FACTORS AFFECTING SUSTAINABILITY OF SOLAR MINI - GRID SYSTEMS IN KISII COUNTY, KENYA

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Factors Affecting Sustainability of Solar Mini - Grid Systems in Kisii County, Kenya

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DECLARATION

This research is my original work and has not been submitted for an award of a degree in any other university.

Signature…………………………………………………………….Date…………………

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This thesis has been submitted for examination with our approval as the University Supervisors

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DEDICATION

I dedicate this research project to my family especially my dear wife Beatrice, children Joylyan, Tamara and Jabin who are my strong pillars and sources of great inspiration. My parents Joyce and Remigius for their unceasing prayers for God's blessings upon me to be the best I can. May the supreme almighty God bless you all.

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LIST OF ABBREVIATIONS/ACRONYMS

AfDB	African Development Bank
AWF	African Water Facility
CBCPGs	Community-Based Co-operative Purchasing Groups
CEF	Clean Energy Fund
CERs	Certified Emission Reductions
CEEC	Certified Energy Efficiency Council
CDM	Clean Development Mechanisms
CFL	Compact Fluorescent Lamp
CGT	Capital Gains Tax
CO_2	Carbon Dioxide
CPGs	Co-operatives Purchasing Groups
CSD 9	Commission on Sustainable Development 9th Session
DSM	Demand Side Management
EC	European Communities
EPRA	Energy and Petroleum Regulatory Authority
ESCO	Energy Service Company
ET	Energy Tribunal
FiT	Feed-in Tariff

GDP	Gross Domestic Product
GHG	Green House Gas
GNESD	Global Network on Energy for Sustainable Development
GOE	Government of Ethiopia
GOK	Government of Kenya
GSMA	GSM Association
GWh	Giga Watt Hour
IDT	Innovative Diffusion Theory
IEA	International Energy Agency
IPPs	Independent Power Producers
IRR	Internal Return of Return
JV	Joint Venture
KAM	Kenya Association of Manufacturers
KenGen	Kenya Electricity Generation Company
KETRACO	Kenya Transmission Electricity Company
KPLC	Kenya Power and Lighting Company
kWh	Kilo Watt Hour
KRA	Kenya Revenue Authority
LCPDP	Least Cost Power Development Plan

LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals
MoEP	Ministry of Energy and Petroleum
MOWR	Ministry of Water Resources
MW	Mega Watt
MWp	Mega Watt Peak
NGO	Non-Governmental Organization
NPV	Net Present Value
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OPA	Ontario Power Authority
P.A	per Annum
PESTEL	Political, Economic, Social, Technological, Environmental and Legal
PPAs	Power Purchase Agreements
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
R&D	Research and Development
RBV	Resource Based View

RCD	Residual Circuit Device
RE	Renewable Energy
REP	Rural Electrification Programme
REREC	Rural Electrification and Renewable Energy Corporation
RESOP	Renewable Energy Standard Offer Programme
RET	Renewal Energy Technology
REV	Renewable Energy Ventures
ROI	Return on Investment
SCF	Strategic Climate Fund
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy For All
SHS	Solar Home Systems
SPB	Simple Payback Period
SPSS	Statistical Package of Social Science
SPVPPs	Solar Photovoltaic Power Plants
SREP	Scaling-Up Renewable Energy Program
SSA	Sub-Saharan Africa
SSM	Supply Side Management
TW	Terawatt

TWh	Terrawatt Hour
UAP	Universal Access Programme
UN	United Nations
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
USAID	United States Agency on International Development
USD	United States Dollar
VAT	Value Added Tax
WEC	World Energy Council
WEO	World Energy Outlook

ABSTRACT

The main objective of this study was to investigate factors affecting sustainability of solar mini-grid systems in Kisii County, Kenya. The specific objectives were to establish the influence of energy policy /framework advisory, implementation mechanism and capacity building/training on sustainability of solar mini- grid systems in Kisii County, Kenya. A descriptive research design was used in this study with a target population of 710 drawn from the customers connected to and the operators of solar mini – grid systems within Kisii County. Additionally, solar renewable energy resource was analyzed using Photovoltaic Geographical Information System (PVGIS) to determine the capacity of the installed solar mini grid systems. Energy policy framework, implementation mechanisms and capacity building/training were found to affect sustainability of solar mini - grid systems in Kisii County, Kenya with 63.5% change in sustainability of solar mini-grid system being attributed to these three factors. Evaluation of economic sustainability of solar mini-grid systems solution deployed in Kisii County deduced that the systems as designed and deployed had a 14 year return on investment, and this, on comparison with the useful project life of 20-25 years, was a pointer to a project that may least achieve economic sustainability. The study concluded that the systems as designed and deployed, were sustainable against environmental and social sustainability indicators. The study recommended that from a policy stand-point, the Government should map out exclusive zones for decentralized solar mini-grid systems deployment to improve on their economic sustainability through reduction of competition amongst other solar mini-grid implementers. The Government should also from a regulatory perspective, sanction a mandatory feed-in tariff mechanism where it is impractical to zone off areas exclusive for solar mini-grid deployment, especially in areas earmarked for national grid extension programme.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Mini-grid systems are defined as one or more local small-scale off-grid generation and distribution units supplying less than 11kW of electricity to domestic, commercial, or institutional consumers over a local distribution network. They can operate either in a stand-alone mode or can also be interconnected with national grid infrastructure when available. According to the International Energy Agency- IEA, (2012) and GSM Association – GSMA, (2012 -2013), over 1.6 billion people in the world, have no access to electricity and over 1.0 billion people in the world have access to unreliable electricity. The lack of access to electricity is most acute in developing countries such as Asia and sub-Saharan Africa. Further, the majority of these un-electrified population reside in rural village areas. According to IEA, (2012), the average electrification rate (in terms of population) across the developing countries is 76%, with approximately 92% in urban areas and only around 8% in rural areas. This paints a grim picture of lack of energy access on a massive scale with attendant effect on development within the rural unserved areas.

In order to bridge the energy access gap, various energy generation methods have been deployed including those that use fossil fuels that have environmental impacts. This energy scenario has significantly changed in the last few years due to increasing environmental concerns and the attention shifted towards the environmental effects of the energy generation. A correlation was sought between energy, development and sustainability (Leva and Zaninelli, 2006) and there existed a strong relationship between the quality of the living environment and energy generation, implying that the use of fossil fuels for energy production has generated environmental effects that negatively impact social wellbeing beyond acceptable limits.

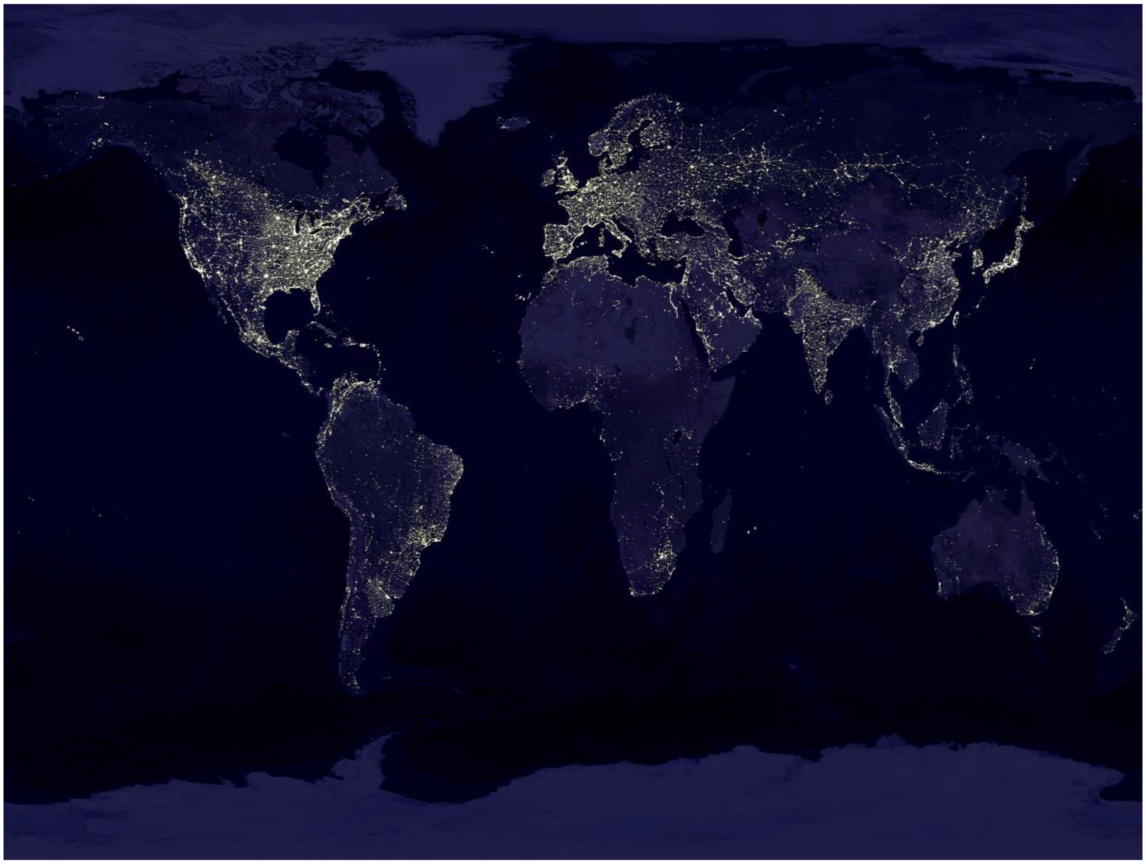

Figure 1.1: A satellite image of the globe showing electricity densification across the world.

From figure 1.1, there is high electricity densification in the developed world such as European and North America continent unlike the developing world such as Africa, Asia and South America.

There has been a rapid growth in new renewables because of increased uptake of the relevant technologies. The contribution of renewables in electricity matrix is about 19%, and it is estimated that about 16% of global electricity comes from hydro sources and 3% from new renewable (Ranjit, *et. al.*, 2013). Global investments in renewable energy, increased by 32% in 2010, to a record US$211 billion. The increase was mainly attributed to wind-farm development in China and small-scale solar PV installations in Europe (UNEP, 2011). The total continent's investment rose from US$750 million to

US$3.6 billion, largely, due to strong performance in Kenya and Egypt. Africa is vastly endowed with renewable and non-renewable sources of energy (Quitzow, *et. al.*, 2016).

International Energy Agency – IEA, (2017) estimated that the African continent has 1,750TWh potential of hydropower and 14,000 MW of geothermal potential. According to African Development Bank, (2017), the continent received abundant solar radiation throughout the year, and recent studies had confirmed the availability of abundant wind energy resources along some of African continent's coastal and specific island areas. According to IEA, (2017) South Africa which had 4.9% of the global coal reserves remained the major coal producing country in Africa producing 277.9 Million tonnes in 2017, followed by Zimbambwe which had about 26billion tons of global reserves and produced about 0.1% of global coal production. Other countries that had coal reserves included Botswana with over 40 billion tons of coal reserves, Mozambique had about 22 billion tons, Tanzania had 1.5 billion tonnes of coal reserves and produced about 0.25Million tons, and Zambia had 0.1billion tons of coal reserves (African Development Bank, 2017).

Hafner, *et. al.,* (2018) reported that at the end of 2007, the continent had over 117 billion barrels of oil from proven oil reserves and over 14.6 trillion cubic meters of proven gas reserves. However, these energy endowments remained largely under-utilized. Africa is among the developing areas of the world, where energy needs are the most urgent. In Africa, less than 7% of the hydropower potential has been developed while more than 92% of its population does not have access to electricity. This highlights the contrasts of a continent well-endowed with energy resources and the deprivations of its population, industries and businesses of the minimum energy services and products that they require to face the challenges of modern lives and economic growth (de Strasser, 2017). Given the low energy consumption in most of African countries and the huge capital outlay to develop hydropower energy resources, ensuring the whole energy security is only possible by scaling- up regional power supply and transmission networks (World Energy Council, 2003).

According to Fowlie, (2018), mini-grids therefore, can be an important alternative to enhance the effectiveness of central grid extension so as to increase access to reliable electricity services in developing economies. Mini-grids are defined as one or more local generation units supplying electricity to domestic, commercial, or institutional consumers over a local distribution network. They can operate either in a stand-alone mode or can also be interconnected with national grid infrastructure. Although mini-grids can use diesel engine generators, renewable energy-based mini-grids (henceforth referred to as mini-grids) use electricity generation technologies that utilize locally available renewable energy sources like solar, wind, biomass, and run-of-river hydro. These electricity generation technologies include solar photovoltaic (PV) and wind-turbines with battery or other storage systems, biomass gasifiers and biogas digesters with internal combustion engines, pico, micro and mini-hydro turbines, and hybrid systems (a combination of more than one generation technology).

Due to their low or often zero fuel costs (except potentially in the case of biomass-based systems), mini-grids can be more cost effective than those utilizing conventional diesel engine generators or kerosene based lighting. According to Pereira, *et. al.*, (2011) most rural communities where the electricity grid is available, access is low at about 30%. Among other reasons it is clear that the cost of initial connection is a barrier. The seasonality of most household income also does not tally with monthly electricity bills, once connected. According to Kamadi, (2016), Kenya is significantly vastly endowed with various renewable energy resources e.g. wind, geothermal, hydro, solar and biomass. Kenya is amongst the African countries where rural electrification is rapidly growing. Energy access in Kenya is still relatively low at just about 44% with the Government's ambitious energy expansion target of 65% access by 2022 (TFE Consulting, 2017).

Statistics from Rural Electrification and Renewable Energy Corporation (REREC) indicate that, currently, there are 127 rural electrification projects in the pipeline, out of which funding for 22 projects have already been approved. REREC has adopted in many of these projects, decentralized generation and distribution systems (mini-grids). According to Kamadi (2016), one successful REREC project is the electrification of schools which is a flagship project of the Government to enable digital learning in schools. Besides rural electrification projects by REREC, there are other projects being initiated and run by communities in different parts of the country, there are also Energy Service Companies which have been licensed by the Energy and Petroleum Regulatory Authority (EPRA) to offer energy access to rural areas using decentralized systems and these will form the source of data for this study. The utilization of solar energy in general and solar mini-grid system in particular has drawn much attention across the globe as outlined in sections 1.1.1.

1.1.1 The Global Perspective

Globally, Sergio, *et. al.,* (2012) carried out a study entitled 'Solar Energy Potential in Mexico's Northern Border States'. The authors observed and alluded to the difficulty in obtaining comprehensive data regarding the development of solar energy in Mexico, much of the information in the report was obtained through site visits, personal communication with state government officials, journal and newspaper articles. A total of thirty-three (33) newspapers and journals were reviewed and analyzed. Three of these had a national circulation, while the rest were local newspapers from Mexican Border States. Where possible, the information found in newspapers was confirmed by a second or third publication. The emergence of governmental and non-governmental organizations that seek to promote and regulate the development of renewable energy in Mexico, combined with the lack of a single agency serving as an information clearing-house, complicated comprehensive analysis of renewable resource development. Energy projects under 1 MWp (MW peak power) capacity had no reporting or regulatory obligations. Such small, often unreported projects are the most common use of solar energy in Mexico. In fact, there are only two CRE-approved Photovoltaic (PV) projects, one 3.8 MWp in Aguascalientes and another in 30 MWp in Jalisco.

Adachi, (2009) conducted a study on the adoption of residential solar photovoltaic (PV) systems in the presence of a financial incentive: A Case Study of Consumer Experiences with the Renewable Energy Standard Offer Program (RESOP) in Ontario (Canada). Traditionally, high initial capital expenditure and long payback periods have been identified as the most significant barriers which limit the diffusion and uptake of solar photovoltaic (PV) systems. In response therefore, the Ontario Government, through the Ontario Power Authority (OPA), initiated the Renewable Energy Standard Offer Program (RESOP) in November, 2006. The RESOP offers owners of solar PV systems with a generation capacity under 10MWp a 20 year contract to sell electricity back to the grid at a guaranteed feed-in tariff rate of $0.42/kWh. While it is the objective of incentive programs such as the RESOP to begin to lower financial barriers in order to spur the uptake of solar PV systems, there is no assurance that the level of participation will in fact rise. The "on-the-ground" manner in which consumers interact with such an incentive program ultimately determines its effectiveness. The experiences of current RESOP participants were presented, wherein the factors that are either hindering or promoting utilization of the RESOP and the adoption of solar PV systems are identified (Adachi, 2009). A significant finding obtained from this research is that weaknesses in the administration and promotion of the RESOP have been mitigated by the presence of CBCPGs and third parties assisting consumers in the purchase, installation, administration, and connection of their solar PV systems. Recommendations of this study include the creation of new and enhancement of existing CBCPGs, a simplification of the required administrative processes, and an increase in the compensation rates.

Markus and Tina, (2011), in their study on factors determining the success of decentralized solar power systems in remote villages (a case study in Chhattisgarh, India) investigated the organization and design factors of decentralized rural electrification through solar power in light of views from the World Bank, the Millennium Development Goals, Indian Governmental Policy and some additional complementary views. The choice and design of the technology as well as organization of Operation & Maintenance (O&M) are crucial factors, but poverty, illiteracy and geographical remoteness add to the difficulties. In the state of Chhattisgarh, India, a few interesting ways of O&M have been developed and are investigated in this study. Solar Home Systems (SHS) and photovoltaic micro-grids (SPVPP) are also compared. As foundation for the investigations and assessments, a field survey in eleven (11) villages with 168 respondents was conducted. For SPVPPs, the O&M structure was found to work regarding the upkeep of batteries as the plants generally did not degrade over time. However, as florescent lights (CFLs) were normally replaced by incandescent lights, the light hours and reliability decreased and users were found to no longer be able to rely on the supply.

Provision of CFLs is therefore proposed to be included in the sphere of responsibilities of the implementing agency (Markus & Tina, 2011). Quality of installation for SPVPPs has been found to make a very huge difference for the output, and an investment in better inverters is advised on both social and economic grounds. Technical problems were usually found to create social conflicts especially for the operators in the villages, and maintenance costs were large due to failed inverters. Efficiency of the SPVPPs was found to have been grossly overestimated, and thus too little capacity installed, which contributed to the social problems. SHSs are cheaper per kWh, and a more suitable solution for villages with low homogeneity and social cohesion as no cooperation is required. The trust levels within the village and whether there is a presence of minorities is proposed to be investigated when choosing which type of system to install.

1.1.2 The Regional Perspective

African countries have not been left out in the adoption and utilization of solar energy and numerous studies have been conducted on the subject. For instance, Tawiah, (2014) carried out a review on solar utilization in Ghana. The study objective was to review the barriers of the implementation of solar energy and solar home systems (SHS) in Ghana. The study focused on using financial mechanisms such as subsidy as a means of promoting SHS and use the payback period to explore into off-grid solar home system (SHS) as an alternative source of energy. The research method involved both literature review and case analysis of a householder in Ghana. The study investigated the role of financing mechanism such as subsidy in making SHS more affordable. In this particular work a load requirements of all electrical appliances from a household leaving in Dawenya a suburb of Tema in Greater Accra Region, with the help of solar radiation database on PVGIS was used to determine the payback period. A sensitivity analysis was further conducted and the result determined that a modest subsidy of 10% would yield a payback period of about 12 years. The study found that Ghana has enormous solar radiation capacity that can be harnessed to assists the already existing power generation plants but at the time of the research it was evident that little has been done to utilize this solar potential.

It was also realized that there are some barriers which are underpinning the promotion of solar energy utilization in the Ghana, governmental support, country's energy policies, insufficient information and awareness creation and so on and which those things must critically be looked at (Tawiah, 2014). From the findings the study recommended that a more pragmatic approach and more relevant solar widespread strategy need to be adopted to assist the current power crisis the country is facing. It will also be of more use to implement motivations towards solar energy promotion from a long-term focused sustainability point of view rather than from a default option associated with the need to expand the country's electrical capacities. It will also be of importance to implement a stable and legal framework which is complete and transparent before a long term investment can be attracted. Barriers hindering the expansion of solar energy should be identified and dealt with, solar market should be structured or designed so as to determine the wide dissemination of small scale installation. The development of local manufacturing industries should be one way or the other be supported by a strong political will.

African Water Facility, (2008) sought to investigate the utilization of solar and wind energy for rural water supply in Ethiopia. According to the study, despite concerted efforts by the Government of Ethiopia (GOE) to increase water supply in the country, over half of the rural population still lack access to water. To improve access, the use of solar and wind energy for water pumping is a viable option in rural areas since over 83% of the population has no access to the electric grid to power mechanized pumps. However, there were no projects that were under implementation which comprehensively addressed the use of renewable energy for water supply. Therefore, the GOE approached AWF to fund a pilot project on the utilization of solar and wind energy, in order to draw lessons on how to up-scale the use of these renewable energies in the country.

The objective of this project was to aggressively promote and pilot the use of solar and wind energy for water pumping in rural areas of Ethiopia, and so, initiated development of a long-term investment in these technologies under the Government's Universal Access Programme (UAP) where they were appropriate and the most suitable. The methodology for implementation and arrangements were found to be in accordance with the criteria laid down in AWF's Operational Procedures, and the anticipated efficiency, effectiveness and sustainability of the project were considered to be acceptable (AWF, 2008). As well, the MOWR of the GOE shown strong interest in undertaking the project. It was recommended that a grant not exceeding €1,991,880 from the African Water Facility resources be extended to the Ministry of Water Resources of the Government of Ethiopia for the implementation of the project described in the appraisal report. Obligations of the AWF was to make the first disbursement of the Grant to be conditional upon the nomination acceptable to the AWF of the Project Coordinator, opening of a Special Account in a commercial bank in Ethiopia acceptable to the AWF, and preparation of a procurement plan.

Nnamdi, (2014) studied the adoption of solar photovoltaic systems among industries and residential houses in Southern Nigeria. The shortage of electricity in Nigeria creates a huge gap between demand and supply, making individuals and organizations look for alternatives to obtain regular supply of power. The objective of this study was divided into two parts. First identify the barriers and drivers of the adoption of solar PV system among home owners and organizations in Rivers State Southern Nigeria. Second identify the challenges faced by the suppliers of this product for small and large scale suppliers. In order to achieve the objectives of this study, a qualitative research approach was used to carry out the study. A loosely-structured interview and a well- structured interview were used as the method.

Findings from this study suggest that the need for a regular power supply was enough to motivate residential adopters to purchase and install solar PVs and sustainability was a sufficient driver to encourage adoption among the organizations interviewed in this study. On the other hand inadequate policies to encourage subsidies, high cost, difficulty to access finances, high interest rates 20%-22% and short period of payback (3years) for loans involving renewable technology were identified as barriers among residential adopters. Lack of implementation of policies for example double standard shown by custom officials at ports against the zero tax on importation of renewable energy products set by the government, low level of awareness among the public and lack of an organized co-operative group which provides advisory information to potential adopters were among the barriers identified within this study from interviews conducted with suppliers of solar PV systems.

Ogunleye and Awogbemi, (2010) carried out a survey on the constraints to the use of solar photovoltaic as a sustainable power source in Nigeria. Solar photovoltaic is a viable alternative energy for power generation in Nigeria. However, the use is constrained by the high cost of the photovoltaic components. The study pointed out that the daily average power estimates for a 3- bed room flat using low-power consuming appliances is 1.086kWhr. The design analysis shows that it will cost about USD 1,932.11 beside installation cost to generate this amount of power using solar photovoltaic means. 243Whr daily power rate suitable for a room in an apartment will cost USD 451.70 to generate using solar photovoltaic. An average person because of the initial capital cost will opt for a small generator to power his apartment rather than investing on solar photovoltaic. However, on the long run, the man with generator will end up spending more on power generation than the person who invest in solar photovoltaic. The generator will impact negatively on the environment unlike the Solar PV.

1.1.3 The Kenyan Context

In Kenya, Bundi, (2014) did an assessment of factors influencing the choice and adoption of biogas technology among the peri-urban residents of Kisii County. According to the study, despite the potential and demand the adoption level has been low and on a decreasing rate. The study sought to assess the level of people‘s awareness and attitude towards biogas technology, to explore the root causes of low technology adoption in relation to the efforts so far executed in biogas promotion, to assess the efficacy of biogas technology in comparison to other sources of household energy and sought to explain the roles and challenges stakeholders face in their effort to promote biogas technology in Kisii County. Multi-Stage sampling procedure involving purposive selection of resource persons who have been reached by biogas programmes with the purpose of capturing the experiences of biogas users and potential adopters. The study was conducted in the peri-urban of five town centers in Kisii County namely: Kisii, Suneka, Mosocho, Marani and Kiogoro. The study adopted both qualitative and quantitative approaches in data collection and analysis. The study findings showed that 85.71% of the population was aware of the technology and only 114 units in 2007 and 167 units as by December 2013.

Based on the results of the study, there was minimal coordination between stakeholders and lack of a central coordinating body. The study further identified that the government institutions have not fully engaged in promoting biogas technology in the area and instead the responsibility has been left to NGOs without effectual intervention on other factors including information dissemination, access to credits motivation and coordination. Based on the study, the researcher recommended that first the Ministry of Energy should harmonize the policy on energy and environment so as to uphold biogas technology as an alternative clean green energy, secondly there is need for a central biogas coordinating body at the national and regional level to coordinate and monitor stakeholder roles as well as financial management and also introduce technologies that are cheap such as the plastic tubular design through enhanced research.

Ng'eno, (2014) sought to establish the factors affecting the adoption of solar power for domestic usage in Kajiado County, Kenya. According to the author, Kenya envisions transforming itself into a newly-industrializing, middle-income country by 2030. With only 44% of Kenyans having access to grid electricity, solar technology provides the Kenyan government with the opportunity to address energy challenges without the need for expensive power generation projects, transmission and distribution networks. The objective of this study was to establish the factors affecting the adoption of solar power technology for domestic power usage, specifically to assess the extent to which the level of knowledge and awareness of solar technology influences adoption of domestic solar technology, to investigate the extent to which the level of income of households influences adoption of solar technology and finally the extent to which the availability of substitute power source influences adoption of solar technology. A descriptive survey design was undertaken in the study. A stratified random sampling was used to identify a sample and data was collected using questionnaires. A sample of 365 households was studied from a target population of 6733 households.

From the study, only 300 household heads responded which represented 82.5% of the targeted population. The findings indicate that the community has not adopted much to solar technology with only 32% using solar in the region. Out of the three variables studied, all agreed to the research hypotheses concluding that there was a significant relationship between the level of knowledge and awareness, level of income of households, availability of substitute power source and the adoption of solar technology.

The results indicate that the level of knowledge and awareness has a positive effect on adoption of solar technology, level of income of households has a negative effect, while availability of substitute power source does not positively influence the adoption of solar technology (Ng'eno, 2014). The findings of the study may be of use to the Ministry of Energy, to the government in general and to most Energy Solution Companies including Kenya Power and Lighting Company as Kenya looks to achieve vision 2030.

Keriri, (2013) in her study of factors influencing adoption of solar technology in Lakipia North Constituency, Kenya indicated that In one day, the sun sends 10,000 to 15,000 times more energy to the earth than we can all collectively use (Msafiri 66, 2009). Solar power is the conversion of sunlight into electricity, either directly or using photovoltaic panels, a method of generating electricity by converting the sun's radiation into direct current electricity using semi conductors. Kenya envisions transforming itself into a newly-industrializing, middle-income country by 2030, with a globally competitive and prosperous economy and high quality of life in a clean and secure environment. To achieve this vision, energy is identified as one of the foundations and enablers of the socio-economic transformation envisaged in the country. Only 44% of Kenyans have access to grid electricity meaning solar energy provides Kenyan government with the opportunity to address energy challenges without the need for expensive power generation projects, transmission and distribution networks. The objective of this study was to assess the extent to which the level of knowledge and awareness of solar technology influences adoption of domestic solar technology, to investigate the extent to which the level of income of households influences adoption.

The study also sought to establish the extent education of household head influence adoption of solar technology and finally to which extent the availability of substitute power source influence adoption of solar technology in Laikipia North constituency This study aimed at establishing the factors that influence the adoption of solar technology in Laikipia North constituency, a descriptive survey design was used in the study, a stratified random sampling was used to identify a sample and data was collected using questionnaires and structured interview schedules. A sample of 365 households was be studied from a target population of 6733 households; only 300 household heads responded which represented 82,2% of the targeted. The findings indicate that the community has not adopted much to solar technology with only 32% using solar in the region. The findings of the study may be of use to the Ministry of Energy, to the government in general and to most Energy Solution Companies including Kenya Power and Lighting Company as Kenya looks to achieve vision 2030.

Kisii County is located in Kisii in the western Kenya. It has a population of 1,152 282 as per the 2009 census, 245,029 households and covers an area of 1,317.4 sq km. Kisii County is a major business hub in the Western/Nyanza region. Variety of investment opportunities exist in the energy sector. The Gucha river which flows into Lake Victoria has three major falls with potential for mini-hydro plants (http://www.kisii.go.ke, 2016). A captive market exists within the county for the electricity generated including selling to the national grid. Another investment opportunity is in green energy (solar PVs and wind mills) which have great potential in view of the long hours of sunshine and strong winds experienced in the county. Enel Green Power Limited is collaborating with mini-grid technology solutions provider and developer Powerhive to develop and operate mini-grids in 100 clustered villages spread across Western Kenya. The mini-grid project will require an investment of about US$12 million — 93% of which will be paid by Enel Green Power. The installations, which will be developed by Powerhive, will be comprised of mini-grids and will be installed and operated in the Kenyan counties of Kisii and Nyamira. Once completed, the grids will provide clean energy to about 20,000 homes, businesses, schools and health-care centers, serving around 90,000 people in the process. Kisii and Nyamira counties are ideal for mini-grid energy investment due to the high population density which will favour high return on investment as it readily offers the market as well as reduces cost of deployment of the solution.

1.2 Statement of the Problem

Solar power has significant potential to reduce the cost of electricity in rural settings across the developing world. Approximately one fifth of the world's final energy production is consumed by electrical appliances, including lighting (World Bank, 2010). Lighting alone accounts for 19% of global electricity demand (IEA, 2006). In developing countries, lighting is generally thought to rank among the top three uses of energy, with cooking and entertainment (mainly television) and space heating being of even greater significance (World Bank, 2010 and IEA, 2006). While cooking fuel choices have been examined in a number of empirical studies, lighting fuel choices have received less attention. In addition, the adoption and use of renewable energy sources is typically not confined in the context of a specific fuel choice. Yet only in this specific context can adoption of renewable fuel switching be adequately understood. In such areas distant from national utility grids, regional isolated grids – usually referred to as mini-grids – operating on costly diesel fuel are often the main source of electricity to power industry and households.

In Kenya, solar household systems seem to be used to a significant extent for lighting (Jacobs, 2006). Less than 44% of the general population and 5% of the rural population in Kenya have access to electricity (World Bank, 2010). Demand is growing fast for electricity access from both on- and off-grid consumers. Evidence of this includes frequent blackouts due to insufficient supply and the growing popularity of off-grid solutions such as diesel-powered generators and small-scale hydro generation units found both in Kisii and the Mount Kenya highlands that are largely illegal and poorly regulated energy-wise. Adoption of Solar Technology would provide one solution to this evident energy gap but this tends to be neglected in most developing countries. In fact, representative data on solar energy use in Kenya at household level is virtually non-existent.

Despite inadequate, weak or poor policy and legislative frameworks, mini-grids are being developed in a number of countries like Kenya. Some of these mini-grids have been successful because of a number of factors including – government support, community support, proper financing arrangement, sound and/or appropriate technology, etc. According to UNEP, (2011), the unsustainable energy practices of today will need to be reformed if the national developmental goals for a sustainable future will be met. There are significant factors that determine the process of achieving renewable energy projects. Despite the importance of renewable energy there is dearth empirical evidence on the factors that affect sustainability of mini-grid energy in rural areas within Kenya such as aggressive extension of national grid to the rural areas within the country impacting on deployment and sustainability of mini-grid energy. It was against this background that I sought to investigate the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya.

1.3 Objectives of the Study

1.3.1 Main Objective

The main objective of this study was to investigate the factors affecting sustainability of solar mini-grid systems in Kisii County, Kenya.

1.3.2 Specific Objectives

The specific objectives were:

i. To assess the effects of energy policy /framework advisory on sustainability of solar mini- grid systems in Kisii County, Kenya.
ii. To investigate the extent to which implementation mechanism affects sustainability of solar mini- grid systems in Kisii County, Kenya.

iii. To determine the effects of capacity building/training on sustainability of solar mini-grid systems in Kisii County, Kenya.

1.4 Research Questions

The study was guided by the following questions:

i. What are the effects of energy policy /framework advisory on sustainability of solar mini- grid systems in Kisii County?
ii. To what extent do implementation mechanisms of the project affect the sustainability of solar mini- grid systems in Kisii County?
iii. How does capacity building/training affect the sustainability of mini- grid energy systems in Kisii County?

1.5 Significance of the Study

It is anticipated that this study would be useful in providing insight into the factors that influence the uptake of solar power in rural areas in Kenya where there is high solar radiation throughout the year and secure access to electricity is a challenge. The study results would provide representative data on solar energy use in Kenya at household level. This study would be useful for any organization intending to implement renewable energy projects in rural areas. The highlighted issues would be used to define the way-forward that would enhance adopting of good project implementation strategies enhanced by the consideration of various contributing variables mentioned in this study.

The study findings would be of importance to policy makers in the Ministry of Energy who may use it in formulation of policies regarding energy especially in reviewing licensing regimes and zoning areas for renewable energy deployment. The study findings would be used by Energy Service Companies (ESCOs) and by Kenya Power Company as they seek to understand how to bridge the existing energy gap. The study would also be of importance to the Ministry of Forestry and Environment who may be looking at the ways of finding alternative sources of energy from bio fuel to protect the environment. The study would provide valuable information on how solar mini-grid systems' sustainability is influenced by technological, economic, social and environmental indicators, which should be considered when designing, planning and implementing such systems.

The findings from the study would be useful in providing additional knowledge to scholars and academicians on factors affecting sustainability of mini-grid energy. The findings would be useful for reference as regards to implementation and utilization of mini-grid energy in the rural areas. In addition, the findings would provide additional knowledge to the present literature on solar energy technologies and also expose the opportunity in efficiency and sustainability of solar energy as a solution to energy shortages in the country.

1.6 Scope of the Study

The conceptual scope of this study was under-pinned on the factors affecting sustainability of solar mini- grid systems in Kisii County. This study targeted Kisii County where there is an existing stand-alone mini-grid project with similar characteristics to the study objectives and which would allow for generalization of the results. It focused mainly on the staff in the various departments assigned as top, middle and line management in the offices of Enel Green Power in Kisii and Powerhive East Africa as well as the customers connected to the mini-grid energy within Kisii County. The sample was divided into strata that matched the proportions of employees at the offices of Enel Green Power Limited and Powerhive East Africa in Kenya and customers connected to mini-grid energy supplied by the energy service companies operating within the county. The study was conducted between the months of March and

May 2018. Within the subject of sustainability of solar mini- grid systems in Kisii County, the study investigated the various aspects of project economics, planning and implementation that affect sustainability of mini- grid energy in rural areas.

As such, the study sought to investigate the effects of energy policy /framework advisory, implementation mechanism and capacity building and training on sustainability of solar mini- grid systems in Kisii County. The success of this study highly depended on the cooperation of the targeted employees of Enel Green Power in Kisii and those of Powerhive East Africa as well as the connected mini-grid power consumers within Kisii County; there could have been a limitation of some of these stakeholders withholding the information needed for the study for fear of victimization if their seniors got to know they have given out this information, however, the respondents were assured that the information submitted would be treated with utmost confidentiality and would be used for academic purposes only; this effectively reduced this limitation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of the literature on the topic of the factors affecting sustainability of mini- grid energy in Kenyan rural areas. This chapter discusses the literature review of the study on the effects of energy policy /framework advisory, implementation mechanism and capacity building and training on sustainability of mini-grid energy in Kenyan rural areas. This chapter summarizes the information from other researchers who have carried out their research in the same field of study. It's structured on the basis of the research objectives. It involves theoretical review, conceptual framework, and empirical review, critique of existing literature, research gap and summary.

2.2 Theoretical Framework

A theory represents the coherent set of hypothetical, conceptual and pragmatic principles forming the general frame for reference for the field of enquiry. They include set of basic assumption and axioms as the foundation and the body of the theory is composed of logically interrelated, empirically, verifiable prepositions (Camp, 2001). Different theories have been employed to help bring clarity to the study of the factors affecting sustainability of mini-grid energy in Kenyan rural areas. The theories will form the foundation of this study which include institutional theory, resource based theory and stakeholders theory.

2.2.1 Institutional Theory

Institutional theory takes a sociological view of reciprocal interactions between institutions (such as business entities) and society. According to Scott, (2001), 'Institutions are social structures that have gained a high degree of resilience'. Akinola, (2005) observed that institutions 'are embedded in country-specific institutional arrangements' (emphasis added). Differences between national institutions and society affect the level of entrepreneurial activity in each country, the nature and amount of innovation taking place within the country (Kiggundu, 2002).

Scott, (2001) identified three different systems or 'pillars' that support social institutions, namely the regulatory, normative and cognitive systems. In the regulatory system, formal and informal rules are set, monitored and enforced if necessary by means of laws, regulations, and government policies which promote or restrict behaviours within a country (Busenitz, *et. al.*, 2000). The normative system consists of 'normative rules that introduce a prescriptive, evaluative, and obligatory dimension into social life' (Scott, 2001). In contrast, the cognitive system recognizes 'the shared conceptions that constitute the nature of social reality and the frames through which meaning is made' (Scott, 2001). Thus, individuals' cognitive structures and social knowledge combine to represent a nation's cognitive environment.

In contexts where institutional and competitive pressures exert strong influences, the strategic decisions of managers result both in conformity to institutional pressures, which leads to isomorphism and legitimacy, and in differentiation, which, following the resource-based view of the firm, can increase the possibility of creating a competitive advantage through heterogeneity in resources and capabilities. In this study compliance to government policies is a determinant of sustainability of mini- grind energy in the rural areas. This theory therefore supports the first objective of the study: To assess the effects of energy policy /framework advisory on sustainability of solar mini- grid systems in Kisii County, Kenya.

2.2.2 Resource Based Theory

The resource based theory states that the basis for competitive advantage of a firm lies primarily in the application of the bundle of valuable resources at the firm's disposal

(Wernerfelt, 1984), including firm's technology such as solar technology. According to Manoney and Pandian, (1992) firms are able to reach competitive advantage when different resources are employed and these resources should not be imitated by competitors. This may be related to access to solar technology resources, tools and funds available for the firm's competitive edge. From this theory, when households have enough resources of funds and access to solar tools they are able to easily adopt solar technology in their homes.

A resource-based view of an organization explains its inherent ability to deliver sustainable competitive advantage when resources are managed such that their outcomes cannot be imitated by competitors, which ultimately creates a competitive barrier (Hooley & Greenley, 2005) and (Smith & Rupp, 2002). Resource Based View (RBV) explains that a firm's sustainable competitive advantage is reached by virtue of unique resources being rare, valuable, inimitable, non-tradable, and non-substitutable, as well as firm-specific (Finney *et. al.*, 2004, Makadok, 2001). These authors wrote about the fact that a firm may reach a sustainable competitive advantage through unique resources which it holds, and these resources cannot be easily bought, transferred, or copied, and simultaneously, they add value to a firm while being rare. It also highlights the fact that not all resources of a firm may contribute to a firm's sustainable competitive advantage.

Varying performance between firms is a result of heterogeneity of assets (Helfat & Peteraf, 2003) and RBV is focused on the factors that cause these differences to prevail (Lopez, 2005). Fundamental similarity in these writings is that unique value-creating resources will generate a sustainable competitive advantage to the extent that no competitor has the ability to use the same type of resources, either through acquisition or imitation. Major concern in RBV is focused on the ability of the firm to maintain a combination of resources that cannot be possessed or built up in a similar manner by competitors. Further such writings provide us with the base to understand that the sustainability strength of competitive advantage depends on the ability of competitors to use identical or similar resources that make the same implications on a firm's performance. This ability of a firm to avoid imitation of their resources should be analyzed in depth to understand the sustainability strength of a competitive advantage

2.2.3 Theory X and Theory Y

Theory X and Theory Y are theories of human motivation created and developed by Douglas McGregor at the MIT Sloan School of Management in the 1960s. They have been used in human resource management, organizational behavior, organizational communication and organizational development. They describe two contrasting models of workforce motivation. Theory X and Theory Y have to do with the perceptions managers hold on their employees, not the way they generally behave (Sahin, 2012). It is attitude not attributes. For McGregor, Theory X and Theory Y are not different ends of the same continuum. Rather they are two different continua in themselves. *Theory X* assumptions are that these individuals dislike their careers. Theory X people have to be supervised. As for *Theory Y* assumptions are individuals like their careers and are willing to take part in responsibility. Theory Y people don't need supervision and can be expected to turn good productive value in their jobs.

As studied by Holburn *et al.,* (2010), investors of Renewable Energy Ventures (REVs) when making their investment decisions would evaluate the risks and returns associated with the supporting policy as there could be uncertainty caused by any changes of such policy by the government. This encompasses a whole range of issues, including insufficient resource data; substandard product quality; inadequate research and development activity; limited human and manufacturing capacities. There are currently no accurate records of solar, wind, hydro and biomass resource availability in the world. The few data collection stations that exist are furnished with obsolete measuring equipment which is several decades old. Lack of skilled labour to operate and maintain renewable energy equipment is another major deterrent to their widespread adoption, especially in rural areas. Particularly in remote areas with restricted access, on-hands maintenance is needed since frequent visits by repair and maintenance staff is difficult.

Failure to provide regular maintenance of the equipment when it is required leads to their complete breakdown, thereby defeating the purpose of the initial investment (Wilkins, 2002). Furthermore there is a general lack of knowledge among the people about acceptable quality and standards of technology. This means that users and installers alike are not likely to be able to distinguish between good and bad equipment and make informed choices, translating into potentially high occurrences of sub-standard installations (Lewis, 2007). The application of renewable energy to fields such as engineering, geography and architecture is not being taught, and as such these professionals are not aware of the value that renewable energy can add to their work (Pernick & Wilder, 2010). Support for research and development (R&D) plays a vital role in the progression from research and technological development through demonstration to final full-scale commercialization of a new technology.

All renewable energy technologies benefit from R&D support to ensure the continued development of a strong and competitive industry. Support is especially important where renewable energy technologies are still at early stages of development especially on improvement of their generation efficiency. Technological support focuses not only on R&D, but also on demonstration and implementation of new technologies as they mature. For a member State to build up its indigenous capabilities in a developing market such as the renewables market, it is important for the emerging industry to be given consistent and targeted support for demonstration and implementation of projects (Wilkins, 2002).

Deployment of solar mini-grid systems requires a competent and technically skilled implementation team as well as acquisition and customer service team that are endowed with soft-skills to be able penetrate the market for sustainability of the solar mini-gird services. This theory is therefore significant in the third objective of the study which is to determine the effects of capacity building/training on sustainability of mini- grid energy in rural areas within Kisii County.

2.3 Conceptual Framework

To guide the study, the interrelationship between variables discussed in the literature review is presented in the conceptual framework model shown in Fig. 2.1. According to Bogdan and Biklen, (2003) a conceptual framework is a basic structure that consists of certain abstract blocks which represent the observational, the experiential and the analytical/ synthetical aspects of a process or system being conceived. It is a set of broad ideas and principles taken from relevant fields of enquiry and used to structure a subsequent presentation. The interconnection of these blocks completes the framework for certain expected outcomes. A variable is a measurable characteristic that assumes different values among subjects. The independent variables in this study are energy policy /framework advisory, implementation mechanism and capacity building/training while the dependent variable is sustainability of solar mini- grid systems.

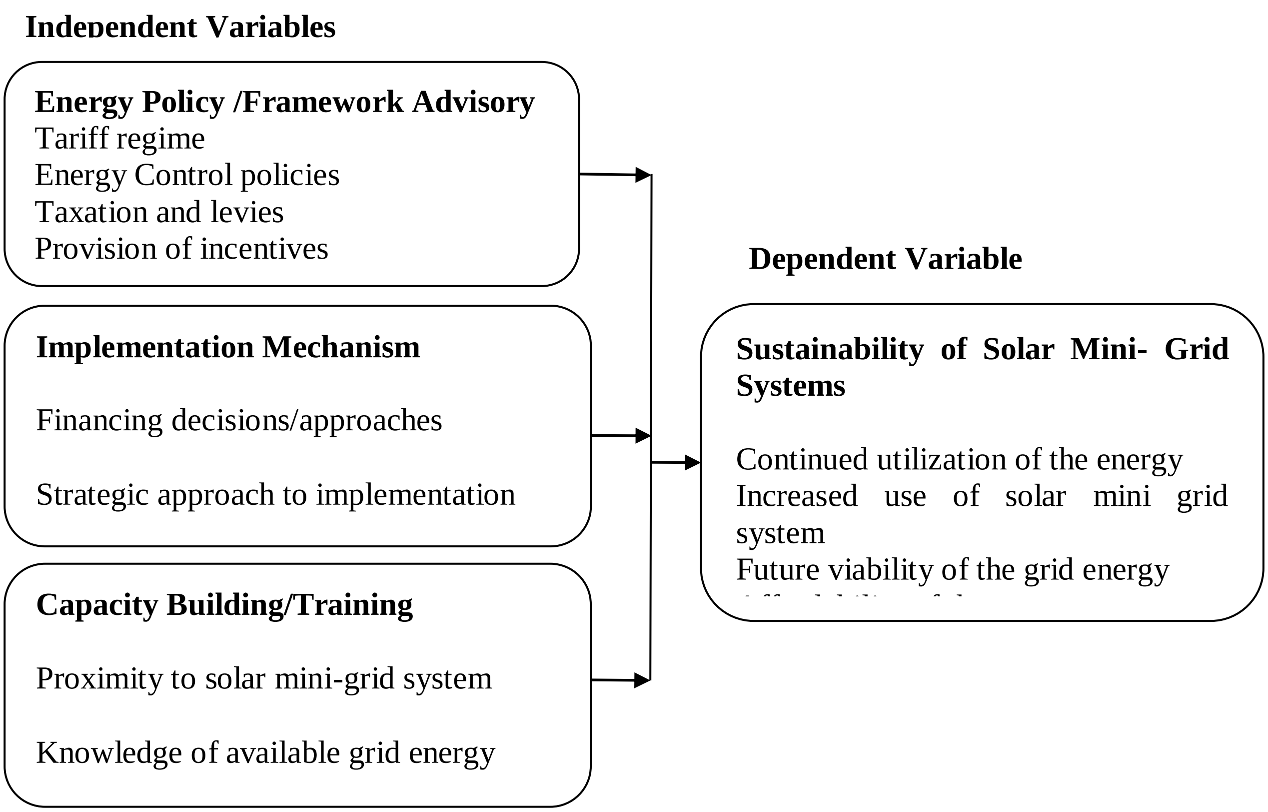

Figure 2.1: Conceptual Framework

2.3.1 Sustainability of Solar Mini- Grid Systems

Energy access is the single most important problem facing humanity today. There is need to find an alternative to oil, the cheaper, cleaner, and more universally available this new energy technology is, the better we will be able to avoid human suffering, and the major upheavals of war and terrorism (Smalley, 2002). Renewable energy comes from natural resources such as sunlight, wind, rain, tides and waves, and geothermal heat, which are naturally replenished. The technologies of choice are emission-free and renewable. Solar energy is the source of all energy on earth; it creates wind and water movement and ultimately creating plants, biomass and animals that become fossil fuels when their organic matter decays.

The sun is powered by several kinds of fusion reactions that have consumed 11 billion pounds of hydrogen each second for the past 4 to 5 billion years and is expected to continue for another 4 to 5 billion years (Lund, 2006). Solar PV energy conversion is a sustainable and environmentally friendly method of producing energy (McKenzie-Mohr, 2000). The energy used to produce PV is recovered in 1-5 years. PV electrical production also discharges no greenhouse gases, such as carbon dioxide, so it will help offset emissions that contribute to global climate destabilization. International cooperation and technology investment over the past 25 years has resulted in considerable gains in solar PV cell performance. Solar cells made from a variety of materials have demonstrated efficiencies >10 percent and are currently manufactured globally.

As the technological proficiency of the solar cell industry matured the total shipments of solar cells increased rapidly. The adoption of solar energy can be analyzed through the following intrinsic relative advantage that influence a purchase decision: Potential solar energy adopters want to know how electricity generated by a solar system is better than electricity generated by the utility. With correct engineering and design, the electricity produced by a solar energy system is no different than the electricity delivered by the utility grid. Solar energy can be more reliable and secure than utility electricity when integrated with a backup system – enabling a truly uninterruptible source of energy for the building (Cooke et al, 2007).

Solar also has a financial advantage over increasingly costly traditional utility electricity. Solar energy both reduced the fixed cost of electricity for the building owner and hedges against further electricity price increases. Solar also holds a relative advantage to other available renewable energy options. Solar energy is easier to integrate with residential and commercial buildings than other renewable alternatives (wind, geothermal, etc.).

2.3.2 Energy Policy /Framework Advisory

Government policy plays a significant role in the development of a sector, from setting rules and standards to providing incentives and enforcing penalties. Policies may have unintended negative impacts on the financing process and on financing costs, reducing the overall effectiveness of these policies (Wiser and Pickle, 1998). An example provides the production tax credit on the renewables project capital structure currently granted by the United States federal government in the form of a 10-year, 1.5 kWh production tax credit to qualified wind power and biomass facilities (Sissine, 1999). Although this incentive is capable to stimulate the development of renewable energy projects, it inadvertently raises financing costs because of its impact on the capital structure (that is the mix of debt and equity used to finance a particular project) of renewable energy projects. This secondary impact has reduced its effectiveness moderately. Although, by providing a return to equity investors, the production tax credit allows a reduction in the wind power sales price, unless the capital structure changes, an energy price reduction can result in a violation of the minimum debt service coverage requirement (that is operating income is not sufficiently high to service the full debt payments).

To combat this problem, the project developer must increase the fraction of higher-cost equity in the capital structure, therefore also increasing the contract price from what it would be under an equivalent cash incentive (which can be used to service debt). A robust mini- grid policy can significantly impact the development of the mini- grid sector. There are different components of a mini- grid policy, all of which are important for its success. However, it is not uncommon that policy makers focus on a subset of these components, leaving their policies somewhat incomplete and therefore impeding the deployment, operation, and long- term sustainability of mini- grid projects. While several governments have made the provision of electricity access their priority, their policies have tended to focus on electrification through central grid extension, and its implementation through traditional utilities. Decentralized mini- grids, in spite of their advantages, have received much less importance. Mini- grid deployment has often been left to private developers and non--governmental organizations with government support limited to the provision of capital subsidy.

When governments have been in charge of developing mini-grids, they have often tended to focus on installation and often haven’t provided adequate continued support for the systems reliable power purchase contracts/agreements are perhaps the single most critical requirement of a renewable energy project (Monroy, 2007). The vast majority of renewable energy projects have been implemented by IPPs. The only possibility for such facilities to sell their power is to have access to the utility’s transmission and distribution grid and to obtain a contract to sell the power either to the utility or to a third party by wheeling through the utility grid. Because renewable energy projects are generally considered risky by financial institutions (Delphi International, 1997), a reliable, stable and hence credible long-term revenue stream is extremely important for obtaining finance at a reasonable cost. While there have been some successful mini-grid programs, there have also been some failures. Inadequate institutional support in combination with technical, economic and social issues have resulted in many unsustainable or defunct mini-grid systems. If mini-grids are to play a significant role in providing access to reliable and affordable electricity, a robust policy framework is essential.

While there are several studies recommending best practices for rural off- grid electrification, we aim to contribute by devising a framework that can successfully account and include those policy practices to make sure they interact coherently among themselves and with the existing regulations. The focus here is on the technical, economical, financial, and social sustainability of mini- grids, in addition to assessing scalability and equity issues, in order to understand the key components that should constitute a robust mini- grid policy. Each policy component may have different ways to be designed and implemented. A comprehensive policy designed to guide the development of mini- grid systems as a significant option for providing electricity access would address three broad categories institutional structure and governance, technical standards and surveys, and financial incentives, financing and tariffs.

Kenya being aware of the energy implications to the realization of the Millennium Development Goals has laid strategies in her development blue print objectives that are aimed to meet each of the goals 1-7 (Gok, 2003). In 2004, the Ministry of Energy in consultation with the stakeholders in the sector developed the Sessional Paper No. 4 of 2004. This policy has a number of broad objectives including ensuring adequate, quality, cost effective and affordable supply of energy to meet development needs, while protecting and conserving the environment. The specific objectives of the energy policy are to: provide sustainable quality energy services for development; utilize energy as a tool to accelerate economic empowerment for urban and rural development; improve access to affordable energy services; provide an enabling environment for the provision of energy services; enhance security of supply; promote development of indigenous energy resources; and promote energy efficiency and conservation as well as prudent environmental, health and safety practices (Moreira and Wamukonya, 2002).

EPRA is mandated by the Energy Act, 2019 to carry out the following functions: regulate the electrical energy, petroleum and related products, renewable energy and other forms of energy; protect the interests of consumer, investor and other stakeholder interests; maintain a list of accredited energy auditors as may be prescribed; monitor, ensure implementation of, and the observance of the principles of fair competition in the energy sector, in coordination with other statutory authorities; Provide such information and statistics to the Minister as he may from time to time require; and Collect and maintain energy data; prepare indicative national energy plan; and Perform any other function that is incidental or consequential to its functions under the Energy Act or any other written law. Other institutions created with the enactment of the Act were the Rural Electrification and Renewable Energy Corporation (REREC) and the Energy Tribunal. There is awareness as the plan recognizes the need to provide adequate, sustainable and cost-effective energy, which is an economic driver to achieve these objectives.

However such recognition, the energy policy of Kenya has not spelt the benefits of renewable energies such as biogas and strategies to promote the technology which may be attributed to the low technology uptake. Presently, Kenya has not provided enough energy that is readily available, reliable and affordable to its population both in the urban and rural areas. Our towns and cities are experiencing power rationing and frequent blackouts which take hours to days. Further the country still relies on imported energy such as crude oil and electricity which strains the foreign earnings that would develop the country. Currently, the country uses 40% of foreign exchange earnings on crude oil importation (EASWN, 2012).

2.3.3 Implementation Mechanisms

Execution of organizational functions is implemented by an increasingly professional, dynamic, and competitive and customer focused management team. The implementation of the strategy must be monitored and adjustments made as needed. Evaluation and control consists of the following steps defining parameters to be measured and defining target values for those parameters. According to management theorists and conceptualists, resources influence implementation of strategies. For instance, Okumus, (2001), support that resources forms an important variable in strategy implementation frameworks. However, this may not always be the case with schools. Financing structures, contract reviews, costs, procedures, timetable and review standards are usually geared toward large-scale projects.

For “small” projects not all traditional “project financing” elements are a “must” and therefore, adjustment of the financing package is required in order to fit the specific nature and structure of “small” projects. Lenders to small projects should show flexibility by keeping their requirements at a reasonable level. The implementation of small projects can be accelerated by reducing the expenses and time delays required to arrange and close financing. Financing of renewable energy projects should be processed on a fast track, utilizing experience with similar projects, standardized procedures and increased reliance on the historical background of the project participants. The financing requirement should be identified at the beginning of the review period to keep the financing process on a smooth fast track (Bronicki, 2000). Renewable energy sources, in particular solar energy, allow a decentralised energy supply, thus minimizing distribution costs of bringing energy to remote areas (such as rural areas) that are vulnerable to poverty.

Apart from the strategies initiated from the supply-side, renewables have lately been promoted by important demand-side initiatives. Voluntary commitments by large and small customers from the large multinationals down to private customers to procure and use renewable energy are becoming more common in developed markets. Innovative solutions to reward green customers with smart subsidies initiated by governments contribute to the success of such schemes. To promote renewable projects a concerted effort to broaden the base of energy project evaluation should be adopted. It should take into account the full societal costs of a project, to promote inclusion of “externalities” (that is GHG emission reduction accountability, avoided fossil fuel costs,) into power tariffs and cost evaluations. The life cycle cost evaluation of energy projects in the future will enable "fair" competition in the energy market and broaden the chances for enlarging the stake for renewables (Monroy & Hernandez, 2007).

Energy stakeholders must have trustworthy mechanisms to constructively discuss concerns and viewpoints in dealing with the challenges of an increased use of renewable resources. For example, a forum to allow groups to reach common ground from which to devise concrete actions for increased use of renewable energy resources. The forum would have to deal with the uncertainty issues and regional variations mentioned earlier. The forum would also have to manage trust problems that might exist among groups that have traditionally had contentious relationships (Mitchel, 1997). Any stakeholder engagement mechanism requires some form of common, transparent way of providing timely information to all sectors before policy decisions are final. This is especially true considering that many energy decisions are usually made based on hierarchal, top-down approaches. The key challenges for project management and stakeholder involvement vary according to technology and geographic context. However, more generic factors pertaining to the kinds of social networks that builds up around new energy projects and to the negotiation and alignment of expectations. These networks were naturally different for different projects, but could involve experts and technology providers, other businesses (as project partners, suppliers or competitors), authorities and politicians at the national and local level, non-governmental organizations and other interest groups, local residents and users. Moreover, it is important to note that stakeholders' positions often evolved during the course of the negotiations: stakeholders are thus not monolithic and their positions are not static.

Stakeholders' expectations that required negotiation pertained to a range of factors. Some of them can be termed "genuine differences of interest", such as the distribution of costs and benefits (the distribution of economic costs among actors, the balance between local and global environmental benefits). There were also sometimes fundamental value conflicts, for example about the instrumental versus intrinsic or amenity value of nature, or different views on desirable future economic and social development. Moreover, fundamental limits to knowledge and certainty were also present, such as genuine uncertainties about the performance, impacts and relevance of different new energy technologies. Other kinds of issues can more readily be termed “organizational problems”, such as creating trust when there was a lack or precedents or poor earlier experiences, communication problems such as articulating the vision of the project or understanding local concerns, culture and communication patterns, or negotiation problems, such as finding suitable procedures for negotiation and arbitration or defining roles and responsibilities

2.3.4 Capacity Building/Training

The adoption of innovations describes a point in time when the adopter of an innovation decides to use the innovation in question. Rogers, (2003) theorizes that the process of adoption commences with an individual driven by precedent conditions such as a felt need to adopt an innovative product or service. The individual will pass along an innovation decision process at a pace that is influenced by their own level of innovativeness and by the perceived characteristics of the innovation. The decision making process is aided by communication channels; either mass-media communications or by local channels such as word-of-mouth. The adoption of innovations describes a point in time when the adopter of an innovation decides to use the innovation in question.

A more thorough quantitative analysis of the Kenyan SHSs market was carried out by Jacobs, (2006), who describes various aspects of the Kenyan SHSs market and presents analyses based on two cross-sectional surveys among rural Kenyan households which were conducted in 2000 and 2001. Jacob, (2000) finds that the benefits of solar electrification are captured, primarily by the rural middle class, that solar plays only a modest role in supporting productive activities and education, and that solar electrification is more related to general market forces than to poverty alleviation and sustainable development.

Based on the 2000 survey, Jacobs further finds that most SHSs are owned by households in the first three wealth deciles. He characterizes these households as belonging to the rural middle class, with annual household incomes well above USD 2,000 (in current USD). In the paper he further argues that the data suggests a trend towards a deepening of access beyond the middle class, with smaller systems becoming affordable for lower-income households as well. Rebane and Barham, (2011) analyze the determinants of SHSs awareness and adoption in Nicaragua. They identify the determinants of four measures of SHSs knowledge. This is followed by an investigation of factors that predict SHSs adoption conditional upon sufficient awareness about SHSs. They used survey data from 158 households in rural Nicaragua, 40 of which had adopted SHSs. Knowledge is predicted most strongly by the presence of other installed SHSs, being male, being young and having a high-quality residence (as a proxy for wealth).

Income, having earned about SHSs from a business or NGO and not living in the Caribbean lowlands (where SHSs were very rare at the time the survey was carried out) are all positive determinants of SHSs adoption, while living near a dealer reduces the likelihood of adoption. The model of adoption that Caird et al. (2008) propose is more directly related to the context of energy efficiency than any of the models discussed in this review and it draws on many elements common to the Diffusion of innovations model, for example the element of communication. The results of research by Caird et al (2008) into the use and adoption of renewable energy systems by householders extends the categorization of adopters depending on their level of engagement with the technology and motivation to reduce energy use. The model they propose presents the consumer as an agent influenced by various sources such as the socio-economic context, consumer variables, communication sources, and product and system properties. Within the two models proposed by Rogers, (2006) and Caird et al (2008), there are common factors that inform the decision making process, namely the innovation attributes, and the categorization of adopters.

2.4 Empirical Review

A plethora of factors affecting the diffusion of solar PV systems have been identified in the literature (Cooke et al, 2007). Amongst them, high initial capital costs and lengthy payback periods are most often cited as the primary barriers to diffusion and are supported by evidence from the United States, Spain, Germany, and the United Kingdom (Faiers and Neame, 2006; Boyle, *et. al.,* 2010; Del Rio and Unruh, 2007; Jacobsson and Johnson, 2000). While economic challenges are those most often cited, it should be noted that other hypotheses have been posited to explain the slow diffusion of solar PV systems. Del Rio and Unruh, (2007) have argued that ―proximate causes, like differential costs of the two technologies or available resources, provide only limited explanatory power, suggesting that institutional factors may play a decisive role in the diffusion process. Jacobsson and Johnson, (2000) state that ―networks and institutions are also constituent parts of a technological system and influence, therefore, the processes of discovery and selection. Further supporting this line of argument is Liberatore, (1995), who warns of the dangers of a process design that fails to adequately account for institutional capacity.

Economic and institutional factors have been identified in the literature as two of the leading explanations for the modest levels of solar PV system diffusion (Rowlands, 2007). For this reason, it is not surprising that money (*i.e.*, high initial capital cost and lengthy payback periods) and institutional support (CPGs and the RESOP) were found to be of considerable prominence as barriers in the decision-making process (Rogers, 2003). Tengvard and Palm, (2009), in studying household motivations for the adoption of residential solar PV systems, found that the most prominent factors for adoption were those related to sustainability. Main barriers include: financing, customization at site (leading to higher costs), costs higher than commercial and utility-scale, paperwork cost is still pretty high. However, the single biggest barrier is education, potential customers are often ill equipped to analyze the cost-effectiveness of solar. Access to financing and better sales team on the solar-side (such as Solmentum) can overcome some of these problems.

As shown in the foregoing, the literature concerning the adoption of domestic solar power systems is limited and typically paints a pessimistic picture of the potential for solar power systems. In summary, most insights on fuel choice stem from the empirical analysis of cooking fuel choices. In addition, the determinants for the adoption of solar energy technologies are typically examined without putting them into the context of a particular fuel choice and often based on non-representative samples and case studies. As lighting fuel choices and the role of lighting in energy use in developing countries have not been investigated as thoroughly as cooking fuel choices, this study focuses on investigating the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. This investigation is important not only due to the role of lighting in household energy use, but also as increased access to lighting is expected to contribute to better adoption of solar technology, the achievement of the UN's Millennium Development Goals (IEA, 2008) and to Kenya's vision 2030.

2.5 Critique of Existing Literature

Solar power presents so many positives it is foolish to discount it now because it is "too expensive" or "impractical". Yet, detailed analysis has focused on the use of solar in rural areas. Solar electricity cannot serve any significant fraction of Kenyan needs, but only few institutions have made an effort to compute the significance of its use in urban residential areas. Del Rio and Unruh, (2007) have argued that proximate causes, like differential costs of the two technologies or available resources, provide only limited explanatory power, suggesting that institutional factors may play a decisive role in the diffusion process. Further, economic and institutional factors have been identified in the literature as two of the leading explanations for the modest levels of solar PV system diffusion (Rowlands, 2007).

In contrast however, Tengvard and Palm, (2009), in studying household motivations for the adoption of residential solar PV systems, found that the most prominent factors for adoption were those related to sustainability. Abukhzam and Lee (2010) in their analysis of adoption frameworks came up with a conclusion that despite widespread interest in understanding factors affecting users attitude towards mini-grid energy adoption, limited attention has been paid to describing factors that affect workforce attitude towards the adoption of a new technology. In most cases a participatory approach is encouraged for the success of many projects.

The overall assumption of this study is that energy policy /framework advisory, implementation mechanism and capacity building/training influence the adoption and sustainability of mini-grid energy in rural areas. As such, this study is a modest attempt to fill the existing gap by investigating the effects of energy policy /framework advisory, implementation mechanism and capacity building/training on sustainability of solar mini-grid systems in Kisii County.

2.6 Knowledge Gaps

An adequate and reliable power supply system is essential for any developing country like Kenya. The supply of electricity is insufficient and unreliable to the over 40 million people living in Kenya. The unsustainable energy practices of today will need to be reformed if the national developmental goals for a sustainable future will be met. The purchase of a solar PV system typically yields negative outcomes at the time of purchase, while positive outcomes are delayed. This causes a dilemma situation, involving a conflict between direct and delayed outcomes that can provoke cognitive dissonance reactions. Here, people are tempted to discount the long-term positive outcomes by employing arguments like too expensive, too much paperwork, it hardly contributes to the environment' or 'cannot oversee the construction process.

As a consequence, initially interested consumers may decide not to invest in a solar PV system. Reducing the complexity of the decision and the time discounting framing of the decision-problem would stimulate consumers to install a solar PV system. This study would be investigating the adoption process of solar photovoltaic system which is a new technology which faces similar challenges like most new technologies facing the problems of acceptability, skepticism, high cost. As the use of these new technologies tend to break the old habits of human beings thus causing a change in behaviour. The focus of this study will be to investigate the factors affecting sustainability of solar mini-grid systems in Kisii County, Kenya.

2.7 Summary

Solar Energy Systems are designed to make installation simple and fast. Insolation or sunlight intensity is measured in equivalent full sun hours. The advantages of solar power as a means of creating energy are obvious: it is pollution free, renewable, and abundant. While state solar programs do not produce solar panels, price them, or control the quality of technology or installation, their program success is integrally linked to the success of solar suppliers. Residential Solar Electric Systems are generally priced by the system size and energy required. Given the enormous downward shift in pricing, one major implication for the industry is that suppliers will need to continue accelerating cost reductions in order to keep up with the price declines and to repair compressed profit margins. Price is one of the single biggest barriers to growing the solar marketplace; many states are addressing the financing of solar to help overcome consumer price concerns.

The strength of a good energy planning process lies in its ability to adequately address short, medium and long term issues and problems in a coordinated and balanced manner. Private sector participation in harnessing these sources of energy will be promoted and encouraged by the Government. One of the reasons that emphasizing increased costs in the short run has little impact on support may be that respondents are also optimistic that shifting to alternative energy sources will save money in the long run. For marketing purposes, state programs can evaluate the product from the perspective of consumers' rational and emotional attitudes towards solar technology. Framing the clean-tech revolution not in the context of something as amorphous as climate change and as divisive as cap-and-trade, but instead on job creation, economic competitiveness, energy independence, and national security.

The more people in a social network who have already adopted a solar PV system, the more information will be available. Moreover, the member's adoption into a network may also increase the involvement of people initially not interested or aware of the possibility to install a solar PV system. While economic challenges are those most often cited, it should be noted that other hypotheses have been posited to explain the slow diffusion of solar PV systems. Government policies need to enhance the adoption of solar panels in urban areas in Kenya. However, a deeper understanding of solar in rural areas needs to be done. This study sought to investigate the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methods used to gather information on the area of the study. It discusses and describes the data collection instruments, data collection procedures, sampling, data gathering and analysis of the limitation of the method proposed. Research methodology is the approach by which the meaning of data is extracted and is a continuous process. It gives the direction to follow to get answers to issues that are of concern. Research is usually designed to handle a problem, something that needs describing, explaining or improving, or about which information is needed so that future occurrences can be predicted and policy decided.

3.2 Research Design

Research design is the plan and structure of investigation so conceived as to obtain answers to research questions. A research design expresses both the structure of the research problem and the plan of investigation used to obtain empirical evidence on the relations of the problem (Cooper & Schindler, 2003). Accordingly, a research design answers questions such as: What techniques are used to gather data? What kind of sampling is used? How will time and cost constraints be dealt with? The study design therefore includes an outline of what the investigator will do from formulating research questions and their implications to the final analysis of data. A descriptive research design was used in this study. This design was appropriate for this research because it is concerned with clearly defined problems with definite objectives. Also the available solar PV resource data of installed system from a PVGIS software for the study area was utilized to assess the solar energy resource potential and the system implementation output with the view of determining the installed system sustainability against consumer power demand.

Descriptive research design was appropriate to describe the characteristics of the target population of consumers and implementers of solar min-grid systems in Kisii County, Kenya. This study integrated both qualitative and quantitative methods. A qualitative methodology deals with non-numerical data, whereas a quantitative methodology treats numerical data relevant for this study. Through interaction between the investigator and informants via a questionnaire the study was able to get accurate information. The study adopted descriptive design which aimed at investigating the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. A descriptive design involved planning, organizing, collection and analysis of data so as to provide information being sought. This design provided in-depth responses which resulted in better and elaborate understanding of the phenomena under study.

3.3 Population of the Study

A population is a large group of individuals or people, or items under consideration for statistical purposes. Mugenda and Mugenda, (2003) define a target population as a group of individuals to which results would be generalized results from. In this study, the population comprised of 10 mini-grid sites in Kisii County where staff and customers connected to the mini-grid sites were drawn to participate in this study. The study targeted customers connected to the 10 solar mini-grid sites whose perspective on the project sustainability was sought as well as personnel who were involved in the installation of solar mini-grid systems as they were better placed to answer questions relating to factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. The total number of customers connected to the 10 mini-grid sites was approximately 600 at the time of the study.

The energy service company had a stratified organo-structure that organized the staff in three categories; top management level consisting of the executives (head of departments and the deputy heads of departments); middle management comprising of functional heads (tactical level of management and comprised of all the senior and middle level officers in all departments of the company who are tasked with the responsibility of implementing policies made). These categories (top and middle management level staff) made a population of 110. Thus the target population of this study was 710 customers and management staff from the mini-grid companies operating in Kisii County. For purpose of this study the target population was stratified through customers, top level and middle level. Mugenda and Mugenda, (2003) explain that the target population should have some observable characteristics, to which the study intended to generalize the results of the study. This definition assumed that the population was not homogeneous.

Table 3.1: Target Population Distribution

Sections	Population (Frequency)	Percentage %
Top management	30	4.2
Middle level management (technical staff)	80	11.3
Customers	600	84.5
Total	**710**	**100.0**

3.4 Sample and Sampling Procedures

A sample is a representation of the population. It is also defined as a subset of the population under the study. A sample was selected that represented the population. The essence of sampling was to allow conclusions about the entire population to be drawn just by the results or observations of the selected elements from a population. A sampling frame is the listing of all the units in the population from which a researcher can make a sample. Study of samples, rather than the population would help to be economical both in terms of money and time. The study targeted 710 as the population out of 20,110 targeted consumers and staff of the ESCO and this was arrived at using stratified random sampling. The choice of the stratified method allowed the population to be divided into smaller strata units, depending on known variables. The proportions between the strata units were the same as the proportions within the population.

The advantage of stratified samples is that when they are properly designed, they are more accurately reflecting the characteristics of the population from which they were chosen than other kinds of samples. In drawing the sample population for the study, the population was divided into two strata units that match the proportions of employees of mini-grid energy companies in Kisii County. The two strata consisted of 110 top and middle level staff spread across various departments. Kotler, (2001) argues that if well chosen, samples of about 10% of a population can often give good reliability. Other literatures have shown that sample size selection to a great extent is judgmentally decided. Stratified random sampling method was used to sample respondent top and middle level staff from the mini-grid companies in Kisii County.

Stratified random sampling technique was used to select the sample. The technique produced estimates of overall population parameters with greater precision and ensured a more representative sample was derived from a relatively homogeneous population. From the above population, a sample of 40% was selected from within each group in proportions that each group bears to the study population. This is as justified by Kothari, (2004) that in a descriptive study such as this particular one, 40% of the accessible population is enough. This sample was appropriate because the population was not homogeneous and the units were not uniformly distributed. This generated a sample of 44 respondents which the study sought information from.

Table 3.2: Sample Size

Sections	**Population (Frequency)**	**Sample Ratio**	**Sample Size**
Top management	30	0.4	12
Middle level management (technical staff)	80	0.4	32
Total	**110**	**0.4**	**44**

Cooper and Schindler, (2011) argue that if well chosen, samples of about 10% of a population can often give good reliability, however, considering that this would only give a sample size of 11 for the energy service company, 40% of the population was considered to allow for a bigger sample that would provide comprehensive response as pertains the aspects of system sustainability that were being investigated. The sample size for the connected customers was determined using the Fisher Formula on the basis of those variables in the sample that are likely to have the greatest variability. The sample size was given by:

$$n = (p \times q \times z^2)/e^2$$

Where: n= is minimum sample size required; p = the proportion belonging to the specified category; q = the proportion not belonging to the specified category; z = the value corresponding to the level of confidence required (90% certain=1.65, 95% certain= 1.96 and 99% certain=2.57); e= 5% = the margin of error required. According to Cochran W.G, (1977), when the population is less than 10,000 the sample need to be adjusted according (n.') to minimum sample size formula as shown below:

n.'= n./(1+n/N) where

n.' = the adjusted minimum sample size

n. = the minimum sample size (calculated)

N = the total population

In order to calculate the sample size, p=50%, q=50% for variables with known and unknown characters as identified in the study, z=1.96 (95% certain) e= 5% (i.e. within plus or minus 5% of the true percentage, the margin of error that can be tolerated) and N=600

$n. = 50x50x [1.96/5]^2$

$= 2500x\ 0.153664$

Adjusted minimum sample size = 384

$n = 384/ [1+ (384/600)]$

$= 384/1.64$

$= 234$

Total sample size = 234 + 44 => 278

According to the formula, the sample size for this study was 234 customers connected to the mini-grid energy in Kisii County. Adoption of this sample size rested on the manageable cost implications and the ease with which the study was conducted within the college time frame. Another reason for the selection of this particular sample is that were limited financial resources to conduct this study being individual financed study. Accordingly, the total sample size was 278 customers connected to the mini-grid sites and staff of ESCOs who installed and operated the mini-grid sites in Kisii County.

3.5 Instruments

Data collection instrument used for this study was mainly questionnaires, desktop interviews and field/site observations. The questionnaires used in this study had an introduction letter addressed to the respondent highlighting on the purpose of the study and assuring the respondent of confidentiality of the information that they would as being purely for academic purposes.

The questionnaire had two sections (section A and B), in which section A. focused on the demographic background information of the respondent including where they work, age, employment status, years of service and education background.

Section B. of the questionnaire was on sustainability of solar mini-grid systems in which th respondents were asked questions on aspects of sustainability of system ranging from continued use, increased uptake, future viability, affordability e.t.c. This section was in 3 parts (A, B, and C) with questions aligned to aspects of the three specific objectives i.e. energy policy/framework advisory, implementation mechanism and capacity building/training.

The questionnaire was to communicate to the respondents what is intended and to elicit desired responses in order to achieve the research objectives, it had open ended and closed ended questions all briefly stated and well-focused in recognition of the busy schedule of the participants. These of questions the respondents complete freedom of response and permitted them to respond in his or her own words. These questions also permitted greater depth of response, and were simpler to formulate and the responses provided an insight into the feelings, background, hidden motives, interests and decisions of the respondent.

3.6 Data Collection Procedure

The data collected for the research was a primary data aimed at getting a more general understanding of the factors that affect sustainability of solar mini-grid systems in Kisii County, Kenya between genders, age-brackets, and education and qualification levels. Data collection was via a questionnaire as this is an efficient and convenient way of gathering the data within the resources and time constraints. The structure of the questionnaire included structured and semi-structured questions as this provided the flexibility for specific and unique responses to some of the questions. The questionnaire were made up of two major parts: The first part contained the background information of the respondents; the second part was sub-divided into four sub- sections covering the various variables representing the factors that affect sustainability of solar mini- grid systems and analyzed the relationship between the independent and dependent variables.

A 5-point Likert scale was applied and it expressed a series of statements that expressed the respondents views from strongly agree to strongly disagree. In addition to the primary data, secondary data was used and collected through desk top research technique as this is most appropriate for literature and materials on factors that affect sustainability of solar mini- grid systems. I started by explaining to all participants in the study the role they were expected to play and the importance of providing honest information through a cover letter forwarding the questionnaire. I also assured the participants that the information they gave was to be treated with strict confidence.

An envelope marked “questionnaire” and thesis topic was provided so that once the employee or the consumer completed the questionnaire, they sealed it to ensure confidentiality is maintained within the organization and guarded against potential victimization by the human resource division or the person designated by the Company to co-ordinate the process. I then proceeded to administer the questionnaires through the designated officers and co-ordinate with them to ensure respondents have adequate time to complete them. The questions included both closed and open-ended questions with sub-headings where necessary to guide the respondents respectively.

3.6 Pilot Testing

Pilot Testing is the measurement of a dependent variable among subjects. Its purpose is to ensure that items in the instrument are stated clearly and have the same meaning to all respondents (Mugenda & Mugenda, 2003). According to Kothari, (2004), the purpose of pre-testing the data instrument is to ensure that the items in the instrument are stated clearly and have the same meaning to all respondents. It is only during pre-testing that a researcher can be able to assess the ease of use of the instrument. Any sensitive, confusing or biased items would be identified and modified or omitted. Pre-testing permits refinement before the final test (Cooper & Schindler, 2003). This is the researcher’s best opportunity to revise scripts, look for control measures and scan the environment for factors that confounded the results. Pre-testing was carried out with 15 respondents purposely chosen from rural areas in Kajiado County where such a project had previously been implemented and the filled in questionnaires were evaluated and corrected against biases.

3.6.1 Validity

According to Williams, (2005) validity is the degree by which the sample of test items represents the content the test is designed to measure. Content validity which was employed by this study was a measure of the degree to which data collected using a particular instrument represented a specific domain or content of a particular concept. Mugenda & Mugenda, (2003) contend that the usual procedure in assessing the content validity of a measure is to use a professional or expert in a particular field. To establish the validity of the research instrument the opinions of scholars and experts including the supervisors were sought. This allowed modification of the instrument thereby enhancing validity. Furthermore, the study assessed the responses and non-responses per question to determine if there was any technical dexterity with the questions asked.

3.6.2 Reliability

Reliability was also confirmed by pre-testing the questionnaire with a selected sample from one of the projects. Reliability of a measure indicates the extent to which it is without bias (error free) and hence ensures consistent measurement across time and across the various items in the instrument. It is an indication of the stability and consistency with which the instrument measures the concept and helps to assess the “goodness” of measure (Sekaran & Bougie, 2014). According to Mugenda & Mugenda, (2003) reliability is a measure of the degree to which a research instrument yields consistent results or data after repeated trials. A researcher should consider the sources of error likely to be present in the study while choosing measure of reliability. The pretest was conducted by both the principle researcher and the research assistants to enhance clarity of the questionnaire.

According to Mugenda and Mugenda, (2003), the accuracy of the data collected largely depends on the data collection instrument in terms of validity and reliability. This instrument was reviewed based on the pre-test experience. Internal consistency method was tested using Cronbach’s Alpha. Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. A "high" value of alpha is often used as evidence that the items measure an underlying (or latent) construct. Reliability with a predetermined threshold of 0.7 is considered acceptable. That is, values above 0.75 indicated presence of reliability while values below signified lack of reliability of the research instrument.

The pilot study was carried among 15 respondents purposively chosen from rural areas in Kajiado County where such a project has previously been implemented and reliability tested using a Cronbach’s alpha. A reliability of above 0.7 was achieved and this was considered reliable as recommended by Zikmund & Barin, (2012) who recommended that a reliability test which yields a coefficient greater than or equal to 0.7 is sufficient enough. The respondents were also informed that the research is meant for academic purposes only and that the study will have no intention of using the information for personal gains. The respondents were not required to indicate their names and participation in the study was on a voluntary basis.

3.7 Data Processing and Analysis

Data from the field was voluminous and cannot be absorbed. It has to be put in the form that an average mind can understand and make sense of (Chadran, 2004). Before processing the responses, the completed questionnaires were edited for completeness and consistency. The raw primary data collected was coded prior to being input into SPSS statistical analysis software. Once coded, the data was then cleaned to ensure accuracy and completeness of the information obtained. In analyzing the data collected, both descriptive and inferential statistics was utilized. The quantitative data that was obtained from the questionnaires was coded and keyed into statistical package of social science (SPSS) analysis software.

Tables were used to summarize responses for further analysis and facilitate comparison. This generated quantitative reports through tabulations, percentages, and measure of central tendency. Cooper and Schindler, (2003) notes that the use of percentages is important for two reasons; first they simplify data by reducing all the numbers to range between 0 and 100. Second, they translate the data into standard form with a base of 100 for relative comparisons. In addition, to quantify the strength of the relationship between the variables, a multiple regression analysis was conducted. Usually, the investigator seeks to ascertain the causal effect of one variable (independent variable) upon another (dependent variable). The researcher also typically assesses the statistical significance of the estimated relationships, that is, the degree of confidence that the true relationship is close to the estimated relationship.

Regression analysis is also valuable for quantifying the impact of various simultaneous influences (independent variables) upon a single dependent variable. Multiple regression analysis involves combining several predictor variables in a single regression equation. With multiple regression analysis, the study can assess the effects of multiple predictor variables (rather than a single predictor variable) on the dependent measure. As such, the data was broken down into the different factors that affect sustainability of solar mini-grid systems in Kisii County. The regression equation was:

$$\mathbf{Y = (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon)}\text{: whereby}$$

Y = sustainability of mini- grid energy, X_1 = energy policy /framework advisory, X_2 = implementation mechanisms and X_3 = capacity building/training. Further, β_0, β_1, β_2, and β_3 = Regression Coefficients and ε = Error term, an error term normally distributed about a mean of 0 and for purposes of computation ε is assumed to be 0. The equation was solved by the use of statistical model where SPSS was applied. This offered a quantitative and qualitative description of the objectives of the study.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter presents and highlight the data analysis, presentation and interpretation of the results on the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. The organized data obtained from the research instruments was cleaned, sorted and coded prior to the analysis. The chapter is divided into different sections featuring the research objectives which were: To assess the effects of energy policy /framework advisory on sustainability of solar mini- grid systems in Kisii County, Kenya; To investigate the extent to which implementation mechanism affects sustainability of solar mini- grid systems in Kisii County, Kenya; To determine the effects of capacity building/training on sustainability of solar mini- grid systems in Kisii County, Kenya.

The research instruments comprised of both structured and unstructured questions aimed at drawing relevant information for this study. Descriptive techniques were used to analyze the data. The data obtained was fed into SPSS version 23.0 and the output was used to compute the statistics needed. The frequencies percentages, and mean scores are computed and presented. The information and data obtained were presented in form of frequency tables for easy interpretation by the readers. The main sections covered include reliability analysis, response rate and demographic information.

4.2 Response Rate

The study utilized a questionnaire presented to the respondents on a personal basis to increase the response rate. The study targeted top management, middle level management and customers from the solar mini-grid companies in Kisii. From the target population, a sample of 278 respondents was selected in collecting data with regard to factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. The results of this study are based on the responses obtained from the field as shown on Table 4.1.

Table 4.1: Response Rate

Category	Frequency	Percentage (%)
Responded	192	69.1
Did not respond	86	30.9
Total	**278**	**100.0**

From the study, I successfully received response from 192 respondents. The instruments were complete and taken as valid for data analysis which translated to a response rate of 69.1%. The 86 questionnaires that were either not received at all or were received incomplete accounted for 30.9% of the sample and therefore not considered in the analysis. According to Babbie, (2002), a 50% response rate is adequate. This implies that the response rate of 69.1% is satisfactory and good for analysis, drawing conclusions and making recommendations. The response rate was improved by the use of drop and pick method, follow-up telephone calls to the respondents, personal visits and explanation of the purpose of the study and its usefulness to the organization and the customers.

4.3 General Information

The general information breaks down the features of the study population. Several aspects to describe the respondents and the organizations were used. The study involved the top and middle level management staff since they are the ones conversant with the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya as well as consumers connected to the installed mini-grid energy. In order to get the background information, the demographic data of the respondents was investigated in the first section of the questionnaire. They are presented in this section under gender, age bracket, category as a respondent, duration served or connected with this mini-grid companies and highest level of education.

4.3.1 Gender of the Respondents

The outcomes presented in Figure 4.1 show the distribution of respondents (consumers and installers) in relation to gender. The subject of gender is considered fundamental in this study largely because it could help get a "balanced view" from both genders. From the study, 63.5% of the respondents were male while 36.5% were female. These results show that the views expressed in these findings can be taken as representative of the opinions of both gender.

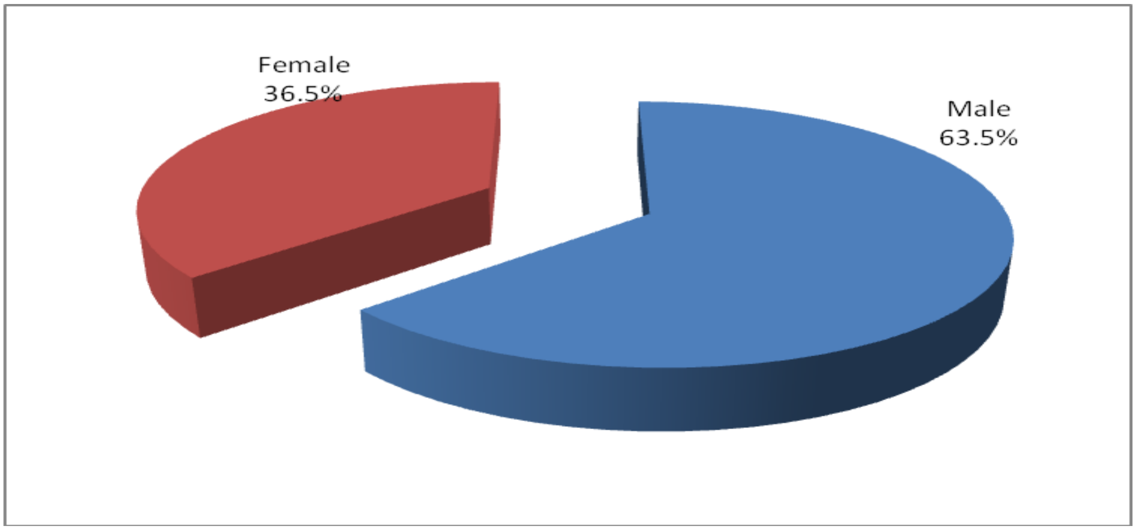

Figure 4.1: Gender of the Respondents

4.3.2 Age of the Respondents

Data on the age brackets of the respondents was sought since the age bracket of the respondents plays a critical role in understanding the issues sought by the study. To a large extent, respondents falling in an optimal age bracket are considered experienced and are likely to relate to emerging issues more directly to benefit the study. According to Figure 4.2, majority of the respondents (comprising 43.2%) indicated that they were aged between 30 and 39 years and hence they were experienced to give accurate data which agrees to the study. In addition, 25.0% of the respondents reiterated that they were aged below 30 years, 19.3% of them indicated that they were aged between 40 and 49 years, while 12.5% of the respondents indicated that their ages were 50 years and above. These results demonstrated that the respondents were well distributed in terms of age hence different views of the factors affecting sustainability of mini- grid energy in rural areas within Kisii County across varying ages are accounted.

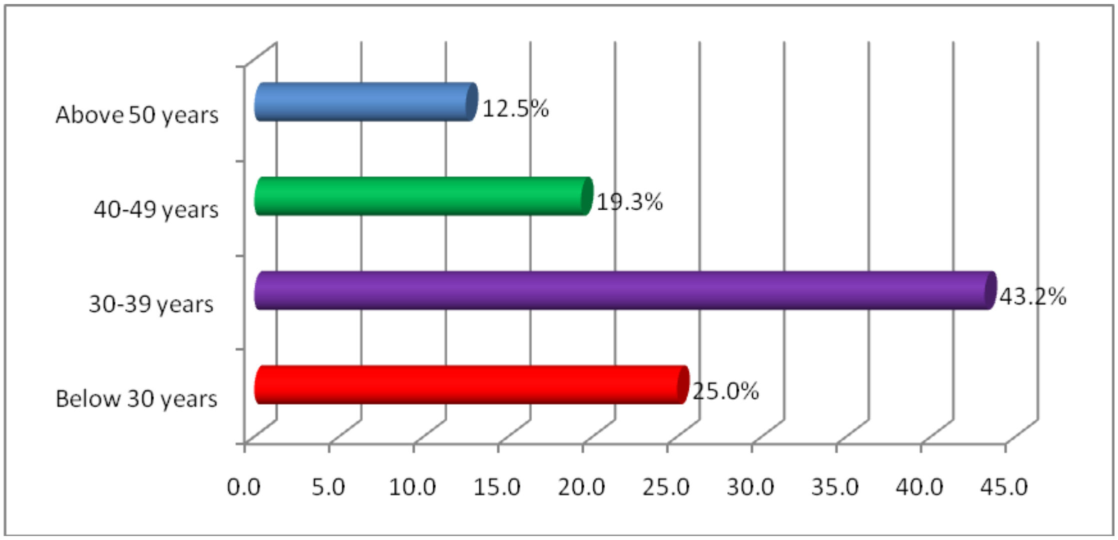

Figure 4.2: Age Brackets

4.3.3 Category of the Respondents

The study targeted to collect data from the customers, top and middle level management of 10 mini-grid sites of Enel Green Power and Powerhive East Africa in Kisii County. This study sought to establish the distribution of the respondents in these categories as outlined in Table 4.2.

Table 4.2: Position of the Respondents

Category	Frequency	Percent
Manager	3	1.6
Departmental Head	4	2.1
Assistant Manager	5	2.6
Unit Head officer	6	3.1
Supervisor	7	3.6
Technical personnel	7	3.6
Customer	160	83.3
Total	**192**	**100.0**

According to Table 4.2, an overwhelming majority (83.3%) of the respondents comprised of customers connected to the mini-grid sites. 3.6% of them indicated that they were technical personnel, another 3.6% comprised of supervisor and 3.1% of them were unit head officers. In addition, 2.6% of the respondents were assistant managers, 2.1% of them were departmental heads, while 1.6% comprised of managers. These findings show that the respondents that participated in the study were mainly those involved in the utilization, formulation and implementation of the decisions concerned with management, planning and implementation of mini- grid energy.

4.3.4 Working Experience

The length of continuous service/years of connectivity to the solar mini-grid system determines the extent to which one is aware of the issues sought by the study. The respondents were therefore requested to indicate the number of years they had been connected or working with the mini-grid companies. This is critical since it reviews the respondents' understanding of factors affecting sustainability of mini- grid energy in rural areas within Kisii County. According to Figure 4.3, 39.5% of the respondents unanimously indicated that they had been connected or working with the mini-grid companies for a period of 10 - 15 years, 33.4% of them had been been connected or working with the mini-grid companies for a period of 5 to 10 years, 14.5% of them had been been connected or working with the mini-grid companies for less than five years whereas 12.6% of them had been connected or working with the mini-grid companies for a period of more than 15 years. This implies that most of the respondents participating in this study had been been connected or working with the mini-grid companies for an ample time thus they were conversant of the information sought by the study.

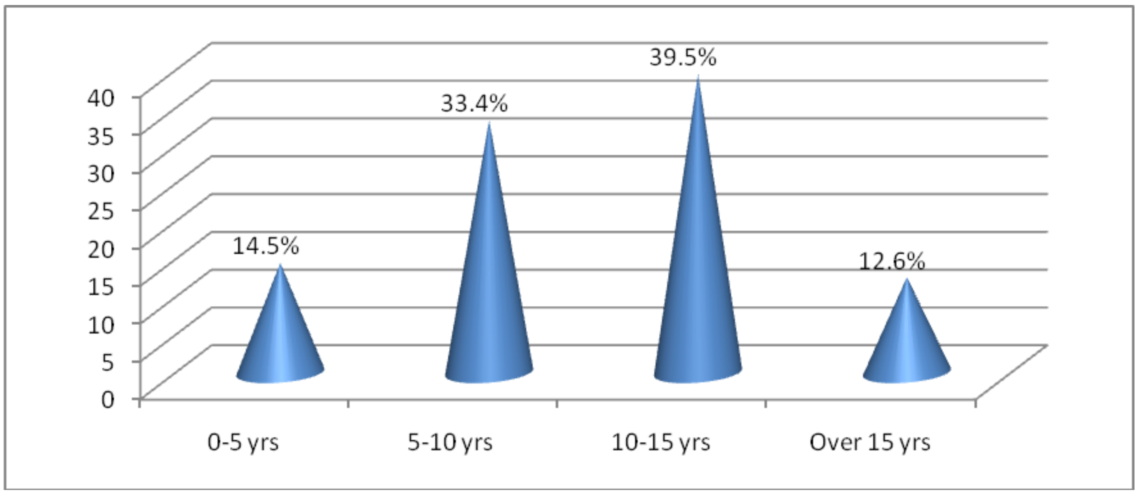

Figure 4.3: Respondents' Working Experience in the Mini- Grid Energy Companies

4.3.5 Level of Education of the Respondents

The study collected data from different categories of education backgrounds to establish whether they understood the factors affecting sustainability of mini - grid energy in rural areas within Kisii County. The results of the study were then presented in Table 4.3.

Table 4.3: Highest Level of Education of the Respondents

Level of Education	Frequency	Percentage
Secondary school	12	6.0
Post-Secondary Qualification level	132	68.7
Graduate level	31	16.4
Post-graduate level	17	9.0

Total	**192**	**100.0**

From the study, majority 68.7% of the respondents indicated that they had obtained post-secondary school's qualification level (i.e. certificate, diploma e.t.c) as their highest level of education. In addition, 16.4% of them were bachelor's degrees holders, 9.0% of the respondents had attained post-graduate degree level of education while 6% of the respondents had obtained other academic qualifications such as secondary school certificate. These outcomes imply that majority of the respondents had at least a post-secondary qualification and hence understood the information sought by this study. These findings further imply that all the respondents were academically qualified and familiar with the information sought by this study.

4.4 Sustainability of Mini - Grid Energy

The main purpose of this study was to investigate the factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya with sustainability indicators such as those pertaining to technical, social, environmental and economic patterns underpinned in the study conceptual framework.

From the study, it's evident that the solar PV mini-grid systems are only sustainable if the technical, social, economic and environmental sustainability indicators are met which for the study project, the installation was only able to meet environmental sustainability indicators.

Accordingly the respondents were required to indicate the extent to which rural inhabitants use mini-grid energy in their homes. From the study, 56.8% of the respondents indicated that rural inhabitants use mini-grid energy in their homes to a moderate extent, 29.5% of the respondents indicated to a great extent, 9.1% of the respondents indicated rural inhabitants use solar mini-grid systems in their homes to a little extent, while 5% of them indicated to a very great extent. The results imply that in general there is a moderate use of mini-grid energy by the rural inhabitants in their homes.

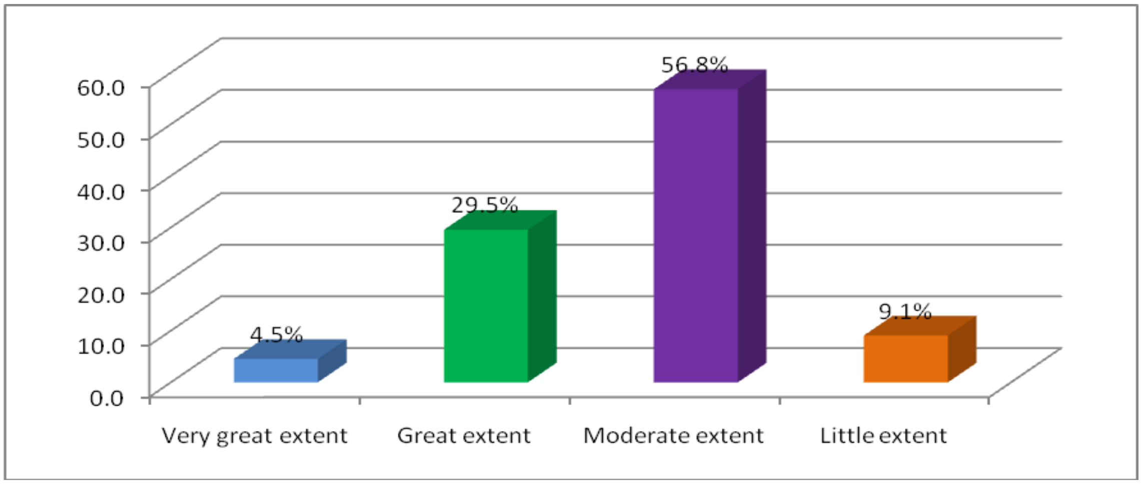

Figure 4.4: Extent to which Rural Inhabitants Use Solar Mini-Grid Systems in their Homes

The study further required the respondent to rate the level of sustainability of solar mini - grid systems in Kisii County. The results are as depicted in table 4.4.

Table 4.4: Level of Sustainability of Solar Mini - Grid Systems

Level	Frequency	Percentage
High level	4	2.1
Moderate level	41	21.4
Lower level	147	76.6
Total	**192**	**100**

From the findings of the study, 76.6% of the respondents unanimously indicated that there is a lower level of sustainability of solar mini - grid systems in rural Kisii County. The remaining proportion comprised of 21.4% of the respondents who reported that there is a moderate sustainability of solar mini - grid systems, while only 2.1% of them reiterated that there is high level of sustainability of solar mini - grid systems. These results imply that there is a low sustainability of solar mini-grid systems in Kisii County.

The study further required the respondents to rate the extent to which the solar mini - grid systems in Kisii County are sustainable in relation to the various aspects provided. Table 4.5 shows the results obtained.

Table 4.5: Sustainability of solar Mini - Grid Systems in Rural Areas

Aspects of solar mini - grid systems sustainability	**Very low Extent**	**Low Extent**	**Moderate Extent**	**Great Extent**	**Very Great**	**Mean**	**Std dev**
Continued utilization of the energy	2.4	9.5	45.2	32.1	10.7	3.389	0.179
Increased use of solar mini grid systems	2.6	17.9	61.5	9.4	8.5	3.034	0.850
Future viability of solar mini grid systems	4.8	8.3	40.5	34.5	11.9	3.404	0.163
Affordability of solar mini-grid systems	3.6	6.0	34.5	46.4	9.5	3.522	0.192

According to Table 4.5, majority of the respondents indicated that solar mini - grid systems in Kisii County there is sustainability of the system due to its affordability to a great extent as shown by a mean score of 3.522. In addition, they reported that future viability of the solar mini-grid systems to a moderate extent as shown by a mean score of 3.404, continued utilization of the energy to a moderate extent as shown by a mean score of 3.389 and increased use of solar mini grid systems to a moderate extent as shown by a mean score of 3.034. These results imply that the solar mini-grid systems is less likely to be sustainable in the future. This could be attributed to the increased usage of other sources of energy, upgrading/future expansion of the Kenya Power energy systems in the region and scalability of solar mini-grids.

The study sought to establish the respondents' level of agreement with various statements regarding sustainability of mini - grid energy in the rural areas of Kisii County. A scale of 1 to 5 was provided where 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree.

Table 4.6: Agreement with sustainability of Solar Mini - Grid Systems in Kisii County

Statements on sustainability of solar mini - grid systems	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std Dev
The solar mini-grid systems is preferred because it is reliable and secure	2.4	9.5	45.2	32.1	10.7	3.389	0.1794
There is high utilization of solar mini grid systems since it is an uninterruptible source of energy	4.8	8.3	40.5	34.5	11.9	3.404	0.1631
This source of energy is advantageous financially than electricity	4.8	8.3	40.5	34.5	11.9	3.404	0.1631
The solar mini-grid system is favourable to rural dwellers due to its environmental cleanliness	2.4	6.0	39.3	41.7	10.6	3.521	0.1896
I think there is a future for solar mini-grid systems in this region	6	13.4	19.4	47.8	13.4	3.492	1.6251
Grid energy market is structured for wide dissemination of small scale installation	2.4	9.5	45.2	32.1	10.7	3.389	0.179
The society in this area are financially able to afford solar installations	2.6	17.9	61.5	9.4	8.5	3.034	0.850

From the study, majority of the respondents affirmed that the solar mini-grid system is favourable to rural dwellers due to its environmental cleanliness as shown by a mean score of 3.521. On the other hand there was neutrality on that there is a future for solar mini-grid system in this region as shown by a mean score of 3.492, there is high utilization of solar mini grid system since it is an uninterruptible source of energy as shown by a mean score of 3.404, this source of energy is advantageous financially than electricity as shown by a mean score of 3.404, the solar mini-grid system is preferred because it is reliable and secure as shown by a mean score of 3.389, grid energy market is structured for wide dissemination of small scale installation as shown by a mean score of 3.389 and the society in this area are financially able to afford solar installations as shown by a mean score of 3.034.

4.5 Energy Policy /Framework Advisory

To assess the effects of energy policy /framework advisory on sustainability of solar mini- grid systems in Kisii County, Kenya, the respondents were asked to rate the extent to which energy policy framework affects sustainability of solar mini - grid systems in Kisii County. The results shown in Figure 4.5 imply that an overwhelming majority of the respondents (represented by 67.3%) recapped that energy policy framework affects sustainability of solar mini - grid systems in Kisii County to a great extent. This was followed by 16.4% of those who indicated that energy policy framework affects sustainability of solar mini - grid systems in Kisii County to a very great extent, then 12.7% who indicated moderate extent, whereas 3.6% of the respondents indicated to a little extent. These results imply that national energy policy framework plays an integral role in sustainability of solar mini - grid systems in Kisii County.

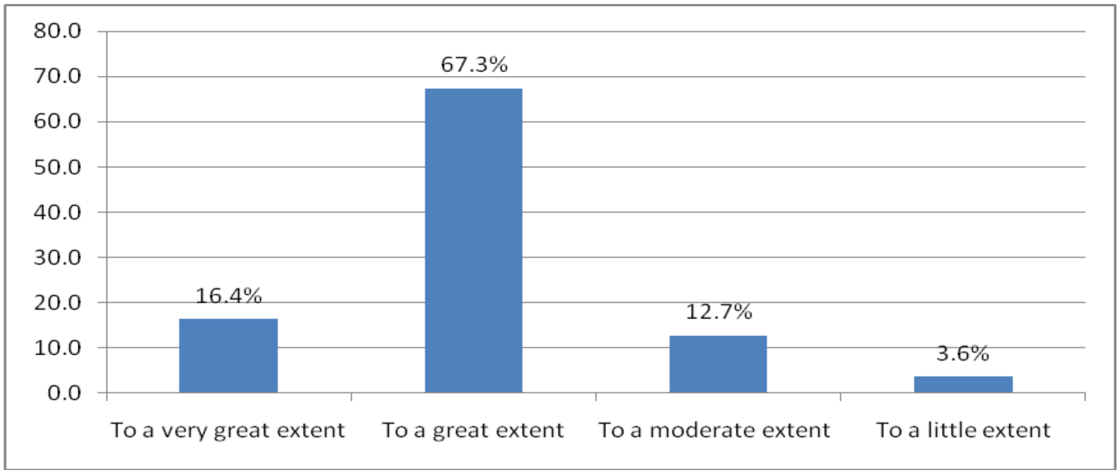

Figure 4.5: Energy Policy Framework affects Sustainability of Solar Mini – Grid Systems

The study sought to establish the extent to which the following aspects of energy policy framework affect the sustainability of solar mini - grid systems in Kisii County. The results are depicted in Table 4.7.

Table 4.7: Aspects of Energy Policy Framework on Sustainability of Solar Mini – Grid

Aspects of energy policy framework	No extent	Little extent	Moderate extent	Large extent	Very Large extent	Mean	Std. Dev.
Tariff regime	6.0	13.4	19.4	47.8	13.4	3.4920	1.6251
Energy Control policies	3.7	13	27.8	50	5.6	3.4110	0.1925
Mini-grid taxation and levies	0	16.7	37	27.8	18.5	3.4810	0.1381
Provision of incentives	0	17.6	26.9	47.2	8.3	3.4630	0.8799

From the results shown in Table 4.7, majority of the respondents recapped that tariff regime affect the sustainability of solar mini - grid systems in Kisii County to a large extent as shown by a mean score 3.4920, mini-grid taxation and levies affect the sustainability of solar mini - grid systems in Kisii County to a large extent as shown by a mean score 3.4810, provision of incentives affect the sustainability of mini - grid energy in Kisii County to a large extent as shown by a mean score 3.4630 and energy control policies affect the sustainability of solar mini - grid systems in Kisii County to a large extent as shown by a mean score 3.4110).

The respondents were required to indicate their level of agreement with various statements regarding the effects of energy policy framework on the sustainability of solar mini - grid systems in Kisii County. The results are tabulated in Table 4.8.

Table 4.8: Effects of Energy Policy Framework on Sustainability of Solar Mini – Grid Systems

Statements on energy policy framework	Strongly	Disagree	Neutral	Agree	Strongly	Mean	Std Dev
Lack of stable legal frameworks affects the installation and utilization of solar mini-grid system	0	6.3	33.3	51	9.4	3.2590	0.7415
The lack of complete and transparent advisory frameworks slows the adoption of mini-grid energy	0	17.6	26.9	47.2	8.3	3.1300	0.8799
There are statutory barriers hindering the expansion of solar energy in the rural areas	0	8.0	30.1	40.7	21.2	2.9030	0.8816
There are corroding policies for alternative energy sources that can be available to the rural people in the near future	0	27	7.0	41.0	23	2.6200	1.1843

According to Table 4.8, most of the respondents (51%) agreed that lack of stable legal frameworks affects the installation and continued utilization of solar mini-grid systems as shown by a mean score of 3.2590, 47.2% agreed that lack of complete and transparent advisory frameworks slows the adoption of mini-grid energy as shown by a mean score of 3.1300, there are statutory barriers hindering the expansion of solar energy in the rural areas as shown by a mean score of 2.9030 and there are corroding policies for alternative energy sources that can be available to the rural people in the near future as shown by a mean score of 2.6200. These results imply that energy policy framework influences the sustainability of solar mini - grid systems in Kisii County.

4.6 Implementation Mechanisms

The second objective of the study sought to investigate the extent to which implementation mechanism affects sustainability of solar mini- grid systems in Kisii County. As such the study sought to establish the extent to which implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County. According to Figure 4.6, 46.6% of the respondents indicated that implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County to a great extent, 40.9% of them indicated to a moderate extent, 9.1% of the respondents indicated to very great extent, while 3.4% of the respondents recapped that implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County to a little extent due to approaches and decision taken in project finance, levels of stakeholders involvement and internal organizational issues. Separately, figures 4.6.1 and 4.6.2 for consumers and implementers respectively, 50% of the consumer responded that implementing mechanism affect solar mini-grid system sustainability and 57% of the implementers indicated that implementing mechanism affect the system sustainability to a greater extent. These remarks imply that the implementation mechanisms have a crucial effect on the sustainability of solar mini - grid systems in Kisii County.

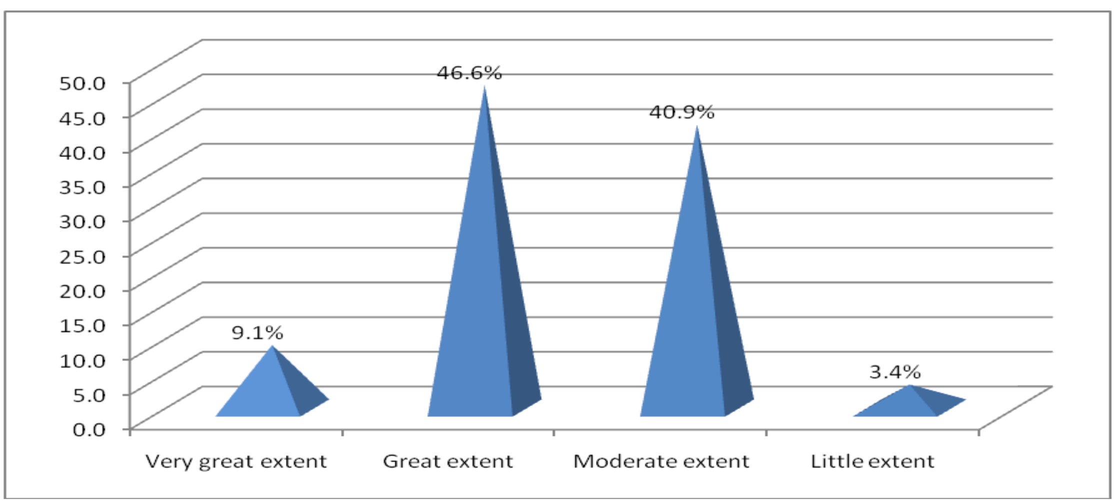

Figure 4.6: Extent to which Implementation Mechanisms affect Sustainability

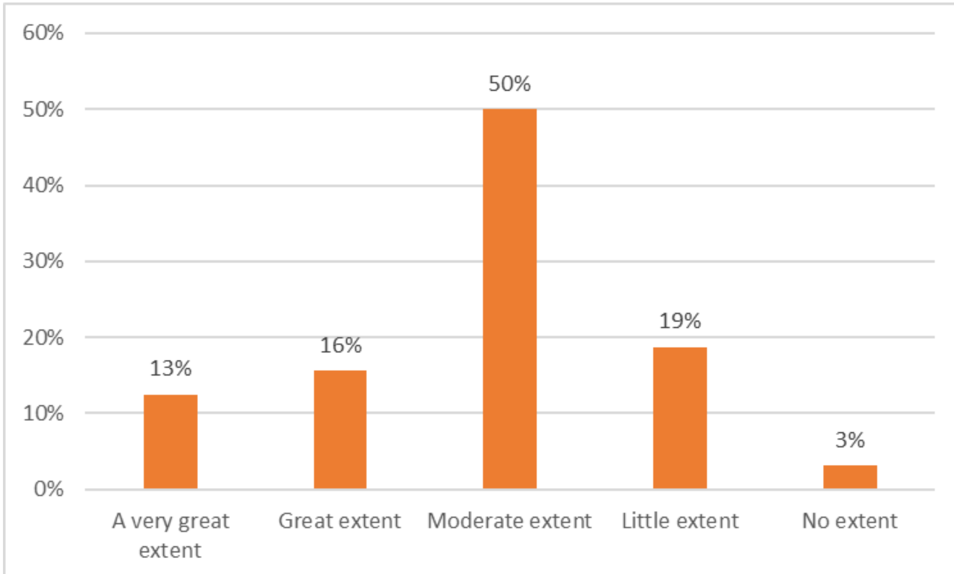

Figure 4.6.1: Extent to which Implementation Mechanisms affect Sustainability – Consumers

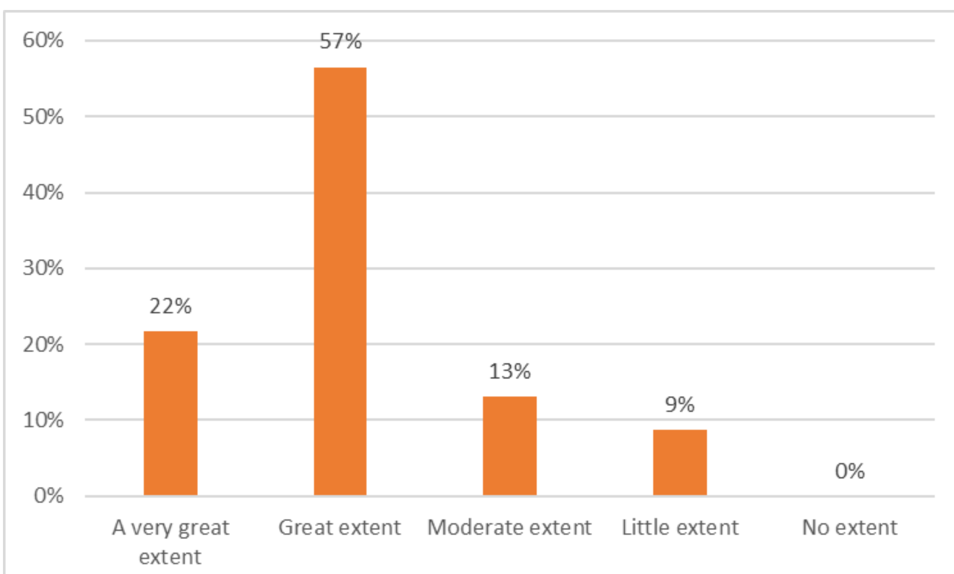

Figure 4.6.2: Extent to which Implementation Mechanisms affect Sustainability – Implementers

The study was interested in establishing the extent to which various aspects of implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County. A scale of 1 to 5 was provided where 1= no extent, 2= little extent, 3= moderate extent, 4= great extent and 5 is to a very great extent.

Table 4.9: Effects of Implementation Mechanisms on Sustainability of Solar Mini-Grid Systems

Aspects of Implementation Mechanisms	Very low Extent	Low Extent	Moderate Extent	Great Extent	Very Great Extent	Mean	Std dev
Financing decisions/approaches	0	4.2	45.8	37.5	12.5	3.083	0.7755
Strategic approach to implementation	0	5.2	36.5	50	8.3	3.282	0.7162
Level of stakeholders’ involvement	0	3.1	42.7	47.9	6.3	3.3220	0.6608
Internal organizational issues	0	2.1	39.6	54.2	4.2	3.4400	0.6066

According to Table 4.9, internal organizational issues affect the sustainability of solar mini - grid systems in Kisii County to a great extent as shown by a mean score of 3.4400 as well as level of stakeholders’ involvement shown by a mean score of 3.3220, strategic approach to implementation to a great extent as shown by a mean score of 3.282 and financing decisions/approaches to a moderate extent as shown by a mean score of 3.083. These results imply that various aspects of implementation mechanisms have a considerable effect on sustainability of solar mini- grid systems.

Table 4.10 below provides detailed information regarding the respondents’ level of agreement with effects of implementation mechanisms on the sustainability of solar mini - grid systems in Kisii County.

Table 4.10: Implementation Mechanisms and Sustainability of Solar Mini - Grid Systems

Statements on implementation mechanisms	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std. Dev
The implementers utilize trustworthy mechanisms to constructively discuss concerns and viewpoints in installation of solar mini - grid systems in this area	0	0.0	29.2	62.5	8.3	3.4590	0.5882
Stakeholder engagement mechanism enhance transparency in the projects	0	27.1	6.8	41.4	22.6	2.6280	1.1772
Communication between the departments influence success of solar mini - grid systems in the rural areas	0	7.7	7.7	53.8	23.1	2.7680	0.63043
The ease of coordination in the organization structure facilitates meeting of expectations in the rural projects	0	27.1	6.8	41.4	22.6	2.6280	1.1772
The managers support application of appropriate project management knowledge and systems	0	27.1	7	41	23	2.6200	1.1843

From the foregoing results, majority of the respondents showed impartiality with that the implementers utilize trustworthy mechanisms to constructively discuss concerns and viewpoints in installation of solar mini - grid systems in this area, communication between the departments influence success of solar mini - grid systems in rural areas, stakeholder engagement mechanism enhance transparency in the projects, the ease of coordination in the organization structure facilitates meeting of expectations in the rural projects and the managers support application of appropriate project management knowledge and systems as shown by mean scores of 3.4590, 2.7680, 2.6280, 2.6280 and

2.6200 respectively. These results, demonstrate that stakeholder engagement, communication in project management, coordination within various functions and choice of appropriate project management system influences sustainability of mini-grid in rural areas from an implementation standpoint.

4.6.1 Implementation Mechanisms – Financial Analysis

The second objective of the study sought to investigate the extent to which implementation that also involved the determination of the financial viability of the project where key sustainability indicators such as affordability, future viability, profitability was determined from the desktop analysis of the installed mini-grid project based on the all the input costs as depicted in appendix IV.

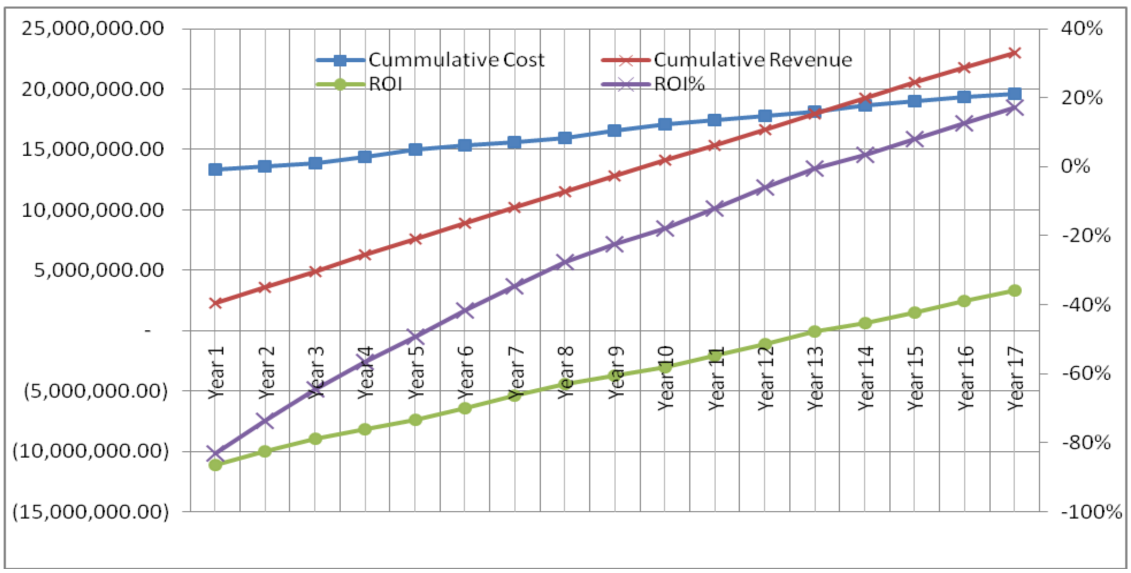

Figure 4.7: Financial Analysis (Return On Investment)

From figure 4.7. above, the project return on investment is after the thirteenth year factoring in minimal maintenance input cost, however, from a simple payback period, the project was able to payback after 5.92 years discounting all other additional input costs. Additionally from Net Present Value of the project, the project is only able to return the investment after year forteen with a cumulative Internal Rate of Return of

47% in year nineteen but with an IRR of 3% in year forteen. The project lifespan is typically 20 to 25 years for most solar mini-grid systems solutions, indicating that with a delayed return on investment, the project is unlikely to be sustainable as the need for total overhaul of most components will be realized mid-stream before or soon just after the return on investment is realized as demonstrated by the schedule of components replacement in appendix IX.

4.7 Capacity Building/Training

In its third objective the study sought to determine the effects of capacity building/training on sustainability of solar mini- grid systems in Kisii County. In this regard the study sought the respondents' views on the extent to which capacity building/training affect sustainability of solar mini - grid systems in Kisii County. From the results depicted in Figure 4.7 39.1% of the respondents reiterated that capacity building/training affect sustainability of solar mini - grid systems in Kisii County to a great extent, 30.4% of them indicated to a moderate extent, 17.4% indicated to a very great extent and 13.0% of the respondents reported that capacity building/training affect sustainability of solar mini - grid systems in Kisii County to a little extent. According to these results, capacity building/training has an enormous effect sustainability of solar mini - grid energy in the rural areas of Kisii County.

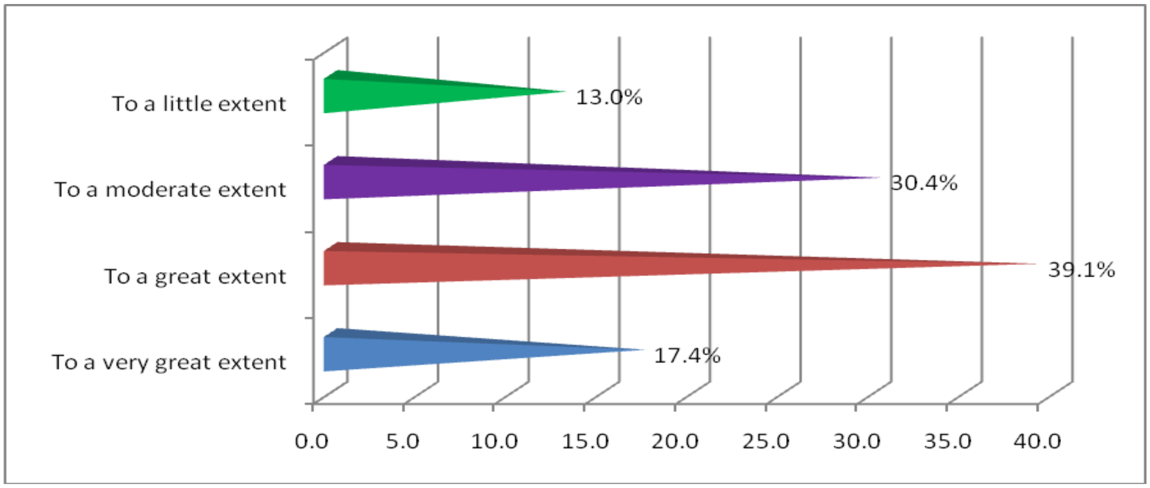

Figure 4.8: Extent to which Capacity Building affect Sustainability of Solar Mini - Grid Systems

The respondents were asked to rate the extent to which the various aspects of capacity building/training affect the sustainability of solar mini - grid systems in Kisii County. Table 4.11 shows the results obtained.

Table 4.11: Aspects of Capacity Building affecting Sustainability of Solar Mini - Grid Systems

Aspects of capacity building/training	Very low Extent	Low Extent	Moderate Extent	Great Extent	Very Great	Mean	Std dev
Proximity to solar mini-grid system	0	7.7	7.7	53.8	23.1	3.3077	0.63043
General knowledge of available grid energy	0	3.1	49	43.8	4.2	3.4896	0.6323
Communication channels to the society	0	17.6	26.9	47.2	8.3	3.4630	0.8799
Perception of solar mini grid energy	0	12.5	14.6	25	29.2	3.3322	1.4923

According to Table 4.11, general knowledge of available grid energy affects its sustainability in Kisii County to a moderate extent as shown by a mean score of 3.4896, followed by communication channels to the society shown by a mean score of 3.4630, then perception of solar mini grid systems shown by a mean score of 3.3322 while proximity to solar mini-grid systems came last with a mean score of 3.3077. These results reveal that these aspects capacity building/training play a key role in the sustainability of solar mini - grid systems in Kisii County. Other aspects that affect the sustainability of solar mini grid systems include security of the infrastructure and presence of local expertise.

The study sought to ascertain the respondents level of agreement with various statements regarding capacity building/training in Kisii County. The results obtained as presented in Table 4.12.

Table 4.12: Effects of Capacity Building/Training on Sustainability of Solar Mini Grid Systems

Capacity building/training	**Strongly**	**Disagree**	**Neutral**	**Agree**	**Strongly**	**Mean**	**Std. Dev**
The solar mini-grid installation companies offer sufficient information on mini-grid systems	2.4	9.5	45.2	32.1	10.7	3.389	0.179
There are capacity building sessions for awareness creation on solar mini-grid systems	2.6	17.9	61.5	9.4	8.5	3.034	0.850
The mini-grid firms offer training on installations and equipment in the area	4.8	8.3	40.5	34.5	11.9	3.404	0.163
The customers are given instructions and demonstration at the household level upon sale or installation	3.6	6.0	34.5	46.4	9.5	3.522	0.192

From the study, majority of the respondents agreed that the customers are given instructions and demonstration at the household level upon sale or installation as shown by a mean score of 3.522. However, there was neutrality on that the mini-grid firms offer training on installations and equipment in the area as shown by a mean score of 3.404, the mini-grid installation companies offer sufficient information on solar mini-grid systems as shown by a mean score of 3.389 and there are capacity building sessions for awareness creation on mini-grid energy as shown by a mean score of 3.034. These results imply that availability of documentation for operations and maintenance of mini grid operations as a customer knowledge transfer mechanisms has a great contribution to sustainability of solar mini-grid systems.

4.8 Inferential Analysis

To complement the descriptive results, inferential analyses was conducted involving regression analysis. Multiple regression analysis was used to quantify the strength of the relationship between the variables. The dependent variable in this study was sustainability of solar mini- grid systems while the independent variables were energy policy /framework advisory, implementation mechanisms and capacity building/training.

4.8.1 Coefficient of Determination

Model summary was extracted which portrayed the coefficient of determination. Table 4.13 shows the results of the model summary.

Table 4.13: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the estimate
1	. 797[a]	.635	.620	.269

From the model summary, R^2= 0.635 and adjusted R square 0.620 reveal that 63.5% change in sustainability of solar mini- grid systems can be explained by the changes of all the predictor variables. It shows that the independent variables had a strong correlation with the dependent variable. On the other hand, 36.5% was explained by other factors that were not part of this study. The results imply that the factors investigated in this study contribute a major part of the sustainability of solar mini- grid systems in Kisii County.

4.8.2 Analysis of Variance

The Analysis of variance (ANOVA) was used to determine whether there was a regression relationship between various factors and sustainability of solar mini- grid systems in Kisii County. The F-ratio in the ANOVA table tested whether the overall regression model was good and fit for the data. The results obtained are presented in Table 4.14.

Table 4.14: ANOVA Test Results

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	6.33	3	2.11	2.912	0.000
Residual	135.36	188	0.72		
Total	141.69	191			

Dependent variable: Sustainability of solar mini- grid systems

Independent variables: Energy policy /framework advisory, implementation mechanism and capacity building/training

The results indicate that F=2.9123, and is significant since p<0.001which is less than p value, p = 0.05. The critical values for F-test (3, 191, at 0.05 alpha is 2.08) which is less than the computed F-value (2.912). This therefore shows that the model is fit for finding out the relationship between the dependent and independent variables.

4.8.3 Regression Coefficients

Regression analysis was conducted to determine the relationship between various factors and sustainability of solar mini- grid systems. The results are presented in table 4.15.

Table 4.15: Regression Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.580	.189		3.079	.004
Energy policy /framework advisory	.489	.093	.227	2.034	.024
Implementation mechanisms	.417	.102	.315	2.133	.038
Capacity building/training	.384	.133	.425	2.881	.039

The coefficients in Table 4.15 answer the regression equation relating to the dependent and the independent variables. Testing the significance of the coefficients at 95% confidence level, the table indicates that all the variables had a significance value less than 0.05 thus confirming the significance of the results. Also, from the table, all the variables indicated a positive coefficient indicating a positive relationship between the dependent and independent variables. Based on these coefficients, the regression model ($Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \varepsilon$) therefore becomes; $Y=0.580+0.489X_1+0.417X_2+0.384X_3$

The model indicates that, holding the predictor variables constant, the sustainability of mini- grid energy would have a coefficient of 0.580. From the results, the regression coefficient for energy policy /framework advisory is 0.489. This had a significant value of 0.024 which is less than 0.05 depicting the significance of the relationship between energy policy /framework advisory and sustainability of solar mini- grid systems.

Therefore, based on these, there is a positive and significant relationship between a unit energy policy /framework advisory and sustainability of solar mini- grid systems. This shows that, a unit increase in the energy policy /framework advisory would result to 0.489 times increase in sustainability of solar mini- grid systems.

The results also show that sustainability of solar mini- grid system is positive and significantly related to the implementation mechanisms. This is indicated by a regression coefficient of 0.417 which is a positive coefficient and a p-value of 0.038 less than 0.05 showing the significance of the relationship. Based on the coefficient, it is evident that a unit increase in implementation mechanisms would result to 0.417 times increase in sustainability of solar mini- grid systems.

Capacity building/training was also seen to have a positive effect on the sustainability of solar mini- grid systems. This is shown by the regression coefficient of 0.384 with a significance value of 0.039 which is less than 0.05 the critical value at the 5% level of significance. This therefore shows that given a unit increase in capacity building/training would result to 0.384 changes in sustainability of solar mini- grid systems.

Therefore, according to the study findings energy policy /framework advisory contributes more to the increase of sustainability of solar mini- grid systems followed by implementation mechanisms, while capacity building/training contributes the least to sustainability of solar mini- grid systems in Kisii County.

4.8.4 PVGIS Estimates of Solar Electricity Generation

PVGIS software was used to analyse the site specific solar energy resource capacity and performance for the study area to determine system scalability for increased demand against the available solar resource potential throughout the year. The outcome of the analysis from PVGIS software for a typical specific site with coordinates as shown is presented below.

Site Details: Site 97, Boikanga, Kisii County, GPS Location: 0°49'40" South, 34°45'49" East, Elevation: 1794 m a.s.l.,

Nominal power of the Solar PV system (Design): 10.0 kWp (crystalline silicon).

Estimated losses due to temperature and low irradiance: 12.2% (using local ambient temperature).

Estimated loss due to angular reflectance effects: 2.8%

Other losses (cables, inverters e.t.c): 14%

Combined PV system losses: 26.6%

Fixed system: inclination=0°, orientation=10°				
Month	E_d	E_m	H_d	H_m
Jan	43.20	1340	5.94	184
Feb	45.20	1270	6.27	176
Mar	46.30	1440	6.41	199
Apr	40.40	1210	5.51	165
May	40.40	1250	5.48	170
Jun	39.70	1190	5.35	160
Jul	40.10	1240	5.43	168
Aug	40.70	1260	5.55	172
Sep	42.70	1280	5.85	176
Oct	42.60	1320	5.88	182
Nov	37.60	1130	5.15	155
Dec	39.90	1240	5.42	168
Yearly average	**41.5**	**1260**	**5.69**	**173**
Total for year		**15200**		**2080**

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Figure 4.9: Energy Consumption Estimates

Source: PVGIS © European Communities, 2001-2017

From the table and graphical simulation of a typical site above with a monthly average energy production of 1260kWh and noting that useful solar irradiation for the particular site locations is between 09.00Hrs to 16.00Hrs i.e. a 6hour window of useful solar irradiation, the average power output will be:

Average Annual Power Output Pavg= Ey/(Tu*D)

Where; Em = Average Yearly Energy Production in kWhr

Tu =Useful Solar Irradiation Time in Hrs

D = Number of Days in a Year

Therefore, for the above typical site, the average power output will be.

Pavg = 15200/(6*365) = 6.94kW

Comparing the average daily power output against the installed capacity of 10kWp, the generation is at 69.4% efficiency with the shortfall attributed to system, distribution and service losses.

The above output compared to daily load demand for 100% consumer uptake of 200homes;

Each home from the installed residual circuit device (RCD) can consume a maximum of 40Watts of power for 3 hours a day, the maximum demand per site therefore, was 8kW i.e;

Site Maximum Power Demand, P_{max_demand} = (Max. Power Per Home x No. of Homes) kW,

P_{max_demand} = (40 * 200) = 8kW

From the PVGIS simulation of site energy production and average power demand as represented in Figure 4.9, it's evident that the system as installed may not be able to provide for 100% consumer uptake at maximum power demand with a deficit of 1.06kW that is not met, a 13.25% power supply deficit, and further providing insight in to the implementation mechanism objective of the study.

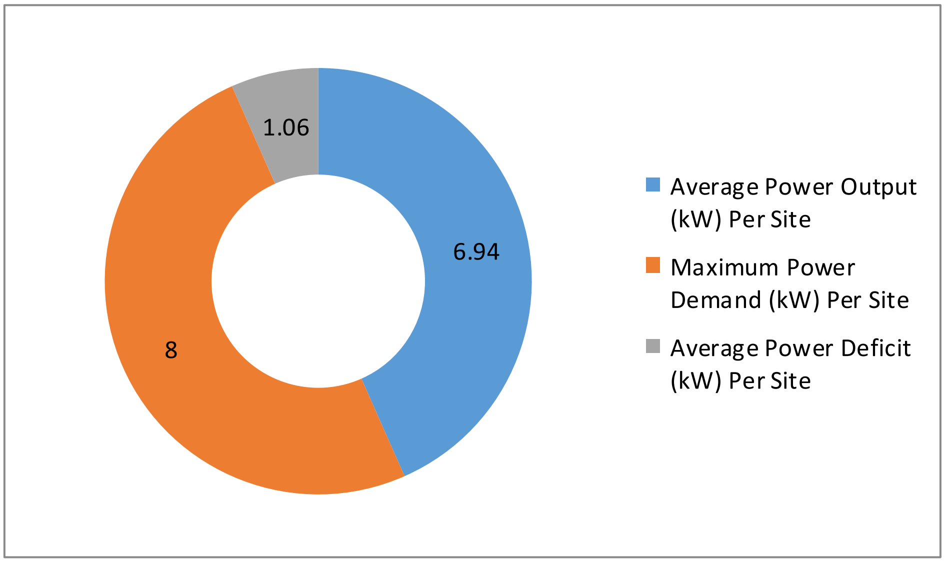

Figure 4.10: PVGIS Analysis of Average Power Output vs. Max. Power Demand

From figure 4.10 the average power output from the solar mini-grid generation plant, there's a 1.06kW deficit to meet the maximum consumer demand of 8.0kW

Table 4.16: PVGIS Comparison of Average Monthly Power Output vs. Max. Demand

	Average Power Output (kW)	*Maximum Power Demand(kW)*
Jan	7.20	8.00
Feb	7.56	8.00
Mar	7.74	8.00
Apr	6.72	8.00
May	6.72	8.00
Jun	6.61	8.00

Jul	6.67	8.00
Aug	6.77	8.00
Sep	7.11	8.00
Oct	7.10	8.00
Nov	6.28	8.00
Dec	6.67	8.00
	6.93	**8.00**

From Table 4.16 comparison of average monthly power output is much less than the average monthly power demand throughout the year.

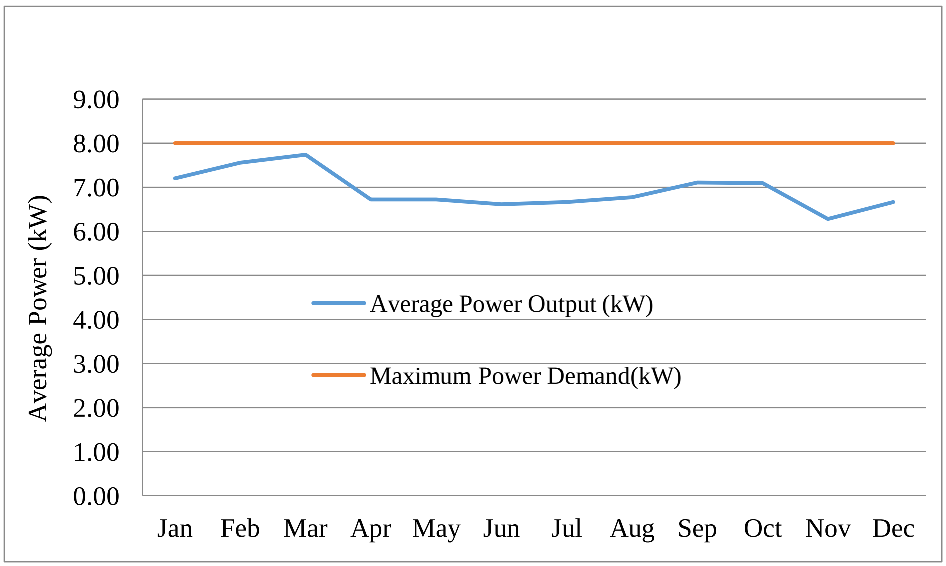

Figure 4.11: PVGIS Comparison of Average Power Output vs. Power Demand

From Figure 4.11 comparison of average monthly power output is much less than the average monthly power demand throughout the year, indicating that the solar PV mini grid as installed is not meeting the consumer demand.

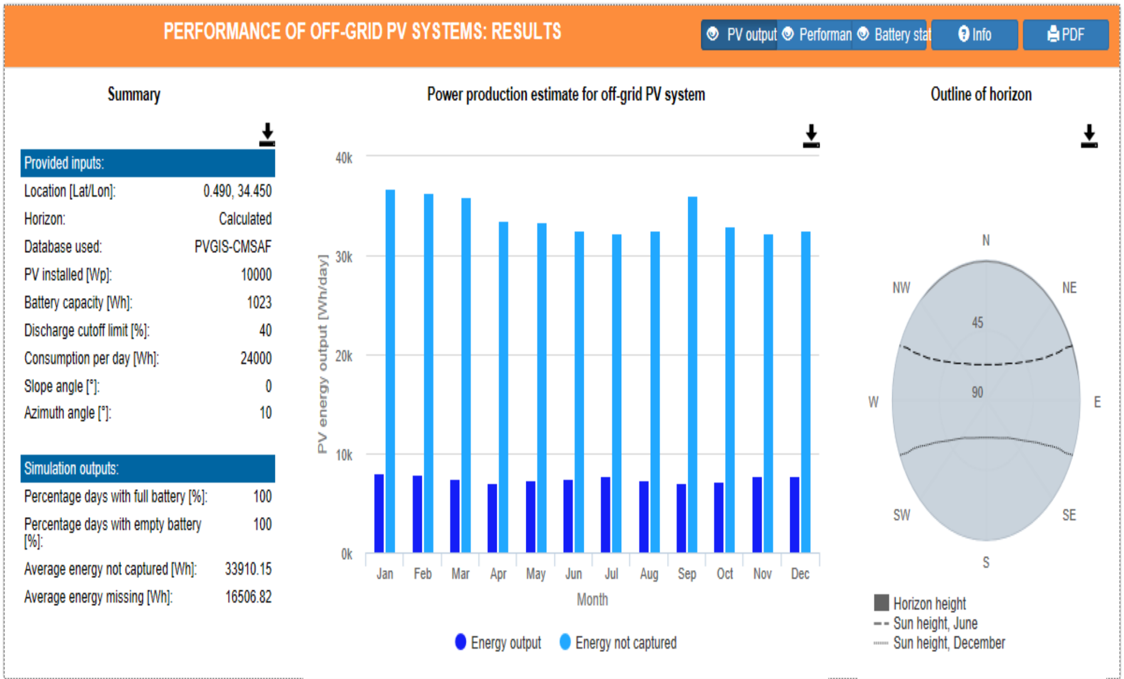

Figure 4.12: Performance of Off-Grid Systems

Source: PVGIS © European Communities, 2001-2017

From the PVGIS simulation of site 97, Boikanga, 0°49'40" South, 34°45'49" East, Kisii County, it was observed that the solar PV mini-grid system as designed and installed, was not fully optimized with an average of 33.9kWhr of energy not being harnessed by the system, it is therefore evident that the site location had adequate solar energy potential to meet the existing demand, this points into the various aspects of implementation mechanisms e.g, financial and economic consideration, strategic approach and internal issues whilst sizing the solar mini-grid systems.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter is a synthesis of the entire study and contains a summary of findings, conclusions and recommendations. The chapter is aimed at summarizing and making commendable inferences based on the objectives of the study. The study results lead to the recommendations and conclusions from the analysis done in chapter four. The chapter finally presents the suggestions for further studies.

5.2 Summary of Findings

The study found that 56.8% of rural inhabitants use solar mini-grid systems in their homes to a moderate extent on a Likert's scale of 1 -5. From the study, there is a lower level of sustainability of solar mini - grid systems in Kisii County, Kenya at 76.6%. The solar mini - grid systems in Kisii County, Kenya are greatly sustainable due to affordability of their systems to a great extent. In addition, 40.5% of the responded indicated that solar mini - grid energy in Kisii County are moderately sustainable with a mean score of 3.404 due to future viability of the grid energy, continued utilization of the energy and increased use of solar mini-grid systems. The study established that solar mini-grid systems is favourable to rural dwellers due to its environmental cleanliness, however, there was neutral response that there is a future for solar mini-grid systems, there is high utilization of solar mini grid system since it is an uninterruptible source of energy, this source of energy is advantageous financially than electricity, the mini-grid energy is preferred because it is reliable and secure , grid energy market is structured for wide dissemination of small scale installation and the society in this area are financially able to afford solar installations.

The study revealed that energy policy framework affects sustainability of solar mini - grid systems in Kisii County with 67.3% of responded indicating to a great extent. Tariff regime, mini-grid taxation and levies, provision of incentives and energy control policies affect the sustainability of solar mini - grid systems in Kisii County to a great extent. The study established neutrality on that lack of stable legal frameworks affects the installation and utilization of solar mini-grid systems, the lack of complete and transparent advisory frameworks slows the adoption of solar mini-grid systems, there are statutory barriers hindering the expansion of solar energy in the rural areas and there are corroding policies for alternative energy sources that can be available to the rural people in the near future.

The study found that implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County with 46.6% of the respondent being affirmative. Internal organizational issues, level of stakeholders' involvement, strategic approach and financing decisions/approaches affect the sustainability of solar mini - grid systems in Kisii County to moderate extent. (The respondents showed impartiality with that the implementers utilize trustworthy mechanisms to constructively discuss concerns and viewpoints in installation of solar mini - grid systems in this area, communication between the departments influence success of solar mini - grid systems in rural areas, stakeholder engagement mechanism enhance transparency in the projects, the ease of coordination in the organization structure facilitates meeting of expectations in the rural projects and the managers support application of appropriate project management knowledge and systems).

The study found that capacity building/training affect sustainability of solar mini - grid systems in Kisii County with 39.1% of the responded in agreement. General knowledge of available grid energy, communication channels, perception of mini grid energy and proximity to solar mini-grid energy system affect sustainability of solar mini grid systems in Kisii County. The respondents agreed that the customers are given instructions and demonstration at the household level upon sale or installation, while they indicated neutrality on that the mini-grid firms offer training on installations and equipment in the area, the mini-grid installation companies offer sufficient information on mini-grid energy and there is capacity building sessions for awareness creation on mini-grid energy.

From the model summary, 63.5% change in sustainability of solar mini- grid systems can be explained by the changes of energy policy /framework advisory, implementation mechanisms and capacity building/training. From the ANOVA test, the critical values for F-test were less than the computed F-value showing that the model is fit. The regression coefficients showed that if all the variables are kept constant, sustainability of solar mini- grid systems would have a coefficient of 0.580. Energy policy /framework advisory had a regression coefficient of 0.489; implementation mechanisms had a regression coefficient of 0.417, while Capacity building/training had a regression coefficient of 0.384. At 5% level of significance all the variables had positive relationship with the sustainability of solar mini- grid systems. The study found out that environmental sustainability indicators were met by solar mini-grid systems. The study however, noted that implementation mechanism has an effect on the sustainability of solar mini grid systems if the generated energy is not adequate to meet the consumer energy demand.

5.3 Conclusions

56.8% of the respondents indicated that there is moderate use of solar mini-grid systems by the rural inhabitants in their homes, there is low sustainability of solar mini-grid energy in Kisii County with 76.6% of the responded alluding to this due to scalability of the solar mini-grid. The solar mini-grid systems meets environmental sustainability indicators but not economic and less of social indicators, that the solar mini-grid systems as deployed is less likely to be sustainable in the future due to the increased usage of other sources of energy, upgrading/future expansion of the Kenya Power energy systems in the region and scalability of micro-grids. (There is a little probable future for solar mini-grid systems from economic and social indicator aspects, there is high sustainability of solar mini grid systems since it is an uninterruptible source of energy, solar mini-grid energy is partially advantageous financially than electricity, the solar mini-grid systems is partially preferred because it is reliable and secure, grid energy market is structured for wide dissemination of small scale installation and the society in Kisii County are partially able to afford solar installations).

The study deduces that energy policy framework plays an integral role in sustainability of solar mini – grid systems in Kisii County. There are various aspects of energy policy framework that affect the sustainability of solar mini - grid systems in rural areas including tariff regime, energy control policies, mini-grid taxation and levies and provision of incentives. Accordingly, energy policy framework affects the sustainability of solar mini - grid systems in Kisii County.

The findings deduce that implementation mechanisms have an effect on the sustainability of solar mini - grid systems in Kisii County. Financing decisions/approaches, strategic approach to implementation, level of stakeholders' involvement and internal organizational issues have a considerable effect on sustainability of solar mini- grids. From the findings, there is insufficient support from local organizations and local communities as well as shortage of locally available materials.

The study deduces that capacity building/training has an effect sustainability of solar mini - grid systems in Kisii County with 39.1% of the respondents indicating that this as a great effect on sustainability. Proximity to solar mini-grid system, knowledge of available mini-grid energy, communication channels to the society and perception of mini-grid energy play a key role in sustainability of solar mini - grid systems in Kisii County, Kenya. Accordingly, availability of documentation for operations and maintenance of solar mini-grid operations as a customer knowledge transfer mechanisms has a great contribution to sustainability of mini-grid energy.

From the regression analysis, energy policy /framework advisory contributes more to the increase of sustainability of solar mini- grid systems with a coefficient of 0.489 followed by implementation mechanisms with 0.417, while capacity building/training contributes the least with 0.384 to sustainability of solar mini- grid systems in Kisii County, Kenya.

5.4 Recommendations

Since regulatory policy affects sustainability of solar mini-grid systems, the Government of Kenya through Ministry of Energy and Petroleum (MoEP) should consider zoning and mapping out areas exclusively for development and deployment of decentralized solar mini-grid projects. This should beside zero rating tax on solar equipment including all balance of systems so as to influence lower pricing thus making it more affordable for purchase and installation of solar system as well assure the investors in energy sector of favorable return on investment.

EPRA should collaborate with other Government agencies in the power sector e.g. KPLC and REREC during approvals of power generation applications for avoidance of duplicity of power projects within the same area and also guiding on the implementation mechanism e.g. only approve grid tied systems for non-remote areas where there's grid expansion program and decentralized stand-alone systems for remote areas.

The Government should subsidize solar mini-grid solutions where investors have deployed local grid network to areas where there were no national or county grid extension programme so as to spur confidence in economic viability of such projects,

The study recommends that there is need to provide training and education to increase the level of knowledge and awareness on the use of solar energy. This can be done through seminars, workshops and public barazas where members are invited for training and demonstration on the use and benefits of solar energy. There is also need to ensure proximity to mini-grid energy system, knowledge of available grid energy, communication channels to the society and perception of solar mini-grid systems among the stakeholders.

The study has investigated the factors affecting sustainability of solar mini-grid systems in Kisii County, Kenya and established that energy policy /framework advisory, implementation mechanisms and capacity building/training are the main factors affecting sustainability of solar mini- grid systems in Kisii County, Kenya. There are however many other energy sector projects in various other rural areas in Kenya whose management and areas of operations are either similar or different from those in Kisii County. This opens opportunities for a study which would ensure generalization of the study findings for all the mini-grid energy projects such as pico, micro hydro e.t.c in Kenya and hence pave way for new policies.

The study recommends that further research be carried out on other emerging factors affecting sustainability of energy projects and their overall effects on the operations of such projects. It would be in the interest of the organizations if the stakeholders know the influence of aspects of technological advancements and globalization on the sustainability of energy projects. The study recommends that a similar study should be undertaken for a different infrastructure development projects in different sectors so as to compare and contrast results.

The study also recommends that further study be conducted to investigate effect of zoning and mapping areas within Kenya for exclusive deployment of decentralized solar mini-grid systems on their sustainability.

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APPENDICES

Appendix I: Introduction Letter

Dear respondent,

RE: DATA COLLECTION

I am a postgraduate student at Jomo Kenyatta University of Agriculture & Technology pursuing a Degree in Master of Science specializing in Energy Technology. For the purpose of completing my program, I am carrying out a study on **FACTORS AFFECTING SUSTAINABILITY OF SOLAR MINI - GRID SYSTEMS IN KISII COUNTY, KENYA.** You and your organization have been selected to participate in this study.

The attached questionnaire has been designed to help gather data from respondents. In respect to this you have been identified as one of the respondents. Therefore, I kindly request you to facilitate the collection of the necessary data by answering the questions as precisely and factually as possible. This information sought is purely for academic purposes and this I assure you of strict confidentiality of the information given.

Yours faithfully

George Odhiambo Ponde

MSc. (Energy Technology), JKUAT

Appendix II: Research Questionnaire

This questionnaire is designed to collect data on the Factors Affecting Sustainability of Solar Mini - Grid Systems in Kisii County, Kenya. This questionnaire consists of two major sections. Kindly respond to all questions by putting a tick (✓) in the box matching your answer or write your answer in the space provided if it is not included in the choices. The information given here will only be used for purposes of this study and will be treated with utmost confidentiality. Your cooperation will be highly appreciated.

SECTION A: BACKGROUND INFORMATION

1. Name of the Organization: ....
2. Gender

    Male [ ] Female [ ]

3. Age Bracket

    Below 30 years [ ] 30-39 years [ ]

    40-49 years [ ] Above 50 years [ ]

4. What is your category as a respondent?

    Manager [ ] Unit Head officer [ ]

    Supervisor [ ] Departmental Head [ ]

Assistant Manager [ ] Technical personnel [ ]

Customer [ ] Other…………………… [ ]

5. How long have you been serving or connected with this Mini-grid company?

0-5 yrs [ ] 5-10 yrs [ ]

10-15 yrs [ ] Over 15 yrs [ ]

6. What is your highest level of education?

Postgraduate [ ] College Diploma/certificate [ ]

Bachelor's Degree [ ] Secondary school level [ ]

Others (Specify.....................) [ ]

SECTION B: SUSTAINABILITY OF SOLAR MINI - GRID SYSTEMS

7. To what extent do the rural inhabitants use solar mini-grid systems in their homes?

To a very great extent	To a great extent	To a moderate extent	To a little extent	To no extent

8. How would you rate the level of sustainable utilization of solar mini - grid systems in Kisii County, Kenya?

Very high level [ ] High level [ ]

Moderate level [ ] Lower level [ ]

Not at all [ ]

9. Rate the extent to which the solar mini - grid systems in Kisii County, Kenya are sustainable in relation to the following aspects. Use a scale of 1 to 5 where 5) Very great extent 4) Great extent 3) Moderate extent2) Low extent 1) Very low extent

Aspects of solar mini - grid systems **Sustainability**	**1**	**2**	**3**	**4**	**5**
Continued utilization of the energy					
Increased use of solar mini grid systems					
Future viability of the grid energy					
Affordability of the solar mini-grid systems					
Other (Specify……………………………………..)					

10. Please rate your level of agreement with the following statements regarding sustainability of solar mini - grid systems in Kisii County, Kenya? Use a scale of 1 to 5 where: 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree

Statements on sustainability of solar mini - grid systems	**1**	**2**	**3**	**4**	**5**
The solar mini-grid systems is preferred because it is reliable and secure					
There is high utilization of solar mini grid systems since it is an uninterruptible source of energy					
This source of energy is advantageous financially than electricity					
The solar mini-grid system is favourable to rural dwellers due to its environmental cleanliness					
I think there is a future for solar mini-grid systems in this region					
Grid energy market is structured for wide dissemination of small scale installation					
The society in this area are financially able to afford					

solar installations					
Other (specify…………………………………………..)					

PART A: Energy Policy /Framework Advisory

11. To what extent does energy policy framework affect sustainability of solar mini - grid systems in Kisii County, Kenya?

To a very great extent	To a great extent	To a moderate extent	To a little extent	To no extent

12. To what extent do the following aspects of energy policy framework affect the sustainability of solar mini - grid systems in Kisii County, Kenya? Use a scale of 1 to 5 where 1= no extent, 2= little extent, 3= moderate extent, 4= great extent and 5 is to a very great extent.

Aspects of energy policy framework	**1**	**2**	**3**	**4**	**5**
Tariff regime					
Energy Control policies					
Mini-grid taxation and levies					
Provision of incentives					
Other (Specify……………………………………..)					

13. What is your level of agreement with the following statements regarding the effects of energy policy framework on the sustainability of solar mini - grid systems in Kisii County, Kenya? Rate on a scale of 1 to 5 where: 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly

Statements on energy policy framework	**1**	**2**	**3**	**4**	**5**
Lack of stable legal frameworks affects the installation and utilization of solar mini-grid systems					
The lack of complete and transparent advisory frameworks slows the adoption of solar mini-grid systems					

There are statutory barriers hindering the expansion of solar energy in the rural areas					
There are corroding policies for alternative energy sources that can be available to the rural people in the near future					
Other (Specify……………………………………..)					

PART B: Implementation Mechanisms

14. With regard to this County, to what extent do implementation mechanisms affect the sustainability of solar mini - grid systems in rural areas?

To a very great extent	To a great extent	To a moderate extent	To a little extent	To no extent

15. To what extent do the following aspects of implementation mechanisms affect the sustainability of solar mini - grid systems in Kisii County, Kenya? Use a scale of 1 to 5 where 1= no extent, 2= little extent, 3= moderate extent, 4= great extent and 5 is to a very great extent.

Aspects of Implementation Mechanisms	**1**	**2**	**3**	**4**	**5**
Financing decisions/approaches					
Strategic approach to implementation					
Level of stakeholders' involvement					
Internal organizational issues					
Other (Specify……………………………………..)					

16. What is your level of agreement with the following statements on implementation mechanisms affect the sustainability of solar mini - grid systems in rural Kisii

County, Kenya? Use a scale of 1 to 5 where: 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly

Statements on implementation mechanisms	**1**	**2**	**3**	**4**	**5**
The implementers utilize trustworthy mechanisms to constructively discuss concerns and viewpoints in installation of mini - grid energy in this area					
Stakeholder engagement mechanism enhance transparency in the projects					
Communication between the departments influence success of mini - grid energy in the rural areas					
The ease of coordination in the organization structure facilitates meeting of expectations in the rural projects					
The managers support application of appropriate project management knowledge and systems					
Other (Specify………………………………..……………………..)					

PART C: Capacity Building/Training

17. To what extent does capacity building/training affect sustainability of solar mini - grid systems in Kisii County, Kenya?

To a very great extent	To a great extent	To a moderate extent	To a little extent	To no extent

18. How would you rate the extent to which the following aspects of capacity building/training affect the sustainability of solar mini - grid systems in this rural area? Use a scale of 1 to 5 where 1= no extent, 2= little extent, 3= moderate extent, 4= great extent and 5 is to a very great extent.

Aspects of capacity building/training	**1**	**2**	**3**	**4**	**5**
Proximity to solar mini-grid energy system					
Knowledge of available grid energy					
Communication channels to the society					
Perception of solar mini grid systems					

Other (Specify……………………………………..)					

19. Rate your level of agreement with the following statements regarding capacity building/training in Kisii County, Kenya? Use a scale of 1 to 5 where: 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree

Capacity building/training	**1**	**2**	**3**	**4**	**5**
The mini-grid installation companies offer sufficient information on mini-grid energy					
There are capacity building sessions for awareness creation on mini-grid energy					
The mini-grid firms offer training on installations and equipment in the area					
The customers are given instructions and demonstration at the household level upon sale or installation					
Other (Specify……………………………………..)					

20. What other information would you like to share sustainability of solar mini- grid systems in Kisii County, Kenya?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

21. What do you think should be done to enhance the sustainability of solar mini- grid systems in Kisii County, Kenya?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Appendix III: Solar Mini-grid (10kWp) Sites Details

#	Mini-grid Site Location	Mini-grid Site Name	Mini-grid Site Coordinates		Customer Applications	% Uptake (200)	Connected Customer	Sample Population size	Respondents No (%)	Approx. Site distance from last TX (m)
			Latitude	Longitude						
1	Nyakoe	185	S 00°37'34.4"	E 034°44'6.2"	185	93%	105	54	51%	1200
2	Nyatieko	179	S 00°46' 00"	E 034° 41'10"	187	94%	107	45	42%	1300
3	Boikanga	97	S 00°49' 13.6"	E 034°40'9.9"	151	76%	83	30	36%	2680
4	Keberacho Area	Kirwa C	S 0.89°18'00"	E 034°64'10"	193	97%	110	45	41%	3700
5	Regina I	Regina I	S 0.89°18'00"	E 034°37'21"	163	82%	93	32	34%	2500
6	Nyamarambe Market	90A	S 00°49' 17.5"	E 34° 38' 35.9"	62	31%	30	9	30%	5750
7	Nyaramba B	Nyaramba B	S-0.9°49.3'49"	E 34.67°0.2'44"	10	5%	5	2	30%	4300
8	Nyangweta Kitere	265	S -0.8°43'9"	E 34° 61' 39"	34	17%	17	5	30%	3500
9	Saramba Area	268	S-0.59°0.19'4"	E 34.8°37'33.8"	78	39%	40	8	20%	5000
10	Mwakibagendi	191	S 00°35' 36.8"	E 034°46' 29.0"	24	12%	10	4	39%	6500
					1087		600	234		

Appendix IV: Financial Analysis – Cost Calculation

PROJECT FINANCIAL ANALYSIS

Assumptions

1 One site at 97% Uptake utilize as representative of all the sites for revenue calculation (193/200 customers)

2 Batteries to be replaced after every 48months

3 Solar PV assume 2% breakages over a period of 1 year

4 Maintenance fee to increase by 10% after every 2 years

5 Lease rental escalation of 7.5% Annually

Calculations

1	CAPEX	Qnty	Unit Price USD	Unit Price (KES)	Total (KES)	Cost Per Site
1.1	Solar PV Modules	1920	83.66	8,533.58	16,384,472.73	819,223.64
1.2	Batteries 12VDC	480	300.27	30,627.50	14,701,201.16	735,060.06
1.3	Inverters	60	7,492.73	764,258.57	45,855,514.04	2,292,775.70
1.4	Meters	220	156.00	15,912.00	3,500,640.00	175,032.00
1.5	Protection (RCDs)	4000	104.95	10,704.86	42,819,458.55	2,140,972.93
	Total CAPEX					**6,163,064.32**
2	Construction Materials	20	36,139.08	3,686,186.00	73,723,720.00	3,686,186.00
3	Services Cost	20	17,515.69	1,786,600.00	35,732,000.00	1,786,600.00
4	Rental Cost	1	2,352.94	240,000.00	240,000.00	240,000.00
5	Maintenance Cost	12	441.18	45,000.00	540,000.00	540,000.00
6	Add Office Cost	7.50 %	-	-	-	931,188.77
	Total Cost (Annual) (CAPEX + OPEX)					**13,347,039.10**

Appendix V: Financial Analysis – Revenue and Cost Calculation

Revenue Calculation

Year	Application Fee	Standing Charge	kWHr/Day	Days	KSh/kWhr	Total Revenue	Homes	Total	Cost	Cum Reve	Cum Cost	ROI	ROI %
Year 1	4,000.00	7,200.00	0.01	365.00	13.00	7,266.43	200	2,253,286.00	13,347,039.10	2,253,286.00	13,347,039.10	(11,093,753.10)	-83%
Year 2	0	7,200.00	0.01	365.00	13.00	7,266.43	180	1,307,957.40	214,134.32	3,561,243.40	13,561,173.42	(9,999,930.02)	-74%
Year 3	4,000.00	7,200.00	0.01	365.00	13.00	7,266.43	185	1,364,289.55	268,134.32	4,925,532.95	13,829,307.73	(8,903,774.78)	-64%
Year 4	0	7,200.00	0.01	365.00	13.00	7,266.43	185	1,344,289.55	581,664.35	6,269,822.50	14,410,972.08	(8,141,149.58)	-56%
Year 5	0	7,200.00	0.01	365.00	13.00	7,266.43	185	1,344,289.55	581,664.35	7,614,112.05	14,992,636.43	(7,378,524.38)	-49%
Year 6	0	7,200.00	0.01	365.00	13.00	7,266.43	180	1,307,957.40	322,134.32	8,922,069.45	15,314,770.75	(6,392,701.30)	-42%
Year 7	0	7,200.00	0.01	365.00	13.00	7,266.43	180	1,307,957.40	322,134.32	10,230,026.85	15,636,905.07	(5,406,878.22)	-35%
Year 8	0	7,200.00	0.01	365.00	13.00	7,266.43	180	1,307,957.40	322,134.32	11,537,984.25	15,959,039.38	(4,421,055.13)	-28%
Year 9	0	7,200.00	0.01	365.00	13.00	7,266.43	175	1,271,625.25	581,664.35	12,809,609.50	16,540,703.73	(3,731,094.23)	-23%
Year 10	0	7,200.00	0.01	365.00	13.00	7,266.43	175	1,271,625.25	581,664.35	14,081,234.75	17,122,368.08	(3,041,133.33)	-18%
Year 11	0	7,200.00	0.01	365.00	13.00	7,266.43	175	1,271,625.25	322,134.32	15,352,860.00	17,444,502.40	(2,091,642.40)	-12%
Year 12	4000	7,200.00	0.01	365.00	13.00	7,266.43	180	1,327,957.40	322,134.32	16,680,817.40	17,766,636.71	(1,085,819.31)	-6%
Year 13	0	7,200.00	0.01	365.00	13.00	7,266.43	180	1,307,957.40	322,134.32	17,988,774.80	18,088,771.03	(99,996.23)	-1%
Year 14	**0**	**7,200.00**	**0.01**	**365.00**	**13.00**	**7,266.43**	**180**	**1,307,957.40**	**581,664.35**	**19,296,732.20**	**18,670,435.38**	**626,296.82**	**3%**
Year 15	0	7,200.00	0.01	365.00	13.00	7,266.43	170	1,235,293.10	322,134.32	20,532,025.30	18,992,569.70	1,539,455.60	8%
Year 16	0	7,200.00	0.01	365.00	13.00	7,266.43	170	1,235,293.10	322,134.32	21,767,318.40	19,314,704.02	2,452,614.38	13%
Year 17	0	7,200.00	0.01	365.00	13.00	7,266.43	170	1,235,293.10	322,134.32	23,002,611.50	19,636,838.33	3,365,773.17	17%

Appendix VI: Financial Analysis – Return on Investment (ROI)

Year	Cumulative Cost	Cumulative Revenue	ROI	ROI%
Year 1	13,347,039.10	2,253,286.00	(11,093,753.10)	-83%
Year 2	13,561,173.42	3,561,243.40	(9,999,930.02)	-74%
Year 3	13,829,307.73	4,925,532.95	(8,903,774.78)	-64%
Year 4	14,410,972.08	6,269,822.50	(8,141,149.58)	-56%
Year 5	14,992,636.43	7,614,112.05	(7,378,524.38)	-49%
Year 6	15,314,770.75	8,922,069.45	(6,392,701.30)	-42%
Year 7	15,636,905.07	10,230,026.85	(5,406,878.22)	-35%
Year 8	15,959,039.38	11,537,984.25	(4,421,055.13)	-28%
Year 9	16,540,703.73	12,809,609.50	(3,731,094.23)	-23%
Year 10	17,122,368.08	14,081,234.75	(3,041,133.33)	-18%
Year 11	17,444,502.40	15,352,860.00	(2,091,642.40)	-12%
Year 12	17,766,636.71	16,680,817.40	(1,085,819.31)	-6%
Year 13	18,088,771.03	17,988,774.80	(99,996.23)	-1%
Year 14	**18,670,435.38**	**19,296,732.20**	**626,296.82**	**3%**
Year 15	18,992,569.70	20,532,025.30	1,539,455.60	8%
Year 16	19,314,704.02	21,767,318.40	2,452,614.38	13%
Year 17	19,636,838.33	23,002,611.50	3,365,773.17	17%

Appendix VII: Financial Analysis – NPV

NET PRESENT VALUE (NPV)					
	Discounted Rate				
Year	10.00%	12.50%	15%	17.50%	20%
Year 1	(11,298,597.28)	(11,344,118.21)	(11,387,659.97)	(11,429,348.89)	(11,469,300.76)
Year 2	(10,323,679.42)	(10,395,623.73)	(10,464,440.03)	(10,530,327.97)	(10,593,470.58)
Year 3	(9,351,550.51)	(9,451,056.22)	(9,546,235.60)	(9,637,364.80)	(9,724,696.94)
Year 4	(8,711,133.45)	(8,837,796.53)	(8,958,952.52)	(9,074,952.93)	(9,186,120.00)
Year 5	(8,070,716.38)	(8,224,536.83)	(8,371,669.43)	(8,512,541.07)	(8,647,543.05)
Year 6	(7,203,798.52)	(7,384,042.35)	(7,556,449.49)	(7,721,520.15)	(7,879,712.87)
Year 7	(6,336,880.66)	(6,543,547.87)	(6,741,229.54)	(6,930,499.24)	(7,111,882.69)
Year 8	(5,469,962.79)	(5,703,053.38)	(5,926,009.60)	(6,139,478.32)	(6,344,052.51)
Year 9	(4,895,604.19)	(5,154,384.18)	(5,401,912.86)	(5,638,908.41)	(5,866,029.15)
Year 10	(4,321,245.58)	(4,605,714.97)	(4,877,816.12)	(5,138,338.50)	(5,388,005.79)
Year 11	(3,487,356.94)	(3,797,515.73)	(4,094,189.35)	(4,378,238.57)	(4,650,452.40)
Year 12	(2,602,257.26)	(2,939,243.47)	(3,261,578.11)	(3,570,196.37)	(3,865,955.55)
Year 13	(1,735,339.40)	(2,098,748.99)	(2,446,358.16)	(2,779,175.46)	(3,098,125.37)
Year 14	(1,127,951.56)	(1,517,784.54)	(1,890,668.25)	(2,247,684.57)	(2,589,825.21)
Year 15	(327,092.15)	(741,880.54)	(1,138,634.65)	(1,518,505.61)	(1,882,548.61)
Year 16	**473,767.26**	**34,023.45**	(386,601.06)	(789,326.65)	(1,175,272.02)
Year 17	1,274,626.67	809,927.44	365,432.54	(60,147.70)	(467,995.42)

Appendix VIII: Financial Analysis – IRR

Year	Cashflow
Year 1	(13,347,039.10)
Year 2	3,561,243.40
Year 3	4,925,532.95
Year 4	6,269,822.50
Year 5	7,614,112.05
Year 6	8,922,069.45
Year 7	10,230,026.85
Year 8	11,537,984.25
Year 9	12,809,609.50
Year 10	14,081,234.75
Year 11	15,352,860.00
Year 12	16,680,817.40
Year 13	17,988,774.80
Year 14	19,296,732.20
IRR	**47%**

Appendix IX: Solar PV Mini-Grid Component Replacement Schedule

#	Component	Life Span (Years)	Replacement in Year	Remarks
1	Generation (Solar PV)	25	N/A	Replaced on Vandalism based on site information and generalized over project life time
2	Storage (Battery and Monitoring)	7	7 and 14 Years	Depending on site cooling, replaced upon inspection and maintenance based on site condition
3	Generation (Shelters)	15	15	On end of life or based on site rust/corrosion conditions
4	Conversion (Inverters/controllers)	15	15	Cost of maintenance factored monthly/annual maintenance programme
5	Distribution Network	21	N/A	Cost of spares factored in maintenance programme
6	Service Network	21	N/A	Cost of spares factored in maintenance programme

Appendix X: Mini- Grid Energy Sustainability Indicators

1. SOCIAL						
#	**Indicator**	**Components**	**Performance Status**	**YES**	**NO**	**Comments**
1.1	Accessibility	Increased Uptake	% Uptake		X	Capacity limitation of the installed system
1.2	Affordability	Consumer Income Levels	Ksh 10,000 per annum	X		Largely affordable,
1.3	Disparities	Energy Use per Household for each income group	kWHr/Each income group		X	Capacity limitation of the installed system
1.4	Safety	Fatalities/Energy Produced	No of Fatalities/kW	X		No statistics at time of study
2. ECONOMIC						
2.1	Overall Use	Energy User Per Capita	Energy Use/Total Population	X		Fairly dense population
2.2	Overall Productivity	Energy Use Per GDP	Total Energy Use/GDP	X		Fairly dense population
2.3	Supply Efficiency	Conversion Efficieny	Output Energy/Input Energy		X	Energy losses due to cable lengths no transformers
2.4	Production	Resources to Production Ratio	Estimated Resources/Total Energy Production		X	Capacity constraint
2.5	End Use	Industrial Energy Use Intensity	Energy Use in Industrial Sector		X	Capacity constraint
		Agricultural Energy Use Intensity	Energy use in agricultural sector		X	Capacity constraint
		Service and Commercial Energy Use Intensity	Energy use in service sector		X	Capacity constraint
		Household Energy Use Intensity	kWhr/Household		X	Capacity constraint
2.6	Scalability/Modularity	Ease of expansion to meet load demand	Speed of upgrade		X	Constrained by design
2.7	Reliability	Outage per Energy Unit	Frequency of outage/kWHr		X	High maintenance requirements
3. ENVIRONMENTAL						
3.1	Climate Change	Greenhouse Gas Emmission per Capita	CO_2 equivalent/population	X		Environmental friendly solution
	Air Quality	Air Pollutants	PPM/kWHr	X		Environmental friendly solution
	Water Quality	Contaminants Dischare in liquid effluents form energy system	PPM/kWHr	X		Environmental friendly solution
	Soil Quality	Soil area with acidification exceeding critical load	sqm/kWHr	X		Environmental friendly solution
	Solid Waste	Ratio of solid waste to Unit Energy Produced	Tonnes/kWHr	X		Environmental friendly solution