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Investigation of productive use by solar PVs in rural Tanzania

-A case study

Master of Science Thesis in the Master Degree Programme, Industrial Ecology-for a Sustainable Society

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Abstract

This master thesis investigates and assesses the productive use and spread of solar PV (photovoltaic) systems among rural SMEs (small and medium enterprises) in two rural regions in Tanzania. It also analyzes sustainability aspects of productive solar PV usage and the future prospects for this type of activities. As the situation is today there is a lack of electricity in a major part of the country and there is a big need for rural electrification. In recent years there has been a lot of effort and money put into the solar PV industry in order to achieve a higher quality of life for the rural poor. One of the goals except for producing electricity, has been to achieve a self-sustaining market where solar PV are used for generate income in rural areas, i.e. productive use of solar PVs. The aim of this report is to, by a case study, map to which extent there is a productive use of solar PV and what type of businesses that has evolved. Moreover, the features of these businesses have been investigated in order to predict future prospects and diffusion for these types of activities. In addition, the research has comprised a sustainable development approach in order to investigate how and if productive use of solar PVs fit into the norms of sustainability on an economic, social and environmental level.

It was found that, within the two investigated areas, there was an extensive use of solar PVs for productive use. The most common type of business was cell phone charging business, followed by barber shops cutting hair. Other businesses that were found were TV-shows, cold beverage sales and light equipped hostels.

The prospects for further diffusion of solar PVs seems to be good, mainly because of the short payback times encountered, but also due to appropriate actions on a governmental level that has resulted in acceptance and awareness among the inhabitants. In addition, people saved money and time switching from other energy sources such as generator to Solar PVs because of low running costs.

Concerning the sustainability issues, solar PVs for productive use definitely is a step towards a sustainable development, particularly on a local level. On a larger level, PVs alone might not be the sole solution but is still of importance. However, there are some improvements that can be done such as a more effective usage of batteries and implementation of recycling stations for used batteries in order to decrease the environmental load.

During the initial phase of the project literature studies were performed in order to gain as much knowledge as possible within the subject of solar PVs for productive use and also aiming to be prepared for a working in a completely different environment and culture. On site, interviews with businessmen and other for the study important people were conducted. The gathered information from the interviews was then analyzed and evaluated in order to be able to draw appropriate conclusions.

Acknowledgements

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Finally our gratitude goes to David in Mwnaza who was helping us a lot and showed good spirit.

List of Abbreviations

PV	Photovoltaic
SMEs	Small and medium Enterprises
TV	Television
FAO	Food and Agriculture Organ
MEM	Ministry of Energy and Minerals
SIDA	Swedish International Development cooperation Agency
UN	United Nations
RASP	Reliable Affordable Solution Providers
PUC	Productive Use Containers
CO_2	Carbon dioxide
IPCC	International Panel on Climate Change
TaTEDO	Tanzanian Traditional Energy Development Organization
TANESCO	Tanzania Electric Supply Company
REA	Rural Energy Agency
UDSM	University of Dar es Salaam
TAREA	Tanzania Renewable Energy Association
UNDP	United Nations Development Program
P2P	Peer two Peer
Tsh	Tanzanian shilling
Wp	Watt peak
GSM	Global System for Mobile communication
NGOs	None Governmental Organizations
VAT	Value Added Tax
PU	Productive Use

Table of Contents

1 Introduction

In the western world access to energy, or more precisely electricity, is often taken for granted. The access to electricity is in many cases just as natural as the air we breathe and the only time we actually gets reminded of how dependent we are upon this apparently endless resource, is when there is temporary power cut. But as soon as the electricity is back we goes back to our ordinary habits with energy in abundance and no further worries.

However, this energy access abundance (borderline dependence) is far from reality for a huge part of our worlds inhabitants. In many of the less developed nations, acquiring energy often implies offsetting several hours a day just for traveling to a location where fuel can be obtained. This means that what can be done by the flip of a switch in one part of the world might require a whole day of work in another.

Within the rural areas of less developed countries the conditions in the villages has remained unchanged for generations and the energy use has traditionally been limited to fulfill some basic physical human needs such as cooking and heating. As many of the less developed countries now is experiencing a takeoff with hasty advancement of technology and globalization, many of these needs has changed and the villages are facing a risk of being left behind as the development mainly has been concentrated to the urban areas. Being left behind could lead to tremendous gaps between the rural and urban areas with severe consequences for the rural inhabitants. This implies an emerging demand for electrification within these areas. In the case of Tanzania the low access (6%) to the national grid together with limited national liquidity and infrastructure restricts further expansion. To cope with the shortage of electricity, the use of solar photovoltaics (PVs) has been advocated and is by many regarded as a relevant option for rural electrification.

The use of solar PVs as means for rural electrification has shown to be of great advantage especially in areas such as East Africa which has a huge demand for electricity and a great amount of sun hours. Further, there are several policies and strategies that have been implemented to stimulate the market for solar photovoltaic (PV) systems with mostly positive results as the existing Solar PVs out in the rural areas are generating enough electricity to operate the most basic domestic appliances such as radio, TV and light. [1] [2]. Moreover, the technology is often indirectly associated with other multidimensional advantages such as being a carbon neural source of energy, providing socio-economic advantage and being a possible stimulant for economic growth [3]. The economic growth and socio-economic advantages are supposed to be achieved by using Solar PV as an aid for income generation is often referred to as productive use[1].

Currently, knowledge of the extent of productive use of solar PVs within rural small and medium enterprises (SMEs) in Tanzania is limited. Therefore it is of interest to study PV usage among SMEs in rural areas, where the possibilities for these businesses to exploit the solar PV technology are investigated together with their actual extent and future prospects.

[1] Productive use in this context means the use of solar PV systems to create goods and/or services either directly or indirectly for the production of income or value.

1.1 Objective

The primary objective of the thesis is to investigate and assess the productive use and spread of solar PV systems among rural SMEs in Tanzania. The secondary objective is to analyze sustainability aspects of productive solar PV usage in Tanzania.

1.2 Question formulation

The following questions need to be answered in order to achieve the objective of the study:

- What types of business has emerged in the rural areas, to what extent, and what does the business specific features look like?
- What does the prerequisites and evolvement of solar PVs for productive use look like?
- How can productive use contribute to sustainable development and are the solar PVs a future energy source for productive use?

1.3 Delimitations

Due to lack of fund, resources and time an entire investigation of productive users in Tanzania is of course impossible. Instead focus had been set on field studies on two geographically different areas. Further, the term sustainable development is very diffuse and abstract. This makes the assessment of the PV technology prospects rather problematic, and therefore this thesis will only handle a few more concrete key aspects that are associated with the term sustainable development, which will be further explained in the sustainable development section. Moreover, the term productive use, just as sustainable development, can be rather abstract and interpreted in several ways. Therefore focus has been set solely on rural SMEs that more or less directly generate income with help of solar photovoltaic technologies.

1.4 Disposition of thesis

The thesis starts with the theoretical framework used as a clarifying background for the study. In these chapters concepts like sustainable development and productive use will be handled. After the theoretical framework section, a description of the methodology used in the study will be presented. The chapters that follow will handle the empirical study that has been conducted on site together with the results of the study. The succeeding chapters will concern analysis, discussion and recommendations. The last chapter will state the conclusions derived from the study.

2 Theoretical Framework

This section will explain the basic concepts that will be used in the report, starting with productive use since this is the main subject within the report. The concept of productive use will constantly recur and it is important to get a good comprehension of the term. Secondly, the concept of sustainable development will be handled as this is the ultimate goal with productive use of solar PVs. The results and findings will be analyzed with so called sustainability indicators aiming to evaluate the progress towards sustainable development, also find in this section. Finally, the diffusion of innovation model will be presented. This model will function as framework for evaluation of how productive use of solar PVs is perceived out in the rural areas and if it fits into the rural Tanzanian society.

2.1 Productive use

This section will outline the rather abstract concept of productive use of energy. It will explain how the term has evolved from a more traditional hand on term, to a contemporary more abstract term. Moreover, the subareas which the term can be divided into will be explained, and finally some examples for further comprehension will be shown.

2.1.1 Traditional view of productive use of energy

Within the traditional view, productive use of energy in rural areas is often expected to result in increased rural productivity, greater economic growth and a rise in rural employment. This would in turn result in raised incomes and less migration of the rural poor to urban areas. Moreover, the traditional view often implies, with respect to agricultural production, that electricity primarily would be used to provide motive power for agriculture machinery and industries connected to agriculture such as water pumps, fodder choppers threshers, grinders and dryers [17]. The result of this will often be a modernization in agricultural production, which in turn will lead to involvement of external industries and an increase in the amount of labor needed and an overall rural development.

Further, the traditional view also often implies that once a rural area is provided with electricity and access to new fashioned energy the rural industries will expand and improve the quality of the rural production. There are also several other indirect positive effects that are supposed to follow in the footsteps of electrification such as social benefits in terms of improved quality of life and increased equity[18]. However, many of the proposed indirect positive effect on a socio-economical level has shown to be less than expected. In the county of India, there has been a lot of effort put on agricultural productive use but the proposed desired socio economic effects have shown to be insignificant [19]. In the neighboring country of Bangladesh on the other hand, where both agricultural and rural home electrification has been promoted, there has been a reasonable success concerning rural social economic development [17]. A lesson learnt from this is that the rural situation is more complex and there is more to the rural area than just agriculture. Thereby an evolution of the term productive use has occurred to comply more than just the traditional view but also several services and other more indirect means that will generate income in a rural community.

2.1.2 A contemporary view of Productive Use of energy

As mentioned above the term rural productive use of energy has evolved to contain more uses of energy that just the traditional rural uses of energy. In 1992 the FAO (the United Nations Food and Agriculture organ) stated their definition of productive use of energy in rural areas as following;

"*In the context of providing modern energy services in rural areas, a productive use of energy is one that involves the application of energy derived mainly from renewable resources to create goods/or services either directly or indirectly for the production of income or value*"[20].

This definition would imply that for instance a light bulb in a rural home can be of productive use by improving education levels of students in rural homes getting extra studying hours. Since there is a well-documented relationship between lifetime earnings and education level, the use of a light bulb in a household might be considered productive. Another commonly mentioned example of indirect productive use originates from obtaining lights in rural nonfarm businesses. It has been proven that obtaining light increases productivity and thus also increases incomes of the rural people. The list of these types of indirect productive uses of energy in a rural context can be made very long.

Concerning the more direct uses of energy in a rural context, there is an area which the traditional view of productive use disregards, namely the nonagricultural businesses. In reality, far from everyone in the rural areas are farmers and there is a demand for services and goods even within the local communities. It can therefore be helpful to distinguish two different types of direct productive use applications. The first type is characterized as self-suppliant and being a part of the local market, meaning businesses that provide goods or services within the local boundaries. Whilst the second type of direct productive use is characterized by focus on production for external markets. In the rural case, this often implies the agricultural productive uses often associated with the traditional view. The first type of productive use appliances can improve quality of life within the rural community while the second moves beyond and can aid the integration of the rural area with the national/international economy [20].

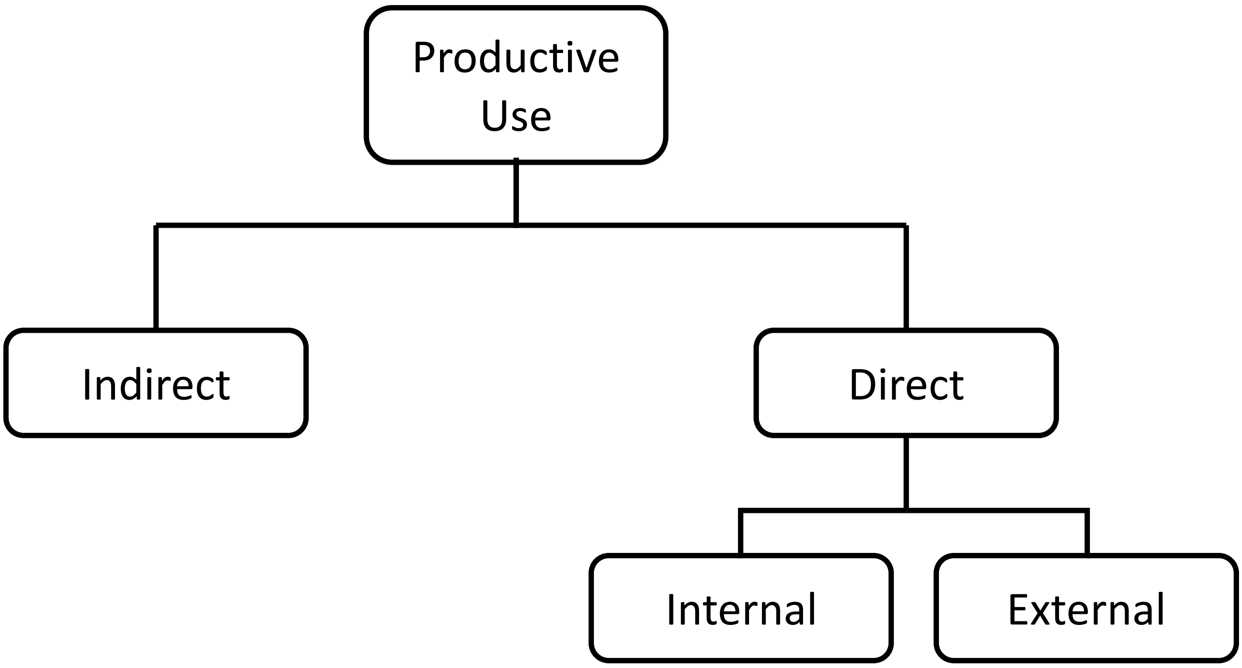


Figure1. The contemporary view of productive use of energy can be divided into indirect and direct ways to generate income/value. Within the direct use of energy it is possible to distinguish between internal use that will benefit the local rural community and external use that will be of more significance in a national or international context.

To summarize, it is possible to derive three different sub-chapters (see fig 1) within the contemporary term of productive use, the first one being indirect productive use. Productive uses of energy that will fall under indirect productive use are often characterized by a long pay-back period and intangible effects. Examples of this are numerous and could for instance be that a lamp powered by electricity instead of kerosene can have health benefits due to reduced indoor pollution. The reasoning behind this is that a healthier person will be able to work more thus also enabling the person to generate more income, making the use of the lamp productive. However, many argue that that these types of uses cannot be accounted as productive uses, because even though they can improve quality of life and in the long run be a part of increased rural income, the linkages to increases of income are less than obvious and impossible to quantify [17].

The second sub chapter is the direct external applications for productive use of energy. In this chapter one can usually find appliances that lie under that traditional view of productive use such as water pumps for irrigation, driers and other mostly agricultural appliances which will increase productivity and thus income. An example from this type of appliances can be the use of biomass gasification in silk and similar textile industries, which in India have demonstrated to have payback rate of 6 months and displacing the traditional fuel uses that includes fuel wood, diesel and kerosene. The biomass gasification project in India has further shown that the small scale users of the appliance, local entrepreneurs as well as the Indian textile industry as a whole has benefitted from this productive use[20].

The third sub chapter of productive use is the direct internal appliances. This type of productive use is as mentioned above characterized as a productive use that will generate income/value directly to the local community, this mostly by providing goods or services within the internal local market. An example of this has emerged in the recent years with the spread of the communication technology such as the mobile phone. In rural Tanzania for instance where only 2% [1] of the population is connected to the national grid but still has a lot of cell phone users; there has been an emergence of cell phone charging businesses. In this case renewable technologies, mainly photovoltaic, have for long been a reliable and cost-effective source of energy. Trends in the energy technology as well as availability and costs for telecommunications equipment are creating a great potential for this type of productive uses which will further empower the local internal markets offering new job opportunities as well as rural economic growth [20].

2.1.3 Productive Uses of Photovoltaics

As mentioned in the previous chapter solar PVs have for long been regarded as a reliable and cost-effective source of energy. It should be especially applicable in off-grid areas for low power appliances. The technology should also have numerous benefits such as; it is environmentally friendly, high reliability, no need of fuel, rather simple technology and it has low operating costs.

The availability of the technology has during recent years increased in the rural areas of several developing countries as a result of initiatives established by local governments and several international institutions to promote renewable energy sources. In Tanzania for instance where the government (MEM) together with SIDA, World Bank and UN has played an important role in promoting and in some cases supporting usage of solar PV technology in the rural areas. This project has been running since the new millennia and has had managed to support the diffusion of the technology to many of the rural areas within Tanzania.

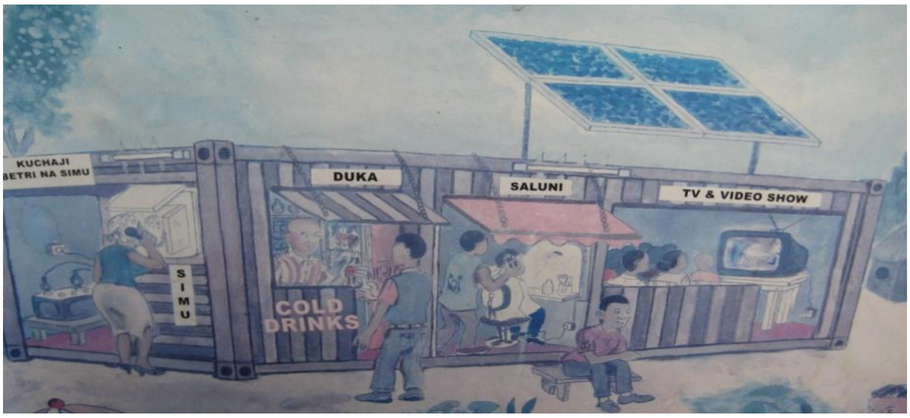


Figure 2.Drawing by a Tanzanian organization used to raise awareness on productive uses of solar PVs.

Examples of productive uses of solar PVs that can be found in many of the world's developing countries:

- **Crops Drying**

  In Malawi which has a big tobacco industry some farmers use tobacco driers that utilize the solar radiation together with a fan powered by a solar PV. This has enabled the farmers to shorten the drying time and minimizing the amount of labor needed while at the same time as increasing the quality of product [22].
- **Electric Fencing for Live Stock**

  In Brazil on a buffalo farm producing mozzarella cheese one has been able to increase the productivity of cheese production by 149% by installing electric fencing. In this case the use of a temporary electrical fencing has enabled the farmers to control the grazing of the cattle, intense rotational grazing. As a result of this the cattle has managed to put on weight at the same as the fence keeps away other invasive species thus also increasing the productivity of mozzarella production [23].
- **Productive Use Containers (PUCs)**

  An interesting concept commissioned by Greenpeace and conceptualized by RASP (Reliable Affordable Solution Providers) consulting can be found in South Africa. The Productive Use Container (PUC) was first displayed in 2002 at the World Submit on Sustainable Development in Johannesburg, South Africa. The concept is based on a rebuilt 40ft maritime container powered by solar PVs that house 5 small enterprises that more or less are depended on electricity to conduct business (see fig 2). These enterprises may include tailors, cell shops, electronics shop, and business centers etc. The PUC have been deployed in several South African rural villages and has proven to have many benefits such as high security, easy transportation and deployment due to its robust nature. Further derived from the South African cases the PUC also functions as a village center and meeting point for the local inhabitants [24].

2.2 Sustainable development

Sustainable development is a concept that during the last decades has become widely used and popular when it comes to describing diverse projects in developing countries. Although it is a common used term it can be interpreted in many ways and a single and clear stated definition is missing. This paragraph will give a brief outline of the term sustainable development together with the Bruntland definition from 1987. Moreover, for this report appropriate indicators that will be used for evaluation of the contribution of productive use towards sustainable development will be presented.

2.2.1 Sustainable development - the term

The term sustainable development itself can be divided in two parts where sustainable means the capacity to endure, maintain or support whereas development is described as the progress where one is going from one state to another and the latter state is regarded as the more preferred one [4]. Together the two parts combines the concern for carrying capacity of natural systems with social challenges facing humanity [5]. Moreover, the term sustainable development can be seen from different angles, namely strong and weak sustainability. Strong sustainability implies that the society does not affect or tear the natural resources at all, and builds on the idea that there are certain functions that the environment performs that cannot be duplicated by humans. The ozone layer is mentioned as one example of an ecosystem service that is difficult for humans to duplicate, photosynthesis and the water cycle are others. On the other hand, the concept of weak sustainability advocates that it is enough if the total capital resources of the society do not decrease. This implies that it is possible to assign monetary value to natural resources and also to replace the natural capital as long as the total capital does not decrease [6][7].

2.2.2 The three dimensions of sustainable development

Except for the different angles, the field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability [8]. To meet the needs of the common man, development on several dimensions should be necessary. For instance high productive economic activity can coexists with high levels of poverty, hence both economic and social dimensions needs to be knotted and evolve together. Another crucial dimension in sustainable development which is extra critical for the future generations is the environmental dimension. This dimension differs itself from the others due the long time effects and high inertia that characterizes the factors within it (see fig.3). Hence the three imperatives that need to be integrated to achieve sustainable development are the economic, social and environmental dimensions.

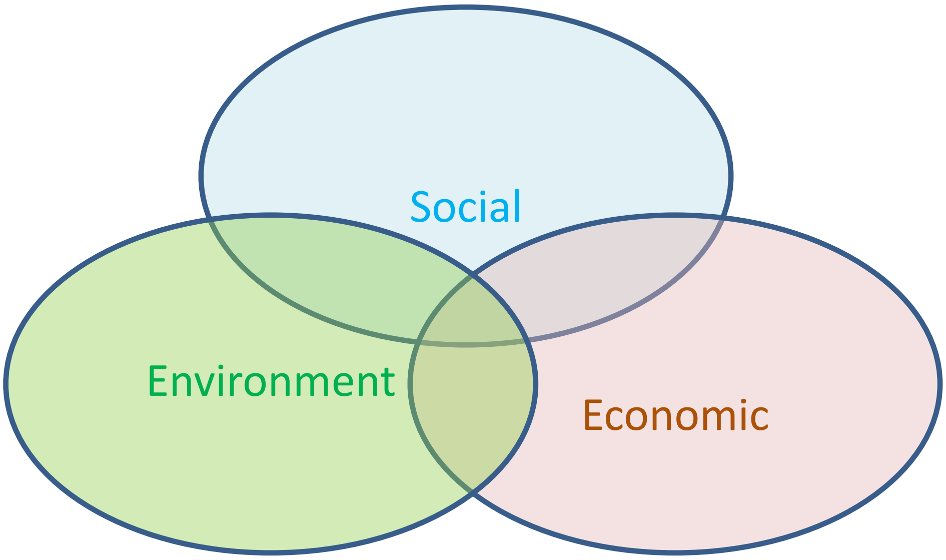


Figure 3: The three dimensions on sustainable development.

- The social dimension is needed to provide governance that propagates the value that people need and want to live by [9]. Examples of factors that may be connected with the social dimension are; poverty eradication, social capital, culture, institutions and gender issues [10].
- The economic dimension is needed to provide adequate material and living standard for humanity [9]. Where factors such as macroeconomic stability, growth and economic efficiency may be desirable [10].
- The environmental dimension implies the need to stay within the biophysical carrying capacity of the planet to assure future needs [9]. The important factors may include; increases of substances in the ecosphere from lithosphere, increases of manmade substances to the ecosphere and physical degradation of the ecosphere [11].

2.2.3 The Bruntland definition

As mentioned, there are several different definitions of the concept sustainable development, however, the most known and maybe accepted definition was defined by the world commission on environment and development (Bruntland commission) in 1987 and states that;

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

It contains within it two key concepts:

- *The concept of **needs**, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *The idea of **limitations** imposed by the state of technology and social organization on the environment's ability to meet present and future needs."*

The definition made in the Bruntland report brings up the dependency of humans on the environment to meet needs and well-being in a much wider meaning than merely exploiting resources: 'ecology and economy are becoming ever more interwoven – locally, regionally, nationally and globally'[30]. The Bruntland definition together with the report Our common future also stresses that humanity, whether in an industrialized or a rural subsistence society, depends for security and basic existence on the environment; the economy and our well-being now and in the future need the environment. In addition, it also points to the global interconnections: environmental problems are not local but planet wide. This means that actions and impacts have to be considered internationally to avoid displacing problems from one area to another by actions such as using up more than an equitable share of the earth's resources or releasing pollution that travels across national borders [12].

2.2.4 Solar PVs and Sustainable Development

Solar has during recent years been discussed as the major future energy source due to, in the perspective of humanity, its infinite flow of energy. In additional, the use of energy from the sun is regarded to be totally free from CO2 and other emissions that might make up a threat to mankind and its surroundings.

There are numerous factors that negatively can affect the progress of sustainable development. A factor that threatens the progress can come into existence from one dimension and become a menace to the other dimensions. A typical example of this is one of the biggest issues on the global agenda right now, namely the emissions of atmospheric greenhouse gases. The problems with increased greenhouses gases are primarily of environmental nature, but also in the highest degree a threat towards the other dimensions. It is the usage and combustion of fossil fuels that is the main source to the increased levels of CO_2 in the atmosphere, which in turn will lead to an increase in temperature on the planet. The International panel on climate change (IPCC) has predicted a raise in temperature from 1,1 to 6,0 °C during the 21:th century, depending on how much CO_2 that will be emitted in the nearby future. How much effect such an increase will have is under discussion, where some claims barely noticeable effects and others severe effects with melting polar ices and drought as a result. Even if there are several existing opinions and scenarios about the severity of the effects, most scientists agree on the fact that there will be visible effects affecting our way of living. As a step in the right direction towards a decrease of the emissions of CO_2, the usage of renewable or CO_2 neutral energy sources have been advocated. One, amongst other options for renewable energy is the usage of the energy containing light, generated by the sun.

Sustainable development can, as mentioned above, be interpreted in several ways and be seen in several dimensions. Two distinct angles of sustainable development with regard to PVs are; firstly sustainability of the technology itself, mostly concerning factors affiliated with the environmental dimension of sustainable development and secondly sustainability of the user of PV systems (e.g. a business or a rural family). This angle implies more economic and social dimension characteristics.

In the first angle of looking at sustainable development of the solar PV it is possible to identify several distinct advantages such as; avoiding consumption of resources and degradation of the environment by emissions and pollutants. Moreover, the use of solar PV systems is a CO_2 neutral source of energy and does not contribute to the global warming. A 1kW PV system producing 150 kWh each month prevents 75 kg of fossil fuel from being consumed. It avoids 150 kg of CO_2 from entering the atmosphere and keeps 473 l of water from being consumed [13]. However, studies have also shown that large-scale exploitation of solar PVs could lead to other types of undesirable environmental impacts in terms of material availability and waste disposal [14]. Other impacts that have been discussed are the need of land for installing enough solar PVs for supply on a large scale. However, calculations have shown that an area of 250000 km^2 (1-2% of the total area of the Sahara) with solar PVs put up in Sahara would be enough to cover the current global energy need [1].

The second angle concerns the socio-economic effects of solar PV usage, such as work- or income-related activities that can be supported by the use of solar PVs. These activities can in a longer run lead to increased macroeconomic growth by increased real income and an overall improved quality of life. More direct examples of this might be increased sales, less fuel costs, increased communications capabilities, improved education [15] and poverty alleviation [16]. This will be outlined more thoroughly in the productive use chapter where the concept of productive use will be described.

2.2.5 Sustainability indicators

In means of rural development there are plenty of indicators that can be used in order to measure and evaluate movement towards sustainable development. In this report the movement will be evaluated with regard to the three dimensions of sustainability, where each dimension will contains a set of indicators. These indicators will be the base for further discussions in the analysis section.

The indicators that will be used in this report are based on those stated by the FAO, Food and Agriculture Organization of UN. The indicators has underwent modifications in order to be better adapted to our objective and one section has been excluded due irrelevance.

Following indicators will be used with regard to the three dimensions of sustainable development:

Economic dimension:

- Employment: Ability to deliver new services and jobs, both for man and woman.
- Profitability: Ability to deliver a decent rate of return and profitability.
- Investments: Ability to attract new investments

Social dimension

- Income: Ability to serve as mean for additional income
- Health and safety: Ability to contribute to improved health
- Education and Housing: Ability to improve education and housing situation.

Environmental dimension:

- Air, soils and water quality: Ability to improve or maintain quality of air, soils and water
- Topography and climate: Ability to improve or maintain topography and climate, where the latter concerns both local, regional and international levels [31].

2.3 Diffusion of Innovations

As the idea of productive use of solar PVs perceived as a new in the rural areas of Tanzania, it can be seen as an innovation. This chapter will therefore handle innovations theory that is of interest when understanding and assessing the dynamics for productive uses of solar PVs in Tanzania. It will explain the nomenclature used when speaking of diffusion and the most common model regarding diffusion of innovations area. The nomenclature and model will later be applied on the results and function as a base for the discussions. The diffusion of innovation theory is of particular interest as it can contribute to an explanation of the past, present and possible future states for the innovation, productive use of solar PVs, in rural Tanzania. In addition, the diffusion of innovations model is an important tool when it comes to evaluation of the attitudes and perceptions among people out in the rural areas. In order to reach success with the implementation of solar PVs for Productive use proper support among the contemplated users is needed.

2.3.1 Innovation & Diffusion

An innovation is commonly described as an idea, practice, or an object that is perceived as new by a unit of adoption, usually an individual or a social system [25]. The process of how communication and possible implementation of an innovation is spread is commonly referred to as diffusion. It can also be described as the process, in which an innovation is communicated through certain channels over time among members of a social system [25].

2.3.2 Main Elements for Diffusion

The four main elements or key variables for a successful diffusion of a new idea are the innovation itself, the communication channels, time, and the socials system.

2.3.3 The innovation itself

The rate of adoption (fig. 4) of an innovation within a social structure depends greatly on how the individual perceives it. The perception in turn depends on a few main characteristics of the innovation.

- **Relative advantage**
  The degree to which a new idea (innovation) is perceived as advantageous compared to coexisting or earlier ideas. The degree of relative advantage can for instance easily be quantified in economic terms, but factors such as social prestige , convenience and satisfaction can be equal importance although more problematic to quantify. Important here is to stress that it is not the objective advantage that will matter but how the individuals within the social structure will perceive it. The greater the perceived relative advantage is, the faster the rate of adoption of the innovation will be.

- **Compatibility**
  The degree, to which an innovation is perceived as being compatible with the existing values, experiences and needs to fit into the social structure. An idea that is compatible with the present values and norms within a social structure will have a faster rate of adoption than an incompatible one. An incompatible innovation requires adoption of a new value system which is a relatively slow process.

- **Complexity**
  The degree to which an innovation is perceived as difficult to use and understand compared to other alternatives. An innovation that is perceived as a complicated and difficult to use by individuals in a social system will have a slower rate of adoption than a simple one. This is a consequence of the additional skills that the adopter will have to master before adoption.

- **Trialability**
  The degree to which an innovation may be experimented with on a limited basis compared to other alternatives. Ideas that can be experimented with will generally have a faster adaptation rate than an innovation that is not divisible. The higher degree of trialability the less uncertainties the possible adopter will have, who can learn by doing.

- **Observability**
  The degree to which the results of the innovation are visible to others compared to other alternatives. The easier it is for the societal system or an individual to observe the results of the innovation, the higher will the possibility of adoption be. This type of visibility will stimulate peer discussion of the innovation, as friends, neighbors and relatives of the adopter often will show interest in the innovation and possibly become adopters themselves.

To sum up, how an innovation is perceived by a social structure depends on the degrees of relative advantage comparability, observability, trialability and complexity. These degrees will in turn play a key role concerning the innovations rate of adoption.

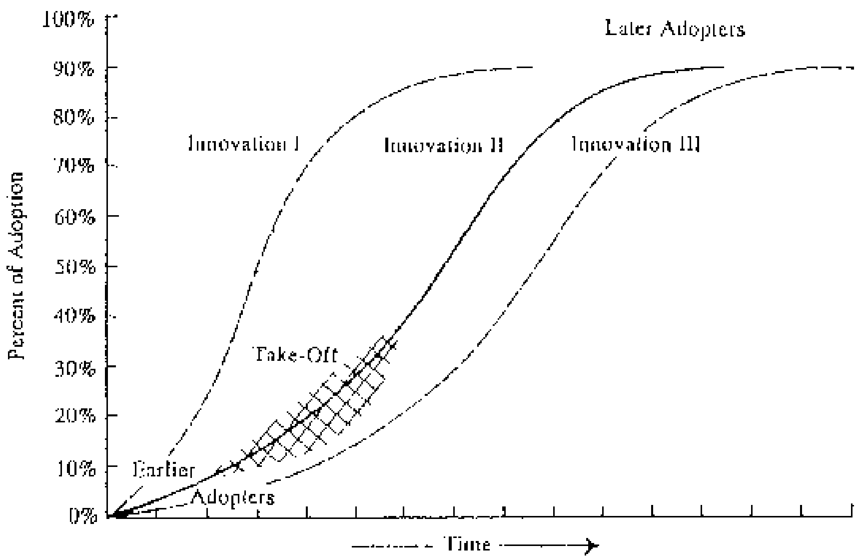


Figure 4. Figure showing three innovations with different rates of adoption [26].

2.3.4 The Communication Channels

The second element that is of importance for diffusion of an innovation is the communication channels. A communication channel can be described as the means that messages get from one individual to another. This can occur in many ways such as mass media and spoken opinion between friends or relatives. Media channels have been shown to be more effective in creating knowledge of the innovation, whilst interpersonal communication channels are more effective when forming and changing attitudes towards the innovation. Most individuals evaluate an innovation, not on basis of scientific research conducted by experts, but though a subjective evaluation of near-peers that has experience of the innovation. This implies that in the end it is the interpersonal communication channel that will have the most significant impact on the adoption rate [25].

2.3.5 Time

The third element in diffusion of innovations is time. Time plays an important role in diffusion in three different ways. Firstly, time is involved in the innovation-decision process, in the form of the time it takes for the individual between obtaining knowledge until the decision to adopt or reject the innovation. To decrease uncertainties concerning the innovation the individual tends to seek and confirm information on several stages before making the decision to implement the new idea. In many cases this will also mean that the attitude toward the innovation also will have to change during this time period. The innovation-decision process can be divided in four steps as shown in figure 5.

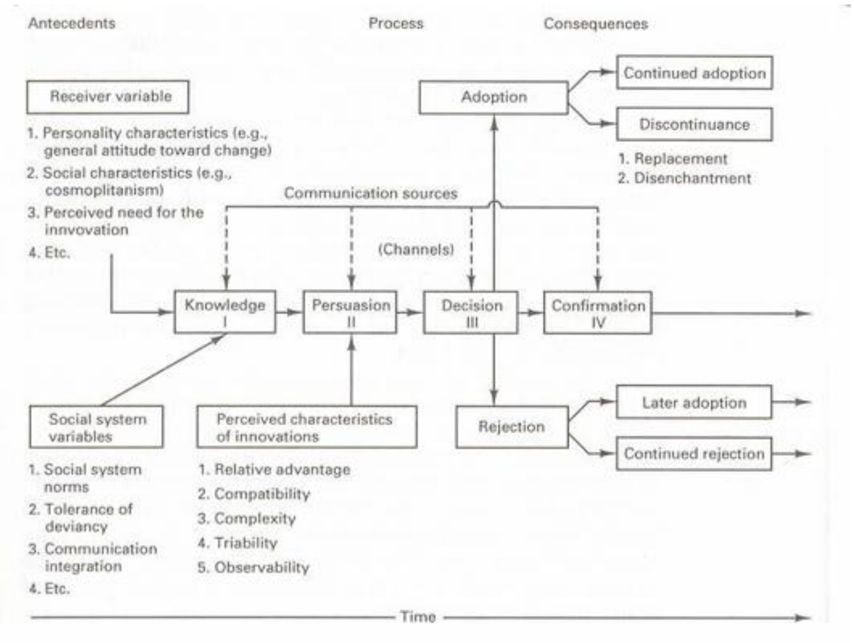


Figure 5. A concept model of the innovation-decision process [26].

The 4 steps in innovation-decision making [26]:

I. Knowledge
When the individual first gets to know about the innovation (e.g. by media or near-peers)

II. Persuasion
When the individual forms an attitude towards the innovation by the perceived characteristics

III. Decision
The choice weather to adopt or reject the innovation is made by the individual

IV. Confirmation
The individual evaluates the innovation-decision made by deciding whether to continue or discontinue the use/rejection of the innovation.

The second way time is involved in diffusion is the adopting individuals' innovativeness. This is the degree to which an individual is adopting the innovation compared to the other members of the social structure. The innovativeness of an individual can be categorized in five different categories:

- **Innovators**

  Individuals that are placed first on the innovativeness scale are the individuals that are the first to adopt the innovation, the innovators. They usually represent the first 2.5 percent of the social structure. They are often willing to take risks, have great financial lucidity, have good technical knowledge, are often close to scientific sources and have interaction with the other innovators mainly outside the system borders [26]. Although the innovator might not be a respected by the other members of the society, the innovator will play a crucial role in the diffusion process by importing the innovation from outside the borders of the system boundaries. Thus the innovator takes the role as a gate keeper of new ideas into the societal system [25].

- **Early adopters**

  The next 13.5 percent of individuals in the societal system are categorized into the early adopters' category. They have the highest degree of opinion leadership they are also typically having a higher social status and having more financial lucidity. They are also having higher education and are more socially forward than late adopters. What separates then to the innovator is that they have strong bonds and influence within the own system compared to the innovators who tends to have more outer-border bonds. It is this category that it is the most influential when creating an opinion of the innovation and often severe as role models for the rest of the societal system. They often make a subjective innovations-decision based on peer to peer discussions with others within the same category.

- **Early majority**

  The next 34 percent are referred as the early majority and consists of individuals that adopt an innovation after varying degree of time. This time frame is significantly longer than for the innovators and early majority. Significant for these individuals is that they having slightly above average social status, they have contact with early adopters and show some opinion leadership. This is the largest category together with the late majority and consists of one third of the societal system. Certain uncertainties when making the decision to adopt is needs to be removed often by peer to peer discussions.

- **Late majority**

  The next 34 percent of adopters are placed in the late majority category. They tend to adopt the technology lightly after the average member of the society and often approach the innovation with a high degree of skepticism. In additional they are often slightly below average social status and less financial lucidity. Lower financial lucidity and high degree of skepticism often means that most uncertainties must be removed before the decision to adopt is made. Pressure from peers is often necessary then making a decision.

- **Laggards**

  The last 16 percent of adopters are the so called laggards. Individuals in this category tend to be focused on traditions and have low social status. They show little or no opinion leadership and are having the lowest financial fluidity. Decisions made by this group are often made in terms of what has previously been done. They are also the oldest group and tend to be near isolates with the rest of the system only communicating with family members and old friends.

They also tend to have strong resistance towards innovations until all uncertainties have been removed.

The third and last way that time is involved in diffusion of innovations is the rate of adoption (fig 5). This means the relative speed with which an innovation is adopted by the members of the social structure. The rate of adoption us usually measured in the number of members of the social structure that adopts the innovation within a given time period. As mentioned previously the rate of adoption is heavily influenced by the five perceived attributes of the innovation itself.

2.3.6 The Social Structure

The fourth and last element for diffusion of innovations is the socials structure. Social structure is defined as a set of interrelated units that are engaged in a joint problem solving to accomplish a common goal. The units consist of individuals, organizations, informal groups and/or subsystems. The social structure also constitutes a boundary where the innovation will diffuse within. Inside a social structure norm, opinion leadership, change agents, types of innovation-decisions and consequences may play important roles for diffusion of the innovations Here opinion leadership is the degree to which an individual is able to in informally influence other individuals’ attitudes or overt behavior in a desired way with relative frequency. A change agent or agency is an individual or organization that tries to influence the clients’ innovation-decisions. Decision making can be done on several levels such as on an individual level, a collective level or authorial level; thereby the type of innovations-decision will influence the dynamics of diffusion in different ways [25].

There is also a final term that is crucial when understanding the dynamics of innovations diffusion, namely critical mass. When an innovation has reached a certain amount of users’ further rate of adoption becomes self-sustaining. The users up until this point are referred as the critical mass (shaded area in fig 4). The concept of a critical mass implies that stimulation of innovation use should be focused on these innovation users that lie on the critical mass point and under, the early adopters, to obtain a successful diffusion. The early adopters are as mentioned above often opinion leaders and serve as role models for the rest of the societal structure.

3 Methodology

The aim of the methodology section is to ensure the reader to understand how the study is carried out and give the reader an opportunity to form an opinion and follow the results and the analysis presented in this Master thesis in a structured way. The emphasis in the methodological section has therefore been to provide the reader with a logical and structured methodology, which has been applicable on the study.

3.1 Choice of method

Since the objectives of the thesis was to investigate assess the productive use and spread of solar PV systems among rural SMEs in Tanzania and to analyze sustainability aspects of productive solar PV uses in a less developed country, a case study approach was chosen together with literature studies in order to reflect and represent the objective. This choice was natural since a case study is a relevant way of collecting empirical data, approaching complex issues and giving a holistic picture. Moreover, a few different steps were used in order to achieve and accomplish the case study. These steps are as follows: design, preparation, collection, analysis and reporting of data.

3.2 Collection of primary data

In order to achieve the objective, the case study was carried out in two different areas of Tanzania. The reason for choosing two different areas was that it implied the possibility to do a comparison of the achievements so far. In addition two areas were chosen because it will give a better foundation for a holistic view and enables in depth studies. The choice of the two areas will also enable various perspectives and views of the productive use of solar PVs.

The main difference between the two areas is their proximity to larger cities and their exposures to promotion campaigns conducted by various authorities, organizations and change agents. By making a comparison of the two areas more reliable results and a better indications on how solar PVs actually are used to generate income will be obtained. In additional, features and prerequisites that are feasible in different geographical areas can be evaluated. The criteria for the areas are:

- The area should be considered as rural.
- No/limited access to national grid.
- Usage of solar PV technology within the area.

3.3 Collection of secondary data

This part of the research has mainly consisted of gathering information and data from literature and old reports. The gathering of information has been done on our own but also in collaboration with the supervisor for the Master thesis, Dr. Bångens. The major part of the literature comes from data bases and catalogues that have been found in libraries in Sweden and Tanzania but also from databases on the internet. The literature covers a wide range of subjects such as the solar PV and energy situation in Tanzania to theories and facts that are used throughout the report. Prior to the field trip, an in depth study of the existing literature was performed in order get background information and be as prepared as possible for the work onsite.

3.4 Course of action

The work with the Master thesis can basically be divided into three parts: Initial research, onsite study, and final analysis.

3.4.1 Initial research

In order to achieve as good preparations as possible an initial research was conducted. The initial research mainly consisted of collecting and gathering relevant information, not only about solar energy and the productive use of solar PVs in Tanzania, but also about the country and its culture. In addition an interview template (Appendix I) was developed for the interviews performed with the businesses on-site. Furthermore, major companies and organizations dealing with solar energy was targeted and evaluated for potential interviews.

3.4.2 Onsite study

Onsite in Tanzania, contact with people of importance for the study was established. Amongst others, Mr. Sawe head of TaTEDO (Tanzanian Traditional Energy Development Organization) and Prof. Rutashobiya at University of Dar es Salaam were especially helpful when selecting appropriate research areas. The outcome of our meetings was that the area of Kibaha and the region of Mwanza, later specified to Kayenze, were chosen as targets for the study. On site at above mentioned areas, interviews with business owners using solar for generating income were conducted. The interviews took place for about two weeks at each place. Moreover, additional interviews with people involved in the solar business were conducted, mainly regarding challenges and hinders to future diffusion of solar PVs. These people were chosen out of contacts originating from the supervisor and by recommendations from various stakeholders.

Due to unpredictable weather conditions and by security reasons in the field, interviews was documented by hand on paper, but was in the end of the day, transferred to a laptop for safe storage. Moreover, reflections, thoughts and interesting discussions that came up during the fieldwork was written down and stored onto laptops. During this time continuous contact with the supervisor was kept in order to keep him updated and informed of the progression of the study and also to exchange thoughts and ideas.

3.4.3 Final analysis and report writing

The final analysis and report writing took part in Sweden where collected data was summed up and put together in order to identify relevant information. By continuous contact with the supervisor it was ensured that the analysis and the findings were performed appropriately. This contact also implied that the data was structured to extract the most out of the collected material.

3.5 Reliability

The reliability of the study should be regarded as high due to several factors. At first, the literature that have been used as a base for this study originates from scientific articles which are published in journals and papers that are well-recognized with a good reputation, and therefore must be seen as reliable.

Secondly, the interviews have always been conducted in manner where the interview is following a template with short, simple questions that are formulated in a way that would not give information about the sought answer. The interviews were held in English when possible, but out on the field, an interpreter was used due to poor knowledge in English amongst the business owners who was targeted for the interviews. The interpreter had good knowledge in both the English and Swahili language, which minimized the risk of loss of information during the translation. When uncertainties occurred, a discussion with the interpreter was raised after the interview, which further contributed to minimize the loss of information.

Although, there might be uncertainties regarding some of interviews as some of the respondents were employees and did not have insight about the running costs, system features etc. There was also in several cases, a lack of documentation and the answers were given as rough estimates. This error factor is however reduced by the number of interviews made.

Since a large number of people holding important but different positions within the solar industry were interviewed, a reliable picture of the solar energy situation in Tanzania was formed. This picture was built objectively, containing many different angels and perspective which were put together forming a holistic view. The findings did not really contradict with each other which must be seen as proof for reliability.

4 Introduction to results- Present situation in Tanzania

Tanzania is today on of the poorest countries in the world with a BNI less than 440 USD a year [32]. In order to achieve a development towards a wealthier society, stimulation of the market is seen as a major important factor. This stimulation is hard to achieve due to shortage of electricity which functions as an inhibiting factor for business development. Therefore the energy situation in Tanzania is considered to be one of the most important issues to handle in order to reach further development within the country.

As the situation is today, energy consumption in the rural areas accounts for 85% of the total national consumption. The majority of the consumed energy consists of biomass-based fuels, in particular fuel-wood. Biomass-based fuel accounts for more than 90% of the energy supply within the country, whilst commercial energy sources such as petroleum and grid electricity accounts for about 8% and 1,5% respectively. Coal, solar and wind is estimated to account for about 0,5% of the total energy consumption.

At present the electricity consumption within the country is 150 kWh per capita, this can be compared to the goal set up by FN to obtain a good quality of life which is set to 500 kWh. The poor living in the rural areas have to spend 35% of their income on energy in order to maintain the most essential and life-supporting chores such as cooking and heating [29].

4.1 The electricity generation and supply

Electricity generation, transmission and distribution in Tanzania are provided by Tanzania Electric Supply Company also known as TANESCO. The company is fully-owned by the Tanzanian government and is responsible for 98% percent of the country's electricity supply. The total installed capacity stands at 1219 MW of which hydropower comprises 561 MW and thermal energy comprises 658 MW [28]. Estimates made by REA (Rural energy agency) show that only 12% of the total potential capacity from hydropower is exploited. The total energy capacity is estimated to 4.7 GW [29]. In addition, leftovers from the sugar and wood processing plants accounts for 35.8 MW.

With an average of 4.9 inhabitants a per household [33] and a population of 42 million [34] there are currently approximately 8.4 million households in Tanzania, inserting the fact that only 6 percent of the population has a connection to the national grid would imply that 7.9milion households still go unconnected. With the current expansion rate of the national grid of 50000 connections a year would imply that if figures remain the same, the country will be fully connected in almost 160 years. By further inserting population growth of 2.04 percent to the equation would imply an increase of almost 170000 households the by next year, actually making the extension rate of the grid slower than the population growth rate.

4.2 Future challenges

Tanzania is predicted to face a huge increase in demand of electricity in a nearby future due to an increased industrialization and even faster growing population. This causes an increased energy demand where massive investments in generation, transmission and distribution are required. The funding for this enormous project is seen as one of the major challenges. Other challenges that further enhance the importance of additional energy sources are the escalating petroleum prices in a country where poverty is a big problem. The problems that are related to the energy issue are mainly of financial nature such as inadequate private sector investment participation, limited long term financing for small and rural energy projects and often high interest rates on loans from commercial banks. In addition, the small projects often face challenges such as poorly investigated implementation areas, lack of or inadequate project promotion, lack of financial capacity among buyers and absence of credits support facility. There is also a lack of or inadequate development finance institutions which will facilitate the work with financing small power projects [28].

5 Results

This part of the thesis will mainly present the findings and data that were derived from the 37 conducted interviews. These interviews were made on site within the two chosen rural districts for the study. Further, results from interviews made with individuals working at UN, UDSM, Zara Solar, TaTEDO and TAREA is presented together with findings from literature studies on the productive use of solar PV in Tanzania.

5.1 Geographical spread and productive uses.

This section will concern the two areas that were chosen for the study and what types of productive uses that were encountered.

5.1.1 Geographical spread

This chapter presents the two districts that were targeted for the investigation. The prerequisites for the two areas as well as the geographical spread among the respondents will be outlined and presented.

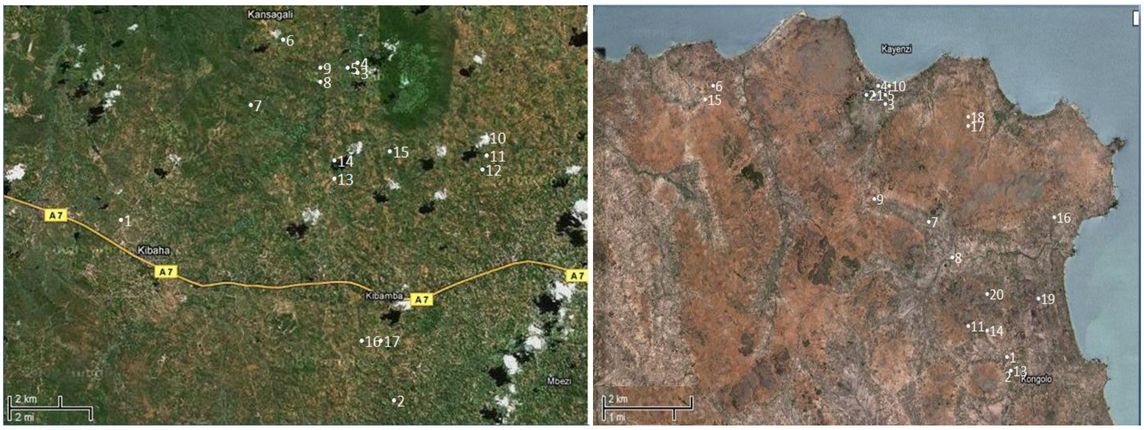


Figure 6 &7. Maps showing the location of the interviewed entrepreneurs. Kibaha on the left and Kayenze on the right. See appendix 1 and 2 (Note difference in scale).

The location of the productive users which were found in the research varied significantly in the two areas. In the Kibaha area, for instance, the national grid was present only a couple of kilometers from the respondents as it followed the A7 highway (fig.6). In some cases the national grid had been extended all the way out to the villages but the connection to the local buildings had not been established. This had been the case for many years and there were no visible sign that something was about to happen in a pending future. In Kayenze (fig.7) on the other hand, the closest electrified area was roughly 30-40km away. It was also clear that the awareness, acceptance and spread of productive uses of photovoltaics were more evolved in the Kayenze area. This is perceived to be a result of the MEM projects that have been conducted the areas near Lake Victoria, combined with the almost complete absence of the national grid.

Some factors where, however, strikingly similar in both areas such as the separation of village centers and the deep rural areas. The unconnected village centers consisted of numerous small businesses and households which had a thriving local economic environment that consisted of restaurants, bars, kiosks, beauty salons, tailors etc. The degree of economic development in these areas seemed to be in direct correlation with the size of the near village. Although, a connection to the national grid was missing, electricity was still quite common and often generated from diesel or petrol generators. The village centers visited was in most cases the last stops of the local traffic and beyond them the roads were usually in very poor conditions, only accessible by motorbikes. The deeper rural areas on the other hand, consisted mostly of small scale farmland and the only place were non-locally manufactured commerce was conducted were in so called “dukas” (the Swahili word for small shop or kiosk). These “dukas” were often very scattered with significant distance in-between and usually served as a local meeting point for the inhabitants of the area.

Regarding the intensity of productive users of photovoltaics, the entrepreneurs located in the village centers were naturally higher as there could be 3-6 businesses driven by PVs in a quite close proximity to each other. This seemed to be the case when one entrepreneur successfully conducts business powered by solar cells, others would soon follow, so called copycats. However, in the deeper rural areas this phenomenon was not observed and the solar entrepreneurs were often situated with greater distance between each other.

5.1.2. Types of encountered productive users

Clearly, charging cell phones are by far the most common type of productive use. However, the nature of these businesses that offered phone charging services differed quite significantly. The most common business type that charged cell phones was the “duka” which traditionally sells daily domestic products such as batteries, soaps, sodas, bread, phone vouchers etc. When equipped with solar systems the interviewed “dukas” could except for sales of daily products also offer phone charging. Many of the respondents further claimed that the phone charging service was the largest contributor of income to the shop. In addition, phone charging indirectly also led to increased sales as costumers tended to purchase other products at the same time as they were charging their phone. In a couple of the visited “dukas” were the installed solar system was of a larger size (100Wp and above) [2], other services were available such as cold beverages and TV-shows in combination with phone charging.

In the village centers where the situation is slightly different compared to the deeper rural areas, several so called teleshops that solely focused their business on mobile phones and telecommunications encountered. These shops powered by solar PVs offered phones, phone accessories, reparations, and phone charging. Surprisingly, even in these types of businesses the respondents claimed that charging of cell phones was their largest source of income. Another interesting observation made in the village centers was that other types of businesses such as barbershops also charged phones on the side of their hair cutting business. In several of these barber shops the attendants also claimed that even there phone charging contributed more to income than hair cutting. Furthermore, one of the barbershops had connected his solar system to his neighbor from which he got a daily extra income

Going back to the deeper rural areas another discovery was made when asking the local people where they charged their phones. Except for the believed obvious answer the local “duka” many of the locals also charged their phones at their neighbors and relatives who had small solar systems for domestic use. This was a frequently occurring phenomenon and a common sight in both investigated areas. All of the interviewed households that charged cell phones had the same story, explaining that they had obtained their system with intention for domestic use only such as powering radio, lamps and charging own phone. However, as they noticed that many people needed to charge their cell phones they started to ask for a small fee, providing them the service. Mutual to all the domestic users was that they only charged a couple a phones a day allowing them to save enough electricity to operate lamps and radios at night. This obviously meant that these “home entrepreneurs” did not make any huge business but as one respondent puts it: ”It gives me some small money to buy everyday stuff such as salt and soap.”

[2] Watt peak (Wp) is the amount of Watts a solar system can deliver when conditions are optimal.

Another rather surprising phone charging business was found at a governmental dispensary that was electrified by photovoltaic panels where a young entrepreneur offered to charge phones for a small fee. This was according to representatives from UNDP a common phenomenon at governmental institutions and telecommunication installations using solar systems within the rural areas.

The second most common type of businesses based on productive use of photovoltaics was the barber shop. The barber shops were only found in the district of Kayenze and as mentioned above mainly found in the village centers. In several cases they made more income on charging phones than cutting hair and one barber explained that this was mostly due to the fact that people don't cut their hair as often as they charge their cell phone. This means that hair cutting has a seasonal demand, for instance during festivities, whilst the phone charging demand stays constant regardless time of the year.

As mentioned previously a couple of the interviewed "dukas" could in addition to phone-charging provide other services such as cold beverages and TV-shows. However this required larger and more costly systems. The interviewed entrepreneurs that sold cold beverages expressed that they had not seen any significant increase in income due to beverage sales since their commission was such a small part of the total price. Thereby they didn't see any particular future in this type of productive use. The entrepreneurs that had TV-shows on the other hand, had seen more positive results and could obtain large incomes by charging cover fees. However, the services of TV-shows that mainly focused on football games had seasonal demands and peaked during major football events such as the Champions league and the World cup. In a meeting with representatives at UNDP, it was found that the TV-show business often showed movies with adult content during nighttime. This was according to UNDP, a very common and lucrative business but since pornography is prohibited by Tanzanian law this was nothing that would be discussed openly.

The last type of productive use found in the investigated areas was a household that besides charging a couple of phones a day also had a few extra rooms that served as a hostel for secondary school students. By electrifying these rooms, the students agreed to a 40% rent increase. Having extra rooms housing secondary school students is a common sight in the investigated areas due to the scarcity of secondary schools in the rural areas, although this was the only one encountered equipped with lights.

It is worth mentioning that in many cases the entrepreneurs businesses were built as an extension of their household so the electricity generated by the installed photovoltaic panels was used to different degrees in their households and their businesses. Common domestic uses where powering radio, lamps and in some cases also refrigerators and TVs.

5.1.3 Additional productive uses encountered in literature

In 2008 the UNDP conducted an assessment of the solar PVs contribution to their supported businesses in the Mwanza region in North West Tanzania [21]. Additional productive uses in the UNDP study that were not encountered in the performed case study:

- **Radio Cassette Vending**
  Where the power generated is utilized to sample radio cassettes to the costumers. With similarity to the barber shop prior to the installation of the system rechargeable batteries and sometimes diesel powered generators where utilized leading to significant operating costs.
- **Electronic Repair Workshops**
  Offers repartitions of various electronics such as radios, TVs etc. were the electricity is used to operate soldering equipment.

- **Milk Packaging**
  A solar PV system is used in a milk processing plant to run the machinery that packages milk in to plastic bags commonly used for distribution of milk.
- **Aquaculture**
  In some aquaculture farms mostly farming cat fish as bate for Nile Perch (a commonly desired food fish in the country, which is one of the main exports from the region) the system is used to power an aeration pump which is crucial for the growth of the fingerlings. When the cat fish fingerlings has grown it is transferred to a bigger pond from where it is later sold as bate.
- **Poultry Farming**
  Rather new way for breeding chickens in rural Africa where chickens are bread indoors and by using electricity powered lights allowing extended feeding times for the chicken thus also accelerating the poultry growth rate.

5.2 General findings

Data concerning procurement year, business type, type of communication channel, supplier, and size of solar systems are all presented in the following section (table 1). This data will later be used for calculations and assessments that will be presented within the chapter of results.

General data, Kibaha					
No.	**Year**	**Buissnes**	**How**	**Supplier**	**Size [Wp]**
1	2008	PU	P2P	A.E.Ltd	-
2	2010	Duka	P2P	A.E.Ltd	56
3	2005	Duka	P2P	BP solar	240
4	-	PU	-	-	-
5	2008	Home	P2P	Umeme Jua	?
6	2010	Duka	P2P	A.E.Ltd	170
7	2009	Duka	Radio	A.E.Ltd	28
8	2003	Home	Newspaper	-	-
9	2009	Home	Radio	-	50
10	2009	Duka	P2P	second hand	-
11	2008	Tele.shop	Techichan	-	80
12	2007	Home	P2P	Solar Planet	68
13	2004	Dispensary	-	Government	300
14	-	Home	P2P	Kariokoo	80
15	-	-	-	-	-
16	-	-	-	-	-
17	2007	Duka	P2P	Kariokoo	56

General data, Kayenze					
No.	**year**	**Buissnes**	**How**	**Supplier**	**Size[Wp]**
1	2006	Tele.shop	Radio	Second hand	-
2	2006	Tele.shop	Radio	AOL Tech	240
3	1999	Duka	P2P	BP solar	92
4	2006	Barber shop	Semminar	-	130
5	2008	Duka	Semminar	MMEE	48
6	2006	Duka	P2P	Zara Solar	28
7	2010	Tele.shop	Radio	-	30
8	2006	Duka	Radio	-	28
9	2010	Home	P2P	Zara Solar	12
10	2006	Barber shop	P2P	Mukesh	95
11	2006	Duka	Radio	-	14
12	2009	Duka	P2P	Mukesh	41
13	2007	Duka	Radio	Zara Solar	21
14	2009	Home	P2P	Mukesh	12
15	2007	Home	P2P	Mukesh	28
16	2007	Duka	P2P	Mukesh	28
17	2009	Duka	TV	Organization	14
18	2009	Barber shop	P2P	-	-
19	2009	Home	Radio	-	24
20	2010	Home	Radio	Mukesh	14

Table1. General data obtained by interviews in the two areas showing procurement year, type of business, communication channel, supplier and size of systems.

5.2.1 Previous energy source

Prior to the procurements of the solar systems most of the respondents (57%) answered that they did not conduct any type of business that involved electricity. If businesses at all existed, it often involved having a “duka” selling basic goods. The remaining 47% of the respondents had however an established business that utilized electricity productively, powered either by rechargeable batteries (often car batteries) or fuel generators run by diesel or petrol (see fig 8). The respondents that previously didn’t have electrified businesses all used paraffin powered lamps as their source of light. Furthermore, some of the previously electrified respondents had decided to keep their old rechargeable batteries and generators to use them as backup systems or in some cases as additional systems. This was particularly common among those using a generator since the effect of the solar system was in most cases less than the generator. Only three of the previous generator users had made a complete transition to photovoltaic.

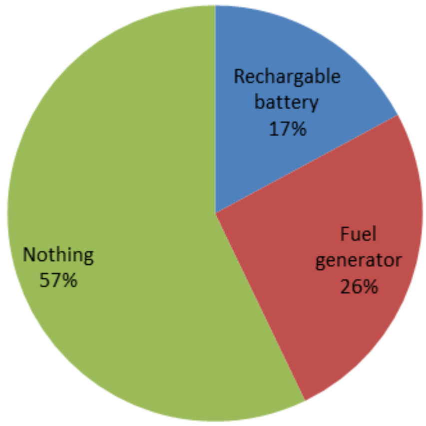


Figure 8. Diagram showing the energy sources previously used

5.2.2 Implications of rechargeable batteries and fuel generators

Although smaller effect than a fuel (diesel or petrol) generator most respondents claimed that a transition to photovoltaic systems had mostly positive implications on their lives. The entrepreneurs that previously used rechargeable batteries had to, every one to five days, travel to the nearest electrified town where the battery was charged during the night and brought back the day after. This was, according to the respondents, very time consuming and unreliable due to unpredictable transports and poor road condition. In addition, the charging also implied an additional travel cost which in some cases could supersede the recharging cost by a factor of four. Besides the bad roads, the reliability of the charging shops in the electrified towns could vary significantly depending on the capacity of the shop and the state of the national grid. In some cases it could take up to six days before being able to put the charged battery back in use. The generator users did not face similar problems of getting to town since the fuel in many cases could be obtained in the un-electrified villages. In addition, it was possible to obtain a great amount of fuel at each time, resulting in a reduced travel frequency. However, the fuel price is still high and a generator is generally very “thirsty”. The table below shows the prices of the different fuels and the monthly fuel costs of the non-solar entrepreneurs derived out of the interviews. It is here worth mentioning that on top of the fuel cost itself the travelling cost to the nearest electrified town in many cases lies around 2000-2500Tsh (1.48-1.85US$)[3] for a one way travel. This cost heavily increases the price for battery charging/fuel procurement as this trip had to be made between six to fifteen times each month.

Regarding old and used batteries they were often just thrown, lying around or given away after usage. It was only in a few cases the batteries were sold and “taken care of”. Taken care of in this case means that the person who bought the battery usually recycled the lead and some other components, to what degree the remaining parts of the battery are recycled is questionable. Known is that a used battery could generate up to 5000Tsh (3.7US$) when sold in second had.

[3] 1350Tsh =1US$ May 2010[35]

Fuel Type	Fuel cost [US$/L] or Recharge cost[US$]	Monthly fuel cost [US$]
Petrol	1.1-1.3	33-160
Battery	0.4-1.1	4-22
Paraffin*	0.74-0.89	7-11

*Note that the paraffin was only used for lighting.

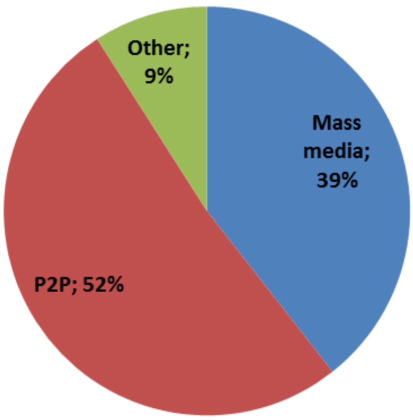
Table 2. Prices and average monthly costs for fuels from the interviews

5.2.3 Reasons for procurement

When asking why people use solar PV a majority of the respondents answered that it was because of low or no access to the national grid and that usage of solar PV is more economical compared to usage of generator. Other answers were that solar PVs are reliable and noiseless. Moreover, a couple of respondents pointed out the environmental advantages with usage of solar PV compared to other energy sources. Further, another reason for procurement was the copycat phenomenon, meaning that others observed the success of their neighbors and thus also procured a solar system, wanting a piece of the pie. This phenomenon was often seen in the village centers and resulted in increased competition and in some cases lowered revenues.

5.2.4 The communication channels

When asked how the entrepreneur had become aware of the photovoltaic technology, more than half of the respondents answered through friends, relatives and neighbors or in other words by peer-to-peer (P2P) discussions. Mass media was also a very common channel of communication since 39% of the respondents claimed to have first heard of the technology through this media (see fig 9). Here radio was naturally overrepresented since it is the only source of media that really has targeted, and is entrenched in the rural areas. In addition, there were a couple of respondents that got to know about the technology and its possible appliances trough seminars set by different organizations that promoted the use of alternative energy.



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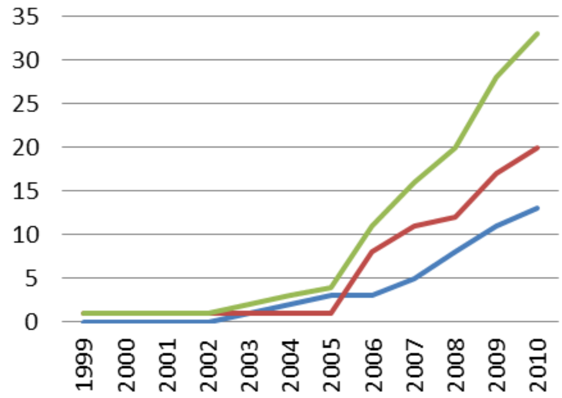
the entrepreneurs aware of photovoltaics

Here, it is important to stress that mentioned above are only the communication channels that created the awareness of the technology and its appliances. When it came to decision whether to procure the system or not, basically all of the respondents had turned to friends or other reliable persons seeking more information and advice.

5.2.5 Procurement year and suppliers

There is no doubt about that the photovoltaic technology is new within the two investigated areas, as all of the respondents had become aware of and procured their systems within the last decade, with emphasis on the last 4 years. Looking at graph 1 one can clearly see that it is in 2006 that the procurements of solar systems really took off, this is perceived to be a result of many factors for instance, the removal if import tax on alternative energy technologies and components. In addition, there has also been a growth in retailers within the same period with numerous of newly established companies selling solar PV. Another explanation for this hastily increases of solar systems may also lie in the fact that the national power company TANESCO faced a very troubling time this period which also resulted in a disbelief in the national grid which further enhanced the solar market. This establishment has enabled significant price drops on solar systems and an increase of demand. The retailers of solar PV cells from where the respondents had bought their systems were all (with one exception) based in the nearest major city. In the case of Kibaha it was Dar es Salaam 60 km away and in case of Kayenze it was Mwanza 70 km away. In both cities there is a great variety of retailers who provides several solar systems of different prices and quality. None of these retailers appeared to be dominant and it seemed as the respondents chose to buy their system on an arbitrary basis. The geographical distance between customer and retailer implied some difficulties regarding assistance and support if a problem occurred (if the supplier offered any support at all). In Kibaha however, the supplier Alternative Energy Ltd. was established in 2008 /2009 and many of the local respondents claimed that they have gotten support from this retailer regardless the origin of their PV-system.



Graph 1. Growth rate of productive users among respondents with amount of users on the X-axis

5.2.6 Installed capacities of the solar systems

The installed capacities of the solar systems utilized by the entrepreneurs ranged from 14Wp to 240Wp. To put these sizes in perspective a 14Wp system can under the right conditions power two light bulbs, a radio and charging a cellphone. While a 240Wp is enough to power a refrigerator, a small TV, 8 light bulbs and charging of a cell phone according to a retailer. Further it was common that after procuring the first solar panel a second and even third one were obtained as the first alone could not fulfill the demand of their services and appliances.

5.2.7 Perceived change of life after procurement of PV

Most of the respondents claimed that the procurement of the solar PV system has changed their way of living as it contributed to increased income and decreased time consuming energy related transportation. Even those who just charged three phones a day experienced a change in everyday life as this extra income allowed them to buy some additional basic goods. Others having larger monetary turnovers and greater revenues had even been able open a bank account and save some money. This was before the procurement of the Solar PV nearly impossible. Further, the procurement of the solar PV system has prevented people from moving their businesses from rural to urban areas due better conditions such as prolonged opening hours, increased energy reliability and less external fuel dependence.

5.2.8 Encountered problems

The majority of the interviewed respondents have not experienced any breakdowns or serious failures regarding their solar PV systems, although 51% of the users were complaining about capacity reduction in less sunny days and during nights. Among the respondents that had faced breakdowns following causations were noticed:

- Inverter breakdowns
- Burnt cables due to wrong ones used
- Usage of diodes instead of charge controller
- Exploding batteries
- Faulty installations with missing parts
- Wrongly mounted panels
- Short circuits
- Problem with power switches
- Overall decreased capacity

Except for these failures, there were a couple of cases where a heavily reduction in capacity was noticed. This reduction was probably due to purchase of fake products or misuse of the batteries. The misuse was often connected to deep cycling and overcharging of batteries resulting in a frequent need to add water/acid and a severely shortening of life length. This seemed to be a direct consequence of lack or misuse of the charge controller[4] since the entrepreneurs that were missing this had to replace the battery and refill the water much more often than those who used a charge controller.

5.2.9 Future development

Regarding future business development the entrepreneurs had several plans and ideas for expansion. These plans and ideas concerned development of existing businesses and further set ups of new ones. Example on such new businesses ideas were freezers for storage of meat/fish, and mining where drills are powered by solar. Most respondents express their will to expand their business with a fridge for selling cold beverages or a TV for showing football games. Even if many plans will stay being wishes, there were some respondents that were about to actualize their plans and already had invested in more powerful panels.

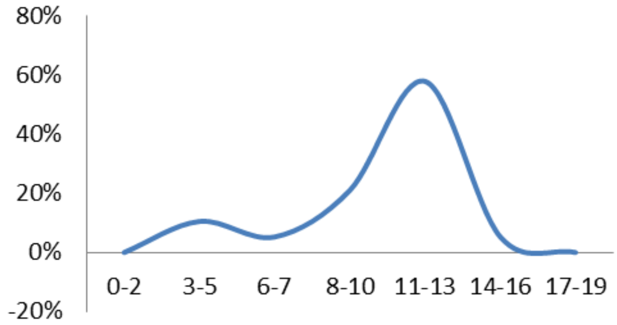
5.3 Financial

This section will handle the economic aspects of the productive use of solar cells, which were encountered throughout the study such as investment costs, incomes and rates of return. It is worth mentioning again that the data collected from interviews was in many cases unreliable as many of the respondents lacked documentation of economics involved. In order to elude this problem, average values of all collected data have been used. Therefore graphs and data which are presented should rather be seen as approximate values than exact calculations.

[4] A Charge Controller is a component that hinders overcharging and deep cycling the batteries and shows the charge level of the batteries.

5.3.1 Prices of solar systems

According to the respondents they had paid between 100,000Tsh and 4,000,000Tsh for their systems which included solar panels, wires, batteries, inverters, charge controller and in some cases also installation. With the current exchange rate (2010 1US$= 1350Tsh) this would mean that the system prices ranged between 74 and 2963US$. Looking at the price per Watt peak, the prices varied from 3 to 16US$ with an average price of approximately 11-13US$ (see graph 2). This result is in line with several other studies conducted and thus confirmed in this study. The variation in price depended a lot on system size, panel type, quality, choice of retailer and accompanied components. The really low prices (3-5US$/Wp) seen in graph 2 are a result of second hand purchases of solar systems.



Graph 2. The prices paid per Wp of installed capacity with percentages of respondents on the Y-axis and price intervals on the X-axis in USD

5.3.2 Running cost of a solar system

Despite many arguments stating that there are no running costs for a solar system, it was possible to distinguish an expense that could be categorized as a running cost. The change of battery was a cost that could be placed in this category. These changes occurred, according to the respondents, on a basis of every three months to two years, depending on battery type and battery treatment. In some cases frequent changes of battery implied a significant periodic cost. The table below (table 3) presents the cost of different battery sizes and their monthly cost depending on the rate of battery change. One can clearly see that the changes can become a significant periodic cost. Other failures encountered such as burnt cables, broken invertors etc, could happen and would obviously imply repair cost and a cost for a new component. But as these failures happen sporadically they cannot be regarded as a running cost.

Battery 100Ah	**Change rate**	**Monthly cost**	**Battery 75Ah**	**Change rate**	**Monthly cost**
US$ 133,3	3 months	44,4	US$ 111,1	3 months	37,0
	6 months	22,2		6 months	18,5
	One year	11,1		One year	9,3
	2 year	5,6		2 year	4,6
	3 year	3,7		3 year	3,1
	4 year	2,8		4 year	2,3
Battery 55Ah	**Change rate**	**Monthly cost**	**Battery 40Ah**	**Change rate**	**Monthly cost**
US$ 88,9	3 months	29,6	US$ 66,7	3 months	22,2
	6 months	14,8		6 months	11,1
	One year	7,4		One year	5,6
	2 year	3,7		2 year	2,8
	3 year	2,5		3 year	1,9
	4 year	1,9		4 year	1,4

Table 3. Monthly cost of batteries depending on the battery change rate.

5.3.3 Revenues

Another observation made was that the incomes generated through the productive use varied a lot depending on size of system and type of business (table 4). The “dukas” that solely charged phones with solar cells having a capacity below 100Wp (usually 14-50Wp), had sales of phone charging services varying from 10-30 telephones a day at a price of 200-400Tsh (0.15-0.3US$) per charge generating a monthly income of 60000-360000Tsh (~44-266 US$). The “dukas” that had larger systems (100Wp and above) could serve up to 80 phone chargers a day and in several cases they also offered other services besides such as TV-shows and cold beverages. The teleshops that focused on mobile services, had sales of phone charging services between 30 and 150 charges a day at a price of 300Tsh per charge which led to monthly incomes of 270000-1350000Tsh (~233-1044US$). The households that was equipped with an installed capacity of 12-50Wp, providing phone charging services, were all strikingly similar to each other. Usually they charged 3-15 phones a day at a price of 300Tsh per charge, which generated 27000-45000Tsh (~20-100US$) a month. A couple of households however had larger systems (up to 68Wp)and could offer up to 50 phone charges a day giving them up until 450000Tsh (~333UD$) of extra income each month.

Business type	Customers a day	Income per provided service [US$]	Monthly income [US$]
Phone Charging			
Duka (14-50Wp)	10-30	0.15-0.3	44-267
Duka (100Wp+)	-80	0.22	-533
Telehops	30-150	0.22-0.3	233-1044
Homes (12-50Wp)	3-15	0.22	20-100
Homes (50WP+)	-50	0.22	-333
Barbershops	5-20	0.37	56-222
TV-shows	-46	0.3	-408
Cold beverages	-	-	--
Hostel	4	1,48	6

Table 4 Encountered incomes from productive uses

Regarding the barber shops, they had an amount of customers spanning from 5-20 persons a day. Each of these customers paid 500Tsh (~0.37US$) per haircut which resulted in a monthly income of 90000-300000Tsh (~56-222US$). Common to all barber shops was that they had rather big systems, ranging from 95-135Wp.The usage of large system was letting many of users charging cellphones by the side of the hair cutting business and thus earn some extra money. In addition, the barber shop that had a solar system connected to its neighbor had an additional daily income of 2500Tsh (~1,86US$).

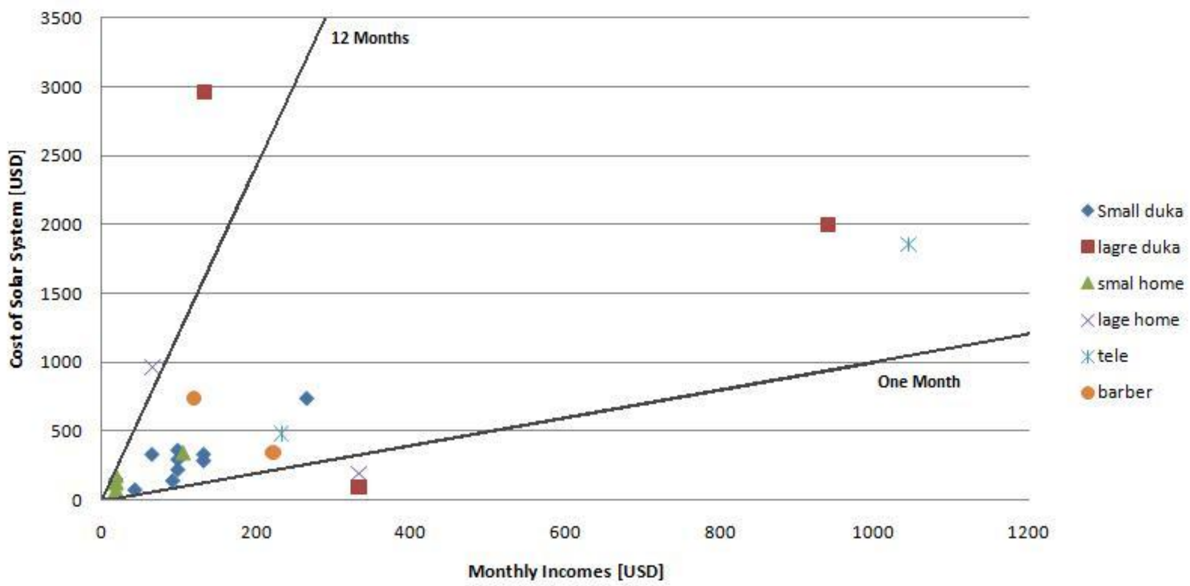
The “dukas” that successfully conducted TV shows (mostly football games) had up to 80 paying customers per show, four times a week, which led to a daily average of 45 customers. With a cover fee of 400Tsh (~0,3US$) per show this would result in an income of 32000TSH (~24US$) per show or 128000Tsh (~408US$) per month. However, there is a seasonal change in this figure since the incomes varies with the football events.

At the secondary school hostel encountered, the tenants had agreed to a rent increase from 5000Tsh (~3.7US$) to 7000Tsh (~5.2US$) a month if lights were installed. With 4 rooms available this would mean 8000TSh (~6US$) of increased income, each month.

The entrepreneur selling cold sodas could not see any difference in soda sales now compared to prior the procurement of a refrigerator. She also claimed that the commission earned per soda was so small that it did not lead to any significant increase in income.

5.3.4 Payback times and rates of return

Regarding the payback time of the investments made in solar PVs, most of the business respondents claimed that they believed they would get their invested money back in a period of three months to one year. When looking at the figures derived out of collected data, this reasoning seems to be rather trustworthy as the yearly income of the businesses ranges from 520US$ and 12116US$ and the prices from 76US$ to 3963US$. This holds even for the households that only charged a couple of phones each day and had yearly incomes of 260-416US$ since the investment costs ranged from 76-341US$. The graph (graph 3) presented below shows a simplified view of the correlation between costs and monthly incomes derived from the interviews. Assumptions made when creating the graph was that running costs are negligible and that the amount of costumers have been constant since the start of solar PV usage.



Graph 3. Graph showing the correlation between the investment cost and monthly revenues for the different types of productive users. The area flanked by the lines corresponds to a payback time between one and twelve months.

As seen in graph 3 the correlation between income and cost of solar system is rather linear with exception for a few extreme points. This linearity implies that rate of return regardless type of businesses is reasonably similar. Moreover, the extreme points can be explained by the low degree of productive use, i.e. how much of the installed capacity that is used for income generating activities. The term degree of productive use is introduced here since many of the entrepreneurs used the solar systems for both domestic and business purposes as the businesses often were connected to, or laid in close proximity to the household. For instance one entrepreneur who had a high investment cost used most of the electricity to power the domestic refrigerator, only making productive income from phone charging. Thus, the correlation between investment and income time will differ significantly from a case were the entrepreneur solely uses the electricity generated for business. Another reason for the existing extreme points is the very low costs which a couple of the entrepreneurs had paid for their systems since they were bought in second hand.

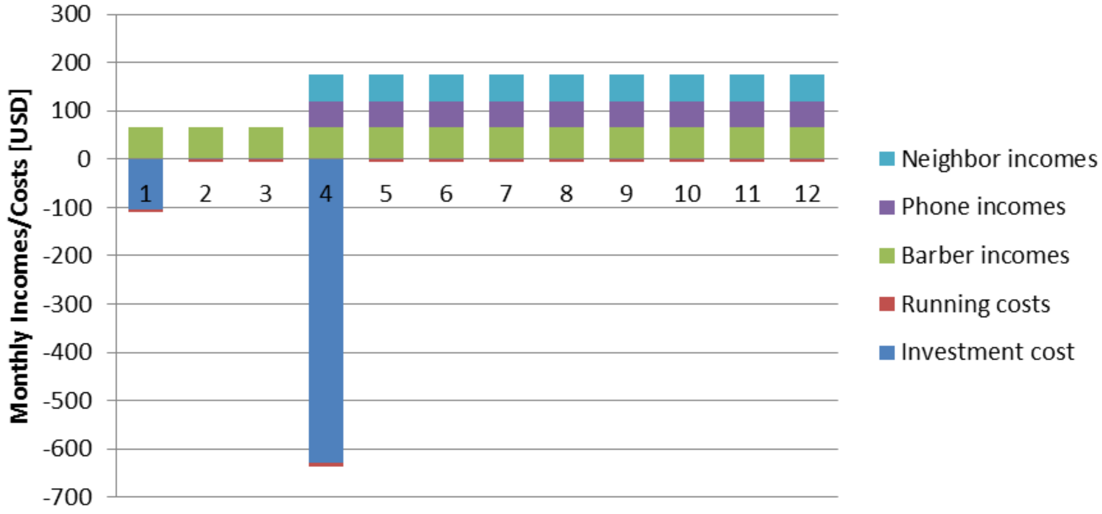
By eliminating the extreme points, one gets a corrected average payback time between 1.5-9 months and a monthly average rate of return between 11-36%. However, this is a rough description of the reality; it was for instance not uncommon that an entrepreneur had more than one type of provided service that was powered by the solar system. In reality also many of the respondents had purchased an additional panel after a few months or years to be able to increase their output of services. Anyhow this calculations and graph gives a statement of the overall payback time and rate of return.

5.3.5 Examples of internal economical dynamics.

To get a clearer picture of the dynamics and payback times of particular businesses some examples are presented below which also includes an estimated running cost which was calculated previously.

Example 1 Barbershop in the village center of Kayenze (Appendix IV)

In this case the barber shop had started out with one 28Wp system to which the entrepreneur added an additional 100Wp after 3 months. Prior to the procurement of the second panel the entrepreneur solely focused on hair cutting with an occasional phone charging service depending on demand for haircuts. After the expansion with the larger panel he didn't experience any increase in demand for haircuts, however he was able to charge phones on a more regular basis (10 a day) and also sell some of his excess electricity to a neighbor at a price of 2500Tsh (1.85US$) a day. He used to change his batteries roughly every second year at a cost of 180000Tsh (133US$). This cost is shown in red in the table below but can almost be seen as negligible when averaged over two years since it is really small compared to the other incomes/costs.

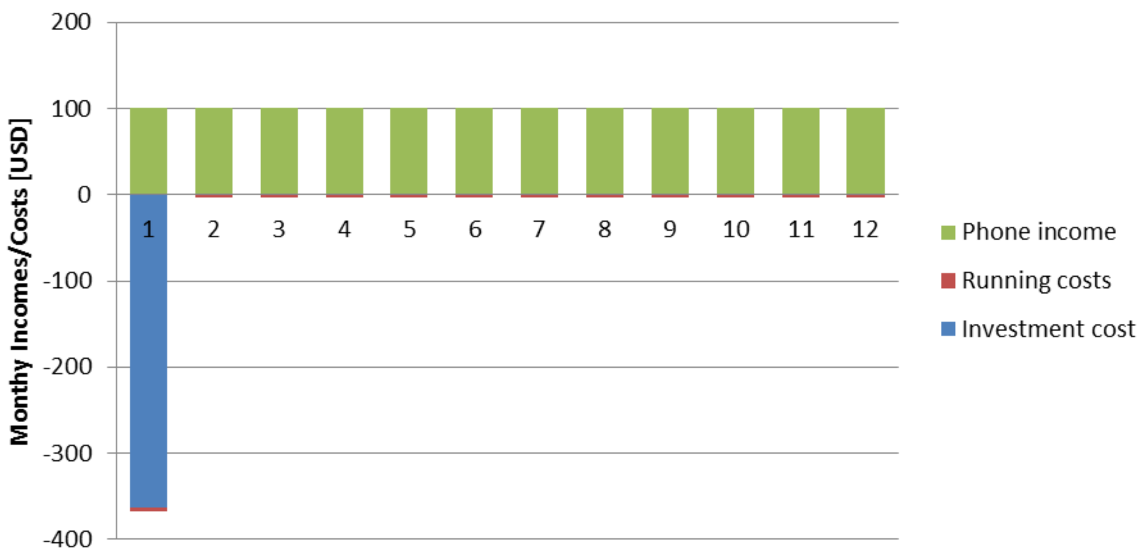


Graph 4 . The investments cost and incomes during the first 12 months of photovoltaic use in USD at a barber shop in Kayenze.

In graph 4, one can clearly see that the first system was fully paid back in only two months, whilst the second panel and its components had a payback period of 3.6 months and had a monthly rate of return of 28%.

Example 2 Duka in Kidumu village outside of Kibaha providing phone charging services (Appendix V)

In this case the system was rather small (28Wp) and was located in a really deep rural area. The solar system was solely used for charging phones (15 a day) with the exception for one light bulb. The system was rather new and procured in December 2009 so no maintenance or battery change had been conducted. However, to get a realistic scenario a change of battery is included with the assumption that it will be changed after two years by a cost of 120000Tsh (89US$) averaged over two years.

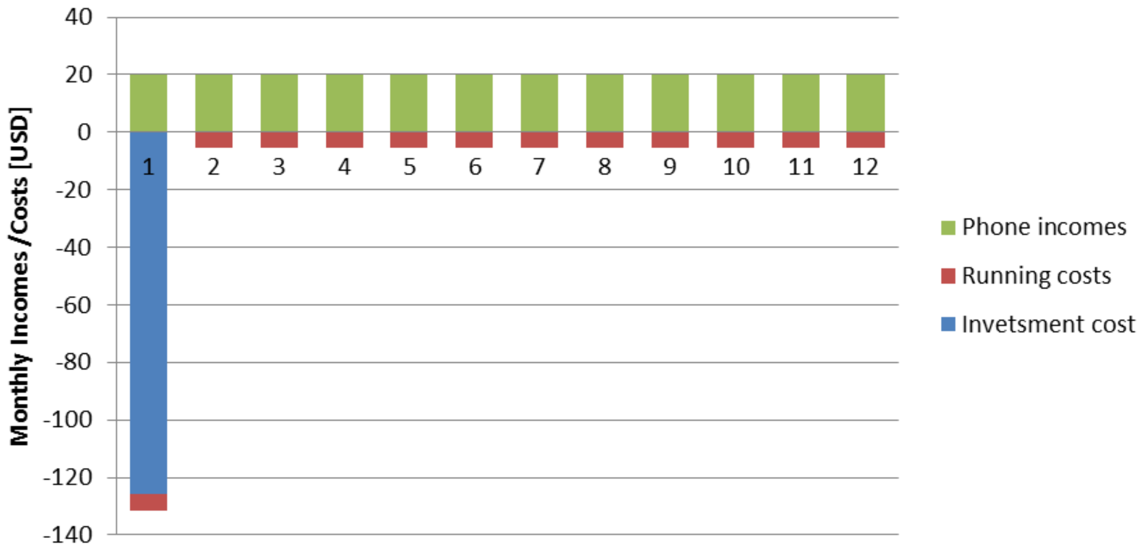


Graph 5. investment costs, running costs and incomes for a small "duka" in Kibesa village using a solar system solely for charging phones

Graph 5 shows the payback time which for this example was 3.8 months with a monthly rate of return of 27 %.

Example 3. A farmer having a home system in Shirigwa outside of Kayenze (Appendix VI)

This example can be described as a worst case scenario with a small degree of productive use of the solar system as its main purpose was to power domestic appliances such as radio and lamps. However the farmer decided to charge 3 phones a day giving him some extra income. The battery was changed on a yearly basis.



Graph 6. Investment costs, running cost and incomes for a farmer providing a modest phone charging service in Siringwa village outside Kayenze.

Even though the entrepreneur had a modest business the payback time in this example is 8.7 months with a monthly rate of return of 11%.

6 Analysis and Discussion

The aim of the discussion is to analyze the results with the questions that were earlier in mind using the theoretical framework as a base:

- What types of business has emerged in the rural areas, to what extent, and what does the business specific features look like?
- What does the prerequisites and evolvement of solar PVs for productive use look like?
- How can productive use contribute to sustainable development and are the solar PVs a future energy source for productive use?

The discussion will start by discussing the findings regarding existing conditions of encountered businesses and their specific features. Moreover the prerequisites and evolvement will be outlined by the four elements that are presented in the diffusion of innovation model, which could be found in the theoretical framework section. This will also constitute the base for making predictions of future prospects regarding productive use of Solar PVs. Further, the encountered types of productive use will be discussed with regard to external and internal (direct and indirect) productive use. In the end of the section there will also be a discussion from a sustainable development perspective based on the analyzed results.

6.1 Encountered rural businesses using solar PVs

This section will discuss the businesses that were encountered out in the two rural areas, with respect to sector specific features and advantages/drawbacks, trying to answer what the prerequisites and evolvement of solar PVs for productive use look like? It will also touch upon observed business trends.

6.1.1 Phone charging

As seen in the results the most common type of business is the phone charging as nearly all encountered businesses did charge phones regardless original business , which is quite understandable since it bear some features that are appropriate for business in rural parts of Tanzania. Firstly, it holds the quality of low investment costs, which is a necessity since the purchasing power often can be regarded as low. The only thing needed after procurement of the Solar PV system is cell phone chargers or other analog equipment, which often can be purchased to a minor expense. Secondly, the provider of the service does not need any education or skills to pursue the business. Thirdly, there is an immense demand for charging cell phones, as roughly 50% of the population in the rural areas has access to a cell phone but only 6 % (2% in rural areas) are connected to the grid. Fourthly, this business generates pure income without any need for commission charges. Lastly, this service requires very small amounts of electricity which is desirable since the power supply from the solar PVs often is limited by small system sizes.

It is clear that there are a lot of people making decent incomes out of using solar PVs for charging cell phones. In some places the entrepreneur had experienced insufficiency in capacity as the demand was simply too high to handle for one single business owner. Since it takes about 2-3 hours to charge a cell phone and an average solar PV system could handle about 8 phones at once, the supply of the service becomes very limited due to not enough capacity. Of course it is possible to overcome such problems with a more powerful system which holds a higher capacity, but as always it is a matter of costs. However, if disregarding the fact that solar PVs are expensive, there could be a heavily extension of this type of businesses in some areas.

As more and more people have seen the opportunity to make some extra money, many of the businessmen have noticed a reduction in income in the last couple of months. This might be an emerging problem and it is primarily caused by increased competition. The competition is caused partly by households charging phones and partly by so called “copycats”. This “copycat” phenomenon where people simply duplicates the neighboring business could make up a threat towards future diffusion of productive use of solar PV since the competition about the customers is growing and it will be difficult to reach a decent profitability. Both the copycats and the increases in domestic phone chargers might contribute to drops in demand for phone charging services and will in the long run lead to less profitability. A deceased profitability will however not imply that this type of business will not survive as the revenues from this service are pure income.

So why is the phone charging business so dominating? By August 2000, Vodacom Tanzania started to operate a GSM cellular network and provided Tanzania with Public Land Mobile Network Services. In September 2005 the government of Tanzania introduced a converged licensing framework which enhanced the provision of communication services within the country by making the telecommunication technology neutral which facilitated entrance for new actors on the market. Ever since the introduction of cell phones into Tanzania there has steadily been a yearly increase in cell phone users and as the situation is today there are about 19.5 million voice telecom subscriptions in Tanzania (the population in Tanzania amounts to 43 millions). Today about 75 percent of Tanzania has mobile network coverage. This implies an immense demand for phone charging and is the reason for the success of the phone charging business [36].

Overall the situation regarding phone charging services will sooner or later reach an equilibrium suited to the market and the sometimes high profits that currently are being seen will probably decrease to a more moderate levels.

6.1.2 Barber shop

Why the number of barbershops is comparably low to the number of businesses charging cell phones is probably due to less revenue that can be acquired out of cutting hair. This is most likely due to the seasonal demand. The barber shops possess about the same features as the phone charging business although there are some significant differences. In a pure barbershop usually the amount of costumers sets the limit for how much income they can generate while in the phone charging business in many cases the capacity of the systems sets the limits. In addition, it is often required by the barber to have some kind of artistic skills regarding haircutting in order to get loyal customers.

The reason why there were several barber shops in the district of Kayenze but none in Kibaha is somehow hard to tell. One factor that might have contributed to this is the solar PV campaigns conducted by the MEM and other organizations within the regions close to Mwanza. Another factor that could have an influence is the complete absence of national grid in Kayenze. The absence forces people to use a hair cutting machine powered by solar PVs, rechargeable batteries or a generator, where the first option should be regarded as the better one, according to the results as it doesn’t require travels nor running costs. In the region of Kibaha on the other hand, there is always a closeness to larger villages that has a grid connection. This fact might have an influence on people’s haircutting behavior as it is easy to visit a barber shop when going to the nearest electrified village. Altogether, the expense to buy a solar system in combination with a lot of barber shops in a not too far distance simply makes it unprofitable to start such a business.

Barber shops are absolutely a good candidate for productive use of solar PVs; however the nature of this business will imply that it will never grow to the same numbers of productive users such as phone chargers.

6.1.3 TV-shows, cold beverages and hostel

Regarding the business with TV shows there is big money to make, especially on showing football games as there is a widespread interest that affects many almost to a religious proportion. However, a business based on showing TV is rather energy consuming and demands a powerful system in order to function properly. This together with an extra investments cost for a television set results in a situation which demands a rather stable economy from to begin with. Same cost issues holds for businesses that are based on selling cold beverages. Firstly, the procurement cost of a refrigerator is rather high, and secondly it is in comparison with e.g. phone charging, more energy demanding and requires a powerful system. Furthermore, the commission from selling beverages is quite low and it will take a very long time to get the invested money back. It is hard to see any particular future for the beverage business alone. However, if there is someone having a powerful system with excess energy it could be a good complement to the ordinary business in order to attract more customers such as a combination of showing football games and serving cold beverages.

The idea of renting out rooms to students equipped with light is a good example of the contemporary view of productive use. Except for generating money to the host it also gives additional value in terms of providing knowledge to the students, which in turn will contribute to increased awareness and knowledge throughout the society. This is exactly what one want to achieve with productive use, a strengthen economy on the local plane and at the same time a contribution to a long term sustainable society. From a purely economic view this type of business might show quite modest extra incomes, a mere 6USD a month in a four room hostel. However, the only thing needed to conduct this productive usage is a couple light bulbs resulting in a payback period of approximately one year.

6.1.4 Business trends

Except for the phone charging related trends such as the copycat phenomenon and the domestic charging it is possible to distinguish a general trend towards fusion of different businesses. An entrepreneur starting with one type of business, will often little by little, combine this with other businesses. Whether this phenomenon is good or bad can be discussed, on one hand it leads to accommodation of more services which at the moment might generate more income, whereas it on the other hand leads to similarity of the shops. This similarity might affect the results in a long term perspective since there won't be any differentiation. It could be discussed to what extent it is possible to diversify on such simple and noncomplex services that are found in this area. The general message however, is that diversification is associated with inferior performance on average [37]. This implies that replication and multi business activities probably should be avoided, and specialization to one business type should be encouraged.

6.2 Prerequisites and evolvement of solar PVs for productive use

In this section the prospects for productive use of solar PVs for further diffusion will be discussed and analyzed. Firstly, the properties of the innovation itself will be analyzed and investigated, based on the findings of the present situation. These findings will be used to understand perceived attributes of solar PVs for productive use from an entrepreneurial perspective. This is done in order to clarify the acceptance of productive use of solar PVs within the social structure of the rural society and will be discussed on both a local and national levels. Finally, the communication channels and the time element will be discussed; aiming to evaluate the time it takes from knowledge about the innovation to procurement of the innovation and to find out if appropriate communication channels are used.

6.2.1 The innovation itself

In this section the properties of the innovation itself will be analyzed and investigated with regard to relative advantage, complexity, compatibility, trialability, and observability in order to understand the perceived attributes of solar PVs for productive use from an entrepreneurial perspective and.

Relative advantage

A sustainable business (no matter if it is poultry farming or phone charging) with a decent rate of return is a necessity and one cornerstone in a successful diffusion of solar PVs for productive use. Without any profitability these types of activities would be less desirable and lose its future prospects. From interviews made it was pretty clear that individuals perceived the usage of solar PVs for productive use as beneficial in both economic and social terms. Those who previously used a generator as source of electricity stated that they were saving a lot of money by using solar PVs instead. This statement is also confirmed by our calculations, made out of collected data, where some businesses lowers their operating costs by 96% by making a transition from generator to solar energy. Others, who did not run any business before starting with solar, are also united in their opinion, solar PVs are good for running business and that the investment pays back in a reasonable time. These statements are further confirmed by the compilation of data. In addition, other relative advantages that were hard to quantify, have been observed. Examples on such advantages are people using solar PVs for business often experienced raises in social status, i.e. people is often asking them for advice.

Complexity

To run a business based on solar PVs should out of the observed results be regarded as simple since there are low levels of additional knowledge needed in order to operate a business. Although, the installation of the system requires some technical skills, there is no need for the user to master them as they are assigned to the technician. The only concern the user has to keep in mind is the maximum load that can be put on the system in relation to its capacity. And when talking to the users the majority of the respondents agree on the fact that it is easy to handle the system, although there are some complaints regarding the information about the capacity of system. This is a point where the distributors of the systems have to improve in order to reach more success in diffusion. If not improved, the customers can perceive dissatisfaction which can result in bad reputation and increased resistance towards solar PVs and thus productive use of solar PVs.

Compatibility

The compatibility concerns how well the innovation, i.e. the solar PV for productive use, fits into the values and social norms within the social system. Since Tanzania during the recent years has experienced a big change in particular cell phone usage but also other electronic equipment such as usage of laptops and TV, a change in the demand and social norms has occurred. This change towards a more electronic intense society with new lifestyles is probably just in the beginning and will peak first in many years. The change in lifestyle based on electronic equipment has resulted in a demand for electricity that was non-existing only a decade ago. This demand will probably grow even bigger in the future as the population gradually changes along with the generation shift. In several studies it is shown that elderly people often are more passive to changes compared to youngsters who often are more open-minded and tolerant when it comes to changes. When this young generation gets older they will probably regard this, with a rural perspective, new equipment as trivial. With the abovementioned situation in mind it seems like the solar PVs actually can be expected to fit into the social system that is developing. From the results it looks like the acceptance of solar PV already has begun and is steadily increasing. In 2006 the solar PV market experienced a kind of breakthrough (due to a number of reasons that will be discussed later) and has continuously grown since then.

Trialability

The concept of trialability means the degree to which an innovation can be experimented with on a limited basis. Since the solar panel itself is a rather advanced component there is not much room for experimentation on the panel itself, however homemade modifications on the system have often results in breakage or reduction in capacity. Several examples of the unsuccessful "modifications" were encountered out in the field. An example of this was that people had removed or bypassed the charge controller, a device that is used for avoidance of deep cycling and overcharging of the battery. This was made in order to temporarily achieve more capacity out of the system. The faulty usage of the equipment significantly reduces the life length of the battery and the capacity increase will only last for a limited amount of time, spanning from a week up to a couple of month. In the end, the misuse and unsustainable use of the solar PV system is leading to unnecessary changes of batteries with costs and environmental tearing as a result. However, despite the encountered fruitless modifications, solar PV can be regarded as relatively user friendly since the expensive components as the panels will not be affected of technical misuse.

As concluded there is not much possibility for trialability of the solar PV technology, but if disregarding the technology itself and instead look at productive use of solar PVs, there are a plenty of room for experimentation. It is only the resourcefulness together with the capacity of the system that sets the limit for what kind of business that can be run. In the study five different types of businesses was found (and several others in literature) within the case study and there is a lot more applications for productive use of solar PV to be discovered.

Observability

In order to reach a more successful and faster diffusion the benefits and positive results has to be visible to others that still not have adopted the innovation. This occurs as discussions are raised between friends, neighbors and relatives about solar PVs and its observed outcomes. If these outcomes are positive, the will to adopt solar PV for productive use will probably increase. Based on the results from the interviews it is hard to tell how visible the results out of the productive use were to others not using solar PVs. But as many of the respondents was pretty successful regarding profit, there should be peer to peer discussions about their success. For example, some of the interviewed businessmen had bought laptops and decoders which both are denoted as extraordinary items out in the rural parts of Tanzania. This type of visible life style changes will probably constitute target for discussion since this type of items often are seen as unreachable among the ordinary citizen.

6.2.2 Social structures

This section resembles the earlier compatibility section but will discuss how the Tanzanian society from a local and national level can have an effect the on the diffusion of productive use of solar PV.

On a family level the decision often lay in the hand of the head of the family (usually the male) and depending on his values and opinions, there will be a change or not. Thus, the decision made on a family level is largely affected by the how the man in the family perceives the innovation. If he is an early adopter he will probably adopt the innovation but if he is more of a laggard, he might be more reluctant. Consequently, the diffusion of the technology, in this case the solar PV, depends on the willingness of the family father to reconstruct old patterns.

On a regional level there have lately been several organizations that have implemented different programs aiming to increase the awareness of solar energy among inhabitants out in the rural areas of

Tanzania. These programs have been especially intense in the areas of Mwanza in northwestern Tanzania and have mainly been financed by UNDP but also by SIDA and MEM. In addition, other organizations have been active in the awareness campaigns, namely TaTEDO and TAREA, which are national NGOs. These organizations have together worked with not only information directly to people but also lobbying towards governmental departments in order to achieve a bureaucracy change that facilitates the implementation of not only solar PV technology but also other renewable energy resources.

This lobbying reached success on national level in 2006 when there was a removal of VAT (value added tax), which is 20% tax that is imposed on scheduled imports into the mainland of Tanzania. This removal was probably a strongly contributing factor regarding the big increase in procurement of solar PVs which, due to our findings, occurred in 2006. It would perhaps be faulty to ascribe this "takeoff" to the removal of the VAT alone, but it is likely to believe that this change served as catalyst that initiated a chain of events that co-operated and complemented each other. Firstly, as mentioned, there was a removal of VAT which facilitated the import of solar PVs to Tanzania. This removal created conditions that made it profitable for distributors to import solar PVs since it now was possible to lower the price for potential buyers. In particular, the price had for a long time been a limiting factor and seen as a major barrier for further diffusion because of the low purchasing power. In addition, it was in 2006 TANESCO had some struggling years and dissatisfaction started to spread among the citizens. This fact should have forced people, who were hoping for an expansion of the national grid, to buy solar PVs since this became the only option for electricity. Moreover, 2006 was the year when many solar companies started their businesses which makes it reasonable to assume an increase in advertising that resulted in increased awareness and also procurement of solar PVs. The establishment of new companies should also have brought about a change in business climate with more competition and lowered prices as a result. It can of course be discussed to what extent this competition is benefitting the locals out in the rural areas since they often are very limited both in their information search and their ability to translocate themselves, but should still be regarded as a movement in the right direction.

Further, the extremely low access the national grid should make the societal system on a national level very open for alternative energy sources such as solar PVs and others. Further this implies that if business continuous as usual there is a great need for alternative energy sources for development of the country.

6.2.3 Communication channels

The spoken word seems to be a strongly contributing factor when it comes to both awareness and final decision about the solar PV system. The second most common way of getting to know about Solar PV is through radio commercials and the third most common way is through seminars about Solar PVs. It is maybe not that strange to find out that it actually is the spoken word that is the most usual way of getting aware of the solar PV and its possibilities for productive use. Out in the deeper rural areas the literacy is not fully developed and the usage of Radio is limited but existing, whereas the TV is practically none existing. It is simply the contact with friends, neighbors and relatives that stands for most of the communicated information. Regarding the final decision, peer to peer discussions was the absolute mean when convincing whether to adopt or reject the solar PV system. In addition, it is probably in human nature to seek advice and guidance from someone that is known and trusted rather than believe commercial messengers when facing an important decision .

At present there are a lot of advertising going on in the urban areas such as Dar es Salaam and Mwanza and big placards promoting Solar PVs is to be seen along the roads. The problem is that advertising like this probably not reaches the targeted audience directly. Thereby, one should not say that this advertising is a waste of time and money, it surely contributes to increase both awareness and acceptance and to build up a solid base for Solar PV technology in a long term perspective as it encourages peer to peer discussions.

Moreover, NGOs for example TaTEDO are trying to get access to public broadcasting for advertising. This might be a good idea since a lot of people are reached, but once again, maybe not the most urgent group in the rural areas. This can be seen by the results of the case study where only a minor part of the respondents claimed that they got to know about solar PVs through TV- commercials. The reason for this is that people in the rural areas simply cannot afford a TV and have a limited electricity access. However, there are a large number of inhabitants in the urban areas that have close connections with the rural population since many have friends and relatives there. TV-commercials should instead therefore indirect target the rural population. TV commercials directed to the rural population is as mentioned rather pointless, however other sources of media such as radio which is more extensively used in the rural areas may be more appropriate for direct commercials. Another idea could be distribution of easily understood flyers with minimum text. Even better would be if the flyers contained involvement of an famous football player since the football seems to be deeply seated into the social life of the Tanzanian inhabitants and the football players seems to be very influential. By using a famous person one is taking advantage of this person's fame and popularity to associate Solar PV with something good and can hopefully gain acceptance and awareness as there is a feeling of affinity. This affinity may resemble peer to peer discussions to a higher degree than normal mass media and will probably lead to discussions.

Further, there are NGOs such as TaTEDO who are promoting the usage of solar PV systems by putting up workshops in rural villages. How helpful these activities are can be discussed since the outcome of the case study showed that only a couple of the respondents had gained awareness through this medium. As the case study only covered two areas it is difficult to say something about the effectiveness of these efforts.

6.2.4. Time

This element is investigated in order to see there are any bottlenecks that are hindering the rate of adoption which is crucial in order to reach a desirable diffusion.

Regarding rate of adoption, the most significant bottleneck encountered in the case study has an economic nature in form of an investment cost. This cost clearly affects the decision making process thus delaying the rate of adoption. At first this cost it will negatively impact the time the persuasion step requires(see fig10) as potential entrepreneurs needs to be convinced weather the investment in a solar system is of interest or not. Subsequently it will impact the time period in the decision step requires as the entrepreneur needs to obtain the money needed. By widening this bottleneck the decision process time would be shortened resulting in a faster rate of adoption. An example of this can be seen in the Tanzanian solar market where an expansion of the bottleneck in form of the previously mentioned VAT removal. This removal played an important role in the increased rate of adoption of solar systems. This is further backed by findings in the case study when looking at the procurement years of productive users as there is clearly a significant increase of adoption after 2006 when the VAT was removed. Another significant drop in solar system prices would therefore most probably also lead to a significant increase in the rate of adoption of productive users. However, how this should be solved is although uncertain, but one suggestion that has been mentioned is to in house the production of solar PV systems thus decreasing the need for import. This would probably lower the prices significantly but such a project is very complex and is probably not seen in a pending future.

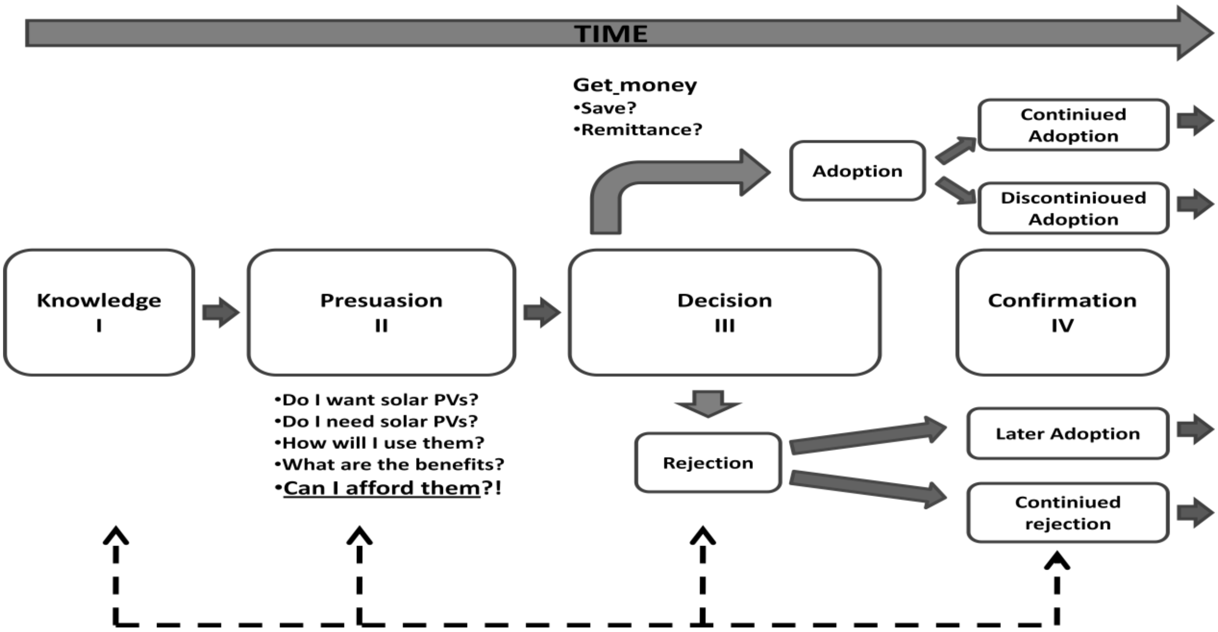


Figure 10. Showing the process of making a procurement decision

Further, the communication channels can also play an important role within the decision making process stimulating a shortening of the transition time between the steps which are seen in the model. This shortening of time can be a result of the abilities of the communication channels to enlighten benefits, providing aid and removing uncertainties etc. As the case study shows it is in particular peer-to-peer discussions that play the key role in persuasion to adopt technology to potential solar entrepreneurs, the effectiveness of this medium should have a significant part in shortening the decision making time.

With the above mentioned in mind this further strengthens the interest to enlighten the economic benefits of productive use of solar PVs in mass media targeting people that has direct or indirect connection with the rural areas, thus stimulating peer-to-peer discussions as well as broadening the economical bottleneck.

6.2.5 Productive use of solar PVs

It is clearly seen that productive use of solar PVs is a rather new but upcoming idea within the two investigated areas. Moreover, it was possible to see that the more or less established productive users that were encountered were focusing their businesses on the internal local markets i.e. providing services to local customers creating income and/or values to stakeholders within the local community. Encountered productive users such as phone chargers, barbers, cold beverage vendors and TV-show hosts will all be categorized as direct internal productive users. These productive uses have shown to be of great profitability for the entrepreneurs in question and according to them it has significantly increased the monetary flow within the boundaries of the affiliated social structure (the surrounding village). This increase monetary flow has already shown to have positive effects and possible spin-off effects of these could be numerous at least on a local level. (Further discussed in next section, Sustainable Development) However, the fact that the monetary flow mainly stays internal implies that there will be a limitation in purchasing power set by customer liquidity. This customer liquidity is mainly caused by nominal external monetary flows.

These nominal flows may further effect the diffusion of these types of productive use as it greatly limits their market. The future for these types of internal productive uses may therefore depend on external productive uses that can stimulate the cross border monetary flows and thus increase internal liquidity (See fig. 11).

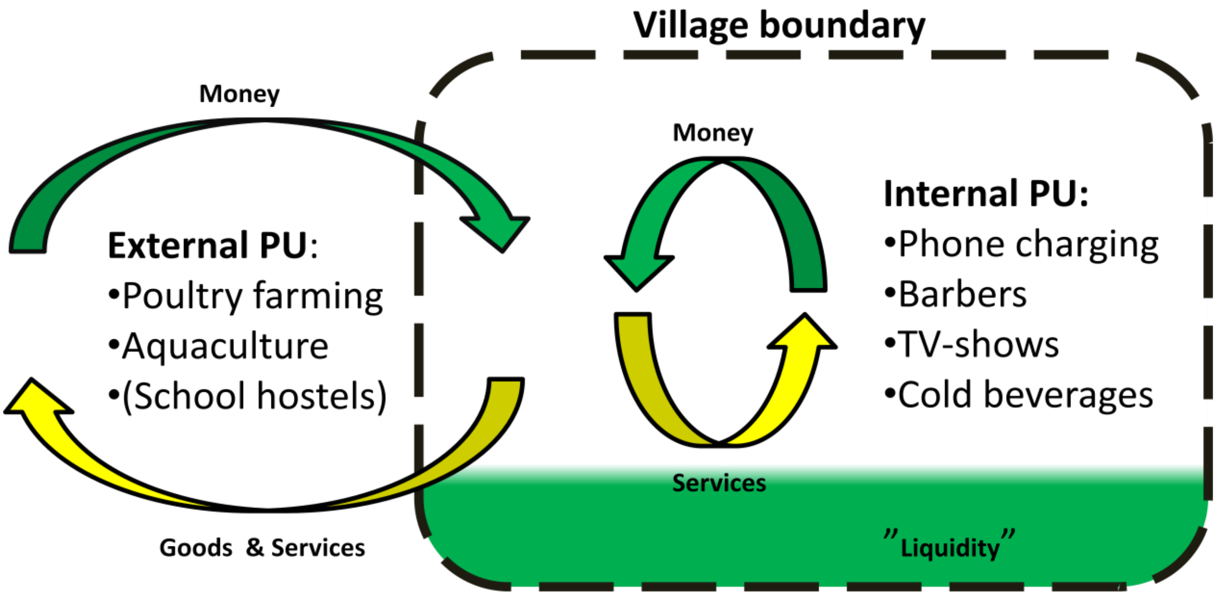


Figure 11. Conceptual picture of the internal and external productive uses encountered and their associated monetary flows.

The only external productive use of solar PVs encountered was the secondary school hostel were the tenant often came from a village that had a large geographical distance to the school. This type of productive use would imply an inter-rural monetary flow from one rural area to another. However this type of monetary flow may be perceived as very insignificant compared to external monetary flows that are generated by for instance agriculture and/or fishing which is traditionally seen as the main generators of income in the rural areas. Although not encountered in the investigated areas there are several productive uses directly with an external nature that can generate income more or less. Examples of these are poultry farming and aquaculture which are powered by solar PV. Such entrepreneurs were identified by the UNDP in an area not too far from Kayenze. By using the solar PVs these entrepreneurs could obtain significant increases in their output thus also increase external monetary flows and internal liquidity. In the long term it is probably these types of productive uses that are needed to achieve a sustainable economic development in the rural areas. However, the future for solar PVs as a contributor towards productive use of an external nature can be questioned as many of rural value adding activities as grinding, threshing etc. might require a lot of energy and thus making another energy sources more desirable.

Regarding indirect productive use of solar PVs, numerous of productive uses will appear just by adopting a solar PV in a rural area. Examples of indirect advantages could be extended opening hours for the "dukas" and fewer days of illness days due to "clean" PV powered lights, resulting in increased productivity. However the concept of indirect productive use of PVs is very vague and practically impossible to quantify thus not further discussed.

6.3 Sustainable development

Since the project investigated the usage of solar PVs as a mean for generating income and thereby rural development, focus in this chapter will be on the economical dimension and the ability to achieve a self-sufficient economy and market growth with solar PVs as a catalyst. In addition, attention will be on the environmental aspect and if the usages of solar PVs is a step towards environmental sustainability. Moreover, some attention will be devoted the social dimension of sustainability. This aspect is of course of importance but are left a bit in the dark since it possesses intangible effects that are hard to quantify.

The economic sustainability will be evaluated with regard to job opportunities, rate of return/profitability and ability to attract new investments. In the case of social sustainability the ability to serve as a mean for: additional income, improved education/housing and increased health will be evaluated. Lastly, the environmental sustainability emphasis will be put on maintaining quality of air, soils and water, habitats and species and the ability to maintain topography and climate.

6.3.1 Economical sustainability

In the results, which originated from interviews made on an individual level, one can clearly see that productive uses encountered, were very beneficial businesses as the derived payback times were often only a couple of months and in almost all cases fell below one year. Not regarding the income generated by productive use the entrepreneurs that previously used generators have managed to lower their running cost by up to 96% by obliterating the need of constant fuel procurements. In addition, another aspect worth mentioning is that in most cases having a PVs system also indirectly increased the sales of the basic products that the shops offered further enhancing profitability. The running costs encountered of the solar systems which is mainly based on the need of battery change is far from optimal and can be lowered significantly just by proper usage or a switch to durable, more expensive, dry deep cycle batteries. By proper use of solar batteries the running cost could practically be seen as negligible when compared to incomes and saved fuel costs. To sum up, the low running costs, the high revenues and the great demand for services absolutely makes productive use of Solar PVs interesting from an individual point of view, particularly a short term perspective.

On a regional level the sustainability of productive use of solar system can be questioned. As previously mentioned most of the markets for the provided services are local meaning that the monetary flow that these businesses creates will to a large degree stay within the local boundaries. This in its turn might imply that the distribution of wealth in the local regions will be dispersed towards the solar entrepreneurs. The future economic development of these areas will in this case be influenced by the solar entrepreneurs and their decision of what to make with their incomes. For instance if after saving some money the entrepreneur decides to leave the rural area and move to the city this may have negative effect on the local economic development. From a local economic development point of view it would be of interest to invest and remain in the local community creating new local job opportunities. However, many of the business have characteristics that limits the numbers of employees, as they are simply too small. Moreover, to reach a sustainable economic development in the affected areas it is also necessary to diversify the types of productive uses as the demand for services such as phone charging will drop the more the area becomes electrified by e.g. home solar systems.

Further, an increase of monetary flow within the rural areas will probably stimulate the awareness and need to think in economic terms. This may influence the economic innovativeness in these areas and have positive economic spin-off effects in a longer time perceptive together with the generation shift. An example of an emergence of economical thinking can for instance be seen in the households that offered phone charging services; prior to the procurement of the system these households often sustained themselves by agriculture with a limited economic responsibility whilst now it is a part of the everyday life. Even though the phone charging service itself might not requires advanced economical knowledge it will probably act as an incentive for further entrepreneurship.

In a long term perspective the economic developments of the rural areas is greatly depending on increased liquidity within the areas, meaning that the areas as a whole simply has to increase their incomes. This is most likely done mainly by increasing the productivity of the traditional income generators to the rural areas such as agriculture and fishing. These activities produce goods that can be targeted for an external market, and thus increases the external monetary flows and local liquidity. The increased liquidity will probably act as a base for the economical sustainability within the villages and giving the rural population more purchasing power. Thereby letting internal productive users take a micro-economical role in the villages providing services improving the overall quality of life and thus taking a more social dimension.

6.3.2 Environmental sustainability

In the transition towards a more developed country there will be effects on the environment; there will be an increase in energy demand and there will be changed consumption pattern, to believe something else would be unrealistic. The change in lifestyle can bring about environmental consequences on varying levels, but the changes can be performed in ways that causes less damage and are less harmful.

As the situation is today, the most common way of rural electricity supply, is through usage of a generator which is fueled by some kind of fossil fuel. Out of the results it is clear that a transition from generator to solar PVs mitigate CO_2 emissions corresponding to an average of 190Kg user and month. This figure is more or less consistent to one full tank of a normal car but and may thus feel a bit insignificant however, remembering that there are almost 8 million households that potentially may face this choice; a change will substantially contribute to a considerable reduction of CO_2 emissions.

There has during the last decade been a discussion concerning the emissions that arises during production of the solar PVs where some claim that the manufacturing process is highly energy demanding and at the same time a consumer of scarce raw materials. However, in a report from 2008 concerning the life cycle emissions of Solar PVs it is concluded that the emissions are insignificant in comparison to the emissions that are replaced when introduced in an average European or U.S. grid [38]. According to their analysis, replacing grid electricity with central PV systems presents significant environmental benefits, which for a normal PV accounts for a 89–98% reduction of GHG emissions, criteria pollutants, heavy metals, and radioactive species. Moreover, it is also mentioned that emissions from any type of PV system are expected to be lower than those from conventional energy systems as PVs doesn't require any fuel to operate.

Regarding other sources for electricity supply out in the rural areas, usage of a generator is often the only option. It is reasonable to assume that the emissions from manufacturing generators are more or less of the same magnitude as the emissions from production of Solar PVs. In addition, the generator consumes fuel throughout its entire life cycle continuously emitting pollutants. These pollutants may have hazardous effects on various levels as they are considered directly harmful to humans as well as they contribute to the greenhouse effect. Moreover, the surrounding areas might be polluted as toxic particles from combustion are transported by wind and absorbed by soils and water bodies. These toxic particles might later be assimilated in plants or animals which, if used as food or fodder, might be harmful for humans and livestock. Another problem encountered as an outcome of usage of a generator was the noise factor, which in our interviews was reported as very disturbing. This noise is totally avoided if solar PVs are used as technology is soundless.

A common local problem identified was the constant changing of PV batteries. At present there are not any, at least from what the case study showed, existing and working recycle stations for the used batteries. They were often just stored, thrown away and in some cases sold for scrap metal. The constant battery changes are not very sustainable since the batteries often contains scarce materials and heavy metals which in most cases are very hazardous and harmful for humans, animals and the surrounding environment. However, this problem can easily be reduced by proper usage of charge controllers as they would substantially increase the life lengths of the batteries reducing battery exchange rate. The problem with recycling of used batteries will however still remain and there is a need for appropriate actions, recycling stations in combination with a deposit system could be an effective instrument to cope with this problem. The fact that people in some cases actually bought the used batteries for scrap metal further lights a small spark of hope for used batteries, as it seems like there is an economical interest in scrap metal extraction. However, how well this extraction is currently made and what happens with the hazardous content of the batteries is unknown and can probably need some improvement.

6.3.3 Social sustainability

The results definitely show that productive use of solar PV is an income generating activity that delivers an extra income to the households. All of the respondents had actually experienced a raise in income since procurement of the system. This pertained regardless if the system originally was bought for the purpose of business or for domestic appliances.

Besides the environmental and economic impacts, productive use of solar PVs will more or less directly affect the social dimension within the implemented areas. Increased economic environments could be a contributor to poverty eradication as it may create more jobs and more economical incentives are introduced with the productive use concept. The successful implementation of productive use of solar PVs together with entrepreneurs desire to further extend their capacities might imply that more and more energy demanding appliances will emerge in these areas and form norm for future generations. A common expressed need by the respondents was to ultimately be able to have a refrigerator for home use as it would be easier to keep food. Introducing the refrigerator to the rural areas can have several positive social benefits such as increasing the life span of perishable foods which would imply less time consumption for obtaining food and cooking. A refrigerator could also have great health benefits as it hinders bacterial growth on foods and can be used for medicinal storage. However, this introduction of appliances that require more electricity could however easily lose its environmental benefits as people that desire this appliance might turn to non-renewable energy. It is thus important that renewable energy is a competitive energy option in these areas in the pending future. Other possible health benefits are to be connected with the transition from generators and kerosene to photovoltaics as this greatly reduces the indoor pollution and reduce health effects such as asthma and other lung deceases. Increasing rural health may have very positive effects putting less strain on the community and improving overall quality of life.

Further in the households were previously only the head of the house usually a male that was the only one that had any economical involvement. In the solar cell households however the woman was often in charge of cell phone charging service as the male of the house often was in the field. This might seem like a modest step towards gender equality however it can be a great incitement for female entrepreneurs in the in rural Tanzania.

Regarding the educational aspect of productive use of solar PVs it is hard to tell to what extent it actually contributes. But as in the case of the entrepreneur who rented out rooms equipped with light it clearly adds an extra value to the students as they were willing to pay a higher rent. These types are good examples of productive use that adds value not only to the entrepreneur but also to the society as the common knowledge within the society increases. By increasing the knowledge among the population one will hopefully achieve an increased long term development.

7 Conclusions

In this chapter conclusions drawn from the study are presented. It is here important to keep in mind that the empirical conclusions pertain to the two areas targeted in the case study. Therefore a similar case study in areas holding differing features could result in different outcomes. Although it is reasonable to believe that similar results will be obtained throughout large parts of the country since the investigated areas should be representative to Tanzania. This is further strengthened by observations made in completely different areas of Tanzania where solar PVs seemed to be used in a similar way as in the investigated areas.

Following conclusions are drawn and will be further explained below:

1) Productive use of Solar PVs generates high rates of return
2) Productive use of Solar PVs is very common
3) There is a high demand for certain services, especially phone charging
4) Productive use of Solar PVs has an overall positive impact on the village economy
5) There is a need of diversification among the provided services
6) Price for a Solar PV system is the most significant barrier for further diffusion
7) Productive use of Solar PVs is a great contributor towards sustainable development
8) There is a need for some kind of deposit system or recycling stations concerning batteries and used PV systems.
9) Solar PVs are excellent for low energy demanding services
10) Solar PVs are by themselves not the sole solution for rural development

Productive use of solar cells has proven to be extremely successful on a local level, as the entrepreneurs encountered, obtained very high rates of return on their investments together with low operating costs. These operating costs were mostly affiliated with the constant need to change the battery which could be costly however these costs are of the very low compared to profit generated by productive use and can easily be lowered to a negligible level if just used correctly. Productive use of solar PVs is therefore of great interest for rural development and should be considered as an incentive for rural entrepreneurship.

It was clear that both of the investigated areas were a part of the solar PV market and both areas housed a significant number of productive users. Currently phone charging businesses were by far the most common and profitable business type. In most cases the charging of phones was the absolutely highest income generator for the entrepreneurs' regardless of their original business idea. Reasons why phone charging as a productive use of solar cells have become so successful are:

- The immense demand, the availability of the mobile phones has increased exponentially in the entire country in the last decade while the access to electricity still remains passive.
- The relatively low investment costs of phone charging equipment, besides the solar system the only thing needed are the sockets and adaptors for the phones.
- The small amount of energy needed, as a phone battery only requires small amounts of electricity even a small solar system is enough to charge a couple of phones. With a bit lager system it is possible to charge numerous of phones at the same time.
- The pure income generated, as there is basically no cost for the entrepreneur per provided service the money generated will be of pure profit. (Nevertheless there is an alternative cost in the sense there will be less energy for other usage.

- No additional skills needed, no particular skills are needed to charge a cell phone it is just to plug it in and wait. This also enables the entrepreneur to run multiple services and businesses at the same time.
- Technical adaptations (if no inverter) as most phone charges run on different amps and voltage.

The same criterion pertains more or less to the other types of productive use found in the areas i.e. as barber shops, TV-shows, cold beverage sales and secondary school hostels. These types of productive uses where however less common and where usually found in businesses that combined these services with phone charging. When isolating these services one could still see that they by themselves were also very profitable with the exception of cold beverage sales, however they do not come near the profits that can be obtained by phone charging. In addition, phone charging seems to be a gate way for other productive uses particularly the ones that require higher levels of electricity. As it is common to start with a small system and then continuously investing in larger systems allowing a diversification of productive use appliances.

The innovation of productive use of solar cells is currently still at a quite early stage in terms of diffusion and can have a prosperous future. It surely plants initiative for rural entrepreneurs and thus can indirectly stimulate economic growth in the rural parts of Tanzania. However it is crucial that it can develop to further extents than just phone charging and internal productive uses. This extremely lucrative business might in a not to long future reach a level where everybody starts charging phones leading to a drastic drop to the market and thus busting the phone charging bubble. Therefore diversifications of productive use businesses are needed. A diversification might however imply that these extremely high rates of return that we are currently seeing in the rural phone charging businesses might be less although still very profitable. In addition it is very crucial to diversify productive use to an external level as it is these types of productive uses that in the end will stand for increases of liquidity in the rural areas. This is particularly important in the long term as rural liquidity sets a limit for the internal productive users.

An important factor affecting the rate of adoption of productive use of solar PVs, which is directly proportional to the diffusion, is the acceptance by the Tanzanian rural society. The outcome of this report shows that most factors are pointing towards an acceptance where productive use of Solar PVs is perceived to fit into the norms and values within the rural communities. Although the positive features and attitudes towards solar PVs for productive use, there is one significant bottleneck that has to be overcome, namely the high procurement cost. At the moment there is a great interest in procuring solar PV system however the possibility to afford such an investment is highly limited. This has earlier been pointed out as the main limiting factor and can further be confirmed in this report.

The peer to peer conversation has shown to be an important communication channel and part of the diffusion of productive use, mainly in the decision making process. Therefore it could be of interest to target new innovators in the areas that's has no or limited exposure of productive use. If a productive use business is successfully established others will soon follow as result of not only direct peer to peer discussion but also by the copycat syndrome. Regarding mass media, particularly radio has been rather successful to create awareness of the rural areas and should focus on just this, creating awareness and an interest of the technology. TV commercials rarely reaches the rural population and should instead focus on reaching the urban population that might have close ties to the rural parts of Tanzania, as they in turn will engage in pear to pear conversation with their rural relatives or friends. Particularly productive use of solar cells should be enlightened aiming to clarify the money making potential to the receiver of this communication. This might ease the decision making process as the procurement of solar systems is usually hindered by high costs.

As seen with the VAT there are actions that can be done for facilitating the diffusion of solar PVs for productive use. The removal of VAT was to a large extent a result of effective lobbying made by UN and other NGOs, but it is not only the NGOs and the UN that are important so called changing agents. Companies who are practicing advertising and promotion campaigns are probably more or equally important when it comes to creating diffusion of solar PVs. There have been cases where solar PVs have been promoted trough seminars and different campaigns initiated by NGOs and other influential organizations. However, in this study these efforts were invisible despite ongoing activities in nearby areas. Therefore the role of the organizations should be to ease the trading conditions and build up a climate that promotes business with technology that is regarded as beneficial as they possess enough lobbying power to actually achieve changes that makes a difference on a national level.

Productive use of solar PVs may be a great contributor towards sustainable development of the rural areas of Tanzania as its associated effects may directly and/or indirectly positively influence the three dimensions associated with this term. The internal productive uses have shown to be great contributors towards social development, whilst the external productive uses may aid stimulation of economic development in the rural areas. Lastly the responsible usage of a renewable energy sources such as Solar PVs is a contributor to a much desirable environmental sustainability.

To achieve a higher degree of sustainable development by productive use of solar PV there are still a few issues that are needed to keep in mind: Firstly and maybe most important more efforts are needed to increase the monetary flow into the villages. Secondly the large amount of batteries and associated components that will circle around as a result of increased solar systems will need to be taken care of in a suitable way preferably with some kind of recycling system. Lastly, the availability of renewable energy sources in the rural areas must be a competitive option as productive uses of electricity becomes a norm, thus preventing a backward trend towards unsustainable energy sources as the demand of electricity increases.

It is clear that external productive uses will play an important role if economic development should be reached. The role of Solar PVs for external productive use is probably however limited as productive users that are of an external nature traditionally seems to be very energy demanding thus requiring extremely large PV systems. This implies that solar PVs themselves might not be the sole energy solution for a sustainable development especially the small scale PVs, but they may still be an important part of the development.

The extremely low extension rate of the national grid strengthens the need for electrification by alternative means. The use of photovoltaic technology as sole mean to achieve this is very limited and as we see it, at this stage, should only be applied in housing, small scale business and for less energy demanding electrification appliances. The much needed external productive uses with higher demanding energy demand should seek electrification by other means such as micro/macro hydro, gasification and bio-fuel plants to various degrees and sizes. It could also be of interest to do a complete makeover of the national grid with a higher degree of decentralization with multiple energy sources. For a sustainable development of the country's energy situation there is not one sole energy solution but a handful of solutions where each one more or less tailored to its user.

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Appendix

Appendix I. Interview template

How/Why

- **How did you get to know about PVs?**
- **Why usage of solar PVs?**
- **What are you using it for?**
- **How is the system appropriate for your business?**
- **From where did you obtain your system?**
- **What model is it?**

Price issues

- **How and what did you pay for the system?**
- **Have you gotten back the money invested in the system?**
- **If NO when do you expect to do so?**
- **If YES how long did it take?**
- **Has the access to electricity improved the possibilities for income earning activities?**

Reliability, maintenance and repair

- **Is it reliable?**
- **Is it easy to get maintenance and repair?**
- **Does the system ever brake down?**
- **If so how often and what is the most common problem?**
- **How much can the repair cost be?**
- **How long will it take until the system is fixed again?**
- **Who conducts the repairs?**
- **After being fixed is there any change in capacity?**
- **Is there any noticeable reduction of income during these times?**

Previous situation

- **What type of energy source did you use previously?**
- **How much fuel was then used in a day/week/month/year?**
- **Who was responsible for getting fuel before the procurement of the system?**
- **Do you use any other energy besides solar energy?**
- **Former fuel, where was it obtained?**
- **Did you notice any degradation in the surroundings?**

Externalities

- **How often do you change battery?**
- **What happens to the battery i.e. recycled/ thrown away**
- **Have the solar PV been beneficial for others than you, i.e. people earning money on your system, examples?**

- **Have the procurement of the system changed your way of living, how?**

Productive use

- **How does it contribute to income?**
- **Since electrification, how has the development of the company changed e.g number of employees, revenue, number of products, manufactured quantity, sales quantity, share of market?**
- **If yes, how much of the increased income is approximately due to the access of electricity?**

Future development

- **How does the company want to develop in the future?**

- **Does the use need to have better access to electricity, Is the demand higher than the access?**
- **For further development, is electricity a primarily need and a crucial factor for this?**

Additional

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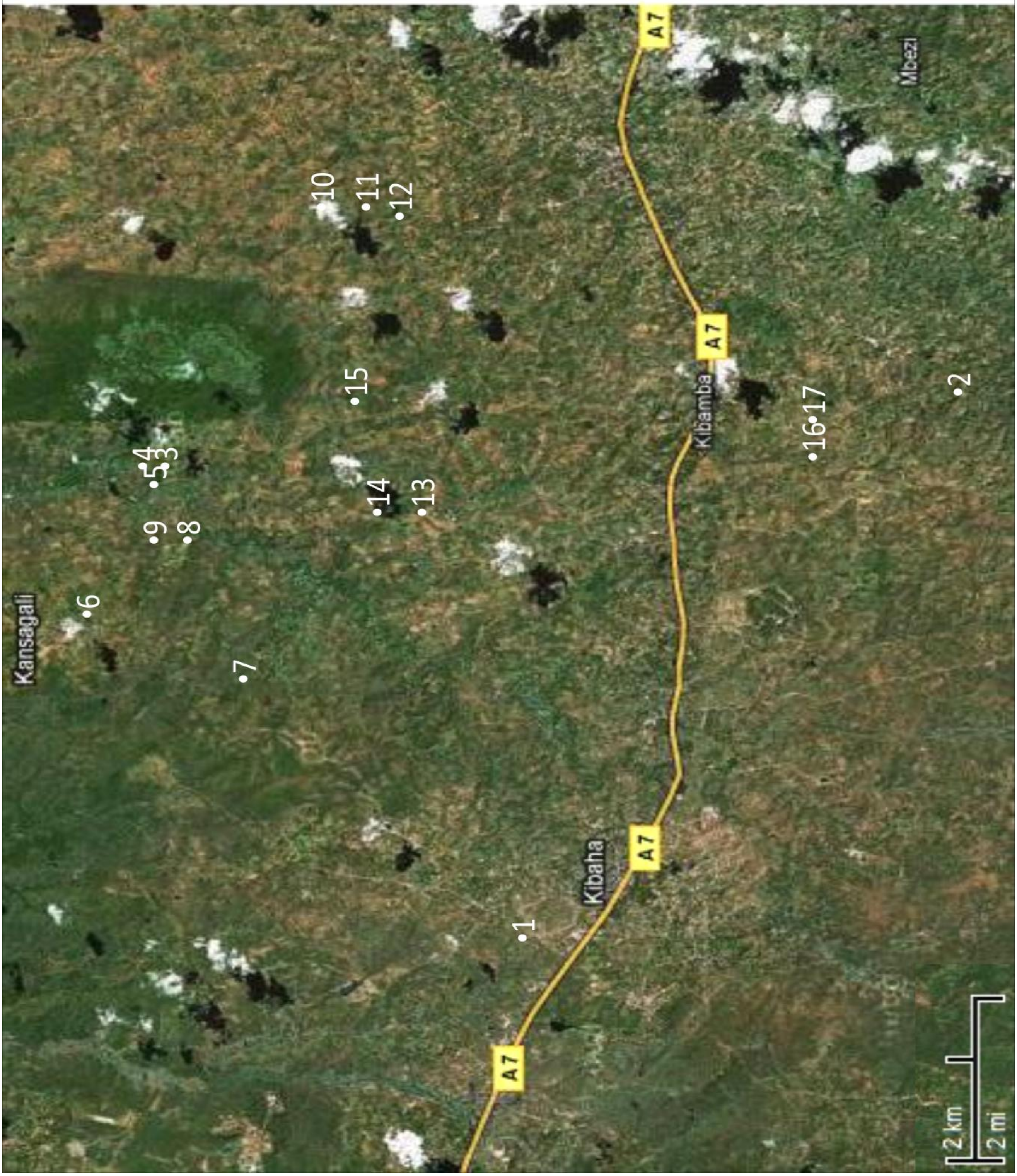
Appendix II. Kibaha



Appendix III. Kayenze

Appendix IV. Barber shop in Kayenze

Appendix V "Duka" in Kidumu near Kibaha

Appendix VI. Farmer in Shiringwa near Kayenze