FACTORS INFLUENCING SUSTAINABILITY OF OFF-GRID SOLAR PHOTOVOLTAIC SYSTEMS FOR RURAL ELECTRIFICATION PROJECTS; A CASE OF RURAL PUBLIC PRIMARY SCHOOLS IN TIATY CONSTITUENCY, BARINGO COUNTY.

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A Research Project Report Submitted in Partial Fulfilment for the Requirements of the Award of the Degree of Master of Arts in Project Planning and Management of the University of Nairobi.

2019

DECLARATION

This research project report is my original work and has never been submitted in any University or College for examination**.**

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This project report has been submitted for examination with my approval as the University supervisor.

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DEDICATION

I dedicate this work is to my family, who have always been with me during my academic journey

ACKNOWLEDGEMENT

The completion of this research project would not have been possible without the assistance and cooperation of a couple of people to whom I am indebted. My special thanks go to my able supervisor Dr. Stephen Luketero for his wise counsel during the development of this research project. His dedication and guidance played a key role in making this document. To all the lecturers and staff of the University of Nairobi Extra Mural Centre, I say thank you for being part of this academic journey.

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ABSTRACT

The UN 2030 Agenda for Sustainable Development adopted in September 2015 includes the goal to end global energy poverty by providing universal access to affordable, reliable, sustainable and modern energy for all. Rural electrification is defined as percentage of the rural population with access to electricity. In Kenya, rural electrification first became a public priority with the establishment of the Rural Electrification Authority (REA), which later changed its name to Rural Electrification and Renewable Energy Corporation (REREC), a government plan to subsidize the cost of electricity supply in rural areas. In 2015, REREC installed several solar PV panels in Tiaty constituency, less than 5 years down the line problems such as low output, panel breakages, siltation are happening and little is being done to remedy the situation. This research study sought to establish the factors influencing the sustainability of solar PV systems for rural electrification, this was be done through the following objectives. To assess the extent to which the institutional factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya, to investigate the extent to which the socio-economic factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya, to establish how technology factors, influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya, and to determine how socio-cultural factors, influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya. These study findings are of importance to policy makers in the Ministry of Energy who may use it in formulation of policies regarding energy. The mixed method research design was used, since it provides a better understanding of research problems. The target population for the research study was 133 primary school head teachers but the accessibe population was 31, 1 REREC county supervisor and 1 renewable energy manager giving a total of 33 accessible respondents. Simple random sampling was used to get the sample of school heads wherease the county supervisor and renewable energy manager were purposively chosen, the sample size for the study was 30 gotten using Yamane formula. Data was collected using questionnaires and coded into SPSS V23 then a correlational analysis done. Data is presented in the form of frequency tables and a Pearson correlation coefficient to measure the strength of relationship between the variables computed. The findings indicated a positive correlation between institutional factors and sustainability of off-grid solar PV systems with ($r = 0.5329$), a positive correlation between economic factors and sustainability of off-grid solar PV systems with ($r = 0.4318$), and a strong positive correlation between technological factors and sustainability of off-grid solar PV systems with (r= 0.6102), wherease a weak negative correlation between sociocultural factors and sustainability of off-grid solar PV systems with ($r = -0.1028$). The study concludes that institutional factors, economical factors and technological factors are key for the sustainability of off-grid solar PV system for rural electrification projects and recommends that emphasis should be put on the same for sustainability to be realized. The study proposes that further research should be done to ascertain the influence of socio-cultural factors on the sustainability of off-grid photovoltaic solar systems for rural electrification in a different area.

CHAPTER ONE
INTRODUCTION

1.1 Background to the study

The UN 2030 Agenda for Sustainable Development adopted in September 2015 includes the goal to end global energy poverty by providing universal access to affordable, reliable, sustainable and modern energy for all. In the academic literature, rural electrification, defined as percentage of the rural population with access to electricity, has been found to be a crucial part of socio-economic development (Cook, 2011). An increase in rural electrification is associated with higher youth literacy rates by upgrading in-school and domestic learning facilities (Kanagawa and Nakata, 2008). Where complementary hard and soft infrastructure are present, access to electricity is generally accepted to result in such positive health, education and income consequences (Cook, 2011).

In 2013, about 1.2 billion people (17% of the global population) did not have access to electricity (IEA, 2015). The lack of access to energy is mainly a rural issue, in 2012 the global urban electrification rate reached 94%, the rural electrification rate constituted only 68% (IEA, 2015). Although it was not explicitly declared a goal, the access to energy was already considered a key factor for achieving the eight Millennium goals (OECD, 2010). Therefore, in 2015, affordable and clean energy was explicitly named as one (goal number seven) of the 17 new Sustainable Development goals, which are to be achieved by 2030. Furthermore, in 2011 the United Nations (UN) initiated the "Sustainable Energy for all" initiative, which focuses on three targets to be reached by 2030: (IEA, 2015) the provision of universal access to modern energy; (OECD, 2010) doubling the energy efficiency rate; and doubling the share of Renewable Energy (RE) globally. The emphasis given to RE can be tracked back to the Agenda 21 in Rio (Sindhu, Nehra, and Luthra, 2016), which highlighted not only the need of reliable and affordable access to clean energy, but also the environmental soundness to be accomplished (Sindhu, Nehra, and Luthra, 2016).

In Kenya, rural electrification first became a public priority with the establishment of the Rural Electrification Programme, a government plan to subsidize the cost of electricity supply in rural areas (Sindhu, Nehra, and Luthra, 2016). Under this initial setup, rural electrification was the joint responsibility of the Ministry of Energy and its implementing partner, Kenya Power (KP), the country's regulated monopoly transmission, distribution, and retail company. Over the next few decades, however, the pace of rural electrification remained stagnant. The cost of grid expansion was prohibitively high and there was a general perception that demand for energy in rural areas was too low to be financially viable. In recent years, there has been a dramatic increase in the coverage of the national electricity grid. In 2003, a mere 285 public secondary schools across the country were connected to electricity. By November 2012, Kenyan newspapers were projecting that 100% of the country's 8436 secondary schools would soon be connected. This recent big push to electrify rural Kenya began with the ratification of the Energy Act of 2006, which restructured the country's electricity sector and created the Rural Electrification Authority (REA), an agency that would operate independently of Kenya Power, and would oversee accelerating the pace of rural electrification.

By 2013, REA announced that 90% of the country's public facilities had been electrified suggesting that a large share of the population had access to the electricity grid. Despite this success, estimates of the national household electrification rate remain just between 18% and 26%. This gap between those who are believed to live within range of power and those who are connected to power suggests that "last-mile" grid connections could be important moving forward.

During the subsequent financial years (2013/14, 2014/15 and 2015/16) REA's focus was on electrification of primary schools to support the Government's Digital Learning Programme. This has been implemented through grid extension in schools within grid network and installation of solar PVs in schools in off-grid areas. Barriers that constrain the deployment of off-grid PV systems for rural electrification have been described in numerous studies (Sindhu, Nehra, and Luthra, 2016). Yet, apart from entry barriers for these solutions, a high failure rate of already deployed systems (feeble sustainability) has also been detected; in Guatemala, 45% of the systems were not operational; in Laos, it was 65%. In this study, the main multidimensional drawbacks that constrain the sustainability of off-grid photovoltaic systems will be studied.

1.2 Statement of the Problem

The adoption of Solar Technology as an alternative source of energy would provide the solution to the evident energy gap in most developing and least developed countries. In Kenya, data on solar energy use at house hold level is virtually nonexistent, the uptake is low and even for those who embrace the technology, the sustainability of the project is not guaranteed. In many public schools, according to KESSP 2005-2010, you find examples of flawed project implementation such as incomplete school buildings, schools without essential instructional resources, and infrastructure, school laboratories with inadequate or no equipment, and so on.

In Kenya, solar household systems seem to mainly 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.

The government of Kenya through the Rural electrification authority contracted private consultants to install solar pv systems in 133 public primary schools in Tiaty constituency, Baringo county, after commissioning the projects the burden of operation and maintenance was left in the hands of the school heads. This has led to the systems experiencing several problems such as panel breakages, dust accumulation on panels, low outputs and many others, since the heads have no technical know-how on the maintenance of the systems. The main causes for the success or failure of projects is not yet clear as per the studies reviewed. Studies attribute the major issues facing the sustainability of projects to be related to project management processes, team leadership and financing issues (Mullay 2002; Mathie, 2006).

For the successful performance of projects, the issue of sustainability requires greater attention. It is worth noting that the issue of sustainability is not a single day issue, but a lifelong process. Despite the increasing number of government funded projects failing to achieve optimum sustainability, very few studies have focused on the sustainability of such king of projects. It is against this background that this study aims at bridging this knowledge gap by investigating the factors influencing the sustainability of solar photovoltaic systems with a focus on Tiaty constituency, Baringo county – Kenya.

1.3 Purpose of the Study

The purpose of the study was to investigate the factors influencing the sustainability of off-grid photovoltaic systems for rural electrification, a case of rural public primary schools in Tiaty constituency, Baringo County in Kenya.

1.4 Objectives of the Study

The study aimed at achieving the following objectives:

1. To assess the influence of institutional factors on sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya.
2. To investigate the influence of economic factors on sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya.
3. To establish the influence of technological factors on sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya.
4. To assess the influence of socio-cultural factors on sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya.

1.5 Research Questions

The following research questions guided this study: -

1. To what extend does institutional factors influence the sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya?
2. To what extend does economic factors influence the sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya?
3. To what extend does technological factors influence the sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya?
4. To what extend does socio-cultural factors influence the sustainability of off-grid photovoltaic systems for rural electrification projects in Tiaty constituency, Baringo County in Kenya?

1.6 Significance of the Study

This study is useful in providing insight into the factors that influence the sustainability of off-grid solar PV for rural electrification in Kenya. This study is useful to any organization intending to implement renewable energy projects in rural areas. The highlighted issues are used to define the way-forward that will enhance adopting of good project implementation strategies enhanced by the consideration of various contributing variables mentioned in this study.

These study findings are 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 can 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 is also 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 findings from the study are useful in providing additional knowledge to scholars and academicians on factors affecting sustainability of off-grip solar PV systems. The findings are useful for reference as regards to implementation and sustainability of off-grid energy in the rural areas. In addition, the findings 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.

1.7 Delimitation of the Study

The conceptual scope of this study was laid on the factors affecting sustainability of off-grid solar PV for rural electrification in Kenyan rural areas. This study targeted Tiaty constituency, Baringo County where there are existing solar PV off-grid projects with the characteristics of the study objectives 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 primary schools installed with the solar PV. The sample will be divided into strata that matches the proportions of respondents from the different public primary schools.

1.8 Limitations of the Study

The constraints that the researcher encountered in the line of study was lack of cooperation from some of the respondents. This was overcome by the researcher explaining to the respondents the aim of the study and the significance of the study on a national grid. The respondents were also assured of their anonymity.

1.9 Assumptions of the Study

The researcher assumed that respondents will give correct and valid information during the study. The other assumption was that the sample was not biased and was a true representative of the population.

1.10 Definition of Significant Terms

Sustainability	This refers to ability of the solar PV projects to continue working as expected, even after being handed over to the owners.
Institutional factors	This refers to the factors within the public primary schools that are assumed to have an influence on the sustainability of the solar PV project, they include centralization, regulation and standards, stability and enforcement.
Economic factors	This refers to the cost related factors that are assumed to have an influence on the sustainability of the solar photovoltaic projects.
Technological factors	This refers to the factors that are related to the knowledge of use and maintenance of the solar PV systems. They include expert-know how, technician availability and spare parts availability.
Socio-cultural factors	This refers to factors that are associated with the social and cultural aspects of the respondents, such as values, norms, and cultural justice that are assumed to influence the sustainability of solar photovoltaic projects.

1.11 Organization of the Study

This study is organized in five chapters. Chapter one covers the background of the study, statement of the problem, objectives, research questions, significance, delimitations, limitations, assumptions and definition of significant terms. Chapter two outlines the theoretical underpinnings of the study as well as the review of relevant literature. The chapter also contains conceptual framework which outlined the association of study variables.

Chapter three outlines the study methodology that is followed in the course of answering the research questions. The chapter outlines the research design and sampling techniques that are adopted, the target population, the data collection instruments and procedures as well as the data analysis methods to be adopted and ethical issues. Chapter Four covers the analysis of data collected from the field. Data is analyzed using means, standard deviation and other info graphics in representing the analyzed data. The analyzed data is presented in tables. Further, the chapter has interpretation of the findings in write up to explain the tables.

Chapter five details the summaries of findings with regards to the objectives of the study. Main findings are discussed at length with linkages to existing knowledge. The chapter finally has a conclusion of the study and suggested possible recommendation of the study problem.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

It should be noted that the term 'literature review' encompasses the evaluation of all sources of information or data that relate to the topic and is not confined solely to academic publications, (Baker; 2003). This chapter looks at what has already been published by some accredited scholars and researchers on sustainability of off-grid photovoltaic systems for electrification of rural areas.

2.2 Sustainability of off-grid photovoltaic rural electrification projects

Sustainability is the perceived potential for a system or project to endure, build a self-perpetuating capacity within a community, and ultimately reach the end of its predefined life span or evolve into another beneficial form. The sustainability of a system is not a simple univariate, time independent binary condition. Rather, it is a continuous, multidimensional dynamic state variable. Technical, environmental, economic, social, and organizational aspects all influence the sustainability of a project. These key ingredients are all important and interrelated.

EU (2004) defined sustainability as the likelihood of a continuation in the stream of benefits produced by the project after the period of external support has ended. Mulwa (2010) noted that project sustainability concerns itself with the continuity of a project until it attains its set objectives. Sustainability of a project is a development that aimed to meet the present needs without compromising the ability of future to meet its needs (World Bank, 2009). The essence of sustainable project is determined by the people, authority which can be attributed to change of peoples or authority attitudes, leading to a change in their habits. Robert (2008) argued that, sustainability is an essentially vague concept, and it would be wrong to think of it as being precise, or capable of being made precise.

Sustainable project requires that donors and well-wishers support project life-cycle, using the resources pooled together or available. Donors and manager of a project should ensure that the distribution of the benefits of development is done in a more transparent manner and equitably (Elizabeth, 2006). On the same, Ismail and Richard (2018) also cited that there is a need to move from improving living standards to improving the quality of life. This would happen when development becomes fully, participatory and people centered, driven by spiritual values that embrace caring and nurturing at their core.

According to Mbata (2018) the sustainability of any projects requires a team of highly competent managers owing to many dynamics of the project implementation. The failure of a project is largely blamed on lack of professionalism and management skills of the project implementers owing to lack of experience on project management and poor academic background. In order to establish good rapport leaders, need time, resources and authority to invest in a project. Flexibility is critical in the way leaders interpret their own and others' roles and in the activities they and the projects undertake (Carter, 2009). Good leadership play a number of different roles in community-based projects, all of which require trust and good working relationships with local people and professionals. Leadership offer management to the project and thus ensures sustainability.

According to Niyi (2017) inappropriate policy or legislation, insufficient institutional support, unsustainable financing mechanisms, ineffective management systems and lack of technical backstopping are key causes of failure of projects. He further pointed that in a community-based project; stakeholders usually have strong cultural relations with each other and would hardly deny their neighbors to have access to the benefit that accrues from the project. This in turn results to effective project sustainability as they look forward on benefiting with that project. Gebrehiwot (2006) pointed that community participation and other stakeholders in a project should consider the effects of this culture of “no denial” on the capacity of the facility they provide since it may serve neighboring communities.

Williams (2008) observed that failure by community and stakeholders to take up ownership of projects have plunged projects into immense financial huddles threatening the sustainability and hence threatening them to seize operations daily. Involvement of stakeholders and partners whose concerns and experience are intrinsic to the project's success is an important factor for sustainability of projects (Admassu, 2008). The level of community support determines whether a project becomes established, how quickly and successfully it consolidates, and how it responds and adapts to meet changing needs (USAID, 2009). It is therefore important that local communities be involved right from the beginning of the project when decisions are being made about what type of project is required as this would ensure that the project is sustained.

2.3 Institutional factors and Sustainability of off-grid photovoltaic projects

Numerous studies have highlighted the importance of institutions for sustainable rural electrification. Institutions can be understood as a framework of guidelines that set the rules of the game for interactions between human beings; while formal institutions refer to laws and regulations that have been legally enacted by actors and that determine the political, economic and enforcement system, informal institutions can be understood as religious or moral values and traditions that have been established in a certain place, though they have not been legally enacted (Pejovich, 1999). Institutional flaws have been found to constrain the sustainability of off-grid PV systems in Developing countries (Brew-Hammond, 2011). The scarcity of durability/stability and enforcement, weak regulations or standards, incomplete decentralization/participation and the lack of adaptability are among those institutional flaws. Prior efforts have shown that sustainable off-grid PV systems require strengthened formal institutions (Pansera, 2012). Strengthened formal institutional are characterized by their stability (durability) and their enforcement. In Developing countries, these two factors tend to be low, which is problematic for the sustainability of off-grid PV systems.

Cust et al. (2017) argue that even economically viable projects fail simply because the importance of appropriate organizational structure and institutional arrangement of those projects are not adequately appreciated. Past experiences also show that a large number of off-grid electrification projects have seen limited success because focus has been generally on technical installation without paying sufficient attention to the long-term sustainability (Kumar et al. 2009). A study on the functioning of the biomass gasifiers for off grid electrification implemented under the VESP in India has revealed a number of challenges that need to be tackled at village level to ensure the sustainability of the project interventions: Some of these challenges are low concentration of electricity demand (making distribution expensive and difficult); low economic activity (implying low demand for electricity); difficulty on the part of users to pay for electricity; difficulty in operation and maintenance due to remote project location; limited technical knowledge of VEC members and weak fuel supply chain linkages (Palit et al. 2012). Palit (2003) also highlights, based on specific examples from north eastern region of India that lack of availability of adequate maintenance facilities and inadequate capacity building of the technicians acted as a barrier.

The enforcement of formal institutions strongly depends on informal institutions. For instance, although prohibited by law, corruption can be broadly accepted, given that the interpretation of its actual meaning is tied to norms and attitudes. Informal corruptive behavior is a substantial issue for the sustainability of rural electrification efforts in Developing countries. In Nigeria for example, corruption was a major reason for off-grid PV failures and ultimately led to the closure of the Rural Electrification Agency. In the Philippines, the selection of contracting partners for PV system installations appeared to be based on personal preferences rather than on a bidding system for the most competent partner. In Pakistan, although laws and regulations for RE had been implemented, in reality, the promised incentives for companies to invest in RE only existed on paper: the conditions were actually set via negotiations between authorities and companies. In Kenya, relationships and access to high-ranking governmental officials appeared to be much more important than rules and compliance with regulations (Ndegwa et al, 2011). Therefore, although corruption appears to have avoided the introduction of a fee for service approach (where a company/the government is the owner and sells electricity as a service) in Kenya, that approach was shown to be successful in Zambia, where stronger institutions exists (Kovič, 2010).

Centralized formal institutions may lead to inappropriate rural electrification solutions that are not adapted to the users' needs. In Mozambique for instance, local government agents defined household lights as a priority in their preferences, but when the project was implemented, the central government installed solar streetlights instead. This lack of local participation in decision-making has been frequently observed in Latin America; Canessa et al. (2014) concluded in their evaluation of the Eurosolar Program in Latin America that the low participation of communities and municipalities in the project design phase (turnkey solutions "designed from above") led to substantial adaptation issues, making at risk the sustainability of the PV kits.

Decentralization is meant to facilitate participative decision-making, thus enhancing the chances of a technology to meet the needs of the population (Pansera, 2012). Decentralized institutions may be preferred for rural electrification since local users know best what they need and who they can trust. However, in some cases, decentralization based on (local) self-management is too costly because of: conflicts among users; high political costs; or a lack of expertise, know-how and management capacity of local institutions for the administration of the services (World Bank, 2007). Indeed, issues for off-grid systems related to decentralization often arose as qualified specialists with the required (cultural and technical) expert know-how are not available in remote areas.

For example, decentralizing the administrative resources to local authorities had been a major constraint to the PV implementation in Mexico: management tasks (including finance and control) of rural electrification were reassigned to the municipalities without creating the needed capacities (World Bank, 2007). This lack of local agents' capacities on planning and decision-making substantially lowered the efficiency of the systems (World Bank, 2007).

Decentralization may also increase the risk of misalignments among institutions. If responsibilities between local and central government bodies are not agreed upon by all of the involved parties, power games between central and local agents or a lacking coordination between them can lead to unsustainable PV systems. In Nepal for instance, competition and power games between the different government agents have been the result of overlaps in their tasks (Brew-Hammond, 2011). In Sri Lanka, the central government decided to connect a region to the grid; this decision made the off-grid systems that were previously deployed by the local government redundant, because they were not needed any more (Laufer and Schäfer, 2011). These organizational issues are examples of how the sustainability of the systems can be constrained by a lack of coordination between local and national governments.

Several studies have shown that the scarcity of expert know-how on RE can affect the sustainability of off-grid PV systems. The lack of technicians has led to poor implementations (e.g., causing shadowing or the wrong size of cables), the use of uncertified materials and to under-sizing (due to erroneous power capacity estimations). Therefore, sustainable off-grid PV systems require generating critical expert know-how. The latter is often a challenge because of significant gaps in the educational system of developing countries. Tailored PV solutions for local needs would require innovation and development from local universities, but they often do not have the capacities to generate this knowledge. For example, in Bolivian universities, it was found that poor infrastructure, low wages and missing research programs hampered innovations. Pansera (2012) found that the institutionalization of strategic knowledge, which is fundamental to educate experts in solar energy, is still lacking in Bolivia. In Peru, the major constraint concerning human resources has been assigned to the lack of instruction on solar energy; therefore, the country has significant deficiencies in competent technicians. A prioritization of capacity building as a long-term goal is therefore critical for enhancing the sustainability of off-grid PV systems.

2.4. Economic factors and Sustainability of off-grid photovoltaic projects

For an electrification solution to be sustainable, it needs to be cost-effective given that financial resources are scarce, especially in developing countries (Panwar, Kaushik, and Kothari, 2011). Off-grid PV systems can be a cost-effective solution in the case of dispersed populations with low per capita energy consumptions (Ranaboldo et al., 2015). However, governments often favor costly conventional energy sources over RE: indeed, in 2015, global energy post-tax subsidies on coal, petroleum, natural gas and electricity totaled US $5.3 trillion (6.5% of the global GDP), with the greatest share given to coal (3.9% of global GDP). In Malaysia for instance, Petroliam Nasional Berhad (PETRONAS by its acronyms; the oil and gas state company) gave a 60% subsidy on natural gas to the utilities, such that RE had to compete with extremely low prices.

Solar PV systems have a higher initial investment, while lower Operation and Maintenance costs relative to other off-grid solutions (diesel generators). Therefore, low-income households avoid buying these off-grid PV systems, although over the lifetime, they would pay off (Rolland, 2011). Rolland (2011) explains this behavior with the unavailability of financial products (microcredits) in rural areas, as well as with the near future focus of the poor population. The lack of tailored financial products can often be attributed to the deficient know-how on alternatives for financial tools that are valid for rural off-grid PV systems. In Lesotho, for instance, neither the users nor the financial institutions were properly trained to make use of financial solutions, and no lending schemes tailored for renewable systems were offered (UN, 2006). As a result, costly (and therefore, unsustainable) solutions are oftentimes chosen.

Ensuring the sustainability of off-grid PV systems entails making the energy supply reliable (Sharma and Balachandra, 2015). For rural areas, energy reliability demands for the availability of spare parts, as well as user know-how to understand the functionalities, use the systems appropriately and exert simple maintenance. The availability of spare parts has been one of the critical success factors of the sustainability of solar PV in Bangladesh, where spare parts were held in offices that were at most a few kilometers away from the project area (Urmee and Harries, 2011). However, in the case of many other rural electrification projects, spare parts are often not available due to a distribution network focused on highly populated areas (Vleuten et al 2007). The scarcity of spare parts makes off-grid PV systems unreliable, thus compromising their sustainability.

Moreover, user training has been proven to enhance the reliability of the systems. In Bangladesh for instance, training programs have been undertaken by developing countries for creating awareness not only among the installation companies, but also among the customers. Nonetheless, many off-grid PV projects worldwide became unsustainable as they ignored the importance of user know-how. For example, in Uganda, Tillmans and Schweizer (2011) reported a substantial knowledge drop in the chain of information (manufacturer-local supervisor and NGO-local solar company and user) towards the user. This experience has shown that an organizational structure that assures transmitting the know-how for proper handling is indispensable for the systems' reliability.

Ensuring the sustainability of off-grid PV systems requires covering operations and management over their lifetime (Ilskog and Kjellström, 2008). However, numerous project failures can be related to the lack of funds for covering operations and management. For example, in the case of projects funded by private donors, several studies have found that they tend to prefer only paying for the initial costs of the PV systems, avoiding the long-term commitment associated with operations and management; (Laufer and Schäfer, 2011).

Part of the problem is that the operations and management costs of the off-grid PV systems can be hardly estimated, as outlay may vary considerably depending on factors, such as the availability of trained maintenance providers, community dynamics or the possibility of training local users. As a consequence, operations and management costs have been frequently underestimated. For example, Carrasco et al. (2016) found that in Morocco, where more than 13,000 off-grid PV systems were installed, the user fee (a fee for service approach was used) covered only 14.9% of the global costs over the system's lifetime; this fee did not cover operations and management, which led to an unsustainable economic situation. Indeed, a fee for service approach for off-grid PV systems will unlikely succeed when the rural population in Developing countries can hardly afford the operations and management costs for items, such as battery replacement or maintenance devices.

Assuring the sustainability to the off-grid PV systems may therefore involve subsidizing the electricity tariffs of poor population. According to Eberhard et al. (2017), widespread subsidies for electricity never reach the poor; instead, the authors registered highly regressive effects from subsidies for power provision in Sub-Saharan Africa. Therefore, an effective focalized subsidy scheme (cross-tariff scheme) that reaches the poor and assures covering the operations and management is advisable (Laufer and Schäfer 2011, UN, 2006).

2.5. Technological factors and Sustainability of off-grid Solar photovoltaic projects

One of the most important factors hindering the sustainability of solar energy technology is the lack of technical awareness and confidence among the general public who use the technology, decision makers and the limiting numbers of trained installation technicians. As at February 2017, a total of 995 registrations had been completed for solar technicians and contractors for both PV and hot water systems. This is a relatively small number of well trained and licensed professionals considering how much potential exists in the country. This lack of technological awareness results in the loss of potential installers. Therefore, decision to grow and expand a new innovation often starts with awareness. It's difficult for one to implement solar energy projects without knowing about the innovation. The decision-making process is aided by communication channels; either mass-media communications or by local channels such as word-of-mouth.

Rogers (2003) theorizes that the process of demand commences with an individual driven by precedent conditions such as a felt need to adopt an innovative product or service. He further indicates that 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. Within such stages, several factors which could either encourage or discourage adoption of an innovation may arise or may be experienced by the intending adopter, which could affect the final decision to adopt, not adopt or reverse decision (Rogers, 2003). Adoption of innovations could be done by an individual, a company or a group or people. The innovation decision process consists of five key stages which include: knowledge, persuasion, decision, implementation and confirmation.

In regard to knowledge, decision to adopt a new innovation often starts with knowledge gathering through the media such as TV, newspaper, radio or a peer, colleague or mentor. Persuasion involves showing interest in the technology and seeks information about the technology for example cost, user review, features, how it works. It is at this stage that a person begins to consider himself/herself a potential adopter of such technology and active consideration is being made as to whether to adopt the technology or not (Palys and Atchison, 2008). The choice to adopt or reject a technology is made at the decision stage. This process often involves weighing the benefits, cost, trade-offs advantages and disadvantages. During this stage, the choice to reject a technology could also be made. The decision stage is one of the most important for understanding technology adoption and probably one of the most difficult to study.

As noted by Rogers, the process of deciding happens silently and invisibly to the outside researcher; the precise moment of decision can rarely be captured (Rogers, 2003). The implementation stage involves integrating the technology into use. For the adopter, this could mean change from usual habit or practices, sometimes it is slow and takes a lot of time. During this time the technology is evaluated to see if it meets the adopters' expectations and probably more information about the technology is sought at this stage to enhance usability of the technology. The confirmation stage is reached after the technology has been integrated and put into full use by the adopter. At this point the adopter seeks reinforcement for the innovation decision already made. However, a change in original choice to use the technology may occur if exposed to conflicting messages about the innovation. A situation where an adopter chooses to stop the usage of a technology, he/she adopted (Reddy and Painuly, 2004).

2.6. Socio-Cultural factors and Sustainability of off-grid photovoltaic projects

The access to energy is driven by the notion of social justice, which determines the equity/disparity between different groups of people (such as gender or race). Accessibility aims at equal opportunities to receive clean and reliable energy. Off-grid solar PV systems offer an alternative for greater equity, as they may provide energy access to the vulnerable population (e.g., women or indigenous people) where a grid connection would not be viable.

As discussed elsewhere (Cecelski, 2005), energy has been key for equity from a gender perspective and was therefore included in the UN Millennium Development Goals. Household electrification is important not only because women are the main users of residential electricity, but also because they have to carry the burden of collecting biofuels (leading to physical exhaustiveness and a significant loss of their time that could be used for productive uses); girls cannot attend school because they have to help their mothers collect biofuels; without electricity, women do not have access to information through telecommunication on modern family planning, their rights and empowerment; and women are mainly exposed to indoor air pollution (Cecelski, 2005).

Many authors consider that ensuring the sustainability of PV systems in developing countries rural areas stands for socio-cultural, rather than technological challenges (Schäfer, Kebir, and Neumann, 2011). For an energy system to be sustainable, it needs to be socially accepted, which implies the active participation and engagement of the community aimed at enhancing the accountability of the project (Müggenburg et al, 2012). Off-grid solar PV systems can be a great opportunity to assure social acceptance; Burton and Hubacek (2007) found that, compared to large-scale solutions, small-scale energy approaches may have a higher social acceptance.

Nonetheless, lack of communication concerning the applications and limitations of off-grid solar PV systems can lead to false expectations and negative perceptions, thus constraining their acceptance and sustainability (Martinot and Reiche, 2000). In French Guiana for instance, users complained about a lack of relationship and insufficient contact with the installing company; the negative attitude towards the company was the principal factor for rejecting the PV systems. The Renewable Energy Policy Network for the 21st Century (REN21, 2013) confirm that the lack of the commitment of a community leads to a detachment of actual local requirements and the deception of rural users. As argued by Campbell et al. (2016), levels and types of participation need to be mapped to all interest groups of the community that are characterized as "complex, self-organizing, self-imagining, and conceptually productive" actors.

Poor participation has been found to lead to social issues. For example, according to the UN (2006), the lack of involvement of the community resulted in theft of off-grid solar PV components in South Africa. Indeed, vandalism took place in several countries (Papua New Guinea, Tunisia, China), and systems were broken. In Ethiopia, users took the systems with them instead of charging them at home due to envy issues within the community.

This behavior is also believed to be due to the lack of mutual social control. Therefore, Frame et al. (2011) propose that the community should own the systems (PV solutions for community facilities like schools and health centers), which implies getting organized in a committee to administrate and maintain them to generate a sense of responsibility. Still, McKay (2015) compared two models of ownership to set up off-grid PV systems in Nepal and found that social issues emerged in both cases. The first model was based on a cluster solution (community ownership), which connected several houses to a battery bank that was stored in one of the houses; despite significant cost savings of this solution, it had numerous drawbacks. Not only the users complained about the free-rider problem of their neighbors (connecting more devices than initially agreed upon), but they could not even protest about it owing to the cast system prevailing in Nepal. Additionally, when the user who held the batteries in his/her house moved during seasons, the other users did not have access to it. In the case of the individual SHS (second model) by contrast, it was observed that individual owners had sold donated components, since the community as a whole was not the owner, and thus, it did not oppose any pressure.

A case study conducted in Mozambique (Sharma and Balachandra, 2015) provides a positive example of how the participation of the local community can contribute to the social acceptance (and in turn, to the sustainability) of energy solutions: a management committee consisting of different user groups who represented the users' interest was set up for managing and enforcing the agreed terms; it assured direct collaboration with the local government, which in turn communicated with higher government officials. The committee contributed to the engagement and commitment of the users, which made it a key success factor of the project.

Some authors have suggested that culture should be a sustainability dimension, for example, in terms of cultural integrity for indigenous people (Sindhu, Nehra and Luthra, 2016). Culture determines the responsible conduct and motivations of a person, risk assessment, degree of political participation, value formation and environmental awareness. Cultural justice for energy concerns the respect for cultural habits and values when designing an energy solution. Unfortunately, the culture of small rural communities is often not considered in the execution of public policies. For example, in Kenya, the government has been building micro-grids for semi-nomadic communities (who regarded nomadism as a cultural value), who were then expected to adapt their culture to this new reality.

Similarly, Sindhu, Nehra, and Luthra, (2016) caution about social enterprises that implement RE in indigenous communities and unconsciously impose their values and beliefs on the people. Urmee (2014) therefore argues that it is indispensable to understand the community, how decisions are made, their culture, interests and habits, which allows for a more sustainable solution. Hirmer and Cruickshank (2014) argue that creating value (cultural, social, emotional, functional) for the users of an off-grid system is particularly important for its sustainability.

2.7. Theoretical Review

The study will be guided by Resource Based Theory (RDT) and Innovative Diffusion Theory (IDT) that related to implementation of solar energy projects.

2.7.1. Resource Based Theory

According to Wernerfelt (1984), 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 firm's disposal including technology such as solar technology. It suggests that the resources possessed by a firm are the primary determinants of its performance, and these may contribute to a sustainable competitive advantage of the firm (Wenerfelt, 1984). According to (Barney, 2002) the concept of resources includes all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness (Barney, 2002).

If the resources possessed by a firm can easily be replicated by competitors, even though the resources are the source of competitive advantage of the firm, then the advantage will not last long. (Dierickx and Cool, 1989) Describe how the sustainability of a firm's asset position hinges on how easily its resources can be substituted or imitated, and imitability is linked to the characteristics of the asset accumulation process: i.e., time compression diseconomies, asset mass efficiencies, inter-connectedness, asset erosion and casual ambiguity. In the same way, several other characteristics have been explored such as unique historical conditions, causal ambiguity (Reed and DeFillippi, 1990), social complexity, isolating mechanism and so on (Barney, 2002).

According to the theory, internally owned resources are the key source of strategic competitive advantage. If a firm has unique resources, then that warrants superior performance compared to competitors in the same industry (Barney, 1991). Based on the assertion by Barney (1991), the theory can be abridged as; the ownership of valuable and rare organizational resources translates to strategic competitive advantage. Additionally, if the owned resources are both non-substitutable and inimitable, the company will gain from strategic competitive advantage. Consequently, a firm that enjoys competitive advantage over its competitors will enjoy improved performance.

For sustainability of the solar system photovoltaic projects, which can be taken as the competitive advantage of a firm, it is required that a firm must have sufficient resources that can be used to cater the operation and maintenance of the system.

2.7.2. Innovative Diffusion Theory (IDT)

Diffusion is a social process that occurs among people in response to learning about an innovation such as a new evidence-based approach for extending or improving sustainability of projects. In its classical formulation, diffusion involves an innovation that is communicated through certain channel over time among the members of a social system. The typical dependent variable in diffusion research is time of adoption, though when complex organizations are the adopters, subsequent implementation is a more meaningful measure of change.

Research on the diffusion of innovation has been widely applied in disciplines such as education, sociology, communication, agriculture, marketing, and information technology (Agarwal, Sambamurthy, and Stair, 2000). The theory of diffusion of innovation by Rogers, (1995) provides perceptions that individuals may have of adopting an innovation such as solar technology. The theory explains, predicts, and accounts for the factors which influence adoption of an innovation. This is in line with the studied variables. According to Rogers (2003), individuals' technology adoption behavior such as solar technology is determined by his or her perceptions regarding relative advantage, compatibility, complexity and observability of an innovation, (Hikmet 2007).

IDT includes five significant innovation characteristics: relative advantage, compatibility, complexity, trialability and observability (Bennett and Bennett, 2003). Relative advantage is defined as the degree to which an innovation is considered as being better than the idea it replaced. This construct is found to be one of the best predictors of the adoption of an innovation. Compatibility refers to the degree to which innovation is regarded as being consistent with the potential users' existing values, prior experiences, and needs. Complexity is the end-users' perceived level of difficulty in understanding innovations and their ease of use. Trialability refers to the degree to which innovations can be tested on a limited basis. Observability is the degree to which the results of innovations can be visible by other people. These characteristics are used to explain end- user adoption of innovations and the decision-making process. These constructs have relationship with the studied variables. This relates to attitude towards use of solar technology.

Rogers (2003) highlights that studies show that most individuals/organizations do not evaluate an innovation on the basis of scientific studies but rather based on a subjective evaluation of an innovation that is conveyed to them from other individuals/organizations (who have already adopted the innovation) or media. This idea can be further linked to institutional theory which suggests that organizations adopt sustainability practices not because they guarantee an increase in efficiency, but rather because they are deemed "appropriate and legitimate" (Trendafilova, Baiak, and Heinze, 2013). Moreover, according to this approach, there are three main forces driving organizational actions: coercive (codified rules, norms, laws that assign legitimacy to certain organizational practices), mimetic (imitating other organizations perceived as successful), and normative pressures (coming from educational and professional authorities, media, etc. who set standards for "legitimate" organizational practices (Campbell, 2007).

Consequently, a key point in Roger's theory, also supported by institutional theory, is that diffusion of an innovation is "a very social process that involves interpersonal communication relationship." (Rogers, 2003). Hence, the second main component in my proposed framework concerns factors from the external environment, or the social system. Rogers (2003) defines a social system as "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal"; it constitutes the boundary within which an innovation diffuses". Rogers (2003) argues that a system's norms can be a barrier to change. These factors represent social pressures on a firm as a motivation to adopt sustainability innovations (Le et al., 2006). Similarly, Esty and Winston (2006) suggest that in the new world, companies face two major pressures - the limits of the natural world which can constrain business operations, realign markets, and possibly even threaten well-being on the planet, and the growing spectrum of stakeholders who are concerned about the environment. Thus, effectively integrating sustainability into companies' strategies requires action that exceeds organizational boundaries.

With increasing interconnectedness of the world, single organizations or even industries cannot tackle sustainability challenges on their own (Seuring and Gold, 2013). It is becoming increasingly accepted that stakeholders affect the organizational plans and that ineffective stakeholder involvement in sustainability initiatives can hinder the achievement of project objectives (Waligo, Clark and Hawkins, 2013). Generally, companies have limited ability to overcome external barriers to change, which include pressure from competitors, regulation and legislation, lack of knowledge and interest from consumers or investors. (Lozano, 2013).

In the studies on sustainability of solar photovoltaic systems for electrification projects, it can be observed that the projects beneficiaries will work towards sustainability of the projects if only they accepted the technology from the onset.

2.8. Conceptual frame work

Conceptual framework is a scheme of concept (variables) which the researcher operationalizes in order to achieve the set objectives, (Mugenda & Mugenda, 2003). A variable is a measure of characteristic that assumes different values among subject, (Mugenda and Mugenda, 2003). This is illustrated in figure 2.1 showing the two types of the variables.

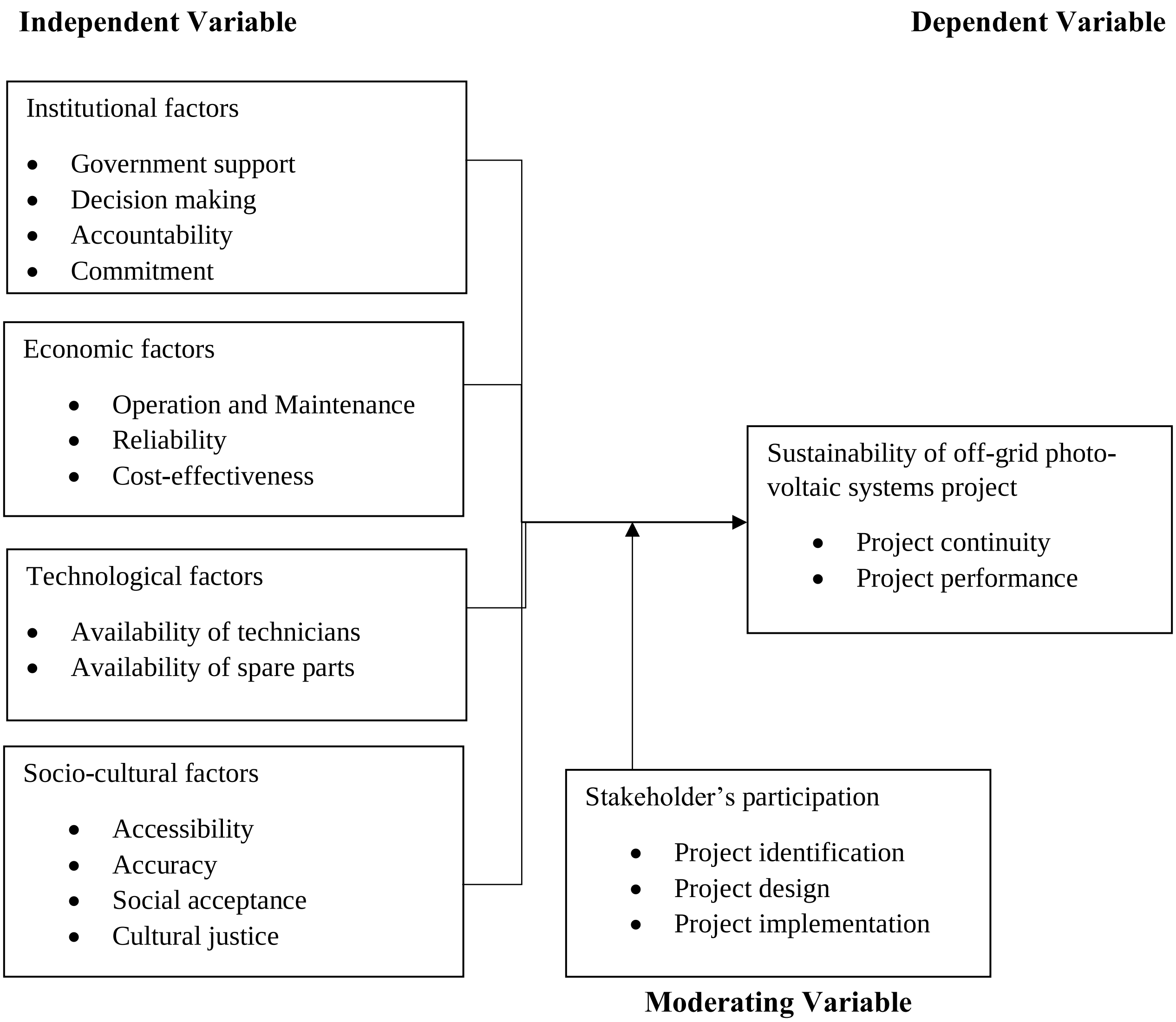

Figure 1: Conceptual framework

2.9. Summary of Literature review

Baker, (2000) asserts that despite the billions of dollars spent on development aid year after year, there is very little known about the actual impact of projects on the poor and this implies that sustainability of such development is still a great challenge. The literature reviewed reveals that in spite of what is known about the value of enhancing sustainability and what has been instituted by different institutions, there are still indicators of poor and even no sustainability of off-grid rural electrification projects. However, there is little that has been done on the relationship between institutional, economic, environmental, and socio-cultural factors and sustainability of off-grid rural electrification projects in Kenya. Literature reviewed reveals the need for further studies on the determinants of off-grid photovoltaic projects sustainability to achieve generalization of results.

2.10 Knowledge Gap

Research has shown that most of projects in sub-Saharan Africa, often demonstrate low levels of sustainability (Gebrehiwot, 2009). The key causes for this include inappropriate policy or legislation; insufficient institutional support; unsustainable financing mechanisms; ineffective management systems; and lack of technical backstopping (Niyi et.al, 2007). However, due to several postcolonial issues such as dynamic political change, rapid population growth, environmental degradation, climate change, misguided development policies, and the shift from agrarian economies to market economies, these systems are in jeopardy of losing their resilience and effectiveness (USAID, 2009).

A World Vision (2011) evaluation report analysis shows that most of the projects across range of sectors have failed to sustain themselves, become self-reliant and the donors have failed to continue running them after funding organizations withdrew their support. Some factors which should have been worked out, to stop this trend of projects collapsing are not done despite support being meant for a specified period with the aim of making the projects self-reliant. Ravallion (2008) noted that a desire to ensure a broad geographic spread of participants can weaken project sustainability. It is against this realization that the current study aims at investigating the determinants of sustainability of off-grid photovoltaic rural electrification projects in public primary schools in Tiaty Constituency, Baringo County.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter initially introduces the nature of the research design, targeted population as well as the sample size and procedure undertaken when conducting the research. It then elaborates, explains and justifies the data collection tools by identifying the pilot testing, validity and reliability of the instruments to be used. The chapter subsequently discusses the time frame, data collection procedures and data analysis techniques to be adopted during the study. Finally, the discussion ends with presenting ethical considerations made and highlighting the operational definition of the variables of the research

3.2 Research Design

The methodology that researchers employ in a scientific enquiry can take the form of qualitative, quantitative or mixed approaches/method (Kalmar *et. al,* 2016). Quantitative research method are used with any numerical data e.g questionnaires; qualitative research methods represent non-numerical data e.g. interviews. While the two methods seem clearly different and constrasting, some authors like, Taylor and Bogdan (1998); Crewell, (2003) and Bryman, (2012)), regard them as complementaly rather than opposing. Mixed approach on the other hand involves marrying of qualitative and quatitative approaches through a transformative process (Christopher and Kidombo, 2010).

Bearing in mind that the purpose of this study was to gain a deeper understanding of the factors influencing sustainability of off-grid rural electrification, the choice of mixed method design was the best, since it provided a better understanding of research problems. When used in combination, qualitative and quantitative data complemented one another and gave a more complete analysis (Creswell *et. al,* 2004). According to Classen *et. al* (2007), mixed method research gives a better way of looking at the principles and values of a population while also considering the happenings at the community level.

The research adopted mixed method design, which gathers both qualitative and quantitative data, analyses both separately, then an intepretaion was done on both to check whether they supported or contradicted one another (Creswell and Clark, 2011). To use the identified research questions, parallel questions was created for qualitative and quantitative aspects of the study.

3.3 Target population

The target population refers to the entire set of units for which the survey data was used to make inferences. The target population therefore, defines the units where generalizations of the research findings will be made.

The survey was conducted in Tiaty Constituency, Baringo County. The study targeted all 133 head teachers of the public primary schools that have been installed with the solar PV systems in Tiaty constituency, the REA Tiaty county supervisor and the Manager renewable energy based at REA headquarters in Nairobi. This gives a population of 135. But for the study, the accessible population was found to be 30, based on discussion with the leadership of the county due to insecurity and lack of proper roads to access the other schools.

3.4 Sample Size and Sampling Procedure

3.4.1 Sample Size

A formula by Yamane (1967) was used for this particular study. This is as follows;

$$\text{Sample size} = \frac{N}{1+N(e^2)} = \frac{33}{1+33(0.05^2)} = 30$$

Where n is the sample size N is preferred target population and e is the margin of error. For this research the sample will be 30 respondents.

3.4.2 Sampling Procedure

According to Saunders *et. al* (2012) probabilistic/random sampling specifies the probability of a case being included in the study while non-probability/non-random sampling uses an element of subjective judgement to select the sample for the study. The research questions required an indepth understanding of the factors influencing sustainability of off-grid rural electrification by exploring different variables, thus justifying the use of probability sampling. For this particular study the researcher used cluster sampling to ensure time and cost efficiency and also to be able to cover a large geographical area.

3.5 Data Collection Instruments

The primary data was collected by use of a semi-structured questionnaire to solicit data on both the independent and dependent variables. Questionnaire is a data collection instrument made of several questions for purpose of gathering information from respondents.

According to Saunders et al, (2012) interviews are the most used data collection instruments for qualitative research. They have several categories, viz; structured, semi-structured and unstructured. Structured interviews are based on predetermined set of questions aimed at removing biaseness. (Saunder et al. 2012, Bryman and Bell, 2015). Unstructured interviews on the other hand to explore a general area in an informal non-directed manner where the interviewee is allowed to talk freely about different parts of the topics.

Semi structured interviews will be the most suitable data collection method for this study. An interview schedule, will be used to collect more in-depth information. This method is preferred because face to face encounter with respondents would encourage them to cooperate in providing the required information. It will also enable the researcher to explain and clarify the purpose of the research and respond to any concern raised by the respondents.

3.5.1 Pilot Testing of the Instrument

One of the major challenges in interview and questionnaire designs is making it clear to all respondents. To identify and solve the problem, the questionnaire was pre-tested in a pilot study. During the pilot trials both the interview and questionnaire participants were randomly selected from the study population. The pilot test was conducted in 6 randomly selected primary public schools in Tiaty constituency where a total of 6 participants were randomly selected from the study area to participate in the pilot phase. The selection criteria were based on convenience, but care will be taken to ensure participants represent various dimensions important to the study and they did not form part of the final study.

3.5.2 Validity of the Instrument

According to Merriam (1998), qualitative research is stated as "holistic, multidimensional and ever changing". It is therefore up to the researcher and the research participant to attempt in different phases of research that is data collection, analysis and interpretation to build validity. Validity considers as to whether the research is true, believable and evaluating what it's expected to evaluate.

Research by Burns (1999), looks at validity as an essential criterion for evaluating the quality and acceptability of research. It is critical to ensure quality of the instruments used by the researcher to help draw conclusions based on the information obtained using the instruments. There are several types of validity that the researcher will use to validate the research study. Content validity measures the adequacy and efficiency of different elements, skills and behaviors.

Internal validity, this study will be concerned with analogy of the research findings (Zahrabi, 2013). On this study the researcher applied methods recommended by Marriam (1998): for example the trangulation: use of several sources such as questionnare and interviews to strengthen the validity of data evaluation and findings; participatory mode of research: the involvement of participants in all parts of inquiry, with the aim of arriving at evaluation conclusions as a result of a consensures among people of different perspectives in relation to the study (Lynch, 1996); Researchers bias: every researcher has their own belief, value and point of view. On this study, the researcher will collect, analyse and interpret data as objectively, remain non judgemental and clear as possible throughout the research process. External validity will be concerned with the applicability of the findings in a different setting. The resercher will ensure that the research design could be generalized beyond the study area to a wider population.

3.5.3 Reliability of the Instrument

According to Nunan (1999), reliability looks at the consistency, dependability and replicability of results obtained from a research study. It is relatively straightforward to achieve similar results in quantitative research since the data is in numerical form as compare to qualitative approach which is quite demanding and difficult since the data are in narrative form and biased. Therefore, instead of obtaining same results it is better to think about the dependency and consistency of the data (Lincoln and Guba, 1985). The aim of this study is not obtain same results but to rather agree that the data collection procedure, findings and results are consistent and trustworthy.

On this study, the researcher will use two types of reliability. External reliability which is concerned with replicability of the study. Of the five aspects of inquiry as guided by LeCompte and Goetz (1985) and Nunan (1999), the researcher will look at the two aspects of inquiry: the status of the researcher; that clarifies that the researchers social position on participants of the study and the method of data collection and analysis; which requires that procedures of data collection be clearly explained. The study will use mixed method research to collect data which include questionnare and interviews.

Internal reliability looks at the consistency in collecting, analyzing and interpreting data. It is involved in finding out whether the data collected can yield similar results if the analysis was done by an independent researcher. To ensure no threats in internal validity, the researcher will use the two strategies espoused by LeCompte and Goetz (1985) and elabotrated by Nunan (1999), which are mechanicaly recording data and low inference descriptors.

3.6 Data Collection Procedure

Data collection procedures will be in line with the research design. Both quantitative and qualitative data collection methods will used to collect primary and secondary data. Quantitative method includes questionnaire survey. The researcher will use both open and closed format questions for this study. Open format questions are those without a predetermined set of response while closed format questions take the form of multiple-choice questions. The items contained in the questionnaire will include both open-ended and closed questions that attempt to identify factors influencing sustainability of off-grid rural electrification. While qualitative method included participant's assessment through semi structured interviews and focus group discussions.

3.7 Data Analysis Techniques

Marshall and Rossman (1999) describe data analysis as a way of organizing data in an orderly structured way so as to make sense out of it. It is considered as messy, ambiguous and time-consuming, but also as a creative and fascinating process. In this regard, the analysis and interpretation of data represents the application of deductive and inductive logic to the research (Best and Khan, 2006).

Antonius (2003) clearly states that data involves information that is collected in a systematic way, organized, then recorded so as to enable the reader to correctly interpret the provided information. As such, data are not collected haphazardly, but with a view of answering the research objectives. Schostak and Schostak (2008) capture the essences of capturing data well when they further state that data are not fixed but are open to manipulations so as to provide alternative ways of finding answers to the research questions.

The researcher collected data, then organized and checked for accuracy, uniformity and completeness. The researcher used Statistical Package for Social Scientists (SPSS v23) to analyze the raw data and present the findings in frequency and percentages from which descriptive statistics was made. Pearson's correlation coefficient was computed to check the strength of relationship between the individual independent variables and the dependent variable.

3.8 Ethical Consideration

At the heart of every research conducted within the area of social sciences are the ethical considerations made by the researcher (Saunders et. al, 2009). According to Saunders et. al, (2009), ethics is interplated as moral choice that affects decisions and behaviors in regards to those who form the subject of a study. In this study the ethical considerations adopted were those made by Rubbin and Babbie (1997) which states that participation in research should be voluntary and based on informed consent to ensure there is no harm to the participant as well as be anonymous, confidential and not deceive issues.

To ensure voluntary participation and informed concent by participants the author will share a consent form that includes information on the purpose of the study, the interview process, the benefit of taking part in the study and the rights of the participant. To safeguard the participant and ensure that no harm can affect the participant the author will observe the physical and psychological comfort of the participant throughout the interview including any communication leading to the discussion. To ensure autonomy of the participants, the researcher will ensure no names will be included anywhere, both in the questionnaires and during the interviews. Further, confidentiality of the raw data collected and the interview transcripts will be ensured by not sharing any of this information without the participants consent.

3.9. Operational Definition of Variables

A variable is an empirical property that can take two or more values. It is any property that can change, either in quantity or quality.

A dependent variable is a variable whose outcome depends on the manipulation of the independent variables. In this study the dependent variable is sustainability of solar PV system projects. Independent variable on the other hand is a variable that is manipulated to cause changes in the dependent variable. In this study the independent variables are institutional factors, economic factors, environmental factors and socio-cultural factors.

An operational definition describes how the variables are measured and defined within the study. It is a description of a variable, term or object in terms of the specific process or set of validation tests used to determine its presence and quantity. It is generally designed to model a conceptual definition. Table 3.2 is a summary of the operational definition of variables in the study showing the indicators, measure of indicators, measurement scale, tools and type of analysis. Nominal scales were used to investigate the various variables in the study.

Table 3. 1: Operational Definition of Variables

RESEARCH OBJECTIVES	VARIABLE	TYPE OF VARIABLE	INDICATORS	DATA COLLECTION INSTRUMENTS	SCALE OF MEASUREMENT	TYPE OF ANALYSIS
To assess the extent to which the institutional factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya.	Institutional	Independent variable	• Expert know-how • Centralization • Regulations and standards • Stability and enforcement	Questionnaire	Interval	Descriptive statistics Inferential statistics
To assess the extent to which the socio-economic factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya.	Economic	Independent variable	• Operation and Maintenance • Reliability • Cost-effectiveness • Education level	Questionnaire	Interval	Descriptive statistics Inferential Statistics
To assess the extent to which the technological factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya.	Technology	Independent variable	• Technical know-how • Availability of technicians • Availability of spare parts	Questionnaire	Interval	Descriptive statistics Inferential Statistics
To assess the extent to which the socio-cultural factors influence sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya.	Socio-cultural	Independent variable	• Public awareness • Societal norms and values • Social acceptance • Education level	Questionnaire	Interval	Descriptive Statistics Inferential Statistics

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION, AND INTERPRTATION OF FINDINGS

4.1. Introduction

This chapter presents the study findings which have been analyzed based on the thematic and sub-thematic areas in line with the study objectives. The purpose of the study was to determine the factors influencing the sustainability of off-grid solar photovoltaic systems rural electrification projects; a case of rural public primary schools in Tiaty constituency, Baringo county, Kenya. The study sought to determine the extent to which institutional factors, socio-economic factors, technological factors and socio-cultural factors influence the sustainability of off-grid photovoltaic systems for rural electrification projects. These were political factors. This chapter begins with demographic information, followed by findings on the objectives of the study.

4.2. Questionnaire Return Rate

The study had a sample size of 30 headteachers of public primary schools installed with the solar photovoltaic system in Tiaty constituency, and interviews were conducted on the REA Tiaty county supervisor and the Manager renewable energy based at REA headquarters in Nairobi. Out of the 30 respondents, 30 responses were obtained giving a response rate of 100%. According to Kothari (2004) any response rate of 50% and above is adequate for analysis.

4.3. Demographic Characteristics of the Respondents

The study sought to collect background information of the respondents in terms of gender, age, and academic qualification. The results are presented in table 4.1

Table 4. 1: Gender of the Respondents

Gender	Frequency	Percentage
Male	25	83.3
Female	5	16.7
Total	**30**	**100**

The findings indicate that the majority of the study respondents were male given by 83.3% while women made up only 16.7%. This clearly indicates that men dominate the headteacher position in Tiaty constituency.

Table 4. 2: Age of the Respondents

Age (Years)	Frequency	Percentage
18 – 25	1	3.3
26 – 30	2	6.7
31 – 35	4	13.3
36 – 40	9	30.0
41 – 45	11	36.7
Over 45	3	10.0
Total	**30**	**100**

Table 4.2 indicates that 36.7% of the respondents, which is the majority were aged between 41 – 45 years, 30% were aged between 36 – 40 years. These are mature individuals who have been in the field for several years therefore having a lot of experience, which will be beneficial to the study in terms of the quality of information they provide as feedback to the questions asked.

Table 4. 3: Academic Qualification of the Respondents

Academic Qualification	Frequency	Percentage
Primary	0	0.0
Secondary	1	3.3
Certificate	21	70.0
Diploma	5	16.7
Degree	3	10.0
Other	0	0.0
Total	**30**	**100**

The research found out that 70% of study respondents had done a certificate and particularly P1 certificate which is the basic requirement for employment as a teacher in primary school. 16.7% had a diploma while 10.0% had a degree. Cumulatively, 96.7% of the respondents had post-secondary school training, which means they were capable of understanding the questions and providing credible information.

4.4. Institutional Factors and Sustainability of Off-Grid Solar Photovoltaic Systems

The first objective of the study was to determine the influence of institutional factors on the sustainability of off-grid solar photovoltaic systems for rural electrification in Tiaty constituency.

The respondents were asked to indicate their level of agreement with regard to some statements. The results are as presented in table 4.4

Table 4. 4: Institutional factors and Sustainability

STATEMENT	MEAN	STD DEV
Government support to project	3.01	0.549
Project manager decision making	2.33	0.391
Project manager commitment	4.01	0.422
Project manager accountability	3.61	0.616
Project manager management capacity	2.03	1.019
Overall	**3.56**	**0.516**

The findings indicate that government support towards the off-grid photovoltaic solar system was considered to be neutral with a mean of 3.01 and a standard deviation of 0.549. In terms of project manager decision making with regard to the solar off-grid PV system, the respondents disagreed with the statement that it had an influence on the sustainability, with a mean of 2.33 and a standard deviation of 0.391. With regard to commitment of the project manager to the project, the respondents gave a mean of 4.01 and a standard deviation of 0.422, indicating that the project managers, who in this case are the school head teachers are committed to making sure that the solar PV systems are sustainable. The accountability of project managers was also considered as an indicator of institutional factors and it gave a mean of 3.61 and a standard deviation of 0.616, which shows an agreement with the statement implying the project managers are accountable. The last indicator for institutional factors was taken as project managers management skills, this gave a mean of 2.03 and a standard deviation of 1.019, indicating that the respondents did not consider it as an important factor in the sustainability of the solar PV systems. In general, institutional factors had a mean of 3.56 and a standard deviation of 0.516, which clearly indicates that institutional factors have an influence on the sustainability of off-grip solar photovoltaic systems.

4.4.1. Correlation between Institutional Factors and Sustainability of Solar PV Systems

The researcher sought to find ought the strength of relationship between institutional factors and sustainability of off-grip solar photovoltaic systems, the findings are as indicated in table 4.5

Table 4. 5: Institutional Factors and Sustainability of Off-Grid Solar PV Systems

		Sustainability of Off-Grid Solar PV Systems	Institutional Factors
Sustainability of Off-Grid Solar PV Systems	Pearson Correlation	1	0.5329
	Sig. (2 – tailed)		0.0417
	N	30	
Institutional Factors	Pearson Correlation	0.5329	1
	Sig. (2 – tailed)	0.0417	
	N	30	30

The findings on table 4.5, show a positive correlation between institutional factors and the sustainability of off-grid solar PV systems, this is indicated by a positive value of the Pearson's correlation coefficient (0.5329).

4.5. Economic Factors and Sustainability of Off-Grid Solar Photovoltaic Systems

The second objective of the study was to determine the influence of economic factors on the sustainability of off-grid solar photovoltaic systems for rural electrification in Tiaty constituency. The respondents were asked to indicate their level of agreement with regard to some statements. The results are as presented in table 4.6

Table 4. 6: Economic factors and Sustainability

STATEMENT	MEAN	STD DEV
Cost of repair	4.21	0.493
Labour cost	3.11	0.441
Escalation of material prices	3.88	0.571
Cost of security	2.01	0.112
Waste rate of material	3.37	0.104
Overall	**3.31**	**0.416**

Table 4.5 shows that the cost of repair has an influence on the sustainability of the off-grid solar PV systems as depicted by a mean of 4.21 and a standard deviation of 0.493, which indicates that there was a strong agreement with the statement by the respondents. The respondents also agreed that the cost of labour and escalation of material prices has had an influence on the sustainability

as indicated by a mean of 3.11 and 3.88 respectively. Cost of security was also considered as an aspect of economic factors, it yielded a mean of 2.01 and a standard deviation of 0.112, which indicates that the respondents disagreed with the statement. This shows that the cost of security is not considered as one of the factors that influence the sustainability of solar off-grid PV solar systems. The overall mean of all the economic factor indicators is 3.31 with a combined standard deviation of 0.416. This shows that the respondents were neutral on the influence of economic factors on the sustainability of off-grid solar PV systems.

4.5.1. Correlation between Economic Factors and Sustainability of Solar PV Systems

The researcher sought to find ought the strength of relationship between institutional factors and sustainability of off-grip solar photovoltaic systems, the findings are as indicated in table 4.6

Table 4. 7: Economic Factors and Sustainability of Off-Grid Solar PV Systems

		Sustainability of Off-Grid Solar PV Systems	**Economic Factors**
Sustainability of Off-Grid Solar PV Systems	Pearson Correlation	1	0.4318
	Sig. (2 – tailed)		0.0313
	N	30	
Economic Factors	Pearson Correlation	0.4318	1
	Sig. (2 – tailed)	0.0313	
	N	30	30

The Pearson's correlation coefficient between sustainability of off-grid solar PV systems and Economic factors was found to be 0.4318 as shown on table 4.6. This implies that a positive correlation exists between the two variables. Thus, an increase in economic factors leads to improvement in the sustainability of the solar systems.

4.6. Technological Factors and Sustainability of Off-Grid Solar PV Systems

The study sought to also find out the influence of technology on the sustainability of off-grid solar photovoltaic systems for rural electrification in Tiaty constituency. The respondents were asked to indicate their level of agreement with regard to some statements. The results are as presented in table 4.4

Table 4. 8: Technological factors and Sustainability

STATEMENT	MEAN	STD DEV
Availability of technicians	4.31	0.449
Availability of spare parts	3.63	0.691
Ease of problem diagnosis	2.71	0.622
Durability of components	3.94	0.416
Overall	**3.65**	**0.532**

Table 4.8 shows that the respondents strongly agreed to the statement about availability of technician with a mean of 4.31 and a standard deviation of 0.449, this shows that if technicians are readily available then the off-grip solar PV systems will be sustainable. Availability of spare parts was also considered as a construct of technological factors; it was found to have a mean of 3.63 and a standard deviation of 0.691 showing that the respondents were neutral on the influence of spare parts availability on the sustainability of off-grid solar PV systems. With regard to ease of problem diagnosis, the respondents disagreed that it has an influence the sustainability with a mean of 2.77 and a standard deviation of 0.622, this can be attributed to the fact that technical issues should be left to technicians to do. The last statement was on the durability of the system components, the respondents indicated it as being an important factor in the sustainability with a mean of 3.94 and a standard deviation of 0.416. The overall mean of technological factors was found to be 3.65 with a standard deviation of 0.532, thus indicating an agreement by the respondents that technological factors influence the sustainability of the off-grid solar PV systems.

4.6.1. Correlation between Technological Factors and Sustainability of Solar PV Systems

The researcher sought to find ought the strength of relationship between technological factors and sustainability of off-grip solar photovoltaic systems, the findings are as indicated in table 4.5

Table 4. 9: Technological Factors and Sustainability of Off-Grid Solar PV Systems

		Sustainability of Off-Grid Solar PV Systems	Technological Factors
Sustainability of Off-Grid Solar PV Systems	Pearson Correlation	1	0.6102
	Sig. (2 – tailed)		0.0313
	N	30	
Technological Factors	Pearson Correlation	0.6102	1
	Sig. (2 – tailed)	0.0313	
	N	30	30

The findings on table 4.9, show a positive correlation between technological factors and the sustainability of off-grid solar PV systems, this is indicated by a positive value of the Pearson's correlation coefficient (0.6102). The p-value of 0.0313 which is less than the significance value of 0.05 indicates that the value is significant.

4.7. Socio-Cultural Factors and Sustainability of Off-Grid Solar PV Systems

The study sought to also find out the influence of socio-cultural factors on the sustainability of off-grid solar photovoltaic systems for rural electrification in Tiaty constituency. The respondents were asked to indicate their level of agreement with regard to some statements. The results are as presented in table 4.4

Table 4. 10: Technological factors and Sustainability

STATEMENT	MEAN	STD DEV
Social acceptance	2.53	0.923
Local norms and values	2.16	0.691
Public awareness	1.88	0.272
Education level	2.63	0.421
Overall	**2.30**	**0.654**

The findings in table 4.10 shows that the respondents disagreed to the statement about social acceptance, posting a mean of 2.53 and a standard deviation of 0.923, this indicates that social acceptance was not considered to have an influence on the sustainability of the off-grip solar PV systems. The norms and values of the locals were also considered and it was found out that they did not have an influence going by a mean of 2.16 and a standard deviation of 0.691. public awareness and education level were also considered and the finding indicated that the respondents disagreed with the statement giving a mean of 1.88 and 2.63 respectively. In general, socio-cultural factors had a mean of 2.30, which indicates that the respondents generally disagreed with it having an influence on the sustainability of the off-grid solar PV systems.

4.7.1. Correlation between Socio-Cultural Factors and Sustainability of Solar PV Systems

The researcher sought to find ought the strength of relationship between technological factors and sustainability of off-grip solar photovoltaic systems, the findings are as indicated in table 4.11

Table 4. 11: Socio-Cultural Factors and Sustainability of Off-Grid Solar PV Systems

		Sustainability of Off-Grid Solar PV Systems	**Socio-Cultural Factors**
Sustainability of Off-Grid Solar PV Systems	Pearson Correlation	1	-0.1028
	Sig. (2 – tailed)		0.0615
	N	30	
Socio-Cultural Factors	Pearson Correlation	-0.1028	1
	Sig. (2 – tailed)	0.0615	
	N	30	30

Table 4.11 indicates a weak negative correlation between socio-cultural factors and the sustainability of off-grid solar PV systems, this is indicated by a negative value of the Pearson's correlation coefficient (-0.1028). The p-value of 0.0615 which is greater than the significance value of 0.05 indicates that the value is not significant.

CHAPTER FIVE

SUMMARY, DISCUSSION OF FINDINGS AND CONCLUSIONS

5.1. Introduction

This chapter provides a summary, discussion of findings and conclusion drawn from the study. The major objective of the study was assessment of the factors influencing sustainability of off-grid solar photovoltaic systems for rural electrification projects in Tiaty Constituency, Baringo County, Kenya.

5.2. Summary of Findings

This section presents a summary of the research findings with regard to the study objectives.

5.2.1 Influence of Institutional factors on the sustainability of off-grid solar PV systems

The first objective of the study was to establish the extent to which institutional factors influenced sustainability. The study established a mean of 3.01 for government support, this implies that it is key for a government sponsored project to continue serving the intended beneficiaries long after the donors have withdrawn. It was also established that project managers decision making skills is not an important component of the institutional factor in the implementation of the solar off-grid PV systems for rural electrification with a mean of 2.33. Project manager commitment towards the project was a very important factor towards sustainability of the projects as depicted by a mean of 4.01. Project managers accountability was also supported by school heads as being an important factor in sustainability with a mean of 3.61; Lastly, project manager capacity was not a very important factor in the sustainability of the project due to the mean of 2.03. In general, institutional factors appears to be a significant factor in the sustainability of the solar PV systems for rural electrification projects, this is due to the fact respondents agreed cumulatively, giving a mean of 3.56. A correlation coefficient of 0.5329 showed a moderate positive relationship between institutional factors and sustainability of the solar PV system for rural electrification in Tiaty constituency, Baringo county, Kenya.

5.2.2 Influence of Economic factors on the sustainability of off-grid solar PV systems

The second objective sought to investigate the extent to which economic factors influence the sustainability of the solar PV system projects and the findings of the project showed that the cost of repair in case of damage was considered to be a key factor in the sustainability of the solar PV projects with a mean of 4.21, escalation of the material prices was second with a mean of 3.88, mean it was agreed that it a key factor as well in the sustainability of the solar PV projects, the research further established that labour cost is also an impediment to the sustainability with a mean of 3.11 and waste rate of materials was also looked at giving a mean of 3.37. The study also looked at the cost of security as an aspect of economic factors, it gave a mean of 2.01, this means that the respondents did not considered it a critical factor in the sustainability of solar PV system of rural electrification project. The overall mean of all the indicators of economic factors put together was found to be 3.35, which shows that there was a consensus on the significance of economic factors on sustainability.

5.2.3 Influence of Technological factors on the sustainability of off-grid solar PV systems.

The third objective of the study was to determine the influence of technological factor on sustainability of the project. It was established that availability of technicians was an important factor giving a mean of 4.31, which indicates the respondents strongly agreed to the statement regarding availability of technicians. Regarding availability of spare parts, the study established a mean of 3.63, indicating the respondents regarded it as a factor that can influence sustainability. Ease of problem diagnosis the mean was found to have a mean of 2.71, this shows the respondents were neutral of the significance of problem diagnosis on the sustainability of the solar system. While looking at the durability of the solar system components as an influence of sustainability, the respondents agreed by posting a mean of 3.94. generally, the combined mean of all the variables making up the technological factors gave a mean of 3.65 indicating that the respondents agree that technology has an influence on the sustainability of off-grid solar PV systems.

5.2.4 Influence of Sociocultural factors on the sustainability of off-grid solar PV systems.

The last objective sought to determine the extent to which sociocultural factors influence the sustainability of the off-grid solar PV systems and the findings showed that social acceptance of the project was considered to be a neutral factor on sustainability of the off-grid solar PV systems with a mean of 2.53. Local people norms and values were also considered and it was observed that their mean was 2.16 implying the respondents disagreed with the statement hence they do not seem to have any significance on the sustainability of the solar off-grip PV systems. Public awareness on solar PV systems for rural electrification was looked at and it gave a mean of 1.88 which shows that the respondents strongly disagreed with the statement. Lastly, the research considered the education level as a determinant of sustainability of the solar systems, this returned a mean of 2.63, which shows that the respondents generally disagreed with the statement. In general, the mean of the sociocultural factors was found to be 2.30 which indicates that the respondents felt they did not have any influence on the sustainability of the solar off-grid PV systems for rural electrification in Tiaty constituency, Baringo county, Kenya.

5.3 Discussions

The study finds that government support influence the sustainability of off-grid solar PV systems for rural electrification in Tiaty constituency, Baringo county, Kenya positively, this is in line with the observation by Rogers (2016) who theorizes that for a government sponsored project to be successful and sustainable, the government need to continuously keep support it so as to meet the expenses that will be incurred in the process of its running. Commitment of the project manager towards the success of the project was also seen to have a positive influence on the sustainability of the off-grid solar PV systems for rural electrification, this is supported by Pansera (2012) who did a study in Nicaragua and posited that the commitment of institutions towards the success of off-grid systems is key. Regarding the accountability of managers, the study showed that there was a positive correlation, this is supported by a study done by (Mason, 2002; Vosniadou, 2002; Chi and Roscoe, 2002) who claimed that accountability is key for the sustainability of water projects in India.

The second research objective looked at the influence of economic factors on the sustainability of solar systems, the cost of repair was considered to have a positive relationship with the sustainability. This is in line with a study by Ilskog and Kjellström, 2008, who indicated that ensuring the sustainability of off-grid PV systems requires covering operations and management over their lifetime. The findings from the study also escalation of material prices had a positive relationship with the sustainability. This is supported by Leach (2017), who did a study on the sustainability of donor funded projects and found that the rise in price of the repair materials such as pipes in case of wear and tear made the projects not to be sustainable. In general, economic factors had a positive influence on the sustainability of solar PV system projects, this is line with a research done by Rajendra (2016), who did a study in Russia and came to conclusion that there exists a positive correlation between economic status of the host community and the performance of community-based projects.

The third research objective looked at the influence of technological factors on the sustainability of solar PV systems for rural electrification. Availability of technical personnel to work on the system in case of a breakdown was viewed as a very important factor for sustainability as observed by a mean of 4.31, meaning the respondents strongly agreed with the statement. It was followed by durability of the components with a mean of 3.94 implying that the respondents feel it has a greater influence on the sustainability of off-grid solar systems. Availability of spare parts was also looked as a component of technological factors influencing the performance it gave a mean of 3.63 indicating that the respondents agreed to it too. Finally, ease of diagnosis of the solar system gave a mean of 2.71 meaning the respondents were neutral on its influence on the sustainability. In general, the technological factors had a combined mean of 3.65 meaning it is a significant influencer of the sustainability of the off-grid solar PV system for rural electrification in Tiaty constituency, Baringo County, Kenya.

The final objective was to assess the influence of sociocultural factors on the sustainability of solar PV systems. The factors considered under this theme were, social acceptance with a mean of 2.53, education level with a mean of 2.63, local norms and values with a mean of 2.16 and lastly, public awareness with a mean of 1.88, none of them was seen to have influence on the sustainability of the solar PV system. The combined mean of the sociocultural factors was found to be 2.30, which means the respondents feel it has no influence on the sustainability of off-grid solar PV systems in Tiaty constituency, Baringo county, Kenya.

5.4 Conclusions

In light of the above findings the study concludes that institutional factors, economic factors and technological factors all have an influence on the sustainability of the off-grid solar PV systems while sociocultural factors have no influence on the sustainability of the off-grid solar PV systems for rural electrification.

5.5 Recommendations

Based on the above findings the researcher recommends that

1. For sustainability of the solar PV systems, the institutions should have managers who are committed to the success of the project, they should also be accountable and the government should provide enough support to the schools installed with the systems.
2. The Study showed that the there was a relationship between economic factors and sustainability of solar PV systems, the study recommends that a budget should be set aside for the operation and maintenance of the system.
3. With regard to technological factors, the study recommends the employment or training of individuals in the project location area so that they can be in a position to repair and maintain the systems.

5.6 Areas of Further Researcher

The researcher recommends that more research needs to be done on

1. The relationship between sociocultural factors and sustainability of the off-grid solar PV systems.

REFERENCES

Cook, P. (2011). Infrastructure, rural electrification and development. *Energy for Sustainable Development*, *15*(3), 304-313.

International Energy Agency (IEA). World Energy Outlook. Electricity Access Database; International Energy Agency: Paris, France, 2015.

Organisation for Economic Co-operation and Development (OECD) and International Energy Agency IEA. Energy Poverty. How to make modern energy access universal? Special early excerpt of the World Energy Outlook 2010 for the UN General Assembly on the Millennium Development Goals. 2010. Available online: http://www.se4all.org/wp-content/uploads/2013/09/Special_Excerpt_of_WEO_2010.pdf

United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Earth Summit. Agenda 21: The United Nations Programme of Action from Rio; United Nations: New York, NY, USA, 1992.

International Renewable Energy Agency (IRENA). Off-Grid Renewable Energy Systems: Status and Methodological Issues; Working Paper; IRENA: Abu Dhabi, UAE, 2015.

Mainali, B. Sustainability of Rural Energy Access in Developing Countries. Ph.D. Thesis, KTH Royal Institute of Technology, Stockholm, Sweden, 2014.

United Nations (UN). Renewable Energy-Based Rural Electrification in Lesotho. Electronic Document. 2006.

Schäfer, M., Kebir, N., & Neumann, K. (2011). Research needs for meeting the challenge of decentralized energy supply in developing countries. *Energy for Sustainable Development*, *15*(3), 324-329.

Müggenburg, H., Tillmans, A., Schweizer-Ries, P., Raabe, T., & Adelmann, P. (2012). Social acceptance of PicoPV systems as a means of rural electrification—A socio-technical case study in Ethiopia. *Energy for Sustainable Development*, *16*(1), 90-97.

Burton, J., & Hubacek, K. (2007). Is small beautiful? A multicriteria assessment of small-scale energy technology applications in local governments. *Energy Policy*, *35*(12), 6402-6412.

Sharma, T., & Balachandra, P. (2015). Benchmarking sustainability of Indian electricity system: An indicator approach. *Applied Energy*, *142*, 206-220.

Renewable Energy Policy Network for the 21st Century (REN21). Renewables 2013—Global Status Report REN21 Secretariat; REN21: Paris, France, 2013

Martinot, E., & Reiche, K. (2000). Regulatory approaches to rural electrification and renewable energy: case studies from six developing countries. *World Bank, Washington, DC, Working Paper*.

Cecelski, E. From the Millennium Development Goals towards a Gender-Sensitive Energy Policy Research and Practice: Empirical Evidence and Case Studies; Draft Synthesis Report to DFID KaR on Research Project 2005.

Urmee, T. (2014). Social, cultural and policy issues of the application of remote area off-grid photovoltaic.

Urmee, T., & Harries, D. (2011). Determinants of the success and sustainability of Bangladesh's SHS program. *Renewable Energy*, *36*(11), 2822-2830.

Sindhu, S., Nehra, V., & Luthra, S. (2016). Identification and analysis of barriers in implementation of solar energy in Indian rural sector using integrated ISM and fuzzy MICMAC approach. *Renewable and Sustainable Energy Reviews*, *62*, 70-88.

Frame, D., Tembo, K., Dolan, M. J., Strachan, S. M., & Ault, G. W. (2011, July). A community-based approach for sustainable off-grid PV systems in developing countries. In *Power and Energy Society General Meeting, 2011 IEEE* (pp. 1-7). IEEE.

Van der Vleuten, F., Stam, N., & Van Der Plas, R. (2007). Putting solar home system programmes into perspective: What lessons are relevant? *Energy Policy*, *35*(3), 1439-1451.

Tillmans, A., & Schweizer-Ries, P. (2011). Knowledge communication regarding solar home systems in Uganda: the consumers' perspective. *Energy for Sustainable Development*, *15*(3), 337-346.

Karekezi, S., & Kithyoma, W. (2002). Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa? *Energy policy*, *30*(11-12), 1071-1086.

Laufer, D., & Schäfer, M. (2011). The implementation of Solar Home Systems as a poverty reduction strategy—A case study in Sri Lanka. *Energy for sustainable Development*, *15*(3), 330-336.

Hansen, U. E., Pedersen, M. B., & Nygaard, I. (2014). Review of Solar PV market development in East Africa. *UNEP Risø Centre, Technical University of Denmark: Kongens Lyngby, Denmark*.

Ilskog, E., & Kjellström, B. (2008). And then they lived sustainably ever after?—Assessment of rural electrification cases by means of indicators. *Energy Policy*, *36*(7), 2674-2684.

Yu, X. (2014). Is environment ‘a city thing’in China? Rural–urban differences in environmental attitudes. *Journal of Environmental Psychology*, *38*, 39-48.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior?. *Environmental education research*, *8*(3), 239-260.

Sandgren, A. (2001). Batteries used within solar electric systems in rural Uganda.

Batteiger, A. (2015). Off-Grid Electrification and its Impacts on the Waste Management System–the Case of Bangladesh. UCL STEaPP.

Bhattacharyya, S. C., & Timilsina, G. R. (2010). Modelling energy demand of developing countries: Are the specific features adequately captured?. *Energy policy*, *38*(4), 1979-1990.

Mufiaty, H. (2014). Solar home systems performance in rural area in aceh case study: Deah mamplam village, aceh besar. *Energy procedia*, *47*, 133-142.

Rolland, S. (2011). Rural electrification with renewable energy. *ARE Publication, June*.

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: a review. *Renewable and Sustainable Energy Reviews*, *15*(3), 1513-1524.

Krithika, P. R., & Palit, D. (2013). Participatory business models for off-grid electrification. In *Rural electrification through decentralised off-grid systems in developing countries* (pp. 187-225). Springer, London.

Ranaboldo, M., Domenech, B., Reyes, G. A., Ferrer-Martí, L., Moreno, R. P., & García-Villoria, A. (2015). Off-grid community electrification projects based on wind and solar energies: A case study in Nicaragua. *Solar Energy*, *117*, 268-281.

Pansera, M. (2012). Renewable energy for rural areas of Bolivia. *Renewable and sustainable energy reviews*, *16*(9), 6694-6704.

Sovacool, B. K. (2011). An international comparison of four polycentric approaches to climate and energy governance. *Energy Policy*, *39*(6), 3832-3844.

Ostrom, E. (2009). A polycentric approach for coping with climate change.

World Bank. Mexico (CRL) Rural Electrification Project Report No. AB2919. 2007.

Brew-Hammond, A. (2011). Terminal Evaluation of UNEP GEF Project Solar and Wind Energy Resource Assessment—SWERA. *United Nations Environment Programme: Nairobi, Kenya*.

Kovič, M. (2010). Investigating technology transfer projects and institutional development in developing countries. *Management of Environmental Quality: An International Journal*, *21*(6), 761-772.

Wlokas, H.L. A Review of the Solar Home System Concession Programme in South Africa; University of Cape Town: Cape Town, South Africa, 2011.

Elusakin Julius, E., Olufemi, A. O., & Chuks, D. J. (2014). Challenges of sustaining off-grid power generation in Nigeria rural communities. *Afr. J. Eng. Res*, *2*, 51-57.

Bawakyillenuo, S. (2009). Policy and institutional failures: photovoltaic solar household system (PV/SHS) dissemination in Ghana. *Energy & environment*, *20*(6), 927-947.

Jordan, A.; O'Riordan, T. Social Institutions and Climate Change: Applying Cultural Theory to Practice; CSERGE Working Paper GEC 97-15; Centre for Social and Economic Research on the Global Environment: London, UK, 1997; p. 56.

Pejovich, S. (1999). The effects of the interaction of formal and informal institutions on social stability and economic development. *Journal of Markets and Morality*, *2*(2).

APPENDICES

APPENDIX I: TRANSMITTAL LETTER

ABDINUR MOHAMEDABDIKADIR,
P.O. BOX 103520-00101
NAIROBI, KENYA

Dear Respondent,

RE: PARTICIPATION IN RESEARCH

I am a post graduate student at the University of Nairobi pursuing Master of Arts in Project Planning and Management. I am carrying out a research on factors affecting the sustainability of solar PV systems; a case of Tiaty constituency – Baringo county as part of requirements for the award of this degree. Your school/office has been selected and consequently you have been sampled as part of the respondents.

I therefore humbly request you to respond to the questions as asked in the questionnaires. I assure you that the information provided will be solely used for academic purposes of this study.

Thank you in advance.

Yours faithfully,

____

Abdinur Mohamed Abdikadir
L50/86015/2016

APPENDIX II: QUESTIONNAIRE

INTRODUCTION

This questionnaire is designed to collect information about factors influencing the sustainability of off-grid photovoltaic systems for electrification of rural public primary schools in Tiaty constituency, Baringo County in Kenya. It contains 5 sections. The information will be used for academic purpose only, I therefore request you to spare about 10 minutes and respond to all the items as truthful as possible. You may use a tick or as directed in each item

SECTION I: BACKGROUND INFORMATION

Please indicate your gender

Female ☐

Male ☐

What is your age bracket?

18 – 25 years ☐

26 – 30 years ☐

31 – 35 years ☐

36 – 40 years ☐

41 – 45 years ☐

Over 45 years ☐

What is your highest level of education?

Primary ☐

Secondary ☐

Certificate ☐

Diploma ☐

Degree ☐

Others ☐

SECTION 2: INSTITUTIONAL FACTORS						
This section is out to establish the influence of institutional factors on the sustainability of PV solar systems in Tiaty constituency, Baringo County in Kenya. To achieve this, you are required to give your opinion on the level of agreement or disagreement on the following statements using a Likert scale of 1 to 5 where; 1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree						
	Statement	5	4	3	2	1
I1	Government support					
I2	Commitment					
I3	Accountability					
I5	Cooperation					
I6	Capacity					

2. (a) Kindly explain some other institutional factors that you encounter.

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2. (b) Please suggest ways that can be used to overcome the challenges

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SECTION 3: ECONOMIC FACTORS						
This section is out to establish the influence of economic factors on the sustainability of PV solar systems in Tiaty constituency, Baringo County in Kenya. To achieve this, you are required to give your opinion on the level of agreement or disagreement on the following statements using a Likert scale of 1 to 5 where; 1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree						
	Statement	5	4	3	2	1
E1	Cost of maintenance and repair					
E2	Cost of operation					
E3	Affordability of solar PV system spares					
E4	Cost of security					
E5	Labour cost					
E6	Waste rate of materials					

3 (a). What are some of the economic challenges that you encounter while working in this project?

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3 (b). Please suggest some actions that can be undertaken to overcome the challenges

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SECTION 4: TECHNOLOGICAL FACTORS						
This section is out to establish the influence of environmental factors on the sustainability of PV solar systems in Tiaty constituency, Baringo County in Kenya. To achieve this, you are required to give your opinion on the level of agreement or disagreement on the following statements using a Likert scale of 1 to 5 where; 1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree						
	Statement	5	4	3	2	1
T1	Solar technicians are readily available					
T2	Spare parts are available					
T3	System diagnosis can be done with ease					
T4	Repair shops are available locally					

4. (a) What are the technological challenges you face?

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4. (b) Please propose some remedies for the above challenges

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SECTION 5: SOCIO-CULTURAL FACTORS						
This section is out to establish the influence of social-cultural factors on the sustainability of PV solar systems in Tiaty constituency, Baringo County in Kenya. To achieve this, you are required to give your opinion on the level of agreement or disagreement on the following statements using a Likert scale of 1 to 5 where; 1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree						
	Statement	5	4	3	2	1
D1	Social acceptance					
D2	Education level					
D4	Local people culture					
D5	Installation accuracy					
D6	Societal norms and values					
D7	Public awareness and information					