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Solar PV Electricity's Progress, Pitfalls and Potential.

How the Lingeka-Nyanza Solar Project is Transforming the Lives of the Energy Poor in Rural Tanzania

Bishar M. Ali

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DECLARATION

I, Bishar Mohamed Ali, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

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ABSTRACT

Energy poverty in the rural areas of Sub-Saharan Africa is one of the main barriers that hinder development. In Tanzania there have been numerous efforts to enable the rural poor access clean and modern sources of energy but these have had limited results. The major reason is that current top-down approaches fail to benefit the energy poor. Decentralized off-grid renewable energy technologies promoted through a bottom-up approach which empowers the poor giving them the responsibility to choose, apply and adapt technology to their communities is increasingly seen as a viable alternative.

In 2011 a solar project under the Climate Change Impacts, Adaptation and Mitigation program was introduced in two remote, un-electrified rural villages in northern Tanzania; Lingeka and Nyanza. This project introduced solar home systems and solar lanterns in these villages and using a barefoot approach trained four women to become barefoot solar engineers, established a village energy committee and a rural energy workshop. In addition the project used an innovative social entrepreneurship business model that allowed the residents to payback for the solar equipment in installments. This money was then used to buy more solar equipment to be sold.

Using both quantitative and qualitative methods, this study examines the socioeconomic impact of the project, how the project impacts empowerment of the women solar engineers and examines the success factors and challenges of the model used to promote solar PV. The study finds that access to affordable solar PV electricity has also enabled households to light up their small business and earn extra income by charging mobile phones for a fee. Pupils in this homes study 1-4 hours more after dark have improved grades. Residents of these villages have also better security at night and are less prone to health hazards associated with kerosene lamps. The study also finds that the solar project has contributed to transformation of gender roles and empowered the four female barefoot solar engineers. These women have not only transformed their villages by providing crucial after sale services but also improved their agency, well being and status in the community.

In solving energy poverty, modern technology is only one piece of the puzzle. Innovative models bridge the gap between solar PV technology and the rural energy poor, as demonstrated by the Lingeka-Nyanza model. This model overcomes major technical, social and institutional barriers that have hindered absorption of solar technology in rural areas by establishing an innovative locally adapted model. Through its innovative social entrepreneurship model, it offers a practical sustainable solution that promises great potential for providing other rural villages with access to solar PV electricity. This study recommends this model to be scaled up as one solution to energy poverty in rural Tanzania.

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And to my family and friends who have encouraged me all through. Your questions about when I'll hand in and your interest in the study's theme kept me going. A special gratitude to Uzma Ali, your unwavering belief, patience and constant encouragement gave me the strength for the final push. And to all those that I could not mention thank you all for your support. In different ways you have contributed to making this a success.

Plate 1. Connecting the village to the globe. One of the houses in Lingeka village that has now access to solar PV electricity. Notice the satellite dish on the left and the rooftop solar panel (right). (Photo by author)

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Abbreviations

BSE	Barefoot Solar Engineer
CCIAM	Climate Change Impacts, Adaptation and Mitigation
CBO	Community Based Organization
GDP	Gross Domestic Product
HDI	Human Development Index
ICS	Investing in Children and their Societies (a regional NGO)
IEA	International Energy Agency
NGO	Non-Governmental Organization
INGO	International Non-Governmental Organization
NOK	Norwegian Kroner
NMBU	Norwegian University of Life Sciences (Norway)
PV	Photovoltaic
REW	Rural Energy Workshop
RETs	Renewable Energy Technologies
SE4All	Sustainable Energy for All
SHS	Solar Home Lighting System
SUA	Sokoine University of Agriculture (Tanzania)
TAREA	Tanzania Renewable Energy Association
TaTEDO	Tanzania Traditional Energy Development Organization
Tsh	Tanzanian Shilling
VEC	Village Energy Committee
Wp	peak watts
$	US dollars

1.0 Introduction

The discovery of fire, invention and utilization of various sources energy by human beings is one of the greatest successes of the human species. Starting with the discovery and use of fire by early man to cover his basic energy needs to the present day where all we need is to flip a switch, has been a long journey that has seen great human development. However, to a significant population in the world today, the comfort of flipping on a switch to enjoy the success of this tremendous development remains bleak. About 1.3 billion people in the world do not have access to electricity and 2.7 billion people in the world still rely on inefficient biomass fuel such as wood, charcoal and dung for their energy needs (IEA 2014a). Energy poverty is primarily a developing countries problem. Moreover this picture looks bleak as one zooms in from the globe to Sub Saharan Africa (SSA) and from the urban areas to the rural areas. In fact 84% of rural population in the world suffer from energy poverty(IEA 2014a). Access to modern, clean and efficient energy source remains a global challenge for millions of these rural households.

This study focuses on a strategic intervention project under Climate Change Impacts, Adaptation and Mitigation (CCIAM) program implemented in Lingeka and Nyanza villages in Meatu District, Tanzania. The five years project that started in 2011 sought to promote alternative energy sources and efficient utilization of biomass energy in order to address energy poverty. By promoting alternative energy sources the project aimed to reduce depletion of carbon sinks and improve livelihoods of the rural poor with a special emphasis on girls and women (Kweka et al. 2011a). The project addressed two core problems; a) lack of reliable and clean energy for lighting, and b) inefficient use of biomass for heating and cooking, by introducing solar home lighting systems (SHS) and improved cooking stoves respectively. Given that girls and women bear the brunt of unreliable and unclean energy sources due to indoor pollution and the burden of firewood collection (Colombo et al. 2013b), the project implementers argued that they would benefit more.

It would have been interesting to carry out a comprehensive study of the project, examining both the solar PV electricity and the improved cooking stoves. However, due to financial and time constraints, and that there already exists numerous literature and research on improved cooking stoves in rural areas (Karekezi & Kithyoma 2002), this study will focus only on the introduction of solar PV electricity in the two villages. Specifically, this study will focus on three closely related issues; (1) the socio-economic and health impact of households that use solar PV electricity, (2) the impact of women Barefoot Solar Engineer (BSE) on women's empowerment and how this affects sustainability of the project, and (3) the model used to promote the use of alternative energy sources in Lingeka and Nyanza villages.

Set in the broad context of energy poverty in rural areas and the use of renewable energy sources, and using a mixed method-research, this study set to answer the following research questions;

1. What are the socio-economic and health impacts experienced by the households in Lingeka village that had adopted solar photovoltaic (PV) electricity?
2. In what way does becoming a BSE impact these women's empowerment?
3. What are the challenges, success factors and potential for scaling up scaling and scaling out of the model used to promote solar PV technology in Lingeka and Nyanza villages?

By focusing on the three research questions above this study seeks to contribute to the energy poverty literature especially in the rural areas in three main ways. Firstly, by contributing with empirical evidence on the socio-economic and health impact of energy access to the rural poor in SSA. Secondly, by contributing to the discussion on gender mainstreaming in rural energy projects. Thirdly, and perhaps more importantly, to contribute to the discussion on how to bridge the gap between the current available technology and the rural poor; those considered at the bottom of the economic pyramid, by examining the model used in promoting alternative energy and how this could both be *scaled up* in rural areas that have modest access to solar PV electricity and *scaled out* to rural areas that do not have access to clean and modern energy sources.

This introductory chapter is followed by a discussion on energy poverty in general and a brief overview of relevant statistics on the status of energy access at the global, regional i.e. SSA and national level. The three villages Lingeka, Nyanza and Mwakisandu where this research was taken are then briefly presented with their geographical and demographic information. The strategic intervention project in Lingeka and Nyanza (hereafter referred to as the solar project) used to promote alternative energy is also described here.

Chapter three will give a literature review placing the issues discussed in a wider academic context. Major pertinent concepts and themes are briefly discussed as well as the importance and rationale of this study. Chapter four presents the conceptual and theoretical framework that will be used to analyze and discuss the three research questions of the study and is subdivided into sub-chapters corresponding to each question.

Chapter five discusses and presents the mixed method approach used to conduct this research. In addition to the discussion of data collection method and analysis, this chapter will also describe the major characteristic of the sample used for the quantitative part of the study. Other issues such as challenges of the research process and ethical considerations will also be discussed in this chapter.

The major findings will be discussed in chapter six, seven and eight. In chapter six the socio-economic and health impact of the project for the rural household will be presented, discussed and analyzed in light of the Energy Quality of Life Framework (Obeng & Evers 2009). Chapter seven will focus on the four women BSE's who form a critical part of the solar PV project in Lingeka and Nyanza. Here a qualitative discussion about the four BSE's in the two villages will be discussed through the CARE women's empowerment approach. The particular model (hereafter referred to as Lingeka-Nyanza model) used to promote solar PV technology in these two rural villages is discussed in chapter eight. Here the structural components of this model are examined and the challenges, success factors and potential of scaling up and scaling out this model discussed. The Lingeka-Nyanza model is analyzed using a 4A's framework. Chapter nine will focus on the implication of this study's findings and conclude this study.

2.0 Background

2.1 Rural Energy poverty in SSA

Energy poverty refers to lack of electricity and dependence on traditional biomass fuels for cooking and heating (Sovacool & Drupady 2012). Statistics of people experiencing energy poverty is thus often disaggregated into two categories; those that do not have access to electricity and people that depend on traditional biomass fuel for their household energy needs. 1.3 billion in the world lack access to electricity and around 2.7 billion people rely on traditional biomass for cooking and heating, these are about 19% and 40% respectively of the world population (IEA 2014a; Sovacool 2012a). Most of these people live in Sub Saharan Africa and Developing Asia as shown in table 1 below. Furthermore energy poverty affects people living in the rural areas in these two regions even more, 85% of people lacking electricity and 81% of the people using traditional biomass fuel live in rural areas (Bhattacharyya 2013). It is important to note that with regards to energy source Africa can be divided into three distinct regions; North Africa which primarily relies on oil and gas, SSA (excluding South Africa) which relies on traditional biomass fuel and South Africa which relies largely on coal (Karekezi 2002).

Table1. Number of people with no access to electricity and dependent on traditional fuels

Region	Population without electricity millions	Electrification rate %	Urban electrificatio n rate %	Rural electrifica tion rate %	No. Of People Relying On Traditional Biomass Fuels For Cooking (Millions)
Developing countries	**1 283**	**76 %**	**91 %**	**64 %**	
Africa	622	43 %	68 %	26 %	657
North Africa	*1*	*99 %*	*100 %*	*99 %*	*4*
Sub-Saharan Africa	*621*	*32 %*	*59 %*	*16 %*	*653*
Developing Asia	620	83 %	95 %	74 %	1,937

China	*3*	*100 %*	*100 %*	*100 %*	*423*
India	*304*	*75 %*	*94 %*	*67 %*	*855*
Latin America	23	95 %	99 %	82 %	85
Middle East	18	92 %	98 %	78 %	10
Transition economies & OECD	**1**	**100 %**	**100 %**	**100 %**	**-**
WORLD	**1 285**	**82 %**	**94 %**	**68 %**	**2,675**

Source: Authors aggregation from Sovacool and Drupady (2012) and IEA (2014b)

A closer look at the electrification rates shows that out of the nineteen least electrified countries listed below, thirteen are in SSA. The least electrified country is Uganda with only 9 % of its population having access to electricity while only 14% of people in Tanzania have access to electricity as shown in figure 1 below. Given that the population growth is expected to be high in SSA and Developing Asia according to World Population Prospects 2010, and assuming a significant level of investment in energy, forecasts by International Energy Agency (IEA) show that around one billion people will still lack electricity by 2030 in these two regions (Bhattacharyya 2013).

Energy poverty was and still is a global problem and even more acutely, a rural problem. In the 1980's although the importance of energy was recognized, its access by the rural poor in developing countries and its status (currently) as a necessary input, infrastructure and cornerstone for development, and even an instrumental right (Colombo et al. 2013b) was not as unanimous. Samanta and Sundaram (1983) observed back then that "[t]here is, indeed, even a conflict in policy perceptions: are these inputs [*electricity in rural areas*] a basic need or a want?" Today, three decades later the significance of access to modern and sustainable energy stands out unquestioned in the global development agenda. The discussion now is no longer whether electricity is necessary but rather how *all* people can access affordable, reliable sustainable and modern energy.

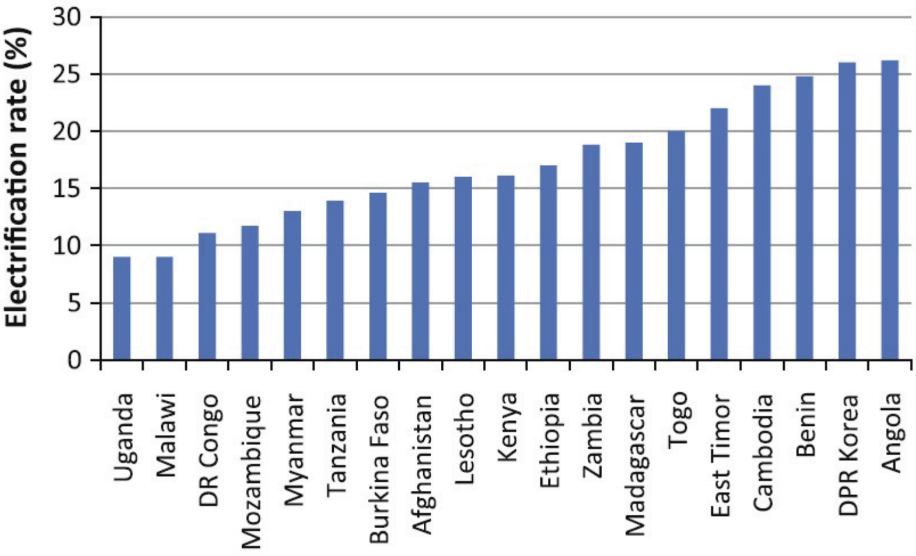

Figure 1: Least electrified countries in the world. Source: (Bhattacharyya 2013)

Many developing countries and international organizations have made efforts to tackle energy poverty. Internationally this has been in the form of recognition of the vital role energy play in sustainable development. For instance although access to clean and modern energy is not expressly mentioned in the now ending MDG's it is considered one of the most fundamental infrastructure in alleviating poverty by many stakeholders (Bhattacharyya 2013; Sovacool & Drupady 2012). Flavin and Aeck (2005) explore, the role of renewable energy and the extent to which their increased use by developing countries can provide reliable and affordable energy services to assist in development and alleviation of poverty. This report entitled *Energy For Development the Potential Role of Renewable Energy in Meeting the Millennium Development Goals* exemplifies the significance energy access to the poor has become in the development agenda. The UN observed 2012 as the year of Sustainable Energy for All (SE4ALL) with the Secretary-General Ban Ki Moon declaring that;

''Energy enables … It is unimaginable that today's economies could function without electricity and other modern energy services. From job creation to economic development, from security concerns to the status of women, *energy lies at the heart of all countries' core interests*.'' (Ban Ki-Moon 2011 emphasis added).

The UN Secretary-General notes that that the world faces two interconnected problems; lack of access of energy by a significant population of the world and the waste and pollution caused by current energy sources. The former is largely a problem experienced by countries in the South and the latter mostly an issue in countries in the global North. The solution, he urges, is to provide energy that is accessible, cleaner and more efficient for all (Ban Ki-Moon 2011). Although access to modern energy was not included in the eight MDG's, many scholars commented on the necessity of modern energy access to ensure the achievements of these goals (Flavin & Aeck 2005). Now energy access is regarded as a goal in itself. Goal 7 of the proposed 2015 Sustainable Development Goals (SDG), which will replace the MDG's, seeks to ensure access to affordable, reliable, sustainable and modern energy for all by 2030 (United Nations, 2014, p. 6).

2.2 Energy situation and the rural poor in Tanzania

Tanzania is the largest country in East Africa and has a population of 44.93 million according to the 2012 census report (URP 2013). Although the country has diverse energy sources such as biomass, hydro, geothermal, natural gas, uranium, wind and solar, most of these remain untapped. IEA estimated that in 2009, 94% of the population depended on biomass fuel for their energy needs while only about 15% of Tanzanians had access to electricity (Bhattacharyya 2013). Moreover the people that have access to electricity suffer from several black outs and brown outs annually. This is estimated to cost 4% of the GDP, a severe deficiency in the power sector that limits Tanzania's economic growth and its global competitiveness (Colombo et al. 2013b). It is estimated that energy consumption in rural areas accounts for about 85% of the total national energy consumption(URT 2003).

The National Energy Policy of 2003 is the main policy document that addresses energy issues in Tanzania. This document acknowledges the importance of developing the energy sector as an important input in the development process (URT 2003). This document also recognizes that rural electrification continues to be a challenge in Tanzania's mission of economic growth and poverty reduction. In order to achieve this mission, the energy policy recognizes the need to utilize indigenous and renewable energy sources and technologies, and building gender-balanced capacity in energy planning, implementation and monitoring (URT 2003).

Tanzania Electric Supply Company (TANESCO) and Rural Electrification Agency (REA) are the two major government agencies, both under the Ministry of Energy and Minerals (MEM), that are responsible for and engaged in several efforts and programs to ensure sustainable and reliable energy access to all areas (URT 2003). REA was created in 2005 to promote and facilitate improved access to modern energy services in rural areas. Funded through budgetary allocations and support from donor partners, one of REA's major role is to promote, coordinate and facilitate private sector initiatives and entrepreneurship in rural energy supply(Eng. Msofe n.d). REA's projects are mostly renewable energy-based and often off-grid type while TANESCO, the main state agency in charge of the power generation and distribution, is responsible for grid extension(Bhattacharyya 2013). REA has facilitated several high-end budget electrification projects funded by the World Bank and Global Environmental Facility. Although this large scale, national and top-down projects have been partly successful they have been faced with several challenges such as inadequate funding, weak institutional framework, implementation and management (Bhattacharyya 2013).

In addition to these government bodies there are several NGO's that work to promote use of alternative energy in Tanzania. Tanzania Traditional Energy Development Organization (TaTEDO) and Tanzania Renewable Energy Association (TAREA) are perhaps two of the most prominent. These two have more than 20 and 15 years of experience respectively of working with energy related issues especially with the rural poor. TaTEDO's major objective is to enable majority of the population, particularly women in rural areas to access sustainable energy technologies and services that contribute to poverty reduction, sustainable development and climate change mitigation and adaptation (*TaTEDO Profile* 2013). TAREA, which is basically a network that brings together local and international stakeholders interested in renewable energy, seeks to promote and advocate the increased use of renewable energy through its network of members and stakeholders, emphasizing the need for quality and best practice throughout the energy sector(*TAREA* 2012).

TaTEDO has several achievements under its belt, and has collaborated in several projects with many INGO's and foreign countries. One the earliest studies carried out by TaTEDO almost two decades ago was not only comprehensive but also remains pertinent today. This study faulted previous studies for addressing energy problem as a 'crisis' and thus neglected the people's perception supposedly suffering from this crisis (Ellegård et al. 1998). Furthermore the study identified projects that could improve the energy situation of the rural people and proposed several renewable energy based projects that they argued should be 'environmentally benign, gender sensitive and contribute to address the situation of the poor'(Ellegård et al. 1998).

As mentioned above REA and TaTEDO have implemented several donor funded energy service delivery initiatives aimed at the poor but these have had limited success as evidenced by the low rural electrification rate. Scholars often point to the flawed approaches to dissemination particularly the top-down approach to planning and implementation of such projects(Kweka et al. 2011b). It is important to point out however, that the energy sector is top-down oriented and experiences from South-East Asia and South America suggest that these approaches work when they are supported by strong implementation strategies (Bhattacharyya 2013). Nevertheless In SSA the top-down approach presents a set of challenges. In their study on drivers and barriers to rural electrification in Tanzania Ahlborg and Hammar (2014) note that Tanzania relies on external funding for its RE projects, has low institutional capacity and suffers from corruption and politically motivated but economically unviable plans that hinder efficient implementation and use of funds. In addition Kweka et al. (2011b) point out that these expensive top-down projects fail to address the needs of the intended beneficiaries and marginalizes the very poor preventing them from making their own decisions. For the rural energy poor a bottom-up and decentralized approach is thus seen as a viable alternative (Kweka et al. 2011b) and as a complement and fore-runner to the national grid making electricity available for the rural energy poor years in advance thus creating demand and a customer base (Ahlborg & Hammar 2014). The Lingeka-Nyanza solar PV project, the subject of this study, is an example of such a bottom-up and decentralized approach.

2.3 Energy situation in Lingeka and Nyanza

In order to give a typical picture of the energy situation in rural Tanzania here is a description of the two study villages. Prior to the beginning of the Lingeka and Nyanza solar project in 2011 a baseline study was carried out to map out the energy access of the two villages. This baseline study is used here to give recent statistics on energy issue in this region. These two villages lie in

Meatu District one of the 5 districts in Simiyu[1] region in northern Tanzania. According to the 2012 census report Meatu district has 299,619 inhabitants spread across its 25 villages (or wards, which is the administrative term) and has an average household size of 7.4 persons (URP 2013).

Two hundred and seventeen (217) households were included in the household survey conducted in Lingeka and Nyanza village for the baseline study. The main cooking energy was biomass fuel. 93% used 3-stone open fire burning firewood, plant residue and only 6.8% used charcoal stoves. The study revealed that contrary to previously held assumption, firewood collection was not a daily household activity (Kweka et al. 2011a). The researchers found that this was due to the limited access of firewood from the forest. Most households, around 55%, bought firewood while those that collected these, would do it once a year, weekly or bi-weekly. Ox carts are used to transport firewood from forests that are then sold in the villages. The study also showed a strongly gendered division of labor where 96% of women and girls said they were responsible for cooking for the family. And in the households where they collected firewood this burden fell on the women (52%) and children (21%).

None of the two villages were connected to the national electricity grid. For indoor lighting most households used either or both kerosene lanterns and battery-powered torches. 89.4% used battery-powered torches and 21.7% of the households used kerosene lanterns. The villagers often connected several dry cells in series and attached a small bulb, a construction they called *Richmond* (see plate 1 below). Many households gave the high cost of kerosene and the health problems associated with its smoke as the reason for not using these lanterns. A few households, about 2% reported that they owned solar home lighting systems while about 2 % owned generators. Since the two villages are not connected to the national grid, diesel-run generators and the solar PV systems served as the major source of electricity. In terms of electrical appliances only 2.8% owned televisions while 41.9% of the household had radios and 51.2 % had mobile phones.

The study also revealed the inhabitants were aware of solar PV electricity and the negative impacts of traditional energy sources but were mostly discouraged from adopting modern energy

[1] Simiyu Region was carved out of Mwanza and Shinyanga Regions in 2012. However the study district boundaries remained unchanged.

sources due to the high initial costs and technical difficulties such as lack of after-sale services. Majority of the respondents indicated their willingness to buy solar home lighting systems if the payments were divided into three or more fairly affordable installments (Kweka et al. 2011a).


Plate 1 Dry cells in series used to make *Richmond*[2] left, and on the right, a common simple one-dry cell torch. Source: Author

2.4 The Lingeka and Nyanza Solar Project

The solar project was launched in 2011 in Lingeka and Nyanza villages. This initiative falls under the CCIAM umbrella of a nationwide program between the Government of Norway and Tanzania. The CCIAM project was scheduled for 2010 -2015 and was expected to cost NOK 94.9 Million (11.4$ million), it brought together several institutions in these two countries notably the Sokoine University of Agriculture (SUA) and Norwegian University of Life Sciences (NMBU 2015). This five year program focused on promoting natural forest conservation, afforestation, reforestation and better agricultural practices for improved livelihoods (SUA 2011). The program included 15 main projects and 11 supporting strategic intervention projects. The most common is the Reduced Emissions from Deforestations and Forest Degradation (REDD +) initiative.

The solar project falls under the strategic intervention project and its main goal was to introduce and promote alternative energy sources and efficient utilization of biomass energy in order to both reduce depletion of forests and improve the livelihoods of the rural population(NMBU 2015). Basically the project promoted the use of improved cooking stoves and introduced the use

[2] The name *Richmond* comes from a contractor who failed to deliver emergency electricity in Tanzania during a power crisis in 2006 (BBC 2008). The scandalous contract gained a lot of media attention and became a household name. The torch's name is reportedly a humoristic take referring to its unreliability.

of Solar Home Lighting Systems (SHS). Lingeka and Nyanza, two remote villages unsupplied by the national electricity grid, were selected as the project site. The project brought together two universities (SUA and NMBU), Tilonia Barefoot College[3] (India), ICS (Investing in Children and their Societies) a local NGO, and the people of Lingeka and Nyanza. NMBU and SUA had the supervisory and advisory role respectively, while Tilonia Barefoot College was responsible for the training of the four women Barefoot Solar Engineers (BSE's). ICS played the implementing role being an active NGO in the region and also involved in a previous similar project in other two villages Mwandu-Itinje and Longalonhiga. The roles of these central stakeholders are discussed further in chapter eight.

Noting the failures of top-down approaches that sought to introduce alternative and modern energy technologies in rural areas, the project was designed to be a bottom-up approach. The project adopted the 'barefoot approach' which, the implementers argued, ''empowers the poor and gives them the responsibility to choose, apply and adapt technology to their communities'' (Kweka et al. 2011a). The barefoot approach included the training of four local women to become 'solar engineers', construction of a Rural Energy Workshop (REW), and the establishment of a Village Energy Committee (VEC).

The initial funding for the SHS and the construction of the demonstration improved cooking stoves was provided by the project. The project funded the travel and training cost for the 4 BSE's in India, 152 photovoltaic SHS and lanterns and two demonstration stoves(ICS & Sokoine University n. d.). Through a series of public village meetings, facilitated by ICS, the villages elected the first VEC and selected four local women to be trained as BSE's. After returning from their six months training in India the BSE's installed the supplied SHS in their respective villages to households that had paid the first installment for the SHS. The payment of the SHS (which included a solar panel, charge controller, a battery, and lanterns) was divided into three installments. This money was collected by the VEC who then bought more solar PV equipment and sold to other members of the village. Apart from installing the SHS, the BSE's offered after-sale services such as repair of broken lanterns and SHS routine maintenance for a fee. The REW acted both as a repair workshop where the BSE's worked and as a storage facility for the solar equipment bought by the VEC.

[3] See more about this college here http://www.barefootcollege.org/solutions/solar-solutions/

Unlike the solar PV electricity project, there seemed to be a less elaborate plan for the promotion of the improved cooking stove. Promotion of improved cooking stoves and solar PV electricity were planned to run simultaneously however improved cooking stoves seemed to be have been abandoned only a few months after the project started. This was among others, blamed on the expensive construction of the improved stove and it's impracticality. Construction of an improved stove cost about 80,000 Tsh (37$) this could not compete with a 3-stone fireplace that almost costs nothing. In addition being a permanent construction many people that lived in rented houses saw it as a poor investment. For those that owned their houses they felt it was unwise to modify the houses they owned to accommodate the inbuilt stove. The focus of this study is however on the solar PV part of the project and thus further discussion on the improved cooking stoves fall beyond the scope of this study.

3.0 Literature Review

The baseline survey mentioned earlier gives two overall objectives of the project. By introducing solar home lighting systems (SHS) and improved cooking stoves the project will, (1) improve the livelihoods of the project participants especially of the women and girls and (2) contribute to reduced depletion of carbon sinks (Kweka et al. 2011a). These two objectives are at the nexus of three broad subjects: energy and development, energy and environment, and gender and energy. This literature review thus concerns itself with these nexus.

Energy is a broad topic and even though this study is limited to household energy this still remains a vast field. In order to limit the scope of this study this literature review concerns itself with three thematic areas; energy poverty, gender issues in energy and renewable energy sources, specifically solar energy, in line with this study's research questions. Although the themes are discussed separately they are inherently interrelated and thus the demarcation is entirely theoretical. The three thematic areas are chosen to give a brief review of the issues and current debates in the context of the aforementioned issues. Therefore the energy-development nexus will discuss the issues related to the socioeconomic and health impacts of access to and lack of modern energy. The energy-gender nexus will give a theoretical basis of the gender related issues of the solar project in Lingeka and Nyanza. Finally the energy-environment nexus will concern itself on the choice of solar energy as a viable alternative source for providing energy access to rural areas and the models used to promote access to these in the rural areas.

3.1 Energy-Development Nexus

Today, access to energy is considered almost unequivocally an "enabler" to development. The chief economist of International Energy Agency, Fatih Birol (2014) observes that energy is a ''critical enabler for all forms of development'' and that apart from direct benefits of access to modern energy there are numerous other positive multiplier effects of this. The current global focus on access to energy by the UN through the SE4All initiative and other multibillion projects notably the Power Africa project launched in 2013 by president Barack Obama (USAID 2015) and the inclusion of energy access as a priority area in the forthcoming post-2015 SDGs seem to point to the global acknowledgement that energy indeed plays a critical role in development and alleviation of poverty. Although this focus on provision of modern energy to the world's poorest is recent it is not new nor has it been without dispute as noted earlier. In SSA, lack of access to modern energy by the poor was seen as crisis in the 1980's and numerous efforts mostly in the form of rural electrification were launched often with limited results (Ellegård et al. 1998).

Literature review suggests that it is only recent that the lack of access to electricity and use of traditional fuels for cooking are viewed as two key dimensions of energy poverty and thus addressed together. Most literature suggests that energy projects in the 1980's and as late as 2000's focused primarily on the provision of electricity and less on the problem of use of traditional biomass. Cook (2013) in *Rural Electrification and Rural Development* viewing rural electrification as a crucial infrastructure of any given country, reviews past and more recent literature on the role and relation of rural electrification to economic growth and development. Cook (2013) quoting Ozturk (2010) observes that the relationship between electricity and development is complex and shows that four different types of causal relationship have been postulated in the literature. There are those that claim that is no relationship between electricity and economic growth. A second position argues that economic growth leads to increased demand in electricity while the third position posits that increased electricity consumption leads to economic growth. The fourth position, which tends to be the majority view, is that the relationship is in both directions. Cook (2013) concludes that rural electrification schemes have not been successful in providing universal access in that it has been unaffordable for most poor people and that the earlier emphasise by World Bank funded projects on cost recovery and reliance of private sector to deliver electricity was misplaced.

The different views on the relationship between energy and development impact policies that seek to promote growth, and the use and conservation of energy. Other scholars have also discussed the complexity of the energy-development nexus. Taking a slightly different perspective on the energy-development nexus Kaygusuz (2012) argues that energy both contributes to and detracts from sustainable development through an interplay of several factors e.g. markets, policies, technological development, social behaviours and social norms. Energy is both an enabler and a pollutant. On the one hand energy enables human activity and contributes to social, economic and environmental development. On the other hand however, the extraction, distribution and use of energy is linked to environmental degradation, emission of greenhouse gas emissions and disruption of ecosystems. The overwhelming view however is that although energy is indispensable, access to modern energy in and of itself cannot alleviate poverty (Bhattacharyya 2013; Kaygusuz 2012; Sovacool & Drupady 2012). Kaygusuz (2012) concluding with a nuanced observation writes that, ‘‘Energy is essential for development; energy that is secure, environmental friendly, and produced and used efficiently is essential for sustainable development.’’ Nowadays the emphasis is not only in the provision and access to modern energy but to *renewable* modern energy sources. The increasing investment in renewable energy by many countries in the global North bears testimony to this.

Empirically, the relationship between development and electricity access at the country level has been demonstrated by several studies where scholars take the GDP or HDI of a country and relate this to electricity access (Bhattacharyya 2013). These studies often show a generally positive correlation between a country’s HDI and its electricity access. However a closer inspection of the data shows that high income does not automatically lead to high levels of energy access of a country (Bhattacharyya 2013). In addition, Energy Development Index has been published each year since 2004 by IEA as a measure of a country’s progress towards modern energy fuels and services and also in contributing to our understanding of the role that energy plays in human development (Birol 2014).

Conceptualising the complex relationship between access to electricity and its positive socio-economic impact at the household level Barnes et al. (2013) demonstrate how multiple interconnections among a broad array of electrical appliances (lamps, TV’s, fridge), their outputs (light, access to knowledge, food preservation) may lead to intermediate outcomes (e.g extended study hours and better income) which may over time lead to comprehensive development outcomes such as improvement in education, income and health. They argue that since electrification enables multiple channels of development outcomes the accumulated benefits can be high. There are several studies in rural SSA that demonstrate this. Taking educational benefit for of electrification for instance two separate studies one in Rwanda (Gustavsson 2007) and another in Zambia (Bensch et al. 2010) show how access to electricity enables school going children to have increased study time in the evening.

3.1.1 Energy Poverty – a new name for an age-old problem?

As noted in the discussions earlier most literature on energy access usually focus on either lack of electricity by the rural poor or their use of biomass fuel. Although links between access to energy (or lack of it) and poverty have been explored in almost all literatures with regards to energy in developing[4] countries, it seems that it is only recent that the concept ‘energy poverty’ has been applied to this age-old problem; reconciling the two issues under one terminology. The concept energy poverty although commonly used now, has no universally agreed definition partly because of the elusive definition of poverty itself (Sovacool 2014). For instance UNDP defines energy poverty as the ‘‘inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other household activities at sunset’’(Gaye 2007 p.4 quoted in Sovacool 2014). This definition focuses on the household energy needs and highlights two basic activities as indicators of energy poverty; lighting at night and energy for cooking.

A broader definition is given by the Asian Development Bank where they define energy poverty as ‘‘the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development’’ (Reddy, A.K.N., & B.S. Reddy. 1994 p. 44 quoted in Masud et al. 2007). Following IEA, energy poverty is in this study defined as the lack of access to modern energy services (IEA 2014a). These modern energy services are defined as household’s access to electricity and clean cooking facilities (e.g. fuels and stoves that do not cause air pollution in houses) (IEA 2014a). Although this definition is similar to UNDP’s it is more comprehensive in that it includes access of electricity beyond the need for lighting at night. With the exponential penetration and use of mobile phones in rural SSA electricity for charging the handsets and for other household appliances such as radio and TV has become almost a basic necessity. This IEA’s definition also forms the basis of the statistics on energy poverty throughout this study.

It is important to mention here that although the discussion and statistics above may seem to imply a simplistic picture of energy poverty, this is not necessarily the case. Following Sovacool (2014) discussions on several misconceptions about energy poverty one begins to appreciate how complex and even counter intuitive the energy poverty picture can be. To mention a few relevant misconceptions here, firstly, although there is plenty of focus on rural areas, energy poverty is not an exclusively rural problem. Studies show that in developing countries the urban poor often suffer even more problems in meeting their basic energy need and often pay higher prices due to

[4] In developed countries the term mostly used is fuel poverty while energy poverty is mostly used when referring to developing countries. See Urge-Vorsatz, Diana Herrero, Sergio Tirado (2012 p.83) in *Building Synergies Between Climate Change Mitigation and Energy Poverty Alleviation*

energy inefficiency. Secondly energy for lighting and cooking/heating are treated in literature as if they are paramount, implicitly downplaying the importance of productive and mobility energy services. Productive energy services have tremendous impact on reducing drudgery and reducing time spent on time consuming duties such as fuel wood gathering and other physical household chores[5]. Insufficient mobility energy services has led to lack of motorized transport in many rural areas causing low mobility to ''stifle the attainment of better living standards'' (ibid), and limiting access to essential services such as education, health and markets. Furthermore Sovacool (2014) argues that there is no 'one-size-fits-all' solution to the energy poverty problem and argues that contextual factors and indeed cultural factors should be taken into account when designing projects to alleviate energy poverty. Finally the alarming idea that providing energy to billions of people will pollute the planet is untrue given that modern energy services tend to be more efficient and less polluting. IEA projects that achieving universal energy access by 2030 will only increase world carbon dioxide emissions by 0.7% (Sovacool 2014).

Notwithstanding the diverse definitions and the complexity of energy poverty, the use of the concept has enlivened the debate and increased enthusiasm on the plight of the energy poor. With a more or less common understanding we can now speak of measuring energy poverty, financing and business models and technologies to eradicate energy poverty and the barriers to alleviating energy poverty (Sovacool 2012b; Sovacool 2014).

In terms of technologies for eradicating energy poverty we can classify these into three; conventional electricity grids, mini-grids and off-grid technologies (Sovacool 2014) . This classification is differentiated on the basis of scale, installed capacity and the investment and technology required. Conventional electricity grids involve capital-intensive expansion of the existing grid to larger areas, usually at the national or international level with capacities exceeding 10 Mega Watts. Mini-grid technologies are located at the community level serving about 100 people with a small to medium technology between 20kilo Watts and 10Mega Watts installed capacity. At the household level we have off-grid technologies such as Improved Cooking Stoves, solar lanterns and SHS with installed capacities of lower than 20 kilo Watts. While extending existing grids tends to be top-down, off-grid technologies often take bottom-up approach. This study focuses on the off-grid technology, specifically the SHS and solar lanterns.

[5] See Hans Rosling's insightful TED talk on the 'The Magic Washing Machine' https://www.ted.com/talks/hans_rosling_and_the_magic_washing_machine?language=en

Other studies differentiate between decentralised (off-grid) and grid extensions approaches based on connectedness (or lack thereof) to the national /regional electricity grid system (Bhattacharyya 2013; Zerriffi 2011).

Technologies, Sovacool (2014) notes, is only 'one piece of the puzzle' in solving the energy poverty problem and therefore there is need for appropriate financing and business models to complement these. Energy provision brings together several stakeholders each with different interests, the government, private stakeholders, regulatory and development agencies communities and households. Despite the social and economic benefits that may be gained by providing energy access to the poor these often 'fall between the cracks' of sometimes opposing interests (Sovacool 2012b). For instance while governments may have ambitious goals to provide modern energy access to the rural poor they lack resources to do this. On the other hand the private sector, with the resources to close this gap, are demotivated by the view that they may lose out on profits by providing to the very poor. This calls for innovative business models that not only address this financial barrier but also navigate the barriers mentioned above. The specific model used to finance, organise and promote the use solar PV electricity in Lingeka and Nyanza village discussed in chapter eight, in this study is a good example of how an innovative model adapted to the local condition can be used to alleviate energy poverty. I refer to this model as the Lingeka-Nyanza model for purposes of brevity.

Energy poverty may thus be a new name for an age-old problem but with renewed enthusiasm and now armed with modern technologies, innovative business models, worldwide acknowledgment of the importance of energy access to all, global commitment and numerous studies, perhaps energy poverty may in the near future be the name of a nearly resolved problem.

3.1.2 Energy ladder or energy stacking?

The most common way of illustrating energy poverty is through the energy ladder. The energy ladder has been used to explain why and how the energy poor can transition to modern, cleaner energy sources and also to inform and support energy policies (Kroon et al. 2013). The energy ladder implies that the primary types of energy used in rural areas can be arranged progressively according to their efficiencies with the most traditional fuels such as animal power, candles and firewood at the bottom and more advanced modern fuels such as electricity and refined gasoline at the top (Sovacool 2012b).

While the energy ladder can be a useful in explaining different energy consumption patterns between the rich and the poor with implications on equity and affordability it has been criticized for not fully capturing the intricacies of household energy consumption especially in SSA and also for erroneously implying a linear and predetermined progression (Sovacool 2014).

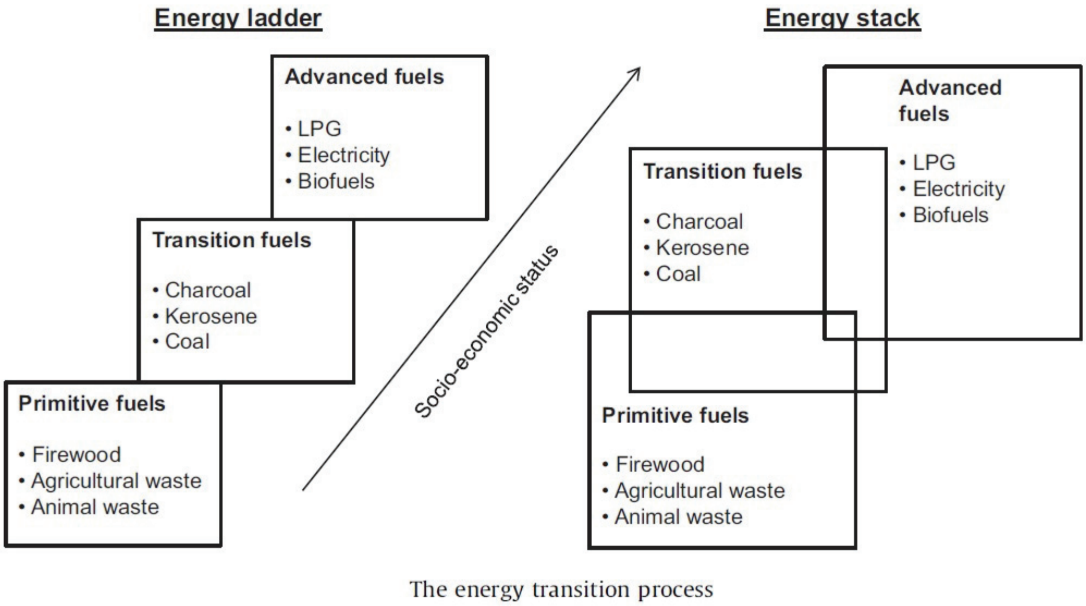

Figure 2: The Energy Transition Process. Source: Kroon et al. (2013)

The figure above shows the energy transition models, on the left is the energy ladder and on the right is the new model conceptualising energy switching behaviour (energy stack). Energy stacking, which at its simplest implies use of multiple energy sources by household has been proven as more accurate by several studies such as the use of charcoal and fuel wood by all income-groups in countries like Botswana, Zambia, Tanzania and Kenya (Sovacool 2012b) .

Kroon et al. (2013) argue that the energy ladder remains a 'myth' and that there is need to look beyond the income level to explain energy transition and take into account how other factors such as government policies, consumer markets and household preferences. They conclude that energy stacking can be seen as livelihood coping strategy for household with irregular incomes can protect themselves from unstable markets, hold onto their cultural practices, while benefitting to some extent from modern fuels(Kroon et al. 2013).

3.2 Energy-Environment Nexus

The second theme is the energy-environment nexus. Environment is understood here as the natural environment that encompasses all living and non-living things including phenomena such as weather, climate and natural resource that affect human survival and economic activity (Johnson et al. 1997). Masud et al. (2007) exploring the linkage between energy-poverty-environment, views energy as the common denominator and argues that there are "reinforcing linkages between inadequate energy access, enduring poverty, and environment degradation that inevitably entraps billions of people in conditions of extreme deprivation". We can view the energy-environment nexus at two levels: at the micro level and the global level. At the micro level it is evident that in SSA, the majority of rural household rely on fuel-based lighting and traditional biomass fuel that not only affect their indoor environment through pollution from smoke and soot, but over-reliance on the locally available fuel sources negatively affect their immediate environment through deforestation, deterioration of land productivity, destruction of natural habitat and ecological imbalance (Masud et al. 2007).

At the global level, the 2010 World Development Report posits that although climate change threatens all countries, developing countries are the most vulnerable. This report estimates that even a minimum temperature rise, would result in 4-5% of permanent reduction in the GDP's of Africa and Asian countries (Bierbaum & Fay 2010). Burning of fossil fuels to supply energy is the leading anthropogenic cause of GHG emissions causing global warming (Bierbaum & Fay 2010). And although the developing countries[6] are not responsible for the bulk of this emissions, the 2.6 billion people in these countries relying on combustible fuels such as biomass, kerosene and low cost diesel (to run agricultural generators), contribute significantly to these emission. In 2005 for instance, about 77 billion litres of kerosene and diesel was used for fuel-based lighting globally (Pode 2010).

Replacing traditional biomass fuels and fuel-based lighting with modern energy supplies can reduce emissions of black carbon (soot) thereby improving the health of women and children otherwise exposed to high levels of indoor air pollution, reducing deforestation and land

[6] In 2011 Tanzania produced around 1.9 Million metric tons of CO_2 (ranked 111) while Norway produced 12, 4 Million metric tons of CO_2. (ranked 64) Source: http://cdiac.ornl.gov/trends/emis/top2011.tot

degradation (Bierbaum & Fay 2010) and develop human and economic capacity to adapt in the face of a changing climate (Casillas & Kammen 2010).

Given that the world is largely dependent on high carbon fuels (oil, gas and coal), the noble objective to increase modern energy access for the world poor competes with three other objectives energy policies have to balance. These are, sustaining economic growth, enhancing energy security and improving the environment (Bierbaum & Fay 2010) referred to as the ‘‘disturbing ‘trilemma’’ (Benali & Barrett 2014). In order to tackle this challenge, several energy policy options have been fronted, however two of these stand out. First is energy efficiency, which targets to reduce energy demand and secondly the adoption of renewable energy sources which will diversify the energy mix. Improving energy efficiency and increasing the share of renewable energy sources are also the main objectives of SE4All initiative and at the crux of goal 7 of the proposed post 2015 world development agenda.

3.2.1 solar energy: a bright solution for rural East Africa?

Increasing concerns about environmental preservations, depletion of fossil fuels, climate change and energy security have drawn the world's attention towards renewable energy since the 1950's (Colombo et al. 2013a). There is an array of available renewable energy technologies (RET's) for rural contexts. Barbieri and Simonet (2013) analyse the major RET's for supplying electricity. These include Solar PV, small wind, small hydropower and biomass gasifiers and hybrid systems. They describe each technology and discuss its economic and environmental impact and suitability to specific local contexts. For the purpose of this discussion, the focus is on the solar PV which is the most common of all RET's in SSA (Karekezi & Kithyoma 2002) and the focus of this study.

The push for RET's in rural SSA and East Africa in particular has renewed optimism about technological leapfrogging i.e. bypassing the conventional path of energy development and directly adopting more efficient and environmentally friendly technologies (Murphy 2001). While this idea is optimistic and exciting, Murphy (2001) argues that this might not be the case for rural households in East Africa. He explains that technological *absorption* as opposed to technology *adoption* does not occur in 'leaps' but is an evolutionary process driven by individual and regional accumulation of 'technological capabilities' (Murphy 2001, emphasis in original). While adoption can occur simply by households using a given technology, absorption requires development of this capability, which includes technical, organizational and institutional skills that ‘‘allow productive enterprises to utilize information and equipment efficiently’’(Murphy 2001).

To illustrate the potential and challenges of leapfrogging take the example of using the solar PV technology. For household use, solar lanterns, pico-solar system and SHS are the most common (see figure 3 below). Although Solar PV remains the most common of all RETs in SSA, it has certain limitations that hinder its utilization by many rural poor. With regards to household energy needs, the solar PV is prohibitively expensive and not readily available to the rural poor. Secondly since most of the energy in rural household is used for cooking, the low voltage electricity generated from solar PV cannot replace the use of biomass fuel (Karekezi & Kithyoma 2002). Thirdly, often these technologies are not efficiently utilised and often lack proper maintenance and repair (Murphy 2001). Despite the many benefits mentioned earlier in our discussion about solar PV in rural households, these challenges hinder the adoption of this technology and hence a ‘leap’ in technology may not be realistic. If RET’s are to be regarded as bright sustainable solutions it is imperative that planners focus not only on technical and economic viabilities of RET’s but also improvement of technological capability to the local context and conditions and of the local people (Murphy 2001).

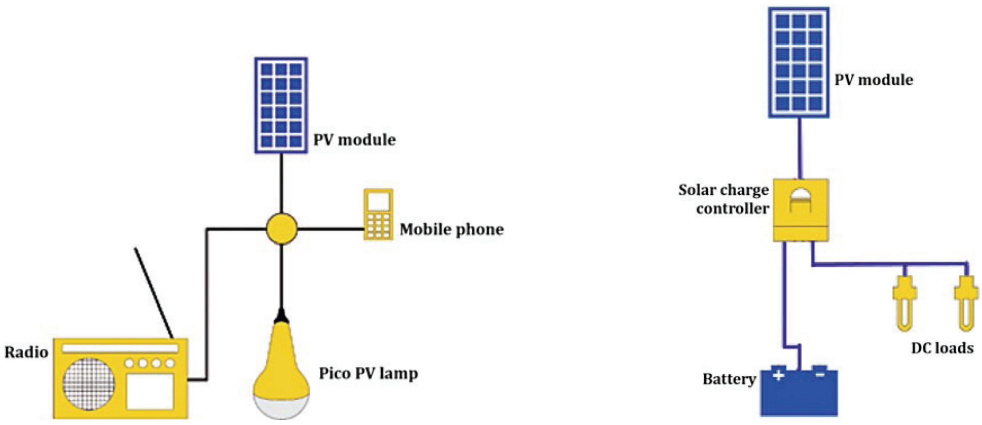

Figure 3. Schematic representation of two common configurations of a Solar Home System (Barbieri & Simonet 2013)

Demonstrating the profound health risks associated with the use of kerosene fuel lighting, Pode (2010) discusses barriers that hinder acceptability of solar-powered lighting in rural areas despite the fact that the latter are more efficient and durable, require less maintenance, are environmentally friendly and contribute to saving lives. Looking at specific solar projects in several African and Asian countries this study identifies economic, technical, market, social and institutional barriers that to varying degree hinder the adoption of solar PV technology in these countries. In rural Tanzania for instance the study lists the major and secondary barriers and suggests mechanisms to overcome these as shown in the table below.

Table 2 Barriers to adoption of solar PV technology in rural, Tanzania

Barrier	**Degree of importance**	**Methodology to redress issue**
Limited awareness of, and experience with PV technology. Energy is a low priority area among users	Major barrier	Increase understanding of solar PV via TV/radio programs, personal networks
Inadequate business knowledge and capacity for distribution.	Major barrier	Build business knowledge and capacity for distribution of solar PV systems.
Limited technical knowledge of installation, operation and maintenance	Major barrier	Training, promotion, trade fair
High cost of solar systems, initial capital investment and operation and maintenance costs	Major barrier	Link installation of PV systems with poverty alleviation projects.
Low purchasing power of the rural people.	Major barrier	Subsidize promotion of solar technology
Difficult access to finance for end users	Secondary	Subsidize promotion of solar technology.
Lack of established dealer network.	Secondary	Build a network of dealer.
Inadequate policy implementation.	Secondary	Formulate/revise policies to support solar PV.

Adapted from Pode (2010)

Pode (2010) notes that one solution to enhancing the acceptability of solar PV technology in rural areas is the formation of acceptable and rural consumer friendly business and finance models. According to him, the success of any new technology depends on viable business model and its widespread adoption by consumers.

3.2.2 Financing and business model for rural electrification

As noted earlier absorption of RET's and especially solar PV electricity is only 'one piece of the puzzle'(Sovacool 2014) and is therefore need for appropriate financing and business models to bridge the gap between the RET's and the energy poor. In other words, now that there are documented viable modern technologies that can reduce energy poverty how do we make this expensive technology sustainably available to the rural energy poor that not only are mostly in need of these but also are hindered by several challenges in acquiring and accessing modern technologies?

Several studies have acknowledged this gap for instance Colombo et al. (2013a) argue that in order to eradicate energy-poverty and preserve the environment there needs to be paradigm shift in how energy is produced, used and distributed. As the impact of climate change and energy security exposes the 'fragility of the current system based of fossil fuels', off-grid RET's begin to be seen as viable alternatives. For off-grid renewable energy sources they identify three crucial elements; sound technical solutions, enabling policies and innovative business models. Emphasizing on the importance of business models as a key issue to be resolved in rural electrification, Zerriffi (2011) notes that providing technology for free to the rural poor has proven to be unsustainable and although subsidies may be important in overcoming the high initial costs, subsidies may diminish the effectiveness of other options that might contribute to overall development in rural communities.

Discussing how the paradigm of energy access and development has evolved from donor gift paradigms famous in the 1970's-1990's, followed by market creation paradigms in the 1990's-2000's Sovacool (2014) suggests a new 'sustainable program paradigm'. This paradigm as shown in the table below unlike its predecessors brings together multiple stakeholders from different spheres, goes beyond technology diffusion to emphasize environmental and social sustainability, involves extensive maintenance and after-sale services and recognizes community's cost-sharing and in-kind contributions.

Table 3. Three Paradigms Of Energy Development And Access

	Donor gift paradigm (1970s- 1990s)	Market creation paradigm (1990s-2000s)	New 'sustainable program paradigm (2010s - ?)
Actors	One, usually a government or donor	Multiple government agencies and/or multilateral donors	Multiple public, private and community stakeholders
Primary goal	Technology diffusion	Market and economic viability	Environmental and social sustainability
Focus	Equipment, often single systems	Multiple fuels (e.g. 'electricity' or 'fuel wood')	Energy services, income generation, institutional and social needs
Standardization	Little standardization between projects	Some standardization	Harmonized with certificates, testing regimes, and national standards
Implementation	One-time disbursement	Project evaluation at	Continuous evaluation and

		beginning and end	monitoring
After-sales services and maintenance	Limited	Moderate	Extensive
Ownership	Given away/ free	Sold to consumers	Cost-sharing and in-kind contributions
Awareness raising	Technical demonstration	Demonstration of business models	Demonstrations of business, financing and social models

Source: (Sovacool 2014)

In our earlier discussion we mentioned that there are several technological options that can expand energy access in rural areas. Financing and business models on the other hand seem to be numerous and context specific. Owing perhaps to their novelty, there seems to be neither formal definition nor classification of the various business models. However following Krithika and Palit (2013) a model is in this study defined as, "an overall framework within which a project operates including the choice of technology, financial viability of the model, institutional set up, role of various stakeholders and the regulatory and policy framework." This definition further distinguishes between business models and participatory models. For a purely business models the investor's prime motive is profit whereas participatory models seek to create access to electricity through sustainable partnership with the local communities. A model that seems to operate between these the two can be defined as a social-enterprise (Samer 2012).

With regards to classification of finance and business models different studies have classified these in the off-grid energy sector differently. For instance while the World Bank classifies the electricity supply models according to ownership (private, NGO), ESMAP classifies these according to type technology and UNDP categorizes the model according to the mode of delivery (commercially led, utility model) (Krithika & Palit 2013). For my analysis however I use a more exhaustive classification by Sovacool (2014) who classifies the finance and business model into the following; a technology improvement model, a microfinance model, a project finance model, a cooperative model, a community fund model, a fee for service model, a cross-subsidization model and a hybrid model.

3.3 Engendering Energy in SSA

I now turn to the third nexus, energy-gender nexus that is relevant to our discussion and one that the Lingeka-Nyanza village project is especially concerned with. Scholars use the term engendering energy to allude to the discussion related to gender issues in the energy sector

(Batliwala & Reddy 2003). In this study the term gender refers to 'the socially constructed roles and socially acquired behaviours and expectations associated with men and women' (World Bank, 2001 cited in Njeri 2002). It is important to mention that gender is not a binary condition and is graduated by other social, cultural and economic factors too such as wealth, age, status (Khamati-Njenga & Clancy 2002). Discussions about gender are therefore not about women issues alone but about men as well and the socially constructed relationship between women and men. However it is no news that globally, the gendered position of women places them at a disadvantage as compared to the men and hence the more relative focus on women in gender discussions. The gendered position of women puts them at a disadvantage having limited access and control over resources and little decision-making power. To further illustrate this point, it is estimated that 70% of the people living in poverty are women and that a third of all rural households are female-headed who often are vulnerable to changes outside their control such as drought (Khamati-Njenga & Clancy 2002; Lambrou & Piana 2006).

While gender issues in energy seem to have received attention at the household level these issues are yet to be substantially addressed at the macro policy level in most countries in SSA (Karekezi & Kithyoma 2002) .Some scholars noting this, argue that energy policy planning has in theory assumed gender neutrality which in reality has resulted in gender-blindness (Clancy n.d.; Khamati-Njenga & Clancy 2002). Given that energy in development plans focuses on large-scale, capital intensive technology projects which are often male dominated, small-scale, management intensive activities mostly carried out by women such as household energy consuming activities, transportation of water and fuel have led to the relative exclusion of women in energy planning (Khamati-Njenga & Clancy 2002). Gender neutrality assumes that good energy plans and programs will benefit women and men equally. In practice however this results in gender blindness which fails to recognize that women and men's energy needs are different, excluding women and not changing gender relations which are mostly biased against women (Khamati-Njenga & Clancy 2002).

Although the focus on gender-energy link at the household level is praiseworthy in that it has raised awareness on issues such as women's time use, drudgery and health, critics argue that this has reduced the gender-energy problem to a rural dimension, fuel wood and cooking (Njeri 2002). This women-targeted approach led to energy development efforts in the 1980's that focused on technological 'quick fixes' such as improved cook-stoves, solar cookers and biogas (Karekezi & Kithyoma 2002; Njeri 2002). Despite reports on the poor performance of such approaches, such projects continue to attract donor support (Njeri 2002). Tracing the evolution of thinking in gender and energy, Khamati-Njenga and Clancy (2002) observe that in the 1990' debates on gender-energy link, broadened to include issues such as transport and modern energy forms especially electricity produced by decentralized RET's and its potential to contribute to income generation in rural areas (Ceceslki, 1995 cited in Khamati-Njenga & Clancy 2002). With the introduction of the MDG's, energy and gender issues was elevated from the project and household level to international policy levels. Havet (2003) explains how the gender-energy nexus can target six of the MDG's; eradicate extreme poverty and hunger, achieve universal primary education, reduce child mortality, ensure environmental sustainability, and promote gender equality and empower women.

3.3.1 Beyond cooking stoves; Gender mainstreaming and women's empowerment

A critical concept nowadays in the development circles is gender mainstreaming. Gender mainstreaming means "ensu[ring] that women's as well as men's concerns and experiences are integral to the design, implementation, monitoring and evaluation of all legislation, policies and programs so that men and women benefit equally and inequality is not perpetuated"(Khamati-Njenga & Clancy 2002). Gender mainstreaming is different from earlier gender approaches to energy which focused at specific projects that could fulfill particular women needs such as the improved cooking stoves (Skutsch 2005). In contrast, gender mainstreaming means that all potential interventions need to be considered from both women's and men's point of view (Skutsch 2005). Gender mainstreaming has thus become both a goal and a methodology for achieving women's equality and empowerment (Clancy n.d.). Women empowerment is a key factor in ensuring that women and men enjoy socially valued goods, opportunities, resources and equal participation in decision making.

Several studies have shown that energy interventions can contribute to gender equality and women's empowerment by involving women throughout the process and in decision-making roles from which they have traditionally been excluded which may contribute to transformation of the gender roles (Winther 2011). A ethnographic study on the effect of a NORAD funded electrification project in 1991 on gender equality in rural Zanzibar, an island off the coast of

Tanzania concluded that the women were empowered and gender equality enhanced to a considerable extent (Winther 2011). The project ensured a gender focus in two main ways. Firstly an equal number of women and men were invited to participate in a surveying course and successful finalists were then hired. Secondly the project had as its main objective to provide electricity for public services (water pumps, health centres, street lighting) with women considered as the prime beneficiaries. Twelve of the 14 finalists were women some of whom were still working in the electricity company fifteen years later. Due to the project 80% of the rural population in Zanzibar had also access to electricity (Winther 2011). Nevertheless although the electrification project succeeded in facilitating a genuinely participatory process during implementation it failed to balance the fact that the prime-decision makers in the village were men that led to ignoring women's potential productive interests in the process. For instance two institutions directly affecting women, a grain grinding meal and a kindergarten, remained unconnected unlike the fish market and the local mosque frequented by men (Winther 2011).

Women have less decision-making powers in their families and communities as compared to men and have therefore limited opportunities to participate in rural energy programs (Lambrou & Piana, 2006). Empowering women would thus imply greater financial autonomy (access to and control over their own financial resources), social freedom which can lead to women making decisions on issues that shape their lives both within the household and at the societal level. Therefore as the gender-energy discussions move beyond fixing 'women's' issues' by providing them with improved cooking stoves, through gender mainstreaming women participation at all levels of energy related projects and policies has become an important eye opener in the quest for women empowerment in and through the energy sector. A study in 2008 for instance concluded that by training women to become barefoot solar engineers in the solar energy program in rural Afghanistan significantly contributed to the empowerment of these women's social and political roles (Standal 2008). This study also found that intervention efforts that enhance women's association with modern, desirable technologies might be turned into more permanent transformations in gender perceptions and roles (Standal 2008; Winther 2011).

4.0 Conceptual and Theoretical Frameworks

This part focuses on the theoretical discussions and conceptual framework that both guided the collection and analysis of the data. It is divided into three parts in line with the three research questions of the study.

4.1 Energy Quality of Life framework

Rio and Burguillo (2008) note that existing literature on renewable energy and its contribution to sustainable development focuses more on the environmental benefits (i.e reduction of global and local pollutants) and less on the socioeconomic impacts. Furthermore, they observe that the existing analyses of the socioeconomic benefits of RE projects have been too general and abstract and also lack a focus on the regional and local level mostly because of the lack of a consistent theoretical framework (Rio & Burguillo 2008). They thus propose an integrated theoretical framework, which allows for comprehensive analysis of the impact of renewable energy that can be empirically applied to identify the socioeconomic benefits in rural areas. Their framework is developed for rural areas in developed countries and has therefore limited applicability to developing countries because of the difference in socioeconomic, political, institutional and cultural contexts (Rio & Burguillo 2008). Moreover most renewable energy projects in SSA are small-scale and focus more on provision of energy at low cost and less on direct employment creation. The Lingeka-Nyanza project, which this study focuses on, is also modest as compared to what the integrated framework envisions. For instance the framework suggests examining the impact on tourism a renewable energy project may have. Although large off-grid projects may have modest impact due to low competitiveness against more famous tourist destinations, this component is virtually non-existent in the smaller off-grid projects typical in SSA rural areas.

Therefore although the framework suggested by Rio and Burguillo (2008) gives crucial concepts and perspectives when analyzing the socioeconomic impacts of a RE project it does not fit within the context of small scale off-grid RE projects that are common in rural areas of SSA. A more appropriate conceptual and analytical framework is suggested by Obeng and Evers (2009) which provides a basic understanding of how solar PV impacts on energy poverty. The figure below demonstrates the Energy Quality of life framework

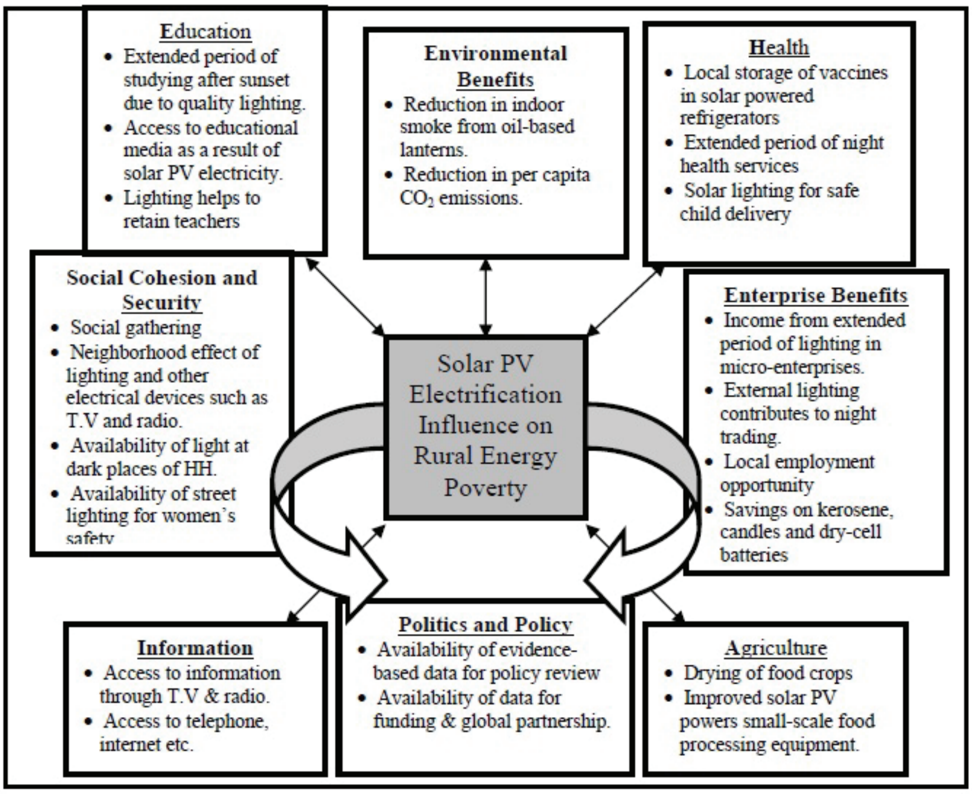

Figure 4 Energy Quality of Life framework. Source (Obeng & Evers 2009)

Although Obeng and Evers (2009) acknowledge that the provision of electricity per se does not alleviate poverty. They argue that its link to poverty is undeniable and that electricity, as a physical infrastructure, can increase social resilience and reduce social exclusion felt by people in rural areas. In particular they explore the non-monetary link between solar PV electrification and the quality of life of rural households. By exploring wider issues, as opposed to the common money-metric and economic based researches (for instance many researches examine the cost-benefit of PV projects in rural areas and the proportion of energy expenditure of the household budget) this framework offers an insightful and a holistic perspective of such projects on the life of the rural poor.

The analysis in this study draws mainly on the quality of life framework to identify variables that are significant when considering the socioeconomic impact of a Solar PV electrification project. As illustrated above the framework identifies seven spheres that may be directly influenced by solar PV electrification in rural areas: education, the environment, health, information, agriculture, enterprise, social cohesion and security. The eighth sphere politics and policy, requires documented evidence and empirical research on the impact on the other spheres in order to both influence policy and perhaps attract funding and investment (Obeng & Evers 2009).

The framework posits that living a quality life depends on the fulfillment of certain life goals in the aforementioned spheres; access to quality food, access to better education and health, better access to information, and security. Solar PV electrification contributes to reducing energy poverty and improvement in these eight spheres. The positive benefits in turn influence adoption and expansion of solar PV in the rural areas. This double relationship indicates that the effect goes both ways and may be considered mutually reinforcing. Additionally the documented benefits on education, health, environment, agriculture, information, social cohesion and security can then be use to influence policy and attract both funding and investment in rural energy.

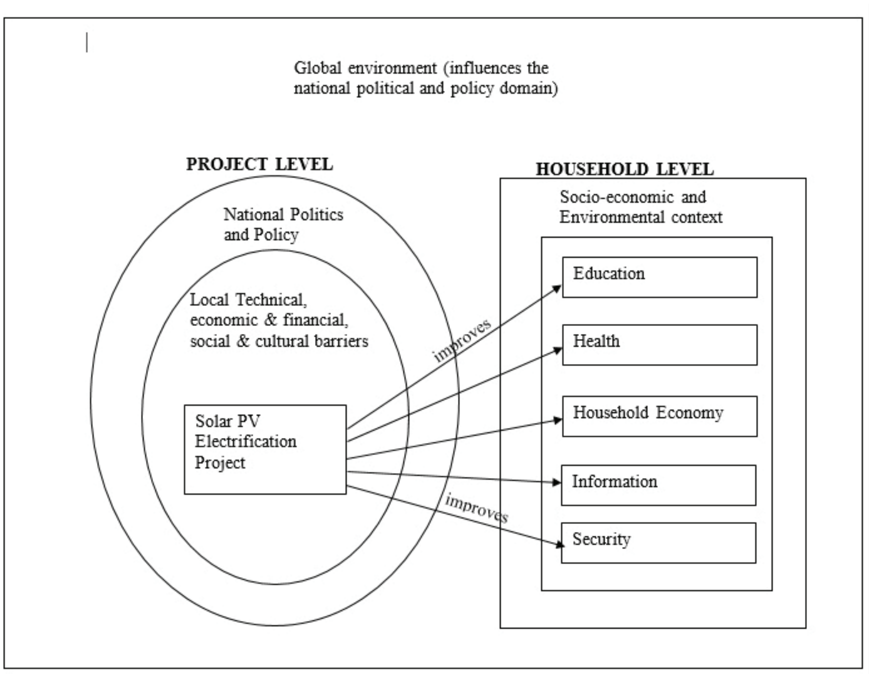

Figure 5 Conceptual framework Adapted from Obeng and Evers (2009)

Adapting this framework to the household we get a different perspective. As indicated by the figure above we see how a specific solar project is influenced at the global level (the larger rectangle) by the global environment such as international trade, partnerships and so on. This in turn influences the politics and energy policy of a given nation, which impacts the local level in terms of economic, technical and cultural barriers (the concentric oval circles). These factors and barriers determine the framework of the Solar PV project. Depending on the specific socio-economic context of the household the Solar PV projects impacts on the household the various spheres such as education, health, information, household economy and security. Through expansion of the socio-economic benefits of the project at the household level the solar project thus contributes both directly and indirectly to reducing energy poverty.

4.2 CARE Women's Empowerment Framework

There are several gender analysis frameworks[7] that could have been useful in analysing the gendered impact of the women BSE in this study. Although gender-analysis frameworks have many similarities, they differ in their purpose, scope and emphasis (March et al. 1999). The choice of a particular framework for gender analysis therefore is not about which framework is wrong or right but rather that how suitable the given framework suits the context and task at hand. Equally important is that the researcher is aware of the underlying principles of the framework and a clear understanding of the aims of the of the study object (Warren 2007). Given that one of the stated goals of the Lingeka-Nyanza project was that the women and girls empowerment, a gender-analysis framework that captured this aspect was selected as most suitable for the study.

Although the term empowerment is much used it is also probably misunderstood, often defined differently by different actors (Khamati-Njenga & Clancy 2002). For instance while the Human Development Report 1995 definition emphasizes that empowerment is about participation, Oxfam sees empowerment as about challenging oppression and inequality while Rowland (1995) notes that empowerment cannot be bestowed on people from the top and is thus a bottom-up process. Feminist activists on the other hand stress that women's empowerment is not about replacing one form of empowerment with another but should rather lead to ''liberation of men from false value system and ideologies of oppression''(Oxaal and Baden, cited in 1997 Khamati-Njenga & Clancy 2002).

[7] A detailed discussion of these is beyond the scope of this paper see however 'A Guide to Gender-Analysis Frameworks' (March et al. 1999) for comparison of these frameworks.

Empowerment is closely related to power. Following on Anthony Gidden's structuration theory we can distinguish between the different modes in which power operates and which objectives it may have (Khamati-Njenga & Clancy 2002; Martinez,n. d.). 'Power *over',* implies dominance and subordination and is often linked to violence and intimidation. 'Power *with*', implies one's ability to influence other agents and structure through cooperation in order to achieve their interests. 'Power *to'* involves personal ability to know, achieve and pursue one's interest for instance power to make decisions. Power *within* is seen as one having self-confidence, self-awareness and being assertive. Acknowledging these different modes of power can be helpful in understanding the tensions generated by empowerment for many women (Martinez,n. d.). While one can view women's involvement and participation in development projects as empowerment, these women may still lack power *within* and power *to* make decisions in their household.

CARE's women's empowerment framework captures aspects of power *to*, *within*, *over* and *with* is used for the analysis and discussion of the second research question. This framework conceptualizes women's empowerment as both a process and an outcome that comprises three dimensions. The empowerment process is non-linear in that it can progress, freeze or regress. As a process empowerment is defined as,

"Expansion of women's individual and collective capacities to access, influence, and control **resources**; to confront and challenge **gender norms and structures of power**; and to negotiate with, influence, control, and **hold accountable the actors and duty bearers** that mediate between structural inequities and women."(Martinez,n. d. emphasis in original).

As an outcome empowerment ensures that women have greater access to, influence over, and control of all forms of capital; economic, ideological, political, social and cultural, and that they have an enhanced ability to understand and analyse the terms and conditions of gender exclusion and discrimination in their local communities (Martinez,n. d.).

The CARE framework also conceptualises social life as consisting of three dimensions as shown in figure 6 below. These are, agency, structure and relations. Agency involves the aspirations, resources, actions and achievement of a woman resulting from their own decisions and actions. Agency captures the idea of 'power *to'* and 'power *within*.' Structure refers to both the tangible and intangible environment that surrounds and conditions a woman's choices and chances. A given societal structure produces agents and is in turn (re) produced by these agents. Structure includes the routines, patterns of relationship and interactions, institutions that establish social norms, order and hierarchy. Structure determines what is 'normal' behaviour and who 'naturally ' has power over what or whom. Examples of structure include kinship, castes, religion and political culture. Relation refers to the social relationship through which a woman negotiates her needs and rights with other social actors. As mentioned above this corresponds to having 'power *with'*.

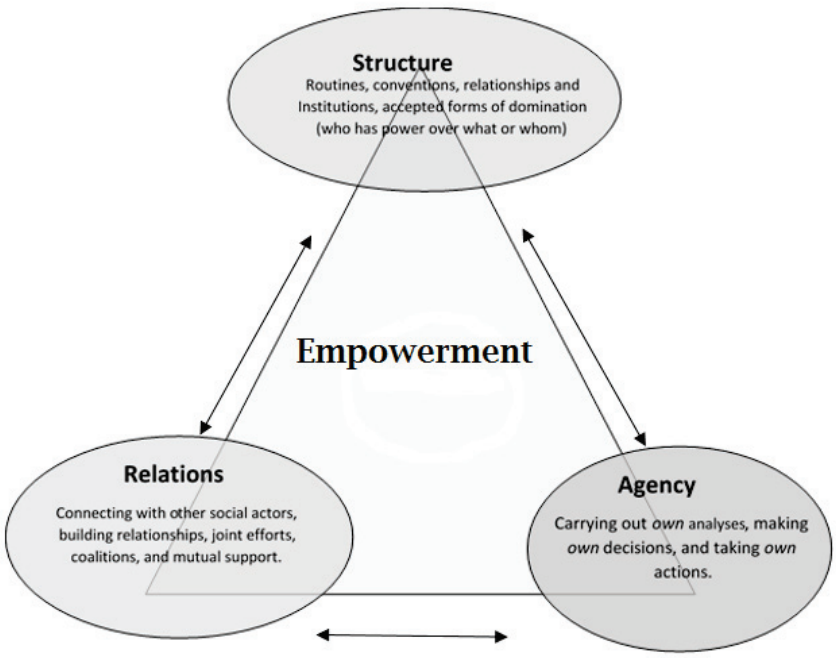

Figure 6 CARE women's empowerment framework. Source (Martinez,n. d.)

Agency and structure are influenced by relationships between and among people. At the same time forms and patterns of relationship are influenced, often in hidden ways, by agency and structure. (Martinez,n. d.). The CARE empowerment framework views the three dimensions are closely related and causation can flow from any of the three. However the framework cautions that there is no guarantee that change in one dimension automatically leads to changes in the other two. According to this framework sustainable changes in empowerment are realised when changes occur across all the three dimensions. Given that empowerment differs from one culture to another and form one context to another, the framework further subdivides the dimensions into 23 sub-dimensions some of which are more relevant in one culture than another (Martinez,n. d.) The table below shows summarizes some of the sub-dimensions in the CARE Women's Empowerment Framework that are relevant in our discussion of the women BSE in Lingeka and Nyanza village.

Table 4 Summary of the sub-dimensions of the CARE Women's Empowerment Framework

	AGENCY	STRUCTURE	RELATION
1	Self-image; self-esteem	Cultural norms, traditions, gender roles	Awareness of gender discrimination
2	Access to Information and skills	Market accessibility (labour, credit, goods)	Negotiation/ adaptation habits
3	Material assets owned		Alliance/coalition habits
4	Control of own labour		
6	Mobility in public space		
7	Decision making and influence in household		

Source: Adapted from Martinez (,n. d.)

4.3 The 4A's Framework

As noted earlier in our discussions, alleviating energy poverty in rural areas goes beyond technical solutions and requires that appropriate financing and business models are designed to ensure the sustainability and the absorption of modern sources of energy by the locals. In this perspective the third research question of this study examined the Lingeka-Nyanza model. This model is analysed through the 4A's framework that has been used to design and develop business models targeting the people at the 'base of the economic pyramid'(Bengo & Arena 2013). 'Bottom of the Pyramid' is a term that refers to majority of the population that is usually ignored by commercial enterprises due to assumptions of their low purchasing power (Zerriffi 2011). This term Zerriffi (2011) has become a powerful organizing idea for creating new opportunities to make money while solving societal problems and meeting environmental goals or rather an opportunity to resolve the the ‘disturbing trilemma’ (Benali & Barrett 2014) mentioned earlier. The people at the bottom of the pyramid is, in this case, the 1.4 billion paper across the globe that do not have access to electricity; the energy poor.

The 4A’s denote four principles: Availability, Affordability, Awareness, and Acceptability against which the model in question is measured. Mapping business model against this model gives a matrix of how low or high the business model scores across each of these four principles. The 4A framework thus asks a set of four questions to the model:

1. How affordable does the model make the product in question (affordability)?
2. How readily can the locals acquire the products (availability)?
3. How likely are the different actors on the supply chain willing to distribute, sell and consume the product (acceptability)?
4. How aware are the locals/consumers of the product (awareness)?

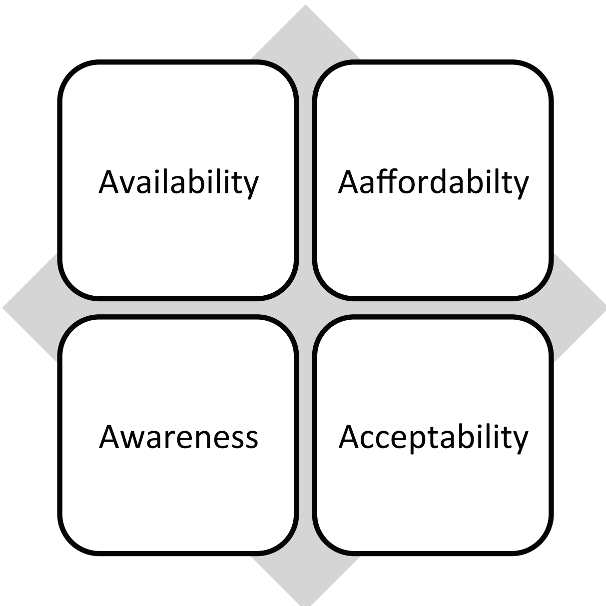

Figure 7 4A's Framework

In this study the product in question are the various solar equipment sold both during the inception of the project and those acquired later by the VEC and the after-sale services offered by the women BSE’s in Lingeka and Nyanza.

5.0 Research Methodology

5.1 Introduction

The choice of research method is determined by the purpose of the study and the suitability of the method to answer the research question(Angelsen et al. 2011; Berg & Lune 2012) . In this study I used a mixed method approach that is a combination of quantitative and qualitative research strategies. Quantitative research can be understood as a research strategy that emphasizes quantification in the collection and analysis of data (Bryman 2008), qualitative research on the other hand refers to "meanings, concepts, definitions, characteristics, metaphors, symbols and description of things" (Berg & Lune 2012). Put simply, quantitative research refers to counts and measures of things while qualitative research refers to its essence and ambience (Berg & Lune 2012). Here the mixed method approach is briefly discussed followed by the study's research design (i.e data collection, storage, analysis and presentation) and the research population and sampling. The section ends with a discussion of some of the ethical issues and limitations of the study.

5.2 A mixed method approach- why and how?

When carrying out research one is often seemingly bound to choose either a quantitative strategy or a qualitative one. Many researchers therefore tend to commit to one of these methods arguing that mixed method research is neither feasible nor desirable (Bryman 2008). There are two main arguments against mixed method research; the embedded methods argument and the paradigm argument. Reviewing the first argument Bryman (2008), notes that the idea that research methods are embedded to ontological and epistemological position is difficult to sustain and that the research methods can be put to a wide variety of use. In other words the seemingly opposing position on ontological and epistemological question between the two methods should be viewed as tendencies and not hard-wired differences. Secondly the argument that the different methods are conceived as different paradigms and therefore incompatible cannot be demonstrated especially in social research. While it is true that paradigms are incompatible, quantitative and qualitative research are in themselves not paradigms. Furthermore there are numerous areas of commonality and overlap between these two for instance the use of quantification by qualitative researchers (Bryman 2008).

The mixed method approach does not however seek to replace either of the two but rather a way of using the best of both worlds to best help in answering particular research questions (Bryman 2008). There are different ways of and reasons for combining the qualitative and quantitative approach such as triangulation, facilitation and complementarity (Hammersly (1996) cited in Bryman 2008) . For this study the mixed method approach enabled collection of relevant information specific to each of the three research questions allowing for both in triangulation of the data and complementarity. Quantitative strategy was mainly used for to fulfil the first question one while qualitative strategy was used for the second and third research questions.

5.3 Research Design

The research design is the overall process of using one's imagination as well as scientific and strategy and tactics to guide the collection and analysis of data (Gray et al. 2007) . Since this research specifically focused on the solar project in Lingeka and Nyanza village, the case study approach was adopted. This approach involves a detailed, intensive, holistic and contextual study of a given case (Berg & Lune 2012; Bryman 2008). Through this approach the researcher sought to explore the impacts of the project, describe the projects model and explain its effectiveness as a case of energy poverty alleviation endeavor in rural Tanzania. Although case study involves distinct stages, for the qualitative part this study adopted a spiraling approach. This approach views the research process not as linear progression, but spiraling forward (Berg & Lune 2012). In this approach the researcher keeps revisiting and refining the different stages as the research progresses as shown in the figure below.

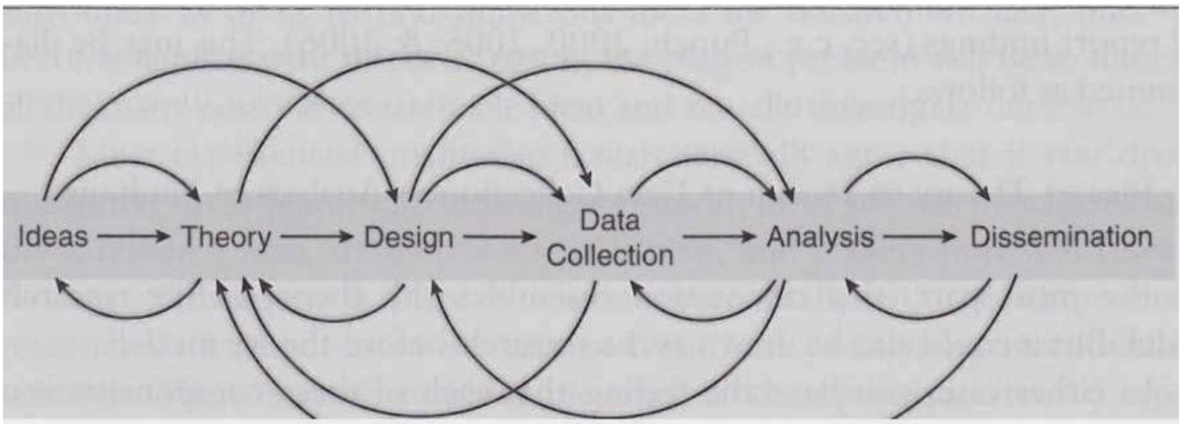

Figure 8 The Spiraling Research Approach (Berg & Lune 2012)

5.3.1 Population and Sampling Design

Population is the universe of units from which a sample is to be selected which would then be used to make some inferences (Berg & Lune 2012; Bryman 2008). The population of this study is the people of Lingeka and Nyanza villages. The study used household as the unit of analysis. In this study a household refers to a person or group of persons who reside in the same homestead but not necessarily in the same dwelling unit, have same cooking arrangements, and are answerable to the same household head (URP 2013). Given that this study employee a mixed method approach, both probability and nonprobability samples were collected.

For the quantitative part, the research employed a stratified random sample. According to Berg and Lune (2012), this sampling strategy requires prior information that enables the researcher to divide the site into strata where a sample is then selected from each stratum. The sub-villages served as separate strata. Two villages, Lingeka (the solar electrified village) and Mwakisandu (the control/ non-electrified village) were selected. Lingeka has 10 sub-villages and Mwakisandu has 8 sub-villages. Mwakisandu was selected as a control village due to its similar socio-economic and cultural characteristic to Lingeka Village and also due to its proximity and ease of access within the limits of this study. According to the 2012 Tanzania population census report Lingeka had a population of 6,803 and an average household of 8.3 while Mwakisandu had a population of 8,941 and an average household size of 7.2 persons (URP 2013).

With the household as the unit of analysis, a questionnaire was used to collect data on the socio-economic conditions and the impact or lack thereof of access to solar electricity. A total of 80 questionnaires was collected, 40 from each of the two villages. Given that the sample was random and stratified care was taken to ensure that at least one household from each of the sub-villages was represented. This data was collected through a structured questionnaire (see appendix 10.2) together with my field assistant who also doubled up as the translator. Although the researcher understands Swahili, some of the villagers understood *Kisukuma* better than Swahili. This made it easier to collect data.

For the qualitative part the researcher used purposive samples and convenience sampling. In order to choose a purposive sample a researcher needs prior knowledge about the group in order to choose the subjects (Berg & Lune 2012). The purposive sample included all the four women BSE's, members of the two VEC's and two representatives from ICS. The convenience sample was used to choose participants of the three focus group discussions from each of the villages. Care was taken however to ensure that each group was representative of the village including men, women and both the youth and the elderly.

5.4 Data collection methods

The data was collected in October 2014 from the three villages. Since the initial questionnaire was based on desktop research, a brief pilot study was conducted to test household questionnaire out in the field. The researcher and his assistant conducted this pilot study jointly in order to ensure a common understanding and interpretation of the questions. Some of the adjustments made were removal of redundant and repetitive questions, use of simpler language to ensure easier translation and cutting down on time to about 30-45 minutes for each questionnaire. In addition to the questionnaires the research used the following data collection methods, qualitative individual interviews, focus group discussion, observation and photographs.

5.4.1 Questionnaires

Eighty questionnaires were administered to random households in Lingeka and Mwakisandu villages. Since majority of the respondents did not understand English, the assistant translated the questions into Swahili and/or *kisukuma* and filled questionnaire forms. The researcher would pose the translated question to the respondent and then note down the responses in English. All the questionnaires were conducted at the respondent's household. Due to the great distances and in order to reach households in remote hamlets the researcher used motorcycle. Even in the remote hamlets the households tended to be sparsely located. Using a motorcycle was an attempt by the researcher to ensure that the random sample fulfilled the validity criteria.

5.4.2 Observation

Another important data collection method used was both direct and participant observation. The researcher was in the field from the 1st to 21st of October 2014. During this period the researcher took transect walks within the village where he observed and took photos of the various solar equipment that were used by the different households. Through direct observation and walks the researcher established rapport with several villagers, which helped in breaking the ice with the informants. The researcher also visited the two Rural Energy Workshops and interacted with the women BSE's as they repaired the solar equipment and the clientele. Both direct and participant observation helped in giving a nuanced picture of the village life. For instance one the transect walk resulted into an impromptu visit to the local school and dispensary in Lingeka village.

5.4.3 Qualitative interviews

For the qualitative part, face-to face interviews with key informants, focus group discussions (FGD) and direct observation was conducted. A total of eight separate key informant interviews were conducted. The interviews were conducted with four women BSE's from Lingeka and Nyanza, two group interviews with the VEC's and two representatives from ICS Seven of these interviews were recorded and transcribed verbatim. For the last interview with the head of ICS, the researcher took notes due to malfunctioning of the recording device. Each interview lasted about an hour. The interview with the BSE's focused on their roles, challenges and experiences over the five years in the project. The interviews with the current VEC of both villages helped gather factual information about the organization and day to day running of the REW as well as their view on the project and the model. The ICS officials were interviewed on their role as the implementing NGO and their perception on the model used to promote solar PV energy in Lingeka and Nyanza. See appendix 10.3 for a copy of the interview guide used.

5.4.4 Focus Group Discussions

Three focus group discussions (FGD) were conducted in each of the three study villages. All the interviews and group discussions were conducted in Swahili. In an attempt to create a heterogeneous group that would reflect the various members of the village, the researcher recruited people of different ages (above 18) both women and men. Each group consisted of 8-10 discussants with equal number of both genders and the discussion lasted about two hours. The researcher acted also as the moderator also in an attempt to ensure that each individual was given a chance to speak. This however proved to be challenging where men tended to be more outspoken than women while the younger participants tended to agree with the opinion of the older people. The FGD in Lingeka and Nyanza discussed the energy situation before and after the project, their views on the project's model and in particular their experience with the BSE's and the VEC. In Mwakisandu, the control village, the group discussed about their current energy sources and the effect of these. A copy of the FGD arranged according to the agendas discussed is shown in appendix 10.3 of this study.

In addition to collection of primary data through the methods mentioned above, secondary data such as medical records from the local dispensary, project reports from ICS and other relevant materials that were deemed relevant were also collected and analyzed. In the case of the medical records the researcher received the data for Acute Respiratory Infection and cases of snake and insect bites recorded at the Lingeka dispensary between October 2012 and June 2014. There was no dispensary in Mwakisandu village that would have given comparative data on health.

5.5 Data analysis methods

According to Berg and Lune (2012) data analysis involves a "careful, detailed, systematic examination and interpretation" of collected data in order to "identify patterns, themes, biases and meanings". This study produced both quantitative and qualitative data. The quantitative raw data was coded and analyzed using SPSS (Statistical Package for the Social Sciences). Analysis of the quantitative data focused on selected socio-economic factors. The following variables were used to represent these factors as shown below:

- Time of study and pupils grade to represent education
- Incidences of night time theft and animal attacks to represent security
- Expenditure on energy to represent household economy
- Frequency of ARI related symptoms (cough, sore throats) and smoke related eye infection to represent health

These variables were then compared between the solar PV electrified village and the control village in order to test the hypothesis that solar PV has a positive impact on the socio-economy and health of a village.

The qualitative raw data in form of the recorded audio interviews was transcribed verbatim into transcripts. These transcripts together with the field notes was then classified and structured through thematic analysis. According to (Bryman 2008) thematic analysis entails extraction of themes form ones data, that are then used to answer the research questions guided by the literature review and the adopted conceptual framework.

5.6 Ethical consideration

Collection of data and indeed the entire research process usually creates an unequal power relation between the researcher and the respondents. For instance communities may not be able to authorize or object to research given that this decision is usually made by government officials or the local NGO (Reyes-Garcia & Sunderlin 2011). Therefore a researcher needs to always be aware of and to address ethical considerations such as privacy, confidentiality and informed consent (Berg & Lune 2012; Reyes-Garcia & Sunderlin 2011). A useful principle is to "*do no harm"*(Berg & Lune 2012 italics in original).

Following this principle it was incumbent upon the researcher to inform the respondents clearly and ensure informed consent prior to collecting any information. Before collecting the data the researcher and his assistant introduced themselves and asked whether the respondents wished to participate I the research. For the respondents of the questionnaire their anonymity was ensured in that their names were not recorded at all. Several respondents were skeptical about my affiliation and questioned whether I was an ICS employee. ICS was one of the major stakeholders in the project and the respondents were wary about criticizing the project. Introducing myself as a student and therefore an independent and neutral observer the respondents felt at ease to criticize some of the components of the project.

Given the unequal power relation between the genders in *sukuma* culture the researcher was aware of the women's reluctance to speak in the presence of men. However this was not a major problem, in the FGD's where there were both men and women, care was taken to get everyone involved in the discussion.

5.7 Quality of Research and limitations of the study

In addition to ensuring high ethical standards throughout the research process, this study also attempted to ensure quality research through observing certain scientific principles. Reliability and validity are two such principles that are often discussed with regards to research (Bryman 2008). Reliability refers to the consistency of a measure of a concept (Bryman 2008) . This criterion ensures that if the study were to be repeated by another researcher using the same procedure and instruments, both studies would produce similar results. In this study, the procedures, measures and concept used have been explained and or defined in details to ensure reliability.

Validity refers to whether an indicator or set of indicators used in the study do in fact measure the intended concept (Bryman 2008). Validity and reliability are thus related in that validity presumes reliability (Bryman 2008). This means that if the measure used is not consistent the results of the study are not valid. This study by using a mixed method research both data collection and analysis and through triangulation of these fulfills the validity criteria.

It is important to point some limitations of this study. Firstly the researcher had limited resources both in times of time and financing. This meant that only a small sample of data could be collected within the time constraint. Although care was taken to ensure random sampling so that the findings of the sample may be generalized a larger sample and perhaps a more focused study on the socio-economic would have enabled an in-depth analysis. Secondly although the researcher set to quantify the socio-economic impact of the solar PV project, capturing the household income and quantifying the energy expenditure that could then be compared with the control village required more statistical rigor. In addition the respondents relied on farm incomes, which fluctuated according to season, and also did not have records of their income and expenditure relying therefore relying on their memory.

6.0 Socioeconomic and health impacts

This chapter gives the results and discusses the findings related to my first research question. This chapter is divided into five sub chapters discussing the main findings. To begin with, a general characteristic of the respondents is given here.

General characteristic of the sample

The sample size was 80 respondents representing their respective households. 37 (46%) of these were female and 43 (54%) were male. Although in some instances several people were present during the structured interview only the major respondent answers were recorded. The table below summarizes the age distribution and number of the average number of people in the sample.

Table 5 Descriptive Statistics

	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Age of respondent (years)	19	90	38,5	1,69	15,01
Total number of people in household	3	28	8,22	0,54	4,81

The average age of the respondents was 38 years which relatively high due to the fact that the respondents were above 18 and the presence of a 90 year old respondent which is regarded as an outlier in statistical terms causing the raise in the average age. Similarly the average number of people in the household is 8,2 given that most families in the rural areas are composed of several generations living together. Majority of the respondents (92%) owned the houses they lived in and thus several generations lived in the same compound.

95% of the respondents said that their main occupation was farming mainly growing both cash (coffee, sunflower) and food crops (maize and beans). The inhabitants also practiced mixed farming rearing cattle, goats and chicken besides growing crops. Some of the respondents had other occupations besides such as businesses, permanent jobs and charcoal selling. Majority of the respondents said that they had at least 7 years of schooling (basic primary school) while 4%

said they had attained their 0-level secondary (13 years) and 20% said they did not attend school at all.

In terms of assets and income of the households the most owned electronic item is the mobile phone with 79% of the sample owning at least one handset. 37% of the households owned one radio while only about 1% owned a TV. In terms of mobility and transport none of the respondents owned a car, while only 3% owned a motorcycle and 68% owned at least one bicycle, some households owned up to three bicycles. Given that the two villages practiced farming majority of the households (95%) owned at least one hoe (*jembe* and *panga)* only a few (32%) however owned an animal-pulled plough.

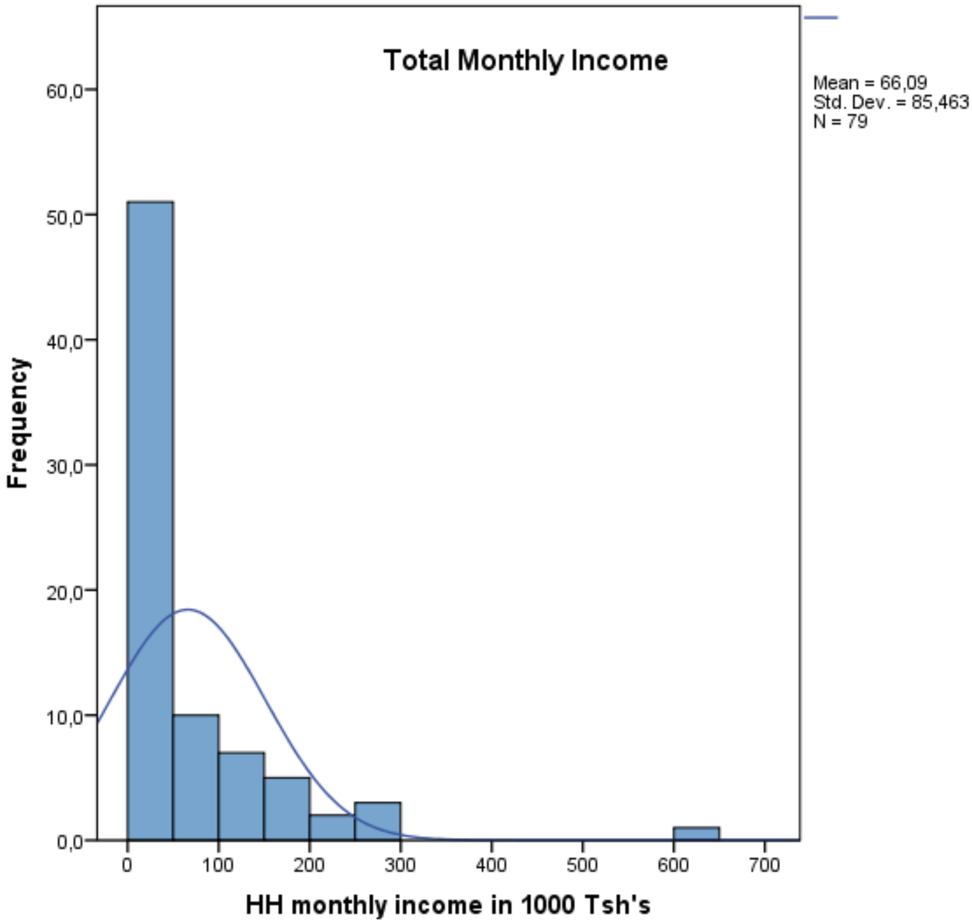

Figure 9 Monthly income estimate of the sample

Capturing income of the sample proved difficult a difficult task. Given that the majority of the respondents were farmers that depended on selling their crops income they had irregular income.

During harvesting season households that had larger pieces of land and grew cash crops earned more. When asked to estimate what they earned both from farm and off-farm earnings most respondents found it difficult to answer given that they did not keep records of their income and thus relied on their memory. The histogram above shows the distribution of the estimated income per month in Tsh. of the respondents (N=79). The histogram shows that majority of the respondents estimated their monthly income to be around Tsh. 50,000 (23$). Given that the research was conducted in October 2014, which counts as mid harvesting season for cotton, most people had not yet received payment for their produce. This may have contributed to the low reported income.

The first research question sought to determine the socioeconomic and health impact of the solar PV project to the households that adopted these in Lingeka village. To answer this question five key areas, following the Energy quality of life framework were selected for this inquiry. These are education, household economy, health, security and information. These variables were then compared between the solar electrified village (Lingeka) and the Non-electrified control village (Mwakisandu).

6.1 Information and type of solar products used in the village

The first and most observable effect of the Lingeka-Nyanza project is that has certainly changed the landscape of energy sources in the village. Comparing across the two villages it is clear that majority of respondents in Lingeka (87%) use solar PV while majority of respondents in Mwakisandu (90%) village used battery powered torches. 10% of the respondents in Mwakisandu reported to owning and using solar PV lanterns in their home daily. Several respondents in both villages used both sources of energy for lighting. Only one respondent in the sample reported to using kerosene lamp daily while no one used candles.

The main use for solar PV by the households that used it was nighttime lighting, followed by charging mobile phones for household members and use for powering radio. None of the respondent used solar PV for TV and only one respondent reported to using the SHS to power the household's portable DVD player. Figure 10 below shows the various types of solar PV equipment lantern used in Lingeka village.

Price , model & specifications	**Image**	**Price , model & specifications**	**Image**
S2 (*Kitumbua)* Price:14,000 Tsh Integrated solar panel with LED light 4 hours of light		S20 (*Kajug)* Price:17,000 Tsh Integrated solar panel with LED light 4-8 hour light	
S250 (*Birika)* Price 57,000 Tsh Separate panel 4-16 hours of light mobile charging		S300 (*Solar kit)* Price: 70,000 Tsh Separate panel 7-34 hours of light Mobile charging	
Solar Home System and lantern Price: 250,000Tsh The SHS included a 10 Wp solar module (rooftop panel), 12V battery, charge controller and s 12V solar lantern (pictured) 10- 20 hours of light several lights can be connected mobile charging small DC devices (radio)			

Figure 11 Types of solar PV systema dn lanterns in Lingeka.
Source http://www.dlight.com/solar-lighting-products/

The type of solar equipment a household owns explains the difference in how these households use solar energy. The graph below shows the number of households and which type of solar equipment owned by these in the both the solar electrified and the control village. The solar equipment's are arranged in increasing wattage and price, are the five most common types of solar products in Lingeka and Mwakisandu villages. The x–axis shows the commercial products' names and in brackets the local Swahili names used by the villagers. The two cheapest product costs around 6.4$ and 8$ and can only be used for lighting. The next two products costs between 26$ and 32$ and produce brighter light and produce enough watts to charge a mobile phone. The last product can be used to light up several rooms and produce enough watts to charge mobile phone and run a small radio. This SHS costs around 115$ each and were the original products introduced by the program five years ago. The other products were sold by the VEC to villagers in Lingeka and neighboring villages.

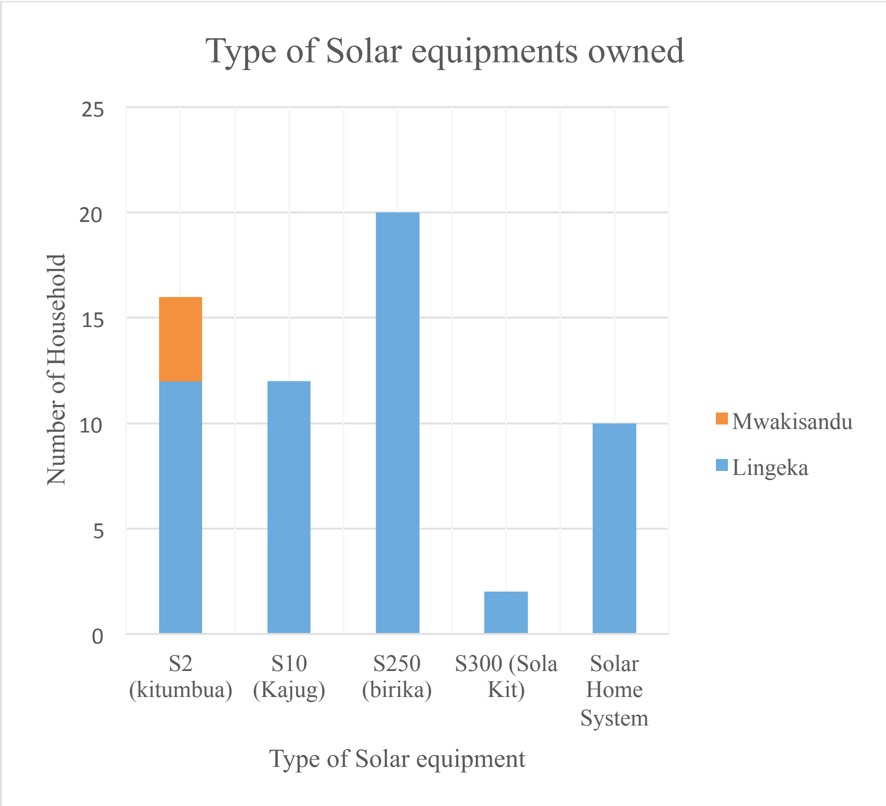

Figure 11 Type of solar equipment used by the sample

As indicated by the graph above, the introduction of the PV electricity in Lingeka village enabled the resident to not only have clean and brighter lights at night but also enabled them to charge their mobile phones and listen to radio. A striking example of how the project has improved access to information and opened up the village to global event is that in 2012 the VEC had for the first time bought a TV and were able to stream the world cup in Brazil to the locals. The VEC charged a small fee for each match. This acted as innovative project that created income for the group and entertainment for the villagers. They also bought a DVD player and started a small ‘cinema’ in the village.

6.2 Education

The second area is the education of the school-going children. Education is a complex term and to quantitatively measure whether this has improved is an even complicated task, I therefore chose several relevant quantifiable proxies to represent education. This proxies have been used in several other researches to measure effects of adopting solar PV on school going children's education (Bensch et al. 2010; Gustavsson 2007).

I selected two variables for this study. These are time of study and perception on exam grades. From my sample the number of households that reported to having school-going children is 56 with data from one household missing N=55. Running a bivariate analysis using SPSS on the relationship between the presence of solar PV in a household and the children's study time and improvement of grades, the correlation matrix below gives a summary of the results.

Table 6. Correlation Matrix

		HH has solar system and or lantern	**Average hours per day children's study time at night**	**Improvement of grades of pupils**
HH has solar system and or lantern	Correlation Coefficient	1,000	,713**	,715**
	Sig. (2-tailed)	.	,000	,000
Average hours per day children's study time at night	Correlation Coefficient	,713**	1,000	,802**
	Sig. (2-tailed)	,000	.	,000
Improvement of grades of pupils	Correlation Coefficient	,715**	,802**	1,000
	Sig. (2-tailed)	,000	,000	.

**. Correlation is significant at the 0.01 level (2-tailed).
n = 55

The Pearson product-moment correlation coefficient (r) was computed using the Spearman's rho method to assess the relationship between the presence of solar PV in the household and the average number of hours children studied at night and the improvement of their grades. The results indicate a positive correlation between the presence of solar PV electricity in a household and average study time of pupils, r = 0,713, n = 55, p = 0.01. And a similarly strong positive correlation between the presence of solar PV in a household and improvement of the children's school grades, r = 0,715, n = 55, p = 0.01. Overall the results suggest that a household's adoption of solar PV electricity increases a child's study time and improves their grades over time.

A closer look at the study time compared between the solar PV electrified and the control village is presented in the crosstab below.

Table 7 Average Number of Hours Children Study At Night

						Total
	Not Study	**≤ 1 hour**	**1-2 hours**	**3-4 hours**	**≥ 4 hours**	
Lingeka	6	1	9	9	1	26
Mwakisandu	23	4	2	1	0	30
Total	29	5	11	10	1	56

The crosstab above shows the average number of hours the pupil studies after dark from the two villages. In Lingeka village the pupils tend to study more and for several more hours as compared to pupils from the control village; Mwakisandu. A close examination of the exam grades reveals that there was also a difference between the solar and the non-solar electrified villages. As the crosstab below shows, the respondents in Lingeka perceived that the grades of their children improved over the past year as compared to the respondents in Mwakisandu village.

Table 8 Improvement of pupil's grades

	Yes better grades	**No change**	**Worse than before**	**Don't know**	**Total**
Lingeka	19	3	0	3	25
Mwakisandu	3	9	1	17	30
Total	22	12	1	20	55

An interesting observation also appears to be the number of respondents that either answered '*no change'* or '*Don't know'* when asked about their children's grades. The data suggests that while parents in Lingeka not only perceive improvements in their children's' academic course they are more aware and appear to monitor their children's progress closely. In Mwakisandu on the other hand the data suggests that the respondents are mostly unaware of their children's school performance.

A possible explanation may be that given that the awareness raising campaign of the solar project that emphasized the benefits of adopting solar may have made the parents more conscious of the relation between their use of solar energy and the education of their children. During the focus group discussion in Lingeka for instance several parents reported to buying the S2 solar lantern (*kitumbua*) for their school-going children. Unlike a candle, or battery-powered torches these was a cheaper and more convenient source of study light for many pupils at night. One FGD participant remarked that it was now easier to let children study unsupervised and for longer hours now that there was no danger of open fires. The respondent reported that unlike when using a lamp or candle the children could sit and study on the bed late into the night without the risk of the bedclothes catching fire.

6.3 Health

With regards to health, this study examined whether there was any difference between households that had adopted solar PV electricity and those that still used traditional fuel sources. The data was collected at two levels. First at the household level the respondents were asked to indicate how often members of the household suffered from common symptoms of Acute Respiratory Infections (flu, sore throat), burns and house fires caused by candles or kerosene lamps, in the last twelve months. These were selected as quantifiable indicators because these are considered health risks that are mostly attributed to indoor pollution from use biomass fuels and kerosene lamps (Pode 2010; WHO 2006). ARI is a general term of several respiratory infections that are considered among the leading causes of deaths of children below five years. Indoor smoke pollution from burning kerosene lamps and burning of biomass fuels is considered a common risk factor of these infections (Madhi & Klugman 2006).

While all the respondents in Lingeka village reported to using solar energy for lighting, only three households (7.5%) in the sample from Mwakisandu reported to using kerosene lamp. Of these three households only one household used kerosene lamp daily while the other two used it occasionally. About 92% of the respondents in Mwakisandu said they used *Richmond* and battery powered torches daily while the rest said they used solar PV lanterns. A few households reported to using both batteries powered and solar PV powered lanterns. The hypothesis then that houses that had installed and used solar PV for lighting would exhibited less ARI related symptoms as compared to houses that use traditional sources of energy such as kerosene lamps could not be conclusively tested from the sample as explained further below.

This study had wrongly assumed that in the absence of solar PV lanterns households would still be using kerosene lamps. A different study in 2011 had found that majority of the respondents did not use kerosene lamps and had switched to using *Richmond* and torches (Kweka et al. 2011a). Several discussants in the FGD in all villages confirmed that only a handful of people still used kerosene lamps. During one of the group discussions a 55 year old woman summed up the reasons for not using kerosene lamps saying ''… *mafuta ya taa yamepitwa na wakati*'' (kerosene belongs to the old times). Many respondents in the village perceived use of kerosene as an obsolete and harmful source of energy. Other reasons given for the switch to battery and solar lanterns was its local availability and that compared to kerosene dry cells were much cheaper. The falling demand for kerosene in the village contributed also to its scarcity.

Table 9. Correlation Matrix - Health

		Number of solar equipment	Flu in HH	Sore throat	Red and Itchy eyes	Cough
Number of solar equipment	Cor. Coeff.	1.000	**.330** **	**.074**	**.109**	**-.091**
	Sig. (2-tailed)	.	**.003**	**.516**	**.335**	**.423**
Flu	Cor. Coeff.	**.330** **	1.000	.429**	.257*	.238*
	Sig.	**.003**	.	.000	.021	.034
Sore throat	Cor. Coeff.	**.074**	.429**	1.000	.299**	.144
	Sig.	**.726**	.000	.	.007	.202
Red and Itchy eyes	Corr. Coeff.	**.109**	.257*	.299**	1.000	-.006
	Sig.	**.516**	.021	.007	.	.958
Cough	Corr. Coeff.	**-.091**	.238*	.144	-.006	1.000
	Sig.	**.423**	.034	.202	.958	.

** Correlation is significant at the 0.001 level (2-tailed) n = 80
* Correlation is significant at the 0.05 level (1-tailed)

Computing the correlation coefficient (r) using the Spearman's rho method to assess whether the number of solar equipment used by a household (independent variable) affects a few selected health indicators (dependent variable) of its members in our sample gives us the results shown above. The data shows that there is a weak positive correlation between the numbers of solar equipment owned by a household and the frequency of flu suffered by household members r=0.330, p=0.003, n=80. This means that houses that had more solar equipment tended to have higher cases of flu. The data suggests an even weaker positive relationship between the number of solar equipment a household owns and the number of reported cases of; sore throat (r= 0.074, p=0.726), red and itchy eyes (r=0.109 p=0.516). Lastly the data shows a weak negative correlation between the number of solar equipment owned by a household and the frequency of cough in the household (r= -0.091, p=0.423). This means that households that had more solar equipment reported less frequency of coughs by the household members. Examining the statistical significance (numbers in bold) however reveals that the p values are not significant neither at the 0.001 level nor 0.5 level ($p > 0.05$), except for frequency of flu (p= 0.003) which is significant at 0.001 level ($p < 0.01$). Greater p values implies that there is higher probability of obtaining the results by chance and

These results therefore mean that there is weak relationship between a household's use of solar equipment and the health of its members these results and hence our results are inconclusive. It is important to note however that there are a myriad of other factors that may affect the health indicators chosen such as use of biomass fuel and presence of other diseases in the household.

Secondly, medical records showing the number of reported cases of ARI from the village dispensary in Lingeka were also collected. Since there was no dispensary in Mwakisandu village to get comparative data, the medical records from Lingeka village is used here to show the trend in the number of these infections over time.

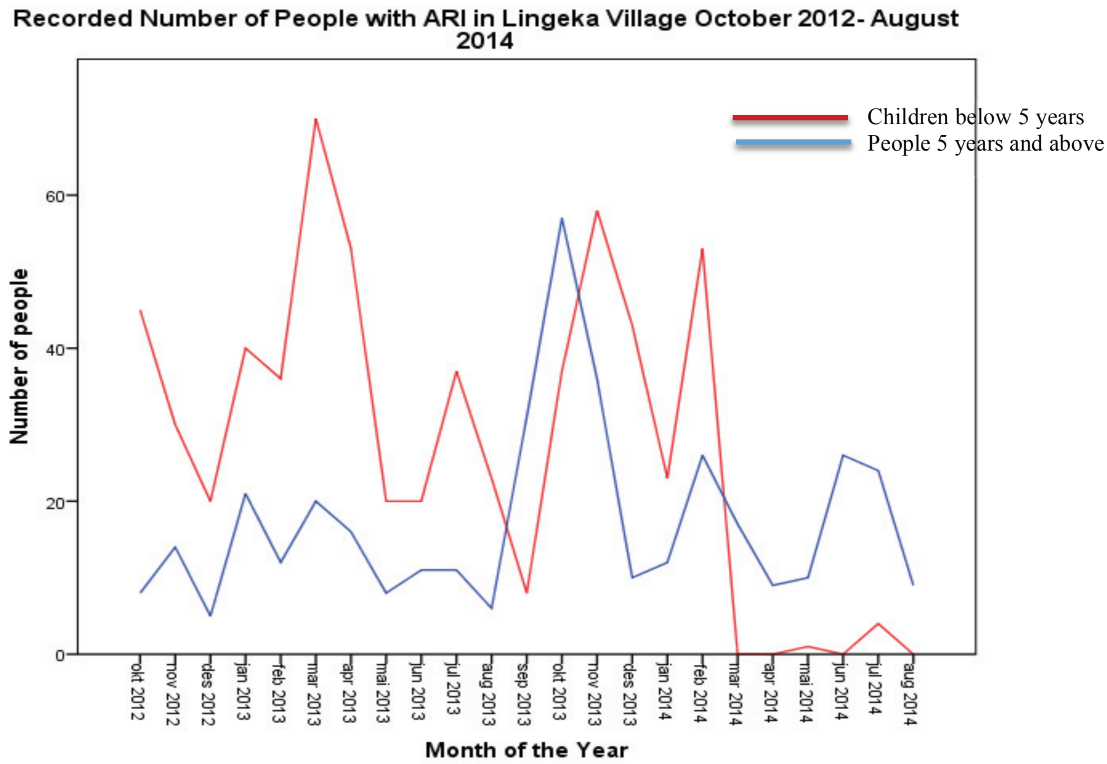

Figure 11 Source: Authors aggregation of data from medical records

Two major observations can be made from the graph above. Firstly that more children below 5 years are at risk from ARI than people above 5 years and secondly there appears to be decreasing number of in the number of recorded ARI cases especially with regards to the children below five years at the beginning of 2014.

Explaining this decrease the medical attendant at the dispensary believed that cases of ARI have dropped in the village because households have stopped using kerosene lanterns. The medical attendant further explained that in the past women delivering babies at night at the dispensary used kerosene lamps. This meant that the vulnerable newly born were almost immediately exposed to these harmful fumes and smoke. Through a different project however the dispensary was fitted with two large solar panels that provided electricity for nighttime deliveries. At the time of the research however (October 2014) none of the solar panels were functional due to lack of proper maintenance and repair. For nighttime deliveries, the medical attendant explained, they used hand held solar lanterns or lights from mobile phones that the expectant women or their family members brought with them.

Although the decreasing number of ARI infections cannot be attributed to the switch to solar lanterns only, households that no longer use kerosene lamps have indeed rid themselves of an important risk factor that may predispose them to these infections. Furthermore there exists several studies that establish the negative health impact of using traditional biomass fuel and kerosene especially when compared to modern energy sources (Pode 2010; WHO 2006).The emphasis here is mostly about the non-polluting nature of modern energy sources especially solar PV lanterns. Traditional sources of energy mostly involve combustion of elements that produces harmful gases (carbon monoxide CO), volatile organic compounds and smoke that have been shown to cause respiratory-related diseases and eye diseases (Madhi & Klugman 2006; Pode 2010; WHO 2006).

During the FGD also several discussants noted that before using solar lanterns and torches a few household would in rare cases burn discarded bicycle rubber tires that although burnt for longer produced toxic fumes. Given that traditional energy sources involves open and direct fire it has been related to fatal house fires that has claimed peoples' lives and property. Many houses have grass-roofed thatches a simple accident of a wick lamp falling over could quickly turn catastrophic. In conclusion although the quantitative data on health impacts was inconclusive findings from qualitative interviews and the group discussion indicate that the people have benefitted by switching from kerosene lamps to torches and solar lanterns.

6.4 Household economy

In terms of the household economy this study focused on the household's expenditure on fuel for lighting, household's expenditure on charging their mobile phones and the impact of using solar PV in for income generating activities.

Although even the cheapest solar PV lanterns was expensive compared to a battery-powered torches many respondents in the sample believed that buying solar PV lanterns was a wise investment. 92% of the respondents that did not have solar PV electricity said that it was too expensive to buy and 2 % said that it was because solar equipment's are expensive to maintain. These households however tended to have running costs in terms of dry cells they had to buy for their torches. A typical household for instance owned about 2 torches that run on two dry cells. This torches cost on average Tsh 1500 while each dry cell cost Tsh. 500. On daily usage a dry cell lasts about a week. Monthly lighting cost for an average household is thus Tsh 8000 (4$), the annual expenditure adds to around 48$. The cheapest solar PV lantern cost about 6,4$ and a household that owns two of this would only have spent 12,8$ at the end of the year. Households that had installed solar PV did not have this monthly lighting expenditure.

On the other hand several households that owned mobile phones had the additional expenditure of charging these phones if they didn't have solar PV electricity. For households that owned solar PV kits that had charging capabilities this was an energy cost they did not have to incur. Households that owned solar PV would instead have extra income by charging money for the locals to charge their phones. Charging a mobile phone once cost around 2000 Tsh (0,9$). In the sample 2.5% of the households said they made an income by charging other people's phones.

About 20% of the respondents in Lingeka reported to using solar PV electricity in their small shops and kiosks at night. One respondent in Lingeka village for instance owned the only barbershop in the village. The owner uses solar PV electricity to power the shaving machine, and also charges mobile phones for a fee and powers a radio to entertain his clients. Using a battery the barbershop would stay open even after dark. Another respondent who owned a tailoring shop says she could now repair cloths at night for her clients she started using solar lanterns. Only one respondent (2.5%) in the control village Mwakisandu reported to using solar PV in her shop.

Apart from the above income earning activities households that had installed and were using solar PV electricity perceived that they had a moderate improvement in their household economy. The reasons given for this are that they had more time for productive work such as being able to cultivate at night and that they now had less recurrent expenditure on energy. During the FGD's respondents that had solar PV said that using powerful solar lights they were able to cultivate their lands at night.

6.5 Security

Darkness sets in already at around 18:30 almost every day of the year in Northern Tanzania. Although this marked the end of the villagers' active working hours, this was both a time for resting and for tackling nocturnal challenges. Given that most of the respondents owned goats, sheep and cattle meant that they had to remain vigilant and protect their livestock from wild animals such as hyenas and wild dogs. Before they used solar lanterns residents of Lingeka had to light bonfires close to animal pens to fend off these nocturnal predators. Since they started using solar PV the powerful bright lights from these have been used to scare away these wild animals. Cases of losing livestock and even attacks by wild dogs have reportedly decreased in Lingeka since the villagers started using solar lanterns. Additionally although night time thefts and scorpion bites (which mostly occur at after dark) are rare in both Lingeka and Mwakisandu villages, the solar powered Lingeka village reported less cases of this compared to Mwakisandu as shown in the table below.

Table 10. Frequency Of Theft, Animal attacks, Scorpion and Snake Bites At Night In The Last Year

		No	**Yes**
Night time theft	Lingeka	39	1
	Mwakisandu	35	5
Scorpion bites at night	Lingeka	40	0
	Mwakisandu	34	6
Snake bites at night	Lingeka	38	2
	Mwakisandu	38	2
Animal attacks at night	Lingeka	33	7
	Mwakisandu	30	10

Apart from normal nighttime activities such as cooking, preparing bed, walking to and from the toilet in both villages, in Lingeka there seemed to be more ‘night-life’ compared to Mwakisandu. This was in the form of dances and ceremonies that either extended into the night or happened during the night. Powered by the solar PV charged batteries, radios and powerful solar bright lights, the dark quiet nights of Lingeka were enlivened whenever there was a party or wedding ceremonies. Relying on solar powered lanterns local shops and kiosks extended their closing time and added to the ‘night-life’ too. In Lingeka there was a bar that closed at around 21:00 often frequented by the villagers.

6.6 Conclusion

Following the Quality of Life framework the above findings demonstrate how the use of Solar PV electricity in Lingeka village has contributed in transforming the socio-economic lives of the locals. This solar electrified village has experienced positive changes in terms of education of its school going children, reduced their exposure to harmful gases from kerosene lamps improving their health and enriched their lives both by adding light to their dark nights and reducing the nocturnal challenges that they faced. However it should be remembered that other factors such as availability of books and indeed a inculcating a reading culture are important if the benefits to education are to be fully realized. In the same way, replacing other sources of smoke such as firewood and charcoal used for cooking will even further contribute to the positive contributions of adopting solar PV electricity. Although Mwakisandu village appears bleak in comparison, the spillover effect from the solar PV project especially in terms of the adoption of solar PV albeit by a minority in the village may be a step in the right direction in terms of adopting solar PV electricity. As noted in our literature review on the energy-development nexus access to clean modern energy is indeed an enabler and has both direct benefits and multiplier effects.

7.0 The Women BSE of the Lingeka-Nyanza Solar Project

In this chapter I discuss the impact of the four women Barefoot Solar Engineers (BSE) in Lingeka and Nyanza Villages. In particular this study will discuss how becoming a BSE can be seen as woman's' empowerment and how this in turn impacts local maintenance, ownership and sustainability of the project. As a point of departure I present the four women BSE's giving their profile, experience and reflections on the project from the qualitative interviews. Following this I discuss the challenges that these women have met and the villagers' perception about training of women to become BSE. Following this presentation I discuss how this women's challenges and experiences can be explained through a gender perspective. Using the CARE framework I discuss to what extent we can say that the BSE's in particular and the women in these villages in general have been empowered. Finally, this chapter ends with a discussion on what lessons future projects can learn from the Lingeka-Nyanza project.

7.1Who are the Barefoot Solar Engineers in Lingeka and Nyanza?

One of the major components of the solar project is the recruitment, training and use of women BSE's. These were local women who were selected by the villagers themselves. The selection process was a participative process lasting for several months before the village made the decision on whom to send for training. The criterion for selection was that they should be trusted local women in their middle ages who have settled in the village. There was no demand that these women should be educated or literate. Four women were selected and travelled to India in March 2010 and trained for six months at the Barefoot College in Tilonia, India. Here is a brief profile presentation of the four barefoot women solar engineers.

When I first arrived in Lingeka village I was warmly welcomed by Nkwaya Stephan, one of the two BSE's in Lingeka Village. During the following two weeks I spent time with Nkwaya observing her repair broken solar lanterns and advising her clients on different issues related to solar PV who were both from nearby and far away villages. She told me that her village, Lingeka, had become famous in the region because of the solar project. Although Nkwaya spent most of her days at the village Rural Energy Workshop repairing solar lanterns, often in company of her 5-year-old grandson, she also acted as my guide and door opener. To the villagers and her clients she was fondly known as 'Engineer'.

Prior to becoming a BSE four years ago, like most women in the village she was a farmer and a housewife. 46-year-old Nkwaya was married and had four children. Having studied up-to class seven (elementary level education in Tanzania), Nkwaya had basic reading and writing skills and could be regarded as semi-literate. Nkwaya had no stable income and depended mostly on her husband, as a BSE however she earned between 60,000 and 30,000 Tsh's (28-14 $) a month. At the beginning of the project together with her colleague BSE in the village she was paid to install the villagers' SHS. Her income was mostly from repairing solar lamps. Nkwaya explained that in 2012 there was drought and a few villagers sold off their SHS. She was involved in these sales as 'quality control', dismantling the SHS and re-installing the SHS for the new owners and advising on price of the used SHS.

The second BSE in Lingeka is Lucia Ngaranga a 44-year-old mother of six children and one granddaughter. Like Nkwaya, Lucia was also formerly a farmer. When I first arrived in Lingeka village, Lucia was away in Arusha. Here she had participated in a competition organized by REA on alternative energy sources for rural Tanzania. The Lighting Rural Competition in 2014 which is held every two years seeks to support innovative and local level solutions that can improve the quality and access to modern energy services for off-grid rural communities in Tanzania (REA 2014). Lucia had entered this national competition showcasing the SHS and herself as the BSE. Although Lucia's project did not win any award, she was proud of the experience and received a lot of attention from the spectators, judges and fellow competitors. She was the only female solar engineer in the competition.

Nkwaya and Lucia were responsible for installing the over 70 initial SHS provided by the project in the village. For each installation they were paid a standard sum of 4000Tsh (2$). Apart from routine maintenance of the installed system, Lucia was also often contracted to install and repair solar systems by clients outside her village. She has installed solar systems for several households, small businesses and even a school in a neighboring village. Lucia attributed the demand of her labor by clients both within and without the village to her expertise and skills and the modest fee she charged. Lucia sometimes enlisted the help of her son when he was not in school. She has taught him simple repair skills and he assists her in climbing the roofs to install the solar panels. Lucia invested the money she earned to build a house for her family and also runs a small shop in the village where she sells groceries and solar equipment.

Plate 2. Lucia Ngaranga, in Lingeka's Rural Energy Workshop repairing a broken solar lantern. Source Author

50-year old Monica Mirega was one of the two BSE's in Nyanza village. Monica is widowed and a mother to seven children. She is the head of her family. Monica was a farmer and had a small shop one of her children helps her run. During the first two years of the project, Monica earned an income through installation and repair of the solar lanterns within her village. In the recent past however, she notes that she there is less demand for her labor and has returned to farming and running her small business to earn a living. Nevertheless, Monica emphasized that she stills felt like an 'engineer' because of her training. A comparison between the two villages shows that use of solar PV in Lingeka is more widespread than Nyanza hence more clients in the former. The solar project appears also to be more successful in Lingeka village than Nyanza village. I will discuss this in chapter eight.

In India the BSE's had also, besides training on installation and repair of solar lanterns, received basic training in entrepreneurship. They were taught how to make candles and chalks. Despite her efforts Monica was not been able to sell the chalks she made to the schools she approached. This is because as a local producer she couldn't compete with other established businesses that bid and won tenders to supply these schools with chalk. As for the candle-maker she said the machines are designed to produce very thin candles that burn quickly which are not attractive to clients. Furthermore there was very low demand for candles in the rural areas with the introduction of affordable solar lanterns and cheap dry cells for handheld torches.

Plate 3 Solar engineers, Monica Mirega (left) and Miriam Musa , posing in front of the REW in Nyanza village. Source Author.

Miriam Musa the second BSE in Nyanza village was a tailor before. She still repairs and makes clothes and is able to do this at night now because of her SHS. Miriam who is 45 years old is married and has eight children. She was at that time of the interview the chairperson of the Village Energy Council and the solar group. Miriam recalls the villagers' skepticism of having women travel to a foreign country for training. She says that the local NGO had carried out a similar project in 2008 in two other villagers (Mwandu-Itinje and Longalonhiga) invited the former BSE's to share their experiences and reassure the villagers.

Monica says that she used to earn an average of 30,000 Tsh (14$) as a BSE but has in the recent past earned much less. Miriam explained that this was not only because of the declining number of clients who used their services but also in part because of poor business skills. Miriam observed that due to lack of spare parts she had to turn away several clients, which with time made the villagers question her competence. These spare parts, which are specific to the lanterns they received from India were unavailable in the local markets. In addition given that the women were trained on a specific type of lantern and SHS this limited their versatility when it came to repairing newer solar models. She says some people preferred to take their broken lamps to local male electricians outside the village. Secondly Miriam said that some clients defaulted on their payment. She says that after repairing a lantern for a client and asks for payment some of them would reply ''*wewe si tunajuana… jamani ndio uniombe pesa basi ntakutafutia'* (aren't we acquaintances… why then do you ask for money now, I will pay you at a later day). Miriam said she demanded for payment upfront.

Although all the four women had varying experiences they all agreed that having the skills and competence as BSE has improved their lives. They feel positive about their contribution to their communities. They are well known in both villages and they use this position to raise awareness on solar energy. Being at the core of the project these women have not only raised their socio-economic level but also enjoy elevated statuses in their villages who often fondly referred to as *sola mamas* or 'engineer'. Nevertheless being a BSE came with its challenges.

7.2 What Challenges did the BSE face?

The BSE's have experienced several technical, practical and gender related challenges. The most common technical challenge was the lack of spare parts, which has reduced the demand of the BSE's service over the years. The women were trained on a specific solar home lighting system and lantern (see figure 3) and were equipped with repair tools and a limited amount of spare parts at the start of the project. These spare parts have now run out and are not available in the local market. The lack of spare parts means that several households now own non-functional SHS and solar lanterns. However what was interesting to observe was the ingenuity and innovativeness of the BSE's. Apart from the SHS imported from India the VEC bought locally available solar lanterns (see figure 10). Although the BSE did not have direct training on these particular types of solar equipment they had identified a common problem that they were able to repair. Lucia said that the BSE's from the two villages sometimes met to exchange ideas. She added that she also consulted a local electrician who taught her other simple repairs.

A second challenge for the women BSE was limited access to the REW. Although the workshop was meant be used by the BSE, the VEC in both villages had locked these limiting the BSE's access to these workshops. There was a time when the BSE's in Nyanza had been completely locked out and the workshop leased to local male mobile phone and radio repairers. It was only after the project officer from ICS stepped in and demanded that the REW only be used for the stipulated function that the BSE's were granted access. In Lingeka the women have always had access but only to one room which is used to both store their solar repair kits and as an arena for open meetings in the village. They have no access to the smaller locked room where the VEC stores the new solar equipment to be sold to the villagers.

A third challenge facing the four BSE's is their relatively diminished power in the VEC. Although they are invited to the meetings, the BSE's say that they do not feel they have influence over the decisions reached by the committee. They often feel as mere technical advisors, weighing in on which brands or types of solar products the committee should purchase. When I enquired whether the challenges they experienced was because they are women, Monica was reluctant to blame this on her gender. She explains that these challenges are due to improper administration and management of the project, which is common in communally, owned projects. Lucia on the other hand feels that her gender explains her challenges. She says ''*ni kwa sababu mimi ni mwanamke.... mwanaume asingekubali..... sisi wanawake ni wanyonge''* (It is because I am a woman… a man would not have accepted [this] … we [the] women are weak).

Miriam who also doubled up as the chairperson of Nyanza VEC tells of some of the villagers' initial skepticism when she was elected. Miriam reports that during her tenure she has been able to oversee the successful purchase of a piece of land and the construction of a new REW. The new REW includes a store, a repair room and a large room that can be rented out for village meetings (see plate 3 above). The VEC in Nyanza had previously been renting a space. Monica is proud of this and says it is proof that ''*Kumbe wanawake wanaweza kuwa viongozi*'' (women are indeed capable of being [good] leaders).

A fourth challenge that all the four women BSE's faced was installing the rooftop solar panels. Partly because of their age and arguably because of their gender, climbing rooftops to install the solar panels posed a unique challenge. Climbing rooftops is considered a 'man's job'. Having the technical knowledge and skill on how to install the rooftop panels meant that these women had to climb the roofs to install the solar panels. The BSE's later trained a few male assistants to help them with this task.

Looking at these challenges it appears that apart from the technical challenge of lack of repair and spare parts, the other challenges are related to the women's gender and position in the society. The locking out of the women BSE can be translated as a symbolic resistance by the male dominated VEC to restrict their power. During the group discussions while some discussants had no problem with the gender of the BSE citing the commendable work these women have done, others expressed their reluctance on the choice of an aging women-only staff. A 22-year-old FGD participant in Lingeka argued that the project ought to train the young men also because the BSE's are all older women who had other duties at home.

The project implementers rational and justification of training only middle-aged women is that these women tend to be more settled than men in the villages. They argue that women, and especially those that have children, once trained will unlike men who may migrate to urban areas, stay in the village and thus benefit the village with their skills and competencies. The availability of reliable and accessible after-sale services is crucial to the sustainability of the project. However some male villagers see the training women not as a sustainability guarantee but as a way to 'raise the women above the men'. As one participant remarked, ''since they are married these women would still have to move if their husbands moved to a different village''.

By specifically training women, the barefoot approach has its goal to empower rural women and contribute to gender equality. Despite the challenges by the four BSE's in Lingeka and Nyanza it appears that by allowing women to engage in what is considered a male dominated area (technology control) have allowed these women to prove that they are capable or just as good as men. As one 50 year old male discussant in Nyanza explained that although men may feel that it does not 'befit them to be led by women', in todays globalized world there are many examples seen that prove women are capable of making good leaders and the BSE's are good role models. This observation echo's Roy and Hartigan (2008) about how ''simple village women'' have not only demystified the sophisticated solar technology and demonstrated that they can effectively manage and control it but also provided services to their community that has given these women ‘‘a new level of acceptance and the respect women they deserve’’.

7.3 Becoming a Barefoot Solar Engineer- is this empowering?

Using the CARE women's empowerment framework we can examine the three dimensions; agency, structure and relations regarding the BSE's. To begin with it is clear that their agency has been clearly transformed. Because of their training these women now possess a set of unique skill that has enabled them to control and dispense their labor, as they will. At the household level none of the three married BSE's reported that their husbands restricted them in any way. Lucia explained that ‘‘my relationship with my husband has become better, I have more say now in decisions now that I also contribute with an income’’ he loves me more. . Since they can now earn their own money these women have greater decision-making and influence within their households and even greater mobility within the public space.

It was clear that these women had positive self-image, high self-esteem and belief in their abilities. During the interviews most of them expressed pride in bringing solar energy to their community. Lucia remembers how, despite the language difficulty during their training they worked hard so that they could make their community proud After the BSE had returned from their training there was feast in the village celebrating their achievement. Becoming BSE has enabled these women to expanded what the people of their village viewed as horizons fro the women. Monica and Lucia said that their daughters have told them they would like to become ‘solar engineers’ when they grew up.

Their agency means that these women relate differently with other social actors in the society. The female BSE is both aware of her gender position but due to her role as means that she relates to the villagers in a different capacity. These women create different social relations. For instance amongst the four BSE's they feel connected and keep in touch with some of their former fellow students from the Barefoot College in other countries and especially Kenya.

What is perhaps difficult to pin down is to what extent the inclusion of the BSE's influences the structure of the society. As explained above structure in this sense refers to the tangible and intangible environment that affects the choices women and men have. In the VEC's women are well represented however from the experience of the female BSE being systematically locked out of the REW's may indicate that there is still a long way to go to change the structures that underlie women subordination.

Nevertheless using the CARE framework one can see the empowerment of the female BSE's in particular and perhaps a process towards empowerment for the common woman in the village. From the women BSE's we see the expansion of their individual and collective capacity to access and influence the resources, especially their labor and by their holding of important and esteemed positions in the project they confront and challenge gender norms and power structures. It is clear however that for the empowerment of the women in rural areas the project has had major contribution with regards to the BSE and by challenging gendered structure and relations in the society.

The BSE have also contributed significantly to the projects sustainability. By making after-sale services available within walking distance of many of their clients has clearly encouraged many people to switch to solar energy. Through gender mainstreaming it is clear that the Lingeka and Nyanza solar project, has not only demonstrated that women can benefit more by switching to modern energy technologies but can also play an integral and crucial role. In other words the project goes beyond the usual 'quick fixes' for solving women's energy issues and views women as part and parcel of the solution.

8.0 The Lingeka-Nyanza model

This chapter focuses on the Lingeka-Nyanza model that was used to promote solar PV electricity in these villages. In particular this chapter examines the challenges, success factors and potential for scaling up and scaling out of this model. To begin with, the Lingeka and Nyanza solar PV project (briefly mentioned in chapter 2) is discussed here giving the major stakeholders roles and the major components of the project. The Lingeka-Nyanza model is then described with a discussion of the barefoot approach and the innovative modifications this model incorporated into the approach. Thereafter the success factors, challenges and potential for up scaling and out scaling of the model are discussed. The success of this model is analyzed using the 4A's framework. Both Lingeka and Nyanza villages followed this model, however as I will discuss later in this study Lingeka village appears to have been more successful with this model compared to Nyanza village.

8.1 Major stakeholders and Components of the Lingeka-Nyanza model

The Lingeka-Nyanza model consisted of several actors and five major components. The following is a list of the major stakeholders and their main roles:

1. Norwegian Government -funded the project through the CCIAM program
2. Tilonia Barefoot college in India – trained the BSE's (the training cost was funded by the Indian High Commission in Dar es Salaam)
3. ICS - the implementing and supervising NGO (regular evaluation and reports)
4. The inhabitants of Lingeka and Nyanza – active participants and beneficiaries of the project

The major stakeholders of the Lingeka-Nyanza project worked closely prior to and during the entire project period. As mentioned earlier, the baseline study had in 2011 found that majority of the people in these villages were not only of aware of solar energy but were also willing to pay to access this energy if they could do it in installments(Kweka et al. 2011a). In addition based on these findings ICS was identified as a local NGO that had extensive experience in this region to act as the implementing partner. Through its regional office in Shinyanga, Tanzania, ICS had carried out a similar solar project in Longalonhiga and Mwandu-Itinje villages in 2008. The experience and lessons learnt from this solar project proved useful in designing the Lingeka-Nyanza model.

One of the major roles the ICS played was facilitating the meetings within the village where the women to be trained as BSE's were selected. The selection process was a participative process lasting for six months before the village made the decision on whom to send for training to Tilonia Barefoot College, in India. ICS also assisted with logistics, helping the women travel to and from India. ICS in addition facilitated the election of the VEC officials and trained them in leadership and simple bookkeeping skills, and carried out regular evaluation of the project. Tilonia College in India was responsible for training and providing the first SHS and lanterns and the repair equipment used by the BSE.

Following the bottom-up approach the inhabitants' participation throughout the entire project period was crucial. The needs-based assessment carried prior to the project's inception provided an important and factual based report on the current energy use patterns and the villagers' ability and willingness to adopt modern energy sources. The people were also actively involved in selecting the women to be trained as BSE's, in electing the VEC, and also through attending meetings. For the VEC, the project required and encouraged that both women and men be represented. The community also contributed to the project in-kind. In Lingeka, the village donated the land that the REW was built on while in Nyanza, members of the solar group contributed with their labor during the construction of their REW.

Since the Lingeka-Nyanza model was based on the barefoot approach (discussed below), it was constituted of these four major components. The first three components are at the core of the barefoot approach while the fourth component is a modification particular to the Lingeka-Nyanza model.

1. Village Energy Committee (VEC)
2. Rural Energy Workshop (REW)
3. The Barefoot Solar Engineers (BSE's)
4. The Revolving fund

Firstly, there were two VEC's one in each village. In Lingeka village the VEC consisted of twelve members (5 women and 7 men) and a similar number in Nyanza (6 women and 6 men).

The committee members were elected by the villagers and included a chairperson, a secretary, a treasurer and their assistants and six regular members. The committee is responsible for; 1) storage and record keeping of the PV equipment, repair kits and spare parts for the BSE's, 2) purchase and sale of new SHS and solar PV lanterns, 3) verifying the credit-worthiness of potential buyers and debt-collection from villagers who had bought the SHS and lanterns. The treasurer kept a record of all the villagers that owed money from the purchase and a record of the amount they had paid and a record of the VEC's asset and capital. Each VEC runs for two years and a new one elected by the villagers. The first VEC elected in 2011 was disbanded two years later after allegations of corruption and mismanagement of the projects funds. The second VEC in both villages was elected in august 2013; this process was overseen by ICS.

For both legal and practical reasons a solar group (*Chama cha Sola*) was registered as a community based organization (CBO) in 2011 with a constitution and the VEC as head of the group. The constitution among other things spelled out the groups' mission, roles and functions of the VEC, procedure for elections and frequency of the group's meetings. The Solar group in Lingeka village consisted of 76 members and the other in Nyanza village had 52 members. These were the people that purchased the first SHS that were provided for by the project. Although the project was aimed to cover the entire village the people that bought the first SHS formed a group that was actively engaged with the solar project. Majority of the villagers were unable to join this group at first partly due to the inability to afford the required 46$ down payment (for the SHS purchase) and partly because of skepticism about the project. An entry fee of 15000 Tsh (about 7$) was set for members of the village who wished to join the solar group later.

Having a locally anchored and formally registered group that was actively involved in the project enabled the village autonomy from, and over dependence on the NGO and the donors. Through strengthening local capacity and engagement, the project was designed to ensure its sustainability after the five-year project period (2011-2015).

Secondly, the REW functioned as a safe, practical and neutral place to store the repair equipment and the new solar lanterns and panels bought by the VEC. Given that the BSE's work needed to use electrically run machines for their repairs each of the REW was equipped a 320 Wp mini power plant. In Lingeka the REW was a three-roomed stone building built on land that was donated by the village and the construction was partly funded by the project. The largest room was used as both a meeting and local events arena. This room was also used daily by the BSE's to repair broken solar lanterns for their clients. The other two smaller rooms acted as storage rooms. In 2014 the Lingeka solar group bought a TV that was powered by the solar panels on the REW's roof. The group was able to show the 2014 football World Cup. Football fans from the village paid a small fee for each match to watch the games. They also bought a DVD player and showed movies at a fee. This acted as an income earner for the solar group.

Unlike Lingeka, in Nyanza village the VEC initially rented a place for their REW. They later built a similar structure to the one in Lingeka. Although building their own structure meant that they no longer had to pay rent and had a bigger space, the construction of the REW cost them a considerable amount of their fund. While in Lingeka the solar group earned money through showing films, in Nyanza the solar group made an income through mobile phones charging.

The third major component of the model is the use of barefoot solar engineer (BSE). As discussed in chapter seven in this study BSE's formed a critical part of the project in both Lingeka and Nyanza. The BSE's major role was; 1) installing the SHS, 2) repair of solar equipment (after-sale services), 3) advising on what solar equipment to purchase (quality control), 4) technical maintenance of the REW's mini power plant, and 5) educating the public on proper maintenance of solar equipment. The BSE's were not part of the VEC but worked closely with them. In Nyanza village however, Miriam Musa, one of the BSE's was voted as the VEC chairperson. During my interview with her she expressed pride of her achievement as VEC chairlady, but also acknowledged that some villagers took issue with her dual role; as the head of the VEC and a BSE.

The 'revolving fund' is one of the two major modifications particular to the Lingeka and Nyanza solar project. The revolving fund is the name given to the sum total of money paid back by the households. This money is then deposited in the solar group's bank account by the VEC and used to purchase new SHS and solar lanterns that are then sold off to other villagers. According to the financial records of the Lingeka solar group in 2013 they had over 22 million Tsh. (around 10,305 $) in their account. Although this money was supposed to exclusively enable solar PV electrification of the village, the solar group also used this money for other purposes such as paying for parties and food for the solar group meetings. While ICS viewed this as a misuse of the project funds for unintended purposes, members of the group viewed this as their money since they paid back for the equipment. Majority of the respondents however pointed out that there was mismanagement and of the funds by the VEC. This was the major reason why the first VEC in both villages was disbanded.

8.2 Unwrapping the Lingeka-Nyanza model

The Lingeka-Nyanza Model is based on the barefoot approach but contains two major modifications; revolving fund and social-entrepreneurship. Although these two modifications are closely related analyzing them as two distinct modifications offers clarity and insight into the Lingeka-Nyanza model. Tailored to overcome both the major and secondary and barriers as identified by Pode (2010), the Lingeka-Nyanza model was designed as a bottom-up practical approach for sustainable rural solar electrification (Kweka et al. 2011b). Here is a brief description of the barefoot approach followed by discussion of the two modifications and how these were integrated to make the Lingeka-Nyanza model.

The barefoot approach is the brainchild of professor Sanjit 'Bunker' Roy[8] who believes that empowering the rural poor means developing poor people's capacity, putting them firmly in control of their lives and giving them the right to decide how they will improve their quality of life (Roy & Hartigan 2008). Barefoot approach criticizes conventional approaches to empowerment as ''patronizing, top-down, insensitive, and expensive'' and that these approaches ultimately disempowers the poor (Roy & Hartigan 2008). The barefoot approach is therefore an alternative approach, which builds on the local knowledge and skills reducing dependency on inappropriate knowledge and expertise from ''outside''. Through Barefoot colleges, first established in early1970's in Tilonia India, Bunker Roy sought to demystify education by valuing traditional knowledge and skills and learning for self-reliance.

The Barefoot College focuses on six areas: education, drinking water, alternative energy, the environment, empowering the rural women and traditional communication. With regards to alternative energy the Barefoot College trains illiterate and semi-illiterate women from rural areas from across the globe. These women receive comprehensive hands-on training on how to install, repair and maintain solar home systems for six months. After successful completion these women

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[8] Professor Sanjit 'Bunker' Roy is a member of the UN of the secretary-general's high-level group on S4ALL and has been named among Time Magazine's 100 most influential people in the world in 2010. See http://www.un.org/wcm/content/site/sustainableenergyforall/home/members/Roy

are referred to as Barefoot Solar Engineer (BSE's). About 700 women BSE's from Africa, Asia and Latin America have electrified over a thousand remote rural villages with solar PV to date (Barefoot College 2015). Recently the Barefoot College announced the establishment of six regional training centers across SSA, two of which will be located in Tanzania. The one in Zanzibar was opened in August this year while the other in Mtwara, is scheduled for opening soon (Barefoot College 2014; Yusuf 2015).

Apart from training semi-illiterate rural women as BSE's, the approach also involves establishment of both an REW and a VEC as locally anchored institutions. The REW works both as repair workshop for the BSE's and a storage facility for the solar equipment. The VEC's main role is to oversee the solar PV electrification and collection of the monthly fee. The households that have the SHS installed pay the monthly fee. This is used to pay the salaries of the BSE's and cater for the costs of spare parts. The barefoot approach can therefore be viewed, as a fee-for-service model based on categorization by Sovacool (2014).

As mentioned earlier the Lingeka-Nyanza model is largely based on the barefoot approach but with two main modifications. The first modification is the introduction of a three-tiered payment plan that replaced the monthly fee for service. The baseline study conducted prior to the inception of the project concluded that majority of the respondents in Lingeka and Nyanza villages were willing and able to pay about two fifths of the total cost of the SHS as the first installment and two equal payments later (Kweka et al. 2011a). In Lingeka and Nyanza village the initial SHS provided for by the donors were each sold at 115 $ (250,000 Tsh). This was divided into three installments, an initial down payment of 46$ before installation of the SHS and two equal installments of 34$ each later. This amount was agreed upon through a village meeting organized by the VEC. 95% of the clients had paid in full the amount within the first two years (ICS & Sokoine University n. d.).

This modification solved an important ownership problem that was experienced in the first solar PV project the NGO had introduced in Longalonhiga and Mwandu-Itinje villages that used a fee-for service model. Replying to why the project used this model in the first project Paulo Mwabusila, a project officer working for ICS said;

> ‘‘The project in Mwandu Itinje and LongaLonhiga was our first rural energy project. We were beginners, and since Bunker Roy was experienced with such projects we entrusted his approach.’’

Bunker Roy was personally involved in both projects and had visited the project sites. Explaining why the barefoot approach was modified for the Lingeka and Nyanza solar project the ICS director, Jonathan kifunda, said that questions about ownership of the SHS began to arise after the first year. Households that had the SHS installed wondered how long they would keep paying the monthly fee. Theoretically the SHS belonged to ICS and the households were hiring this equipment from them. This discouraged proper maintenance by some households while others stopped paying the required monthly fee. This failure provided an important lesson for the Lingeka-Nyanza model. Instead of hiring the SHS, they were sold to the households. Ownership encouraged proper maintenance and repayment. This model meant that the household fully owned the equipment after the last installment. Dividing the payment of the SHS into fixed installments made it affordable to many people in the village.

The money paid back was then be collected by the VEC and used to buy more solar equipment that was then sold to other households. In this way, the initial funding provided by the donors ‘revolves’ as different households pay back the money owed and the VEC collects this and buys more solar equipment to be sold. Hence the name revolving fund.

The second modification to the barefoot approach was the introduction of social-entrepreneurship. Samer (2012) defines a social-entrepreneur as;

> “a mission-driven individual who uses a set of entrepreneurial behaviors to deliver a social value to the less privileged, all through an entrepreneurially oriented entity that is financially independent, self-sufficient, or sustainable.”

Following this definition the solar group (headed by the VEC) can be viewed as the social-entrepreneur whose main mission is to improve access to solar PV to the rural energy poor through innovative business practices that is financially independent and sustainable. The VEC after collecting the money and depositing this into a joint account approached a major local solar equipment distributor and buy these in bulk. Buying directly from the distributor and in bulk meant that the VEC were able sell the solar lanterns at prices that were both competitive and generate revenue that was used to further improve access to solar PV electricity. As Samer (2012) notes, social entrepreneurship tend to operate within the boundaries of two business strategies; non-profit with earned income strategies and for-profit with mission-driven strategies.

The revenue was then used to buy new solar equipment and cover to costs such as transport, and wages for the people that peddle the solar lanterns both within and without the village. The VEC organized the sale such that a few members would peddle the solar lanterns door to door, to other villages and also sell this at the weekly open-air market. Within the village the VEC would sell the more expensive panels and SHS by installments. The prospective buyer however needed to be verified first by a member of the solar group who acted as a guarantor. A payment plan is then written down and the chairperson, the guarantor and the client sign this agreement. Through social pressure this mechanism ensured that the clients paid back what they owed. This is demonstrated by the high repayment rate in both villages.

In addition the VEC are driven to sell more solar equipment, which in turn ensured their availability, and awareness of solar energy in the village. The social enterprise aspect also encouraged diversification of the solar equipment sold in the village. Among the solar equipment that Lingeka VEC had in store were solar panels (ranging from 100Wp to 20Wp), and several models of solar lanterns (see figure10). Explaining this Paulo Mwabusila said that,

> "If they [the VEC] only brought the larger solar equipment [the SHS] it would take two to three years for them [the households] to pay this back because their income is seasonal, they depend on selling their harvest in order to earn money"

The solar equipment's are sold at a low profit to the villagers. The aim is to ensure availability and affordability of the solar equipment's in the villages rather than profit making. Through the revolving fund the VEC have been able to buy and sell solar equipment's mainly within but also outside the village. From the sample in Lingeka village the majority of the respondents (70%) said they bought their solar equipment from the VEC in Lingeka and a few bought the solar equipment from other sources. While about 85% said they used the BSE's for the repair ad maintenance of their solar PV systems.

8.3 The Lingeka-Nyanza Model –Success factors and challenges

The 4A's model described earlier suggests a matrix of four principles that can be used to analyze the Lingeka-Nyanza model. Starting with awareness, solar energy was well known by majority of the villagers already in 2011, 77% of the respondents in Lingeka and Nyanza knew about solar technology (Kweka et al. 2011a). Fives years later not only were all the villagers familiar with solar energy and using it but the reputation of the BSE's and the services they offered had reached far away villages. As described earlier the BSE's repaired and installed solar lanterns for clients both within and outside their village. Through public meetings and intensive awareness campaigns Lingeka and Nyanza villagers ensured that the villagers were aware both of the solar equipment's and the after-sale services offered by the BSE's. Later the solar group through peddling and selling solar equipment also raised awareness of the people on solar energy.

In terms of acceptability majority of respondents in Lingeka and Nyanza villages expressed their satisfaction with solar energy as a source of power. The VEC's purchase of smaller and cheaper solar lanterns meant that there were a variety of types of solar equipment's at different prices to suit the needs of a particular household. From cheap S2 models that only provided light to more expensive S300 models that provided brighter light and electricity for charging mobile phones. Many respondents reported to buying their solar equipment through the project as these were seen to be of superior quality as opposed to cheaper models in the markets that often malfunctioned. With regards to the after-sale services offered by the BSE's in these two villages the lack of spare-parts meant that they were limited in the type of repairs that they carried out. This reduced the popularity of the BSE's as villagers turned to local electricians for the repair services.

The Lingeka-Nyanza model also ensured affordability. The VEC's bought a range of solar products in bulk that enabled them to sell these at affordable and competitive prices. Furthermore dividing the cost of expensive products into installments, allowed the villagers to overcome high upfront costs. Through use of social pressure and good records the VEC ensured that villagers paid back what they owed. In addition, the after-sale services offered by the BSE's were also relatively cheap. Through a village meeting, the BSE's agreed on an equal amount to be charged for instance simple repairs costs around 2000 Tsh.

The Lingeka-Nyanza model also ensured a high level of availability of the solar products. Villagers did not need to travel outside their village to buy solar products or take their broken solar lanterns elsewhere for repair. Both the products and the after-sale services were available within their respective villages. In addition members of the solar group peddled the solar lanterns to other villages and also sold these at the local market. The presence of the BSE in the village meant that a broken solar lantern or a faulty SHS could be repaired on the same day.

The matrix below summarizes the results of the 4A framework applied to the Lingeka-Nyanza Model.

Table 11. The 4A's framework matrix

	Product	**Level**	
Awareness	Solar PV equipment	High	Majority of people knew about the solar products, and were aware of its benefits and used the services of the BSE's
	After- sale services	High	
Acceptability	Solar PV equipment	High	Majority of the people expressed their satisfaction with the solar PV products Due to lack of spare parts some people doubted the skills of the BSE's
	After-sale services	Medium	
Affordability	Solar PV equipment	High	Diversity of solar products at different prices and credit scheme Standardized charges by the BSE
	After-sale services	High	
Availability	Solar PV equipment	High	Products were available within the village The BSE's lived in the village
	After-sale services	High	

Analyzing the Lingeka-Nyanza model through the 4A's framework indicates that the model has indeed been successful. Comparing how each of the two villages experiences with the model to each other however reveals a more complex picture of the model revealing the model's success factors and pitfalls.

One of the main success factors of the model in Lingeka village was the presence of credit facility. In Lingeka village the presence of a longtime local agricultural CBO contributed in two main ways. Firstly this meant that villagers had experience on how to run and manage a local institution, several officials of the VEC and members of the solar group were also active members of the CBO. Secondly the CBO offered its members simple small loans which enabled them to pay the required 46$ down payment for the SHS. Nyanza in comparison lacked a well functioning credit facility and there were reports of mismanagement of funds and mistrust among the villagers there.

The second success factor is the relatively affordable payment plan. By splitting up the cost into three decreasing installments and use of social pressure to encourage repayment, ensured that more villagers adopted solar PV. All the 152 SHS and lanterns were purchased at the beginning of the project and 95% of the household paid back within the first two years (ICS & Sokoine University n. d.). Using this money the VEC bought cheaper solar equipment that was sold on credit. By introducing a variety of solar equipment as indicated earlier, the household could purchase the solar equipment they could afford.

A third success factor is the continuous support and advice offered by ICS throughout the project period. The project was planned such that the villagers' participation was included from the beginning with decreasing support from the project implementers. For instance, during the beginning of the project officer from ICS was a co-signatory for all major withdrawals of money from the bank. The role here was to monitor and deter from mismanagement of the funds by the newly elected VEC. Later ICS left this responsibility to the VEC, requiring that at least two officials signed for any withdrawal. ICS officials also monitored the elections and mediated eventual conflicts and advised the VEC on where to buy the solar products. The goal was that the VEC would run independently with little support from ICS after the five-year project period.

Despite its success the Lingeka-Nyanza model had several challenges and pitfalls. One of the major challenges was the unclear role and relation of the solar group (*chama cha sola*) to the village. The group was formed as a pragmatic and legal solution given that including everyone in the village would have been impractical. Tanzania's Society Act recognizes the registration of local CBO and enables such an entity to open and run a bank account. The solar group thus included the most active members of the villagers that were engaged in the project whom naturally were the project pioneers. Headed by the VEC, the group's major role was to ensure the adoption of solar energy in the village through the revolving fund. The solar group however viewed themselves as an exclusive club, as the 'owners' of the project and used some of the funds to hold expensive meetings.

Secondly all respondents in this study mentioned the lack of spare parts as a major challenge. Although the project provided several spare parts that were used by the BSE, five years later all these had been used up. Several of the SHS and lanterns that were sold were now non-functional due to lack of compatible batteries. Compatible batteries and broken parts for the SHS were unavailable in the local market. The project had however planned to carry out an inventory of available and compatible spare parts in the region. This task was not completed.

Other challenges that affected the Lingeka-Nyanza model included the mismanagement of funds by the VEC, and the restriction of the women BSE's access to the REW discussed in chapter 7. The first was however redressed through election of a more transparent and inclusive VEC. The latter however remains an unresolved issue. In Nyanza there were of vandalism of the rooftop solar panels of the mini power plant. A few panels were reportedly stoned and rendered non-functional by disgruntled villagers.

These challenges notwithstanding, the Lingeka-Nyanza model has proven to be a successful model of disseminating modern source of energy in remote off-grid areas. However a pertinent question remains whether this model can be replicated in other rural areas in Tanzania; how can this model be scaled up and scaled out to other rural energy poor areas?

8.4 Discussion – what next?

Following the literature reviewed earlier in this study it can be indeed argued the Lingeka-Nyanza model illustrates that technologies are merely only 'one piece of the puzzle' in solving the energy poverty problem as argued by Sovacool (2014). Furthermore the Lingeka-Nyanza model also, emphasizes the importance of technological absorption as opposed to technological adoption as discussed earlier in this study (Murphy 2001). By focusing on building local 'technological capabilities' adapted to the local context this model has to a large extent been able to overcome the technical, economical organizational and institutional factors that limits absorption of technology in rural SSA.

Furthermore the Lingeka-Nyanza model addresses almost all the major and secondary barriers of solar PV technology absorption as identified by Pode (2010). The table below summarizes how this model redresses each barrier at the local level.

Table 12 How the Lingeka-Nyanza model tackles barriers to solar PV absorption		
Barrier	**Degree of importance**	**Solution by Lingeka-Nyanza Model**
Limited awareness of, and experience with PV technology. Energy is a low priority area among users	Major barrier	Awareness campaigns on importance of clean energy through village meetings, solar group and VEC.
Inadequate business knowledge and capacity for distribution.	Major barrier	Trained VEC members on entrepreneurial skills Members of VEC peddling solar lanterns door to door
Limited technical knowledge of installation, operation and maintenance	Major barrier	Local women trained as barefoot solar engineers, offer readily available affordable and quality services and repair
High cost of solar systems, initial capital investment and operation and maintenance costs	Major barrier	Grant by donor for first solar equipment's. Funding by donor for the women BSE training Local in-kind contribution (Lingeka donated land for the REW) Revolving fund and social-entrepreneurship to ensure self-sustainability
Low purchasing power of the rural people.	Major barrier	Break down payment into three affordable installments. No collateral required- Use social pressure and informal relation to ensure repayment.
Difficult access to finance for end users	Secondary	Local CBO that offer small loans to clients
Lack of established dealer network.	Secondary	Use local network to purchase solar equipment in bulk
Inadequate policy implementation.	Secondary	This falls beyond the local village's mandate

The Lingeka-Nyanza model however does not adequately address the last two barriers. This is mainly because these barriers fall beyond the zone of influence of the local people. In order to establish a dealer network to supply quality solar equipment and spare parts requires the intervention of other stakeholders such as private businesses that are willing to serve the people at the 'bottom of the economic pyramid'. Forging an alliance with renowned and influential national NGO's such as TaTEDO and TAREA that focus on energy poverty may allow trusted dealers to be connected to local solar groups and VEC's. Policy implementation on the other hand lies in the government's domain. The government can enact policies that allow only high quality solar equipment is sold in Tanzania. In the national energy policy document for instance, under the household energy sector the policy states that there is need to "ensure safe utilization of household energy appliances through regulation of safety standards"(URT 2003).The government can also promote off-grid solar projects by recognizing the BSE's and offering support to local VEC's and solar groups through group training on basic entrepreneurial and managerial skills. This training could be done through existing agricultural extension officers.

As mentioned earlier the Barefoot College opened a training center in Zanzibar in august this year while another in Mtwara, southeast Tanzania will be opened soon. Having a regional training center for the BSE's greatly reduces the cost of training women to become solar engineers. They no longer need to travel to India and in addition the trainers in Tanzania will be speaking the same language as the new trainees. This will greatly benefit both the women and the rural areas they will 'light up'. The local training center offers also a great potential both for scaling up and scaling out of the Lingeka-Nyanza model.

By addressing the challenges discussed above and by utilizing the training centers the Lingeka-Nyanza model can be scaled up and scaled out to other villagers. Of course, this model cannot be seen as panacea for rural energy poverty, but gives valuable lessons that can be adapted to local context in order to address at least allow the rural energy poor access cleaner, modern, renewable energy source. Furthermore although the Lingeka-Nyanza model seems to appropriate in promoting solar PV technology, it is limited to household lighting and powering low-voltage appliances only. The low voltage of solar PV cannot replace other high energy demanding activities such as cooking and thus remains a partial solution to reducing inefficient biomass energy use which negatively affects both indoor and the larger environment (Karekezi & Kithyoma 2002).

It is important to note that the Lingeka-Nyanza model fits closely to the new 'sustainable program paradigm' (Sovacool 2014) discussed earlier in this study (Table 3). As envisioned by this paradigm, the Lingeka-Nyanza model has brought together several stakeholders who play different complimentary and work towards a similar goal i.e. environmental and social sustainability. This model also demonstrates the success of the bottom-up approach where the prime beneficiaries are not merely passive receivers of ‘free donation’ but also contribute in-kind with what they have. The training of local women to become solar engineers has not only ensured affordable and locally available, after sale services but also raised awareness and acceptability of modern energy sources in the rural village. Nevertheless there is need for policy implementation and stricter regulation to ensure that the equipment available in the market is of high quality by setting stricter national standards.

The Lingeka-Nyanza model proves the need for a paradigm shift in how energy is produced, used and distributed especially to the people at the bottom of the economic pyramid. By scaling up and scaling out this model it can be one solution to the ‘disturbing trilemma’: sustaining economic growth, enhancing energy security and improving the environment (Benali & Barrett 2014) . Looking at the Lingeka-Nyanza solar project from a larger perspective indeed demonstrates the need for the three crucial elements as identified by Colombo et al. (2013a) i.e sound technical solutions (decentralized solar PV), enabling policies (the 2003 National Energy Policy) and innovative business models (Lingeka-Nyanza model) if off-grid renewable energy can be used as one way of solving the plight of the energy poor.

9.0 Summary and Conclusion

This study has examined the solar PV project that was initiated five years ago in two non-electrified villages in rural northern Tanzania. By introducing solar PV electricity to the residents of Lingeka and Nyanza village, this study concludes that project has to a large extent improved the quality of life of the households that adopted solar energy. It has demonstrated that children who live in households that have use solar PV tend to study more and have improved their grades. Similarly the use of solar lanterns have replaced harmful kerosene lamps and unreliable battery-powered torches (*Richmond*) improving indoor air quality and by extension the health of the household members. Solar SHS and lanterns have diversified the energy sources available to the residents in these villages, allowing them to earn income through lighting for their business and earn extra income through charging mobile phones. The extensive use of solar energy in the village has reduced the safety hazards that the darkness brings with it. It has enlivened the nightlife of the residents of Lingeka and Nyanza. The introduction, and use of solar PV in these two villages has indeed improved the quality of life of its residents.

The study has also examined and discussed how becoming a barefoot solar engineer has empowered the four BSE's using CARE's Women's Empowerment framework. According to this framework, it is evident that BSE's have their individual and collective capacity to access and influence the resources, especially their labor and by holding of important and esteemed positions in the project they confront and challenge gender norms and power structure in their community. The crucial role played by these women BSE's also contributes significantly to the projects sustainability. By making after-sale services available within walking distance of many of their clients has clearly encouraged many people to switch to solar energy. Through gender mainstreaming it is clear that the Lingeka and Nyanza solar project, has not only demonstrated that women can benefit more by switching to modern energy technologies but can also play an integral and crucial role. In other words the project goes beyond the usual 'quick fixes' for solving women's energy issues and views women as part and parcel of the solution.

Lastly this study examined the innovative business model that was used to promote solar PV electricity in these two villages. Analysing the Lingeka-Nyanza model using the 4A's framework shows that it scores highly in all the four aspects. The model has increased availability and awareness of diverse solar equipment that meets the households lighting needs and power their electrical appliances notably the mobile phones. The model has also ensured affordability and acceptability of solar PV technology by breaking down the payment of solar equipment into manageable instalments and providing local after-sale services. Although based on the barefoot approach the Lingeka-Nyanza model introduced two innovative modifications: the revolving fund and social entrepreneurship. These modifications have enabled the model to redress common barriers that have hindered solar PV in rural solar projects. The innovative Lingeka-Nyanza model if up-scaled and adapted to local context may contribute significantly in alleviating energy poverty that continues to affect the majority of rural poor in SSA.

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11.0 Appendices

11.1 List of interviewees and FGD's

Name	Title/ description	Date and place
Stephan Nkwaya	BSE Lingeka	01. 10. 2014 Lingeka
Lucia Ngranga	BSE lingeka	07. 10. 2014 Lingeka
Monica Mirega	BSE Nyanza	12. 10. 2014 Nyanza
Miriam Musa	BSE Nyanza	12.10. 2014 Nyanza
Josephina Joseph	Nurse	02. 10. 2014 Lingeka
Paulo Mwabusila	Project Officer - ICS	13.10. 2014 Meatu
Jonathan Kifunda	ICS regional Director	15. 10. 2014 Shinyanga
Lingeka FGD	7 people (4 female & 3 male)	06.10. 2014 Lingeka
Nyanza FGD	8 people (3 females & 4 males)	08.10.2014 Nyanza
Mwakisandu FGD	10 people (4 females & 6 males)	12.0.2014 Mwakisandu

11.2 Household Questionnaire

HOUSEHOLD QUESTIONNAIRE

Date: ___________________ Household ID Number: ___________

Village:____________________ Hamlet Name______________________

District_____________________ Region ____________________________

SECTION A. HOUSHOLD COMPOSITION AND ECONOMIC STATUS

A1. Household general information

Respondent's identity	Gender	Age (years)	Marital status	Education level	Occupation
1. *Head* 2. *Spouse* 3. *Son* 4. *Daughter* 5. *Relative*	*1. Female* *2. Male*		*1. Married* *2. Single* *3. Divorced* *4. Widow/widower* *5. Separated* *6.Single parent*	*1. None* *2. Primary* *3.O level Sec.* *4.A level Sec.* *5.College* ***Number of years***	*1 Farmer* *2. Permanent job* *3. Temporary job* *4. Business* *5. Retired* *6.Student* *7. Any other*

A2. Indicate the total number of family members in each category

Age Category	Below 5	6-14	15-20	21-45	46-60	Above 60

Females						
Males						

A3.If farming please indicate what crops you grow

Type(s) of cash crop ____

Type(s) of food crop ____

A4. Number of children attending school

Education level / **Gender**	**Kindergarten**	**Primary**	**Secondary**	**Tertiary**
Males				
Females				

A5. How many buildings are there in compound (*observe*) ____________________
For each building assess the following

	Roof Material				**Wall material**				**Floor material**			**No. of rooms**	**General condition**		
	Thatch	Iron Sheet	Concrete	Earth	Wooden	Mud/ unburnt bricks	Bunt bricks or concrete blocks	Plant Residues	Earth	Wooden	Concrete		Poor	Moderate	Good
1															
2															

3															
4															
5															
6															
7															

A6. Who owns the dwelling? (*Tick one option*)

1) Renting ☐ **2)** Owned permanently by occupant ☐

A7. What assets does the household possess? (*Indicate how many in each case*)

Type	Car	Motor cycle/	bicycle	cart	radio	TV	mobile	solar PV/ Lantern	Plough	Panga /Jembe
No.										

A8. What kind of animals does the household possess and how many in each group?

Type	Cattle	Goats/sheep	pigs	Chickens/ducks	Donkey	Others specify
Total #						

A9. How much do you earn per month (Tsh.)? Both farm and off farm earnings. Estimate in Tsh_____________________

A10. Are you a member of any local group (*kikundi cha sola, CBO, Kikundi cha watumiaji maji, shamba darasa*)? **YES** **NO**

If yes please indicate which local group and your role in this

Group /committee:_____________________

Role:___________________________________

SECTION B. HOUSEHOLD LIGHTING ENERGY SOURCE AND USE.

This section seeks to map out the energy use, access and attitudes towards the solar home system and lanterns.

B1. Does your household currently use solar PV and or lantern? (*circle one answer.*)

Yes **No**

B2. What type of solar equipment do you have?

	Type	**Number of units**
1.	Solar Panel SHS	
2.	S2 (*kitumbua)*	
3.	S20 (ka*jug)*	
4.	S250 (*birika*)	
5.	Solar kit	

B3. How did you acquire this solar system? (*put an X where applicable*)

		Answer	**Year Installed/Purchased**
1.	I acquired from ICS Project (*awamu ya kwanza*)		
2.	I bought from ICS (*awamu ya pili*)		
3.	I purchased it myself (from where)		
4.	Other (please specify)		

B4. Of the sources of energy indicated below which ones does the household use for lighting and how often? Please fill the table *(Indicate with an **X** where applicable.)*

		Frequency of usage Daily Occasionally	**Indicate how many units you have** (put number 1,	**Indicate cost paid for the systems you are using**	**Indicate the main use of the systems e.g.** in kitchen living room, For children to

		Never	2)	(per unit/item)	read
1	Kerosene lamp (*Chemli*)				
2	Wick lamp (*kibatari)*				
3	Candle (*mshumaa*)				
4	Torch (item + dry cell)				
5	Solar PV SHS system	|			
6	Solar lantern				
7	*Richmond*				

B5. Now that your household has access to solar electricity how does your household use this energy? (*Indicate with an X where applicable*)

		Response
1.	Home lighting	
2.	Charging household members phone	
3.	Use to power home TV	

4.	Used to power home radio	
5.	Others (please specify)	

B6. Does your household use the electricity for commercial purposes for example in own shops, hotels or barbershop? If yes please indicate type of business and how is this energy used. (*Indicate with an **X** where applicable*).

Type of business/ businesses	

Solar electricity use in the business	**Answer** **(***Put an X)*
Lighting in the business premise	
Phone charging for pay	
Entertainment system in business i.e Tv or radio	
Others (please specify)	

B7. Have you faced any problems when using solar power? If yes, please state these problems.

1.________________________________
2._________________________________
3._________________________________

B8. When you encounter such problems what do you do? (*Put an X*)

Action	**Response**
Contact the trained BSE	
Contact other local solar electrician	
I repair it myself	

B9. From a scale of one to four, with 1 being not satisfied at all and 4 most satisfied, how satisfied are you with the solar system/ lantern that your household is using? (*Please mark with an X where appropriate*).

1. Dissatisfied	

2.Somewhat dissatisfied	
3.Somewhat Satisfied	
4.Very satisfied	

B10. If household does not have the SHS or solar lantern, please indicate the **MAJOR REASON** for this. (*Please indicate with an **X** where applicable. Please read all the alternatives first before answering, only one alternative is required.*

Reason	**Response**
It is too expensive to buy	
It is expensive to repair and maintain	
Not aware of the solar SHS or lantern	
Solar equipment is not available locally	
Solar energy is not safe	
Other reasons (please specify)	

B11. Since the household does not have the SLHS, what does the household use for home lighting? How much does the household spend per month on each?

Source of lighting	**Indicate X if yes**	**Cost per Unit (ltr., one dry cell)**	**Expenditure per month in Tz Sh.**
Kerosene lantern (*chemli*)			
Wick lamp (*kibatari*)			
Battery powered torches (*Richmond*)			
Candles (*mshumaa*)			

B12. Have you experienced any problems of using the above-indicated source of lighting? (*Circle one*)

YES **NO**

If yes indicate the **MAJOR TWO** problems

1.____

2.____

B13. If you were given a chance to choose among several sources of energy for lighting, what are the chances for solar energy to be selected? *(Tick most appropriate)*

	1st choice	2nd choice	3rd choice
Choice rank			

B14. What would be the reasons for your choice?

____

SECTION C. IMPACTS OF THE PROJECTS ON THE HOUSEHOLD

Subsection I: Education

C1. How many hours on average during the night do your school going children get to study the each day? *(Please tick the most appropriate)*

They don't study at night ☐ Less than one hour ☐

1-2 hours 3-4 hours more than 4 hours

C2.If your household uses solar electricity for lighting how would you compare night time study before and after you used solar for your school going children?

1.	Yes they study more now	
2.	No they don't study more than they did before	
3.	I don't know	

C3. Have you noticed any improvements in terms of your children's grades since you started using solar lighting?

1.	Yes their grades are better now compared to before	
2.	No their grades have remained the same as before	
3.	Their grades have become worse than before	
4.	I don't know	

Type of fuel	# of times collected/wk.	Distance from home (km)	Time spent on the activity

<u>Subsection II: Household economy</u>

C4. Have you experienced any increased income in your household in the previous year?

YES **NO**

C5. If yes explain in what way. (*Indicate with an X)*

Reason	Response
High prices of cotton	
Good rainy season- more yield	
Others (please specify)	

C6. Comparing the times before the household used solar PV and lantern, and the time after, would you say that use of solar has improved the household's income? (*Please tick one*)

No Improvement ☐ Moderate improvement ☐

Significant Improvement ☐

C7. If the household has experienced improvements in its economy**,** how can the household explain this?

	Reason	**Response** *(Yes = 1. No= 2)*
1.	Less expenditure on energy overall	
2.	More income from charging mobile phones for pay	
3.	Savings from reduced medical expenses	
4.	More time for productive work –time saved from buying kerosene	
5.	Other reasons (please specify)	

C8. If the household has not experienced any improvements or is now worse off than before. How can they explain this?

Type of fuel	# of times collected/wk.	Distance from home (km)	Time spent on the activity	Who co
Wood				

Type of fuel # of collected/

Wood

	Reason	Response *(Yes = 1. No= 2)*
1.	More expenditure on solar , repair and maintenance costs	
2.	Expensive solar equipment	
3.	Same expenditure on lighting as before using solar	
4.	Other reasons (please specify)	

Subsection III: Health

C9. Of the illnesses listed below indicate which ones did the people in your household suffer in the past 12 months? *These diseases are mostly associated with smoke in the house*

	Type of Illness	Indicate how often *(tick the most appropriate)*			
		>4 times a year	**2-3 times a year**	**Once a year**	**Never at all**
1	Flu / running nose				
2	Sore throat				
3	Red eyes/ itching				
4	Coughing				
5	Asthma				
6	Burns *(caused by candles and lamps)*				

C10. What do you think are the main causes of these illnesses?

____

C11. Do you think the use of solar lighting home systems contributes to the reduction in these illnesses in a household?

1. Yes ☐ 2. No ☐

Subsection IV: Security

C12. What activities do you do at night that requires use of lighting?

1.______________________________

2.______________________________

3.______________________________

4.________________________________

C13. Please indicate the frequency of the following occurrence in the past twelve months. Use the following table to fill in use this coding **1**= never **2**= rarely **3**= often

Frequency / **Security issue**		**Occurrence** *1= Never, 2= rarely 3= often*
1.	Night time thefts	
2.	Scorpion bites at night	
3.	Snake bites at night	
4.	Animal attacks (hyena)	

11.3 Qualitative Interview Guides

Interview guide for ICS Project Manager

1. Your organization has been involved now for several years in promoting alternative energy technologies in Meatu District. Have you always used the barefoot approach? When and in how many villages have you used this approach?

2. Please give a brief description of the Lingeka-Nyanza model?

a). Why was this approach used to promote alternative energy sources?

b). Have you used other approach (es) before, if yes please explain how different these is/are from the current approach?

3. You have been able to provide SHS to over 150 households in Lingeka and Nyanza villages using this approach. Please explain the successes and challenge of using this approach in general.

4. The Lingeka-Nyanza model has several distinct components. These are;

a. Training semi-literate women BSE’s

b. The Village Electrification Committee and the Rural Energy Workshop

c. The revolving fund

Please explain how each of these components has contributed to the model and the role of each

5. What is the challenge with regards to these components?

a) What is the relation (roles, responsibilities, and duties) between ICS and the two VEC's formed in Lingeka and Nyanza.

6. Given your experience would you say this approach is appropriate promotion model for alternative energy technologies in rural areas? Why or why not?

7. About Improved Cooking Stoves in brief – challenges and way forward

<u>Interview guide for Barefoot Solar Engineers</u>

1. When did you study to become a barefoot solar engineer and where?
2. Briefly describe your role and responsibilities as a BSE.
3. How has your experience as a BSE been for you? The project is now coming to an end, what are your views about the future
4. What are the main challenges you have faced as a BSE?
5. What are your experiences and views on the projects barefoot approach i.e. the revolving fund, the VEC and REW.
6. Do you have any other relevant information that we have not discussed?
7. About types of solar equipment and solar market?

<u>Topic for discussion for focus group discussion</u>

Agenda 1: About the Energy situation in General

- What were the major sources of energy before 2009? Have these changed? If so how and why?
- Please describe the Village's awareness of clean energy alternatives and technology
- What are the disadvantages and advantages of these?

- How does the community value alternative energy technologies?

Agenda 2: About the projects' approach

- Community's participation in the project and during the entire period?
- Community's view and experience with regards to the BSE's
- Community's views and experience with the revolving fund.

Agenda 3: About the institutions established by the project – The VEC and REW

- What is your experience with these institutions thus far
- What works- what are the major benefits and major challenges
- What hasn't worked and Why? Can you suggest a way forward?

Agenda 4: About Solar Energy

- Available solar equipment in the region
- Use of these equipment, traditional and innovative

Agenda 5: Discussants major suggestion for the improvement of the project

What suggestions does the village have with regards to the project?

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