) and import duties affect much the prices of solar PV systems and therefore affect the final customers.

Innovative Financing Mechanisms

The most promising model for consumer finance of solar PV systems should be identified, piloted and evaluated, before being rolled out. Also, the promising supply-chain financing in the solar PV business should identified, piloted and evaluated. The beneficiaries, with the support of stakeholders should identify viable productive uses of solar PV in their areas that would make solar PV technology a business venture rather than just social service provision to households e.g., lighting and powering of other domestic appliances.

Financial engineering is perhaps the most challenging aspect of the projects. The micro finance sector in developing countries is still at an infant stage and access to micro financing, especially from commercial banks is an uphill task. This is not specific to solar PV technology though.

Activities to enhance adoption of Solar PV technology

Awareness Programmes

Awareness creation on the potential role of PV in meeting the basic energy needs of rural communities located away from the electricity grid to stakeholders and the general public is very important. Targeted audiences of awareness activities are decision makers and of solar PV systems and components suppliers, technicians, sponsors and end users. It is also important to educate actors in the financial institutions and business support bodies on the potential and benefits of using of solar PV technology in meeting energy demand of the communities so that they could provide financing for the same. They should be sensitized to make the solar PV option a high priority among the various alternatives.

The end user awareness programme addresses the potential benefits and usefulness of PV systems and availability of 12 VDC appliances that PV systems can power, such as radios, lamps, and television; the technical limitations of PV systems; and the inherent worthiness and value of PV systems and 12 VDC appliances. Awareness creation can be done in close cooperation with the private sector (Kimambo, 2009). This is a very strong instrument in creating awareness of a technology among the people. Mostly people do not want to hear about a certain technology but they want to see it work, as "seeing is believing" (Larsens, 2007). The awareness creation approaches that can be used include road shows; media advertisements, programmes and articles; and distribution posters and information leaflets. Solar PV system demonstrations and video shows can be conducted in public places like market places.

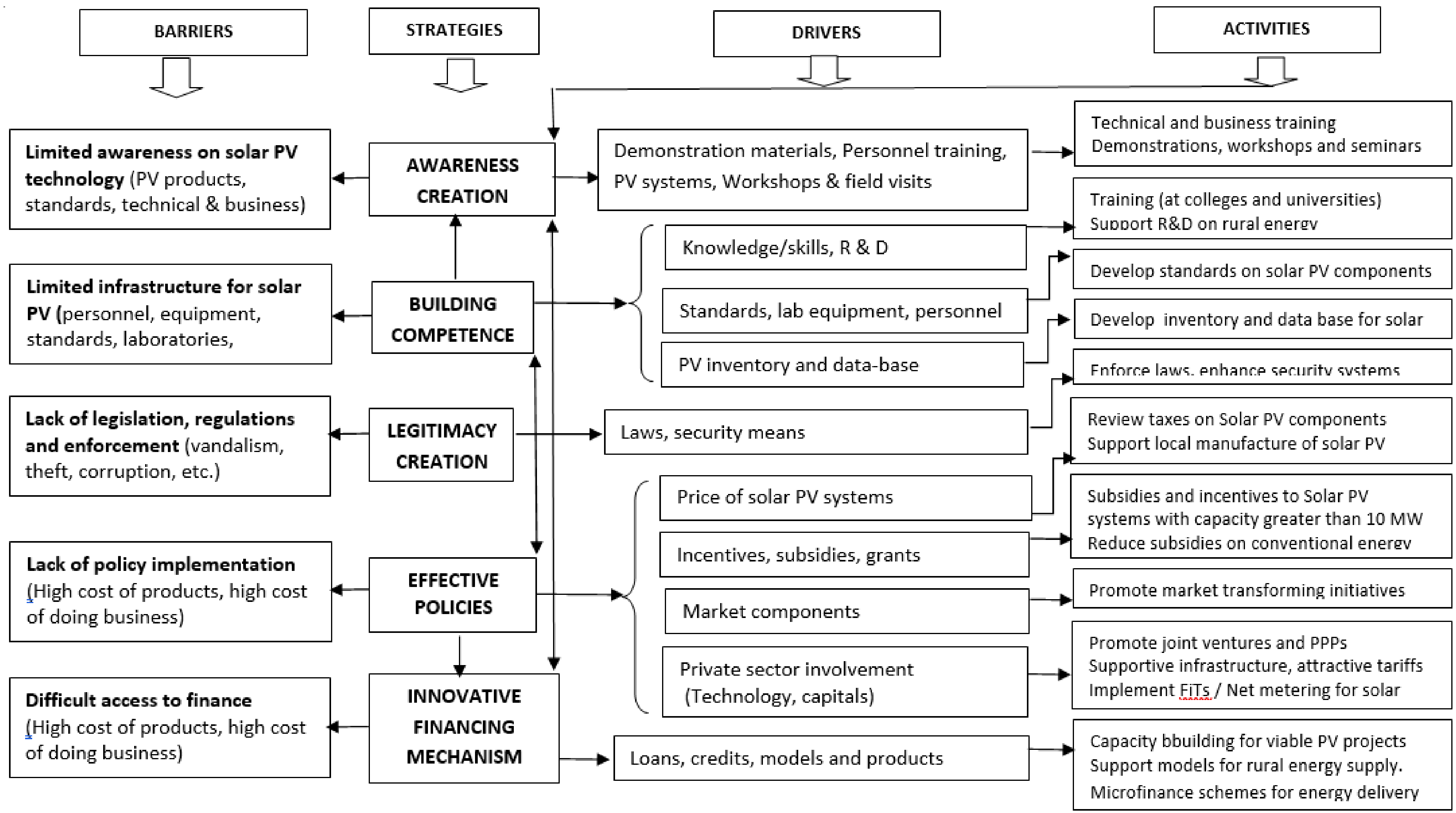

Figure 2: Conceptual framework for solar PV adoption

The awareness creation also can be done by participating in various exhibitions by assembling small solar PV systems and demonstrating them physically, by using video shows and distributing information leaflets, brochures, posters and billboards. Also, selling solar PV products at discount price so that some users can buy and take them to their homes and show others, is another way of creating awareness.

Printed sets of posters describing the benefits of solar PV technology for typical rural households can be placed on notice boards at the market places, district institutions, etc. The brochures could explain the project objectives and activities while leaflets could be used to answer the most frequently asked questions. The billboards have to be placed at the major road junctions of the targeted areas. Educational materials on solar PV technology could be distributed in primary and secondary schools. Another approach to create awareness is to demonstrate through installation of solar PV systems on strategically important locations in order to show the functionality and usefulness of the technology. The strategic locations could be at hospitals, health centers, dispensaries and schools. In each of the sites, the local communities should be required to share the costs of some of the materials such as wires, switches, surface boxes, mounting, batteries terminals, screws, nails, and lighting fixtures, in order to create a sense of ownership. The contribution of the promoters would cover expensive components like solar PV modules, solar batteries, charge controller, mounting structures and labour charges.

It is important for planners to plan for awareness programmes for decision-makers because many solar PV projects have been abandoned due to lack of secured funds for maintenance and replacement of faulty solar PV system components (Kihedu and Kimambo, 2006). If managers and leaders are aware of the importance and benefits of the projects, they will secure funds by including it in their annual budgets. Some of the awareness programme can be in form of seminars, workshops or visits to successful solar PV projects in other locations. This can be done by preparing a series of awareness meetings and workshops with regional and district officials in the targeted zone on the potential role of PV applications in rural electrification and their value addition in rural public service institutions. Solar PV demonstration systems should be installed and site visits of the officials organised to those installations for sensitization. By seeing the importance of the technology, the authorities would provide for solar PV installation in health facilities and schools in their annual budgets. Also, the budgets would provide funds for maintenance of the already installed solar PV systems.

Dealers, technicians and end user need to understand the technology itself, specifically how it works, what it can do, what their limitations are and what their advantages and disadvantages are compared to other sources of energy. In addition, the users need to understand the operation of the systems and simple maintenance like replacement of faulty fixtures. The technicians need to know how to size, install the systems and maintain the systems. The dealers need to know how to conduct the business of solar PV systems profitably. This can be done by conducting training on technical and business aspects of solar PV technology to technicians and dealers respectively. Training materials like training manuals and instruction sheets for users should be well prepared and distributed to trainees. NGOs and other stakeholder who promote Renewable Energy Technologies (RETs) should prepare an information database, which contains information on dealers of quality solar PV products, prices and where to get them. The database should be accessible on websites of the organizations in order to reach as many people as possible. This database should be updated regularly.

Building Institutional Support for Solar PV Energy Applications

There is need for trained technical personnel to establish and expand in-country assessment, development and transfer of RETs. There is also need for people with training and experience required to establish enterprises and implement projects. While this expertise is being created within the private sector, there is more scope of public support for such capacity building. For example, the public sector can help introduce practical technical and engineering curricula in Renewable Energy (RE) into trade schools, colleges, and universities. It can also support research initiatives on the technology in research and academic institutions. The public sector can make RE training accessible to those who are in position to set up enterprises and manage projects. Further, it can support joint ventures with international private sector firms, which can facilitate the transfer of the technology.

In most developing countries, there are no developed standards for RE technology, and specifically on solar PV systems. Standards are needed for equipment manufacturing quality, field performance, systems installation and maintainability. It is recommended that appropriate agencies e.g., national standards agencies, review and adapt the emerging international RE standards to the needs of their markets and industries. One of the barriers to widespread dissemination of solar PV technology in developing countries is the lack of national standards and codes, which often results into sub-standard products in the market and thus unreliable system performance (SEED/UNDP, 2000).

Many developing countries have extensive RE resources suitable for commercial development. Yet in most countries, these resources are not known in detail. Governments should initiate the development of national inventories and databases for these resources. International cooperation in this aspect may be of great assistance. This will help attract investments in renewable energy facilities (SEED/UNDP, 2000).

Building Accountability of Officials and Security of PV Systems

Accountability of officials and leaders is important for sustainability of solar PV systems, especially the publicly owned ones. This covers project leaders, local government officials and village leaders. Irresponsible officials and over bureaucratic procedures cause failures and/or delays of projects by entertain bureaucratic hassle and corruption. For example, most of theft or vandalism cases on solar PV projects were not handled properly by these leaders and the culprits were set free. Project developers have to consider innovative security systems for solar PV systems. Deployment of security guards, installation of security systems like Closed Circuit Television (CCTV) cameras and mechanical protection designs like putting metal grills around modules and batteries are among the options to be considered.

Creating Supportive Policy Measures and Institutional Framework

Electricity markets worldwide are becoming increasingly competitive, deregulated and privatized. Policies that support RE technologies become increasingly important, because the benefits of using renewable energy are not fully accounted for in a competitive marketplace. First-cost considerations often determine investment decisions in competitive markets. For several reasons, competitive markets tend to act against the use of RE systems (Larsens, 2008). So, it is important to support renewable energy as a matter of public policy. A broad range of policies has been effective in stimulating RE technology development and applications in many countries. Some examples of the effective policy initiatives are the following (SEED/UNDP, 2000):

(a) Remove import duty and tax on imported equipment, which in some countries will reduce the price of RETs by large margins.
(b) Provide subsidies and incentives for RE systems greater than 10 MW as a measure to increase access to electricity, especially in rural areas.
(c) Eliminate subsidies on conventional fossil energy resources, which in many regions are very large, making it difficult for RETs to compete, draining public sector resources and compromising market efficiency.
(d) Internalize environmental externalities in order to properly account for benefits of sustainable energy strategies relative to conventional energy sources in terms of costs to the environment and public health.
(e) Promote market-transforming initiatives to help usher into the marketplace viable renewable technologies. For example, instituting minimum renewable requirements through Renewable Energy Portfolio Standards (RPS) for the electricity sector.
(f) Promote efficient markets by developing a transparent legal and regulatory framework, not cluttered with overly restrictive regulations. Efficient markets demand the rationalization of import duties and tax to reflect their impact on the basic price of energy services. Moreover, they require that governments give equal treatment to the range of rural electrification technologies.

Provide public support for renewable energy technology assessment, transfer and adaptation in order to establish a base of knowledge on technology options so that private and public enterprises might make RE-based rural energy services available to end users. Also, producers of RE-based electricity should be granted legal mandate to sell electricity to the grid at attractive tariffs through regulatory measures.

Promoting Private Sector Involvement

Private sector actors can be a source of investment capital that is unavailable in the public sector. They have an incentive to follow through with project implementation and see it through to successful completion thus realizing a return on their investment. The private sector is often the source of technological innovations, either through their independent research, or collaboration that ushers public sector research efforts into the market. Private sector involvement can be promoted through the following measures:

(a) Promoting Joint Ventures and Public Private Partnerships: National and local government authorities working with other stakeholders can identify where Public Private Partnerships (PPP) are needed to attract private sector investment and expertise and to specify the operating rules for these partnerships. Government's oversight and facilitation is especially needed in situations that call for the involvement of international private sector actors.
(b) Establishing Supportive Rural Infrastructure for Projects: The use of decentralized RE systems on a significant scale in off-grid communities in developing countries, depends on the presence of supportive local infrastructure in the aspects of sales, financing, delivery, installation and maintenance for RE systems. The absence of supportive infrastructure has been the reason for project failures (SEED/UNDP, 2000).
(c) Granting producers of RE based-electricity the legal right to sell electricity to the grid at attractive tariffs through regulatory measures, aimed at spurring the development of IPPs using RE technologies successfully.

(d) Feed in Tariff (FIT) for RETs to attract more investment especially in the solar PV industry. FIT policies are a category of performance-based incentives that grant long-term payment contracts to RE producers. Unlike Renewable Energy Portfolio Standards (RPS), under which payments are subject to Renewable Energy Credit (REC) market conditions, FIT payments are generally set at constant USD/kW rates and above the price of grid electricity.

(e) Net metering policies allow unused RE generated electricity to be fed into the electricity grid. This policy essentially enables RE-based power producers, be it at household or business level, to run the electric meter in both directions. Unused electricity is fed into the grid and counted as credit toward the monthly electricity bill.

Innovative Financing Mechanisms

The financing of RE projects cannot be accomplished with a single project or business finance strategy in the way that many large-scale conventional energy projects and enterprises are often financed. Renewable energy projects vary considerably in scale, capacity, energy resource characteristics, points of sale for output, targeted clientele, and commercial maturity. Some of the innovative financing mechanisms are as follows:

(a) Capacity Building for Development of Financially Viable Solar PV Projects: Traditional approaches to renewable energy development have been grant-based. However, in order to stimulate the market, projects must be financially viable and able to meet strict lending criteria, in order to leverage private and public resources. Although there have been some programmes that are targeted at investment in RE projects, there is still the need for capacity building at national level of financial institutions and project developers, in order to put together financially-sound projects that are attractive to the private sector.

(b) Supporting Alternative Models for Rural Energy Supply: Most people in the rural areas of low-income countries cannot afford to buy a solar PV system, but they can afford to pay for energy services on a daily, weekly or monthly basis. The use of kerosene for lighting can prove this, as price of kerosene is higher than that of electricity service per month (Kihedu and Kimambo, 2006). This situation can happen when a rural energy supplier invests on a solar PV system, supplies the energy to users and charges them on a monthly basis or per every kilowatt-hour used. This mode of supplying energy can either be through cables to households and business places, or by installing a PV system in the household and charge them monthly or on the basis of electricity used. This includes using prepaid meters or by leasing of equipment (e.g., lanterns or batteries) after being charged. In areas with scattered users, leasing of charged equipment is more economical than supplying electricity by cables. In both approaches, the energy suppliers cover the technical service and maintenance cost. Therefore, it is a user risk free model. Figure 3 depicts this model.

The rural energy suppliers (normally private sector) invest on a solar PV system with their own capital (or grants secured from government and development partners); do energy supply business; apply for loans from banks and Micro Finance Institutions (MFI) using the PV system and/or business as collateral; and expand the business by investing more, therefore providing service for more customers. They are also a source of revenue to the government, through payment of tax.

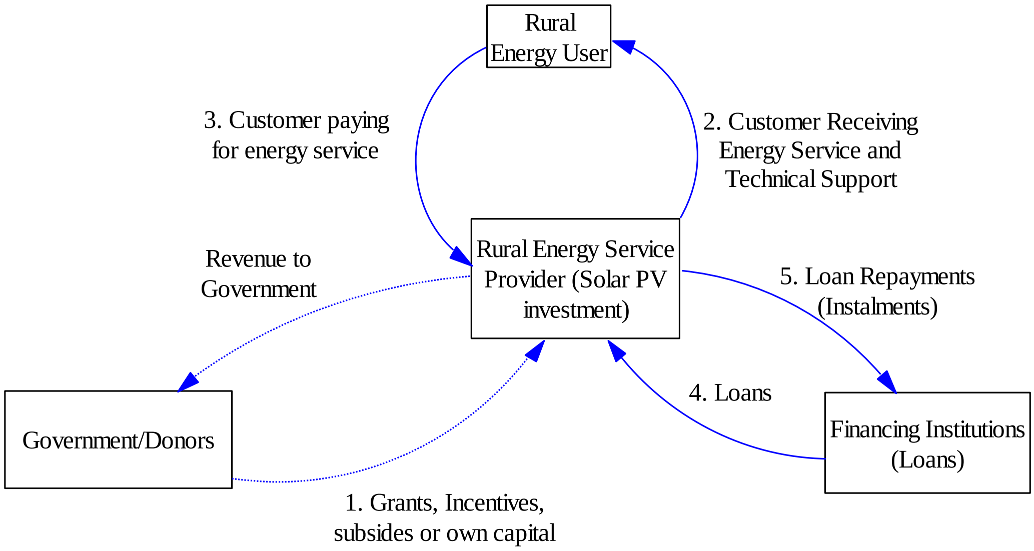

Figure 3: User risk free rural energy supplying model

(c) Developing Microfinance Schemes for Rural Energy Service Delivery: High initial costs are often an insurmountable barrier to accessing rural energy services, especially for low-income households. The availability of accessible financing is key to overcoming this barrier. Micro-credit is the provision of small amounts of credit to clients who are under-served by traditional, formal financial institutions, because of their lack of assets. Micro-finance is characterized by small loan amounts, given as short-term working capital, repaid in small frequent intervals. Three financing mechanisms are discussed in this section. These are End-User and Commercial Bank; End User and MFI; and End User, Commercial Bank and MFI. All these three approaches have to pass through the solar PV dealers that are operating in the targeted area. The end users will receive products and not cash money.

(i) End-User and Commercial Bank: In this financing mechanism depicted by Figure 4, the potential users of the solar PV technology get loans in the form of solar PV systems directly from commercial banks, through certified suppliers or dealers. In this model, the end-user has to have a collateral e.g., a house or a guarantor like an employer, in order to qualify for a loan from a commercial bank. Most of the people in rural areas of low-income countries do not fit into this type of financing mechanism. Another constraint is that the coverage of banks' network in rural areas is very low.

(ii) End-user and MFI: MFIs are available in most rural areas, so rural people can easily access them. Examples of MFIs that operate in Tanzania are Savings and Credit Cooperative Societies (SACCOS) and Village Community Banks (VICOBA). Many rural people are members of these MFIs. Members normally receive loans from these institutions for various purposes and repay back their loans in instalments. Some of these MFIs are operated by employees, e.g., school teachers and others by groups of people with the common goal of helping each other. The members themselves can stand as guarantors to their fellow members.

The model shown in Figure 5 can be used in rural areas but it cannot accommodate a big number of members at the same time as most of the MFIs have low capital. Also, sometimes dealers cannot accommodate a big number of customers at the same time. The *modus operandi* of the model is that interested potential customer applies for a loan from an MFI and the MFI informs the dealer about the request from its member. The dealer supplies and installs the PV systems for the customers and commissions it. Then the MFI pays the dealer for the system and service. The customer then pays back the loan to MFI in instalments. The model includes some agreements between parts involved. Agreements to be signed are between MFI and dealers, and between dealers and end users. The advantage of this model is that customers receive the loan in form of equipment and not cash money. The risk of receiving cash money is that money can be used for other unintended purposes.

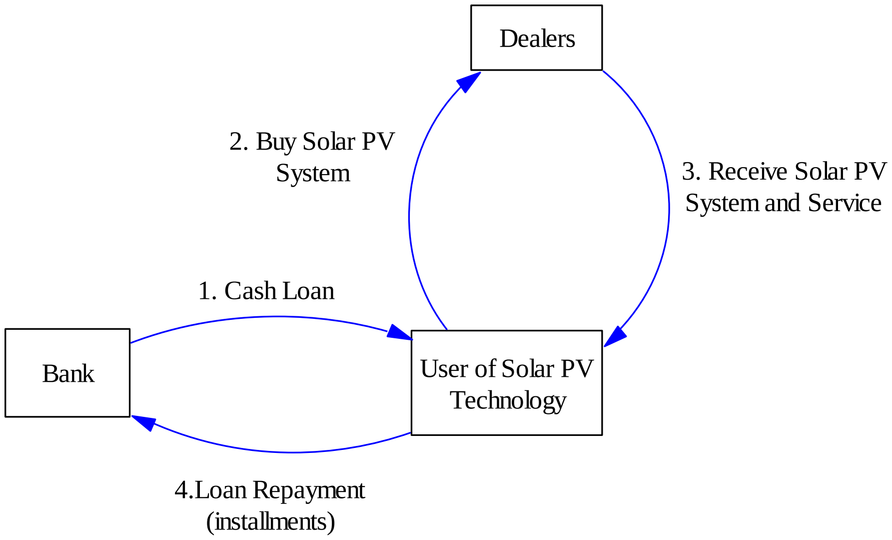

Figure 4: Potential Users Receive Loan from commercial bank in Form of Equipment Model

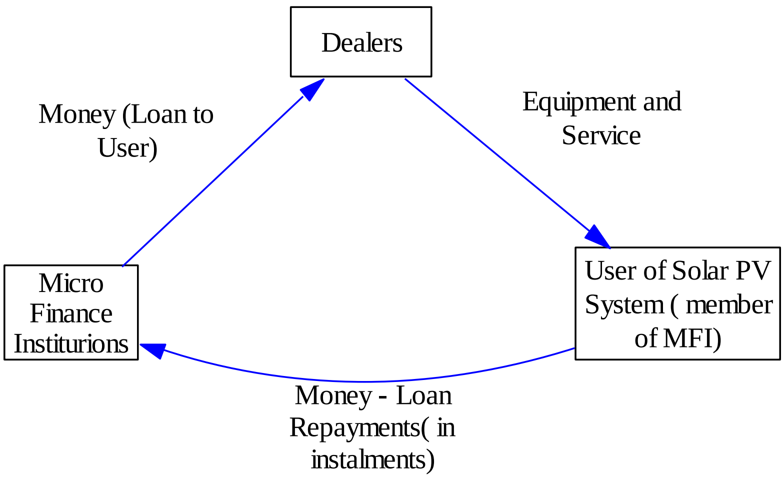

Figure 5: Potential Users Receive Loan from microfinance institutions in Form of Equipment Model

(iii) End-User, Commercial Bank and MFI: This model takes care of all shortcomings of other models described earlier. The key players in the model are Bank, MFI, dealers and user. Therefore, this model combines both the consumer and supply-chain financing models. The user receives a loan in the form of system and service through the dealer. The dealer receives loan from the commercial bank and use their business as a collateral. The MFI can apply for a loan from the commercial bank to cover an increased number of its members who would need loans. The model is presented in Figure 6.

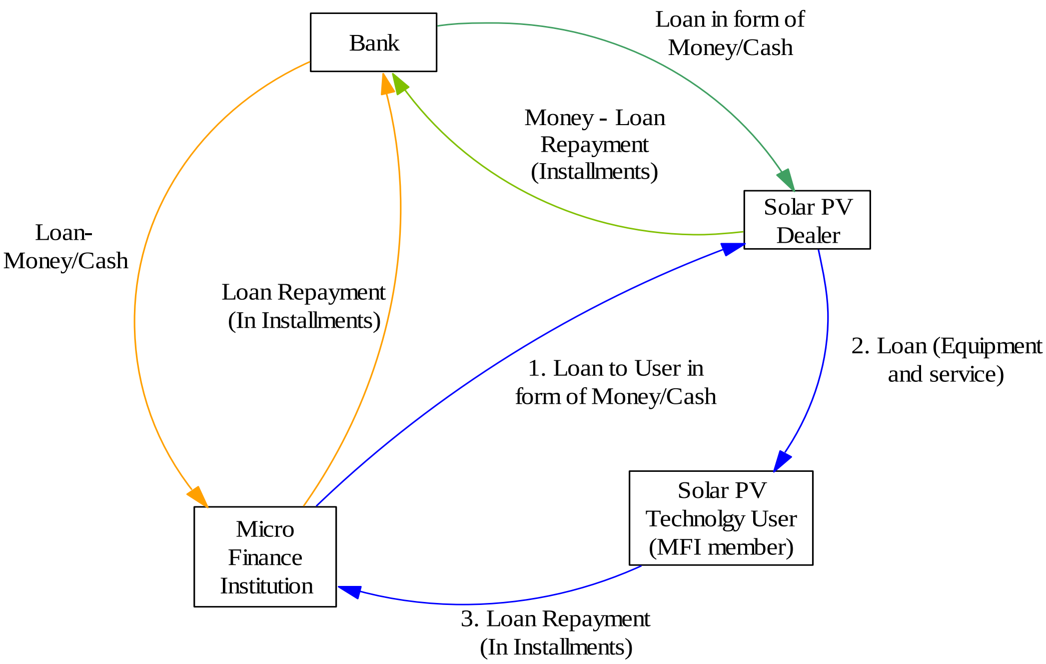

Figure 6: Sustainable solar PV financial model for dealers and users

Model validation results

Validation of the model was done against Mwanza Solar PV Project. This is regarded as a successful project as it made remarkable achievements in awareness raising, policy support and institutional strengthening, private sector strengthening, and replication of experience (Kimambo, 2009). The testing comprised of twenty-one (21) activities from this developed model. Ten (10) out of these activities are government responsibilities whereby the remained ones were Mwanza Solar PV Project activities. In the validation, thirteen (13) out of the 21 activities tested in the Mwanza Solar PV Project were complied with the model activities and this is equivalent to 62%. The details are depicted in Table 1. This translates that the project did not provide a sustainable financing mechanism to maintain existing PV systems and to enhance implementation of new solar PV projects in future. Further, the government and other stakeholders did not provide conducive environment for project implementation and no mechanism for them to run smoothly. If there are poor investment conditions for investors and there is no source of funds/loans to maintain the existing projects and new ones, this means the projects are not sustainable and therefore adoption of solar PV technology will be obstructed. All the funds for end-users and supply chain were being provided by the project through intermediaries (banks and dealers). The government is responsible to make attractive investment conditions and policies.

Table 1: Summary of the model testing

SN	Activities on Developed Framework Model	Mwanza Solar PV Project
1	Conduct demonstrations in important areas	Yes
2	Arrange meetings, visits, workshops and seminars for stakeholders	Yes
3	Provide training on Technical and Business on Solar PV technology	Yes
4	Invest on activities that promote solar PV technology	Yes
5	Provide formal training in VTCs, colleges and higher learning institutions	Yes
6	Support R & D on rural energy	No
7	Review & adapt international standards to fit the market	No
8	Develop solar PV national inventory and data base	No
9	Remove taxes for imported PV components	No
10	Laws enforcement & security provisions	Yes
11	Include subsides and incentives to systems with capacity greater than 10 MW	No
12	Eliminate subsides to conventional energy resources	No
13	Promoting market transforming initiatives	Yes
14	Promote market efficient	Yes
15	Promoting joint venture and Public Private Partnerships (PPPs)	Yes
16	Establish supportive rural infrastructures for project	Yes
17	Grant power producers' attractive tariffs for energy supply service in rural areas	Yes
18	Implement Feed in Tariffs (FiTs) / Net metering for solar PV	No
19	Capacity building for development of financially viable projects	Yes
20	Development of sustainable microfinance schemes	No
21	Development of productive uses of solar PV Technology	Yes

CONCLUSIONS AND RECOMMENDATIONS

The results of the study have shown that awareness programmes have been conducted a bit ahead of other strategies since lack of awareness scored 9% of all challenge categories. Challenges on lack of finance contributed to 32% of all categories of challenges. This means that more efforts are needed on creating sustainable financing mechanisms and their infrastructure (MFIs, dealers, technicians, etc.). This is especially important in rural areas where there are inadequate financial institution networks and people have low purchasing power. Policy and regulation barrier contributed to 31% of all categories of challenges. Delays in implementing effective policies not only hinders the private sector venturing into solar PV technology business, but also prohibits access to finance.

Financing mechanisms in project areas were not sustainable as they were relying on project funds and when the projects ended, the beneficiaries abandoned the solar PV systems and projects because they could not afford the replacement cost of defective solar PV system components. Therefore, the model proposed in this study has developed two mechanisms, which are financing mechanism and energy supply mechanism. The sustainable financing mechanism for dealers and end users was developed to bridge the gap in the Mwanza Solar PV Project, in which the financing was provided by project funds. In addition, the Mwanza Solar PV Project did not create energy supply mechanism, whereby an individual or company invests on a big solar PV system and supply electricity (by cables or by charging users' batteries or solar lanterns) to users and collect charges for services. This is a desirable mode since many of the intended users can afford to pay for services rather than buying and installing the entire systems at their homes.

It is recommended that the government, solar PV stakeholders and development partners should make use of best practices from previous successful solar PV pilot projects. This could help in learning the various approaches used and challenges encountered by these projects when implementing other similar projects in the country or disseminating the approaches used in other areas. The framework model that has been developed in this study has taken into considerations all the shortcomings and challenges experienced during implementation of the previous solar PV projects like Mwanza Solar PV projects. The model incorporates all necessary steps to be followed in order to make a project successful. Therefore, upcoming projects can make use of it especially on the sustainable financing mechanisms and energy service delivery model to serve rural energy needs.

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