SOCIO-ECONOMIC ANALYSIS OF COMMUNITY-BASED MICRO HYDRO ELECTRICITY SCHEMES IN KENYA

By

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Declaration

I, Mary Karumba, do hereby declare that the work presented in this thesis is my own, except where acknowledged and that this thesis or any part of it has not been previously submitted for the award of a degree at any university.

Signed

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Abstract

This thesis addresses three economic and social impediments to the successful deployment of community-based micro hydro grids using a case study from the Republic of Kenya. Kenya is one of the countries in Sub-Sahara Africa currently faced with low rural electricity access rates, but with abundant micro hydro resources spread across vast rural locations. Although majority of financial resources are channeled to grid extension in developing countries like Kenya, many rural households still live 'under the grid' because they cannot afford connection fees and/or cost of grid electricity. Such phenomenon has led to innovative solutions such as the concept of Community-Based Renewable Energy Schemes (CRES), facilitating joint exploitation of a local renewable energy (RE) resources. The government of Kenya in partnership with non-state actors set up demonstration points for Community-Based Micro Hydro Schemes (CBMHS) in two locations, and other communities have adopted this model by setting up their own electrification schemes in Kenya. However, the success of such schemes continues to be very limited in Kenya and other developing countries with majority of them disintegrating after few years of operation. This phenomenon is widely documented in literature, and a variety of barriers to success of such schemes continue to be interrogated in both published and unpublished academic literature. There are issues relevant to both establishment and continued operation of such electrification that have not received much scholarly research, but continue to largely limit delivery of sustainable and quality service, as well as hindering scaling up of these potentially useful rural electrification alternatives. These include: a) mismatch between the provided services by such group electrification schemes and the expectations of their consumers b) lack of supportive capacity for joint effort mobilization and capacity for self-governance within such schemes c) unsubstantiated claims of the capability of small scale renewable energy electrification impact on households that make them not to be considered as equally important energy solutions. This thesis makes a threefold contribution to the literature of rural electrification by firstly analyzing preference for properties of decentralized electricity delivery service in a field dominated by utility provided grid solutions. Secondly, the literature on governance of man-made common pool resources (CPR) is extended by providing evidence for the requirements for successful management of a small-scale electricity commons line a CBMHS. Lastly, the study produces reliable evidence regarding immediate or short-term changes to households anticipated from small scale electrification projects. Overall, the study presents lessons on implementing and sustaining rural communities' investments in decentralized RE electrification while demonstrating why such schemes should now form essential part of rural electrification delivery models. The three research issues are addressed independently in three chapters that follow the introductory chapter of this thesis.

The first paper investigates the preferences for carefully solicited attributes of a micro hydro grid electricity service namely: outages (in terms of frequency and duration); the quantity of electricity delivered into the household (in terms of power packages); ownership regimes and costs. Additionally, the monthly willingness to pay for this service is

estimated to gauge the range of the cost that consumer could accommodate for this service in each month. Optimal experimental design was employed for arranging combinations of the levels of these attributes into concise yet representative choice situations, that were given to 133 members of a micro hydro scheme in Meru County located in Central Kenya. Conditional logit model was then used for analyzing the consumer choices, based on relevant model selection criteria. Despite popularity of community-based RE electricity schemes that offer limited quantity of electricity among practitioners of micro grids in Kenya, results from this paper indicate that consumers prefer unlimited quantity of electricity delivered to their households. This is supported by a high marginal willingness to pay of approximately 8.5 USD for such a service which approximates the monthly bill of grid connected households in the County of the study survey. Community ownership in the provision of service is also a preferred attribute, indicating the importance of allowing the local members to participate as owners in such RE enterprise that target them as primary consumers. There is a lower willingness to pay for outages defined by both frequency and duration, and further research using timings of duration could be more relevant in future. The study outcomes underscore the importance of conducting preference assessments before project implementation which does not exist in most micro hydro schemes resulting in multiple complaints about the service in the operational phase of schemes. The estimates we provide have future use in other analysis like benefit transfer or cost-benefit analyses for such electrification schemes.

Paper 2 examines the sources of common pool property governance difficulties afflicting utilization and maintenance of micro hydro grid electricity and related infrastructure. Such problems are partly responsible for the chaotic end to some community-based RE micro hydro grids in Kenya and other parts of developing world, and there is demand for solutions that can enable schemes to remain operational in the long term. Although there are other impediments, collapse of schemes could be attributed to persistent uncooperative behavior by individuals and/or poor local institutional arrangements for governing utilization of electricity and related infrastructure. There are also other pre-conditions for good governance in electricity commons within the wider literature of common pool resource (CPR) management, which are believed to be relevant for sustaining operations in micro hydro schemes. Data on selected concepts believed to reflect cooperation by individuals with various scheme requirements and information on the quality of institutional arrangements was collected from individuals and schemes located in the Counties of Murang'a, Nyeri and Kirinyaga in Central Kenya. Other field data include individual and group level characteristics on certain relevant aspects that are suggested in literature as important in explaining individual behavior and group outcomes observed in the field. In the first part is an analysis for the role of personal traits on the observed level of cooperation. A simple linear regression model is used for this purpose, while addressing potential shortcomings of this model. The level of cooperation by an individual is captured by an index reflecting the timely fulfillment of selected scheme requirements namely: financial obligations; labor contributions; attending meetings; providing information about vandals and thefts; patrolling infrastructure and contributing materials for repair and construction. The results

demonstrate that some personal circumstances or characteristics lead to increased cooperation with group requirements, which enables continuity in conduct of scheme's business of producing and distributing electricity. Specifically, education and trust for peers are relevant catalysts for cooperation together with higher energy budgets and quantity of electricity allowance per household.

The second part uses choice models to assess if scores relating to the quality of institutional arrangements; observed cooperation and other relevant conditions cited in the literature of CPR governance can be linked to the outcome observed in a scheme (defined as: successfully managed meaning it has not collapsed or unsuccessfully managed meaning it has collapsed). Better quality of the local institutional arrangements in a scheme in this case comprises of: having cheap justice; accountable leaders; matching electricity use to generation; adjusting rules to reflect new developments and ease of enforcing rules. After confirming that suspected endogeneity between the observed outcome and institutional quality or cooperation ratings does not exist in the data, the results of the ordinary logit (or even probit) model show that there are certain conditions that can lead to increased chance of survival of village micro hydro grids. Higher scores on both cooperation and institutional arrangements lead to higher probability of observing a successfully run micro hydro scheme which survives collapse. Therefore, ensuring that the individual components of each of these two indicators are entrenched would lead to schemes remaining operational in the long term. As a result of schemes surviving collapse, some benefits identified later in paper three would continuously accrue to the households connected to such schemes. Other things that must be insisted on in such local RE schemes include: having very clear boundary defining who can use the electricity from the scheme; installing more generation capacity (bigger projects) and increasing group membership which makes it easy to pool the required capital. There is also an implication that higher inequality among participants of a micro hydro scheme is not a risk but an attractive condition that can lead to higher chances of a scheme survival. There is therefore no need to worry about problems like elite capture within community micro hydro grid schemes.

Paper three is dedicated to obtaining evidence for some of the hypothesized impacts of adopting RE micro grids for rural electrification. These include but are not limited to: additional hours of light; mobile telephone utilization and kerosene use in rural households. Here, matching estimators are used to isolate treatment effects by using connected and unconnected households that have comparable set of characteristics as summarized by a propensity score. The study limits itself to five specific impacts of electrification namely: physical kerosene consumed per month; night light hours utilized; duration of night study time by schooling children; monthly kerosene expenditure share in the household budget; monthly expenses for charging mobile phones and number of hours of radio utilization. Two matching methods (Kernel and Nearest Neighbor) are used based on their efficiency-bias trade-off properties. Robustness checks for the assumption of the matching model reveal that the average treatment effects estimated are reliable. There is a significant difference approximated at 1.5 liters in the physical consumption of kerosene between connected and non-connected households, and the implication is that bigger projects delivering more reliable and

higher amounts of electricity to the households can eliminate the use of kerosene. There is a small but significant saving of about 0.92USD in the monthly expenditure on charging cellphone batteries with connected households spending almost nothing on the same. It therefore means that connected households can charge their mobile phones at home free of charge, while those without connection must seek for the same service elsewhere at a fee. The importance of having a usable mobile phone is very important in rural life, ranging from access of market information to mobile money transfer service access. The convenience of not having to travel or pay to charge a mobile phone is a great improvement for connected households. The study also finds a counter effect of decreased period of night study time by schooling children in connected households, attributed to pre-occupation with electricity aided entertainment like mobile phone games and television. Although evening study period is important for improved education outcomes, further analysis of other educational attainment indicators is recommended.

The results from the three studies have several policy implications that could ensure wider adoption and sustained use of community-based micro hydro grids in Kenya. Firstly, bringing back community RE micro grid into the regulation pool (all of them currently fall outside the regulation bracket since their installed capacity is short of the 1MW threshold for permit application) will ensure provision of quality energy service, that meets the expectations of the participants. Assessment of the households' electricity demand and service preferences should form one of the preliminary requirements in the permit application for micro hydro development, so that service delivery is aligned to those preferences. The Energy Regulatory Commission is already doing this for larger and medium scale RE projects and it is easy to accommodate community-based electrification schemes. Additionally, incentives for investing in higher installed capacity should be provided at the foundation stages of every scheme. Households can then receive the much-desired higher quantity of electricity that can be applied to more uses as seen from the preferences assessment. Such incentives include technology and financial capital subsidy, since schemes avoid bigger capacities to avoid the massive initial technical and financial demands of such investments. There seems to be reasonable willingness to pay for a service delivering higher amounts of electricity by the households in our study, meaning that the planned monthly flat rate fee can be revised upwards if a project provides electricity that has no use restrictions to the households. There is also need to assist such communities with technical expertise for determining the optimal monthly tariff for even the limited service that may be offered, because the willingness to pay for limited electricity categories is less than the charges for those services prevailing in the field. Consumers also prefer a community owned enterprise over a private one, implying that community owned schemes should be promoted as opposed to encouraging takeover of local micro hydro resources by private entities. There is growing frustration with the monopolistic services of the main utility companies in Kenya due to extreme outages and inaccurate billing, which could explain the desire for alternative electricity service provider expressed here.

Chapter three implies a clear need for continuously educating members of micro hydro schemes on the importance of fulfilling their personal obligations to keep the scheme operational. Members participating in such schemes need to

be educated on the large opportunity presented by micro hydro grids in meeting household primary electricity demand while not having to rely on the national grid. This is particularly important where members have lower levels of formal education achievements, because they lack exposure to the discussion around the importance of adopting renewable energy as a climate change mitigation strategy. Trust fostering activities within schemes should also be facilitated by social workers, because individual cooperation with scheme rules is higher when they have trust in their peers. Overcoming the governance crisis witnessed in many collapsed schemes could be achieved by facilitating group exchange visits to successfully managed schemes to allow failures to learn from achievers. Learning about effective institutional arrangements from surviving schemes and adapting them to local conditions is particularly useful for upcoming schemes. To facilitate early learning, a national association of community-based micro hydro grid operators could be formalized given that community-based RE micro grids have emerged in other areas outside the study region. Larger projects with higher installed capacity should be encouraged, since they seem to be more likely to remain operational. The findings in chapter five imply that community-based micro hydro grids are important solutions to energy access problem, and they should be given both financial, technical and social support to sustain their operations. Eliminating the use of kerosene use in lighting which is responsible for some health complications can be done through recognizing community micro grids as a form of rural electrification, and according them the necessary regulatory, technical and even social support. There should also be other supportive programs in areas where micro hydro grids are deployed to support realization of targeted goals. One such program is time management for schooling children to ensure that electricity-aided entertainment does not replace evening study activities. Training on home-based enterprises that are made possible by availability of convenient lighting could also lead generation of extra income for households.

Effectively, this study generates new evidence with respect to service preferences as well as impacts of micro hydro electricity service among rural households in a developing country. Points of intervention towards overcoming management failures in micro hydro schemes are established, thereby providing a basis for policy considerations in either regulation or extending support to community-based renewable energy schemes.

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Dedication

This thesis is dedicated to my parents; George and Lydia (RIP) who taught me persistence from day one, and my children George and Faith whose curiosity about my education kept me going every minute.

Dear Mum, you left earlier than I ever thought.

Acronyms and Abbreviations

AVC - Asymptotic Variance Covariance Matrix

ATT - Average Treatment on Treated

CBMHS - Community-based Micro Hydro Schemes

CIDPs - County Integrated Development Plans

CL- Conditional Logit

CPR - Common Property Resources

CPNR - Common Pool Natural Resources

CRES - Community Renewable Energy Schemes

ERC - Energy Regulatory Commission

GVEP - Global Village Enterprise Partnership

IEA - International Energy Agency

IIA – Independence of Irrelevant Alternatives

IID - Independently and Identically Distributed

KMO - Keiser Meyer Olkin

kW- Kilowatt

MEP - Ministry of Energy and Petroleum

MNL - Multinomial Logit

MW - Megawatt

MWTP - Marginal Willingness to Pay

NGO-Non-Governmental Organization

NN - Nearest Neighbor

OECD - Organization for Economic Cooperation and Development

PPPs- Public Private Partnerships

PCA - Principal Component Analysis

PSM - Propensity Score Matching

RE - Renewable Energy

REA - Rural Electrification Authority

RCT - Randomized Control Trial

RPL - Random Parameter Logit

SDGs - Sustainable Development Goals

SED - Social Economic and Demographic

SHS - Solar Home Systems

SSA - Sub Saharan Africa

UNIDO - United Nations Industrial Development Organization

USD - United States Dollar

WTP - Willingness to Pay

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1 Introduction

Access to modern and affordable energy services like electricity is a requirement for the achievement of each of the 17 Sustainable Development Goals (SDGs). Latest estimates from IEA (2016) (see table 2 in Appendix 1) indicate that Sub-Sahara Africa (SSA) nations have the least electrification rates in the world, with only 35 per cent of the households having electricity connection. The health, socio-economic and environmental challenges associated with lack of electricity access are likely to be most serious in rural SSA, since only 19 per cent of households have access to electricity here (IEA, 2016). There exists a persistent inequality in rural-urban electricity access, which has led to massive investment in rural electrification programs through mainly through extension of the national grid. However, Yadoo and Cruickshank (2012) observe that although most countries rely on national grid extension for rural electrification, it is in some instances inconsistent with conditions prevailing in some places. The vastly spread low income households imply high marginal costs of extending and maintaining the grid. This is because rural households mostly consist of low income households, with very small loads or demand for electricity. The use of electricity in rural households is usually limited to lighting and powering small devices, with wood remaining the dedicated fuel for the more energy intensive activities of cooking and heating (Kebede et al., 2010). This has meant that most households remain without electricity access even after years of investing in rural electrification, a phenomenon described by Lee et al. (2015) as living 'under the grid'. Birol (2007) calls for scholars to direct more research efforts towards workable solutions to the problem of energy poverty in deprived societies mostly found in SSA and South Asia.

One such strategy has been a change of focus from grid-based electrification solutions to the use of off grid renewable energy (RE) microgrids[1] (Deichmann et al., 2011; Yadoo and Cruickshank, 2012; Schnitzer et al., 2014; PracticalAction, 2016). This has been motivated by the ability of microgrids to overcome the poor economics and sustainability issues in disfavor of more conventional electrification strategy (grid extension). The developments in climate change mitigation and adaptation discourses discourage the use of fossil fuel dependent technologies, and instead recommends the utilization of carbon neutral approaches in expanding access to modern energy services. Subsequent to this proposition, Palit and Chaurey (2011); Schnitzer et al. (2014) note that although microgrids may deliver a service that is slightly inferior to the grid, they meet the energy needs of rural population who have been observed to largely under-utilize grid facilities in most instances of grid-based electrification. According to Kebede et al. (2010), SSA is endowed with abundant renewable energy resources and adoption of RE microgrids can serve a large proportion of rural households with affordable primary energy needs. Technological developments now permit grid and decentralized RE systems to work side by side according to Urpelainen (2014), thereby eliminating the technological lock in that had previously led to the two systems (stand-alone microgrids and grid) being viewed as

[1] For the purposes of this study we adopt the definition by Schnitzer et al. (2014); Williams et al. (2015). A microgrid is a distributed system of local energy generation, transmission, and use

competitors and not complements. However, there exist multiple barriers to widespread adoption and use of RE microgrids for rural electrification in developing countries (Painuly, 2001; Walker, 2008; Ahlborg and Hammar, 2014; Schnitzer et al., 2014). Such impediments include: technology determination; financing difficulties; technology acceptance and other socio-economic and institutional factors. After calls by Birol (2007), research into the underlying causes of such barriers is crucial towards generating new knowledge and workable solutions than can accelerate the deployment of such alternatives in rural areas.

Scholarly work on rural electrification is directed towards investigating the causes, consequences and potential solutions to each of these barriers. Thiam (2010); Hafez and Bhattacharya (2012); Blum et al. (2013); Sen and Bhattacharyya (2014) among others address some technical and economic aspects by determining the optimal RE mix in microgrids, thereby giving the types of investments that may be incorporated in a project to deliver the expected electricity service. The outcome from such studies generally indicate that viability of microgrids depends on the demand and availability of an optimal mix of RE resources to deliver competitive services. Just like technical and economic viability concerns, the financing models for investments in microgrids have received considerable attention (Mainali and Silveira, 2011; Bhattacharyya, 2013) with a focus turning to methods of bridging the financial gaps amid declining donor and state funding. What has emerged here is that profit motive that has been used as a criterion for investment in the energy sector may not be met in cases of microgrids serving rural communities. As a result, capital is not recoverable meaning that conventional financing models are not ideal. Public-Private Partnerships, non-governmental organization (NGOs)funding, cooperative or even community-based models have been proposed as alternative capital mobilization models (Yadoo and Cruickshank, 2010; Nepal, 2012; Blum et al., 2013). Cooperative and Community-based models derive their motivation from the literature of participatory development and Sen's Capability Approach, and it involves mobilization of resources locally to address a development challenge facing the local community. Many governments in developing countries have laws permitting communities to participate in generation of electricity for both local use or even for sale to other entities (Maher et al., 2003; Greacen, 2004; Maier, 2007; MEP, 2015). It is important to note that each delivery model has its own specific barriers whether or not the technical and economic merits have been met, therefore widening the demand for knowledge on how to overcome all impediments to deployment of microgrids for rural electrification.

Generally, recent research tends to focus on supply-side barriers to microgrid deployment surrounding technological feasibility and economic viability because of the traditional approach of emphasis on cost recovery (for instance: Williams et al, 2015; Blum et al, 2013; Ngan and Tan, 2012; Manuswamy et al, 2011; Casillus and Kammen, 2011 among others). Although this is very important, our view is that it is equally important to address other additional issues outside this domain because they can lead to failure of projects which have met those two criteria. Painuly (2001) general framework of barriers to RE penetration highlights some demand-side issues critical to the dispatch of off grid RE rural electrification that deserve equal attention like technical considerations. Firstly, Hirmer and Guthrie (2016)

acknowledges that empirical work rarely examines value that rural poor households have for an energy service, yet this category of consumers has expectations like the upper bound urban consumers that research tends to emphasize on. The consequence of this trend in literature is lack of consideration for the target consumer's preferences in national and local rural electrification plans (see Birol (2007); PracticalAction (2016)). The expectations of consumers who are supplied with microgrid electrification are rarely sought, since the perception is that they will be satisfied with anything that gives them access to a previously unavailable electricity service. Good governance in energy delivery requires that these expectations must be incorporated in potential electrification plan, as a step to finding relevant solutions for rural population (Bazilian et al., 2014). Scholarly work from different disciplines has attempted to establish the value that target consumers have for an energy service by using various approaches. Hirmer and Cruickshank (2014); Hirmer and Guthrie (2016) and others follow the 'user value approach' to identify the perceived value of energy projects by consumers. Such studies yield a general scope of identifying what is useful to users in an electrification project, ranging from technical to social value. One drawback of this approach is that it does not allow us to quantify such values in a way that can make them useful for further applications like comparison across a set of consumers or technologies, setting the price for energy services, or even estimating the complete set of costs and benefits of electrification projects. The other approach to establishing such value exists in economics and marketing literature, where preference-based approaches that incorporate quantifiable costs of the preferred properties of a service are included as part of value elicitation process (Bergmann et al., 2006; Carlsson and Martinsson, 2008; Abdullah and Mariel, 2010; Gunatilake et al., 2012)). Although such studies are potentially useful, they have largely limited themselves to eliciting preferences for grid relevant attributes. According to Palit and Chaurey (2011) RE microgrid electrification is potentially different from grid services in many ways ranging from the amount of available power to location of generation and distribution facilities. The ownership of grid service in most developing countries is largely vested in public utility monopolies with some privatization and unbundling of services having taken place recently. However, there are now many ownership models, away from single utilities, particularly when it comes to decentralized microgrids. This means that studies based on grid service attributes may not be very informative at inferring the service preferences or expectations of RE microgrid consumers. Hirmer and Cruickshank (2014) also notes that perceived value varies across populations, type of energy resource and circumstances, further raising the demand for case studies to produce relevant solutions. The bottom line regarding this first issue is that a mismatch between characteristics of a delivered microgrid service and preference of the consumer is a potential barrier to survival of such rural electrification initiatives (Hirmer and Guthrie, 2016). Methodologically, the empirical process of establishing such preferences should adopt new developments surrounding preference-elicitation process such as those proposed by Bliemer and Rose (2011) in order to increase the reliability of estimated parameters which convey information about such preferences.

Community-based RE microgrids [2] model highlighted earlier on involves resource mobilization by a group of individuals residing in proximity to a RE resource, who jointly invest in a microgrid generation and distribution infrastructure for purposes of providing themselves with electricity services. Governments in developing countries like Kenya introduced this concept in rural areas by partnering with donors, to set up demonstration projects to enable take up RE microgrids for electrification. The motivation for such initiatives in developing countries is for the participating consumers to provide themselves with primary energy needs, using climate change consistent strategies. Other developmental reasons for emergence of such models of rural electrification include: self-empowerment; increasing technology acceptance and local development control through increased participation by those benefiting from such investments (Walker, 2008). Notably, such models of rural electrification face specific governance challenges due to increased space for local participation (Yadoo et al., 2011; Ferrer-Mart´ı et al., 2012). Greacen (2004) cites common pool problems associated with the use of prohibited electric appliances and the limited capacity often installed in community-based microgrids. Although they argue that technology can solve such problems, the responsibility of ensuring the safety and maintenance of such technology requires collective action by the participants that cannot be guaranteed in every group. However, Greacen (2004) and Maier (2007) note that even if such problems are very often observed in the implementation of RE microgrid projects supported by governments or non-governmental agents, the resolution for the same is largely left to the concerned communities who have no guidelines or prior experiences on approaching such issues. The consequence is recurrent failures that culminate into systemic collapse of the technical and social functions in many schemes. For instance, in a survey of hydro-based microgrids in Malaysian communities, Murni et al. (2013) observes persistent failure by participating households to cooperate with power limits as well as late bill payments as real non-technical setback to sustained operation of micro hydro schemes. There is a recurrent view in literature that since community-based models are encouraged by governments as an alternative way of raising the scarce capital, there is need for the state to support local level institutional capacity to deal with social problems accompanying this alternative model (Nepal, 2012). Attaining self-governance and high levels of participation in development of local energy infrastructure will require wider academic investigations which are still ongoing.

Published literature in energy governance is now emerging (Florini and Sovacool, 2009; Parag et al., 2013 & Goldthau, 2014), and the recurrent theme from this discussion is that energy infrastructure has characteristics of common pool goods. The focus of such studies is larger infrastructure such as cross-national grids within regional power pools, and their objective is to find national level protocols that are effective in management of such capital. However, a closer look at small scale electricity infrastructure such as community-based microgrids in village energy projects manifests similar problems. Greacen (2004); Maier (2007) and Gollwitzer (2014) provide such experiences among communities

[2] Throughout this text, the term community-based microgrid is used to refer to a distributed system of village level RE electricity generation, transmission and use owned by the local community.

in different countries citing issues like: infrastructure over use; withholding labor and other material contributions; temptation to free ride and poor leadership which undermine the long-term sustainability of such development projects. These same issues are highlighted by Florini and Sovacool (2009) as afflicting energy systems, albeit in the context of global energy systems. Theoretical and empirical studies in the literature of common pool resource (CPR) governance Wade (1987); Ostrom (1990); Poteete and Ostrom (2004) has widely investigated conditions associated with successful governance of common pool natural resources (CPNR) like: fisheries, forests and grazing lands. The result from such undertakings is a list of measures that can be taken to mitigate governance problems in communities participating in managing such natural resources. Notably, the same framework used in the study of natural resources (as a socio-ecological entity) can be extended to the study of governance in man-made resources exhibiting characteristics of common pool goods. Empirical work adopting this approach exists for irrigation schemes (Fujiie et al., 2005; Muchara et al., 2014), where field data has been used to link some set of governance conditions to the observed outcomes in groups of irrigation water users. Kirubi et al. (2009) calls for related investigations as a basis for understanding the motivation for individual participation in such groups as well as solution seeking for local governance problems facing community-based microgrids. Studies that have attempted to fulfill such an empirical obligation remain largely descriptive in nature (Greacen, 2004; Maier, 2007; Gollwitzer, 2014), with no attempt to link the governance indicators or level of participation to the observed outcomes in microgrid communities. This means that there is not only inadequate understanding to the dynamics regarding conditions for small scale energy governance, but also lack of entry points for intervening community mobilization programs to ensure smooth conduct of business in this type of rural electrification alternatives. This literature would therefore benefit from the current study, where we seek to establish the individual characteristics linked to observed scale of cooperation as well the predictive conditions for well governed schemes that sustain the intended function of generation and transmitting electricity to the member households.

Thirdly, the decision by any individual in a community to participate in a community electrification project relies on the conviction that such an investment carries some positive potential changes to his household. Allocation of scarce capital resources is also dependent on accounting for an investment's ability to meet the expected electrification goals (Bernard, 2010), that are normally a subset of wider development goals like the SDGs. For purposes of influencing investment into community owned renewable energy microgrids or convincing households to enlist for such undertakings, there is a need to have evidence linking community microgrids to specific aspects of lives of their beneficiaries. Scholarly attempts to quantify the benefits of community microgrids mostly rely on observation of the beneficiaries after electrification (Kirubi et al.,2009; Komatsu et al., 2011; Ferrer-Mart´ı et al., 2012). However, failure to control for initial conditions or other simultaneous influences may lead to potential bias in the claimed impacts (Rubin, 1974; Caliendo and Kopeinig, 2008). Such analysis may not be reliable, creating room for further research that can attribute some impacts to the presence of microgrid electrification only. The estimates produced by such an

analysis may then be credible for other uses such as making choices between potential electrification strategies in future projects, or helping consumers to understand their gains from such investments.

As a result, the greatest empirical challenge in providing such evidence lies in isolating the welfare changes attributable to electricity, from the influences of other extraneous changes that may be taking place in a community or households in the duration of electrification. There are studies in rural electrification literature that have overcome this challenge by applying quasi experimental and econometric approaches that allow such impacts to be isolated (Dinkelman, 2011; Bensch et al., 2011; Khandker et al., 2012, 2013). The evidence they have put forward is however based on grid electricity connectivity. Terrado et al. (2008); Palit and Chaurey (2011) indicate that grid-based electricity may be of potentially different quantity and/or quality from microgrid electricity. The uses to which microgrid electricity can be put within households may be limited to basic needs such as extended lighting and charging communication devices, which in our view are still very important for rural households. Furthermore, recent observations suggest that potential impact of rural electrification varies across environments due to differences in prevailing or initial conditions (Matinga and Annegarn, 2013). A claim of impact in one instance may not hold for another location that is fundamentally different in terms of geographical, economic or social aspects like it happens in most developing countries. This creates a need for more context-based case studies, particularly in SSA where uptake of community-based microgrid is expected to play a large role in enabling access to more affordable electricity. In furtherance of this literature, this thesis devotes a chapter to interrogating the differences between households that are connected to community micro hydro electricity source and those that do not have any access to electricity. There is focus on immediate benefits such as utilization of extended light hours in the evening and expenditure on energy items in the households, which tell us how households are likely to change immediately after electrification. The use of matching techniques by this study overcomes the limitation of past studies that do not isolate the extraneous effects on their impact of interest.

Collectively, this thesis contributes to the general literature of rural electrification by carrying out an empirical analysis of the three issues that are potential barriers of microgrid electrification namely: service preferences; governance of microgrids communities and doubts of potential impacts from micro grid investments. A case study of community owned micro[3] hydro grids in Kenya is used because of the relevance of the rural electrification challenge in this particular environment, and the potential that such alternative models have in increasing access to modern energy. This study adopts theoretical approaches in the study of: non-market valuation; community natural resource management and general impact evaluation to gain evidence for possible policies and strategies that can overcome

[3] Klunne (2013) classifications of the installed capacity of small scale hydro as follows: pico hydro($< 10kW$);micro hydro($< 300kW$); mini hydro($< 1MW$); small hydro, and the schemes considered for this study have a range of installed capacity ranging from 5kW to 300 kW.

barriers to wider adoption of community RE microgrids for rural electrification. This is done through three objectives listed in the next section.

Although rural electrification has been carried out since 1970s in the Republic of Kenya, only a paltry 7 per cent of rural population has access to electricity (refer to Table 2 in the Appendix). Kenya has abundant renewable energy resources like solar, wind and hydro which can be utilized in the deployment of renewable energy microgrid rural electrification. The policy emphasis on grid extension combined with lack of guidelines on addressing the barriers highlighted above has led to persistent failure in community owned microgrids in Kenya (see MEP (2015); PracticalAction (2016)). PracticalAction (2016) additionally notes that the energy needs of vast rural population are rarely incorporated in national electrification plans, due to over-emphasis on the top-bottom approach that guides grid extension. There is a concern here of rampant poor governance and lack of adequate cooperation among participants, which is very crucial for sustaining community owned microgrids but is not given equal importance like technical and financing barriers. The analysis of these issues in the current study seeks to provide literature with some evidence of some claims made before, while providing policy makers with necessary adjustments to the energy policy and regulations. This will be organized around three objectives as follows:

1.1 Objectives of the study

The aforementioned gaps in both literature and policy relating to rural electrification are addressed through three broad objectives as follows:

1. To analyze consumer preferences for attributes of micro hydro electricity in Kenya
2. To establish the necessary conditions associated with successful self-governance in community micro hydro electricity schemes in Kenya
3. To estimate the impacts of micro hydro connectivity on selected indicators of household welfare in Kenya

1.2 Contribution of the Thesis

This thesis belongs to the literature of rural electrification, and uses a case study of a country with potential for RE (micro hydro) electricity for the study of issues preventing accelerated adoption of such initiatives for rural electrification. The overall contributions to literature are: providing evidence for some of the consumer expectations regarding microgrid electricity service; revealing governance requirements for community electrification projects and providing evidence for immediate impacts of community microgrid initiatives. These are issues that past studies have not adequately addressed. Because the current study uses data-based estimations, further contribution is that the

outputs from this study are amenable to further analysis of microgrid investment decisions which could not be obtained from previous literature. Specifically, the contribution follows 3 sub-branches of the literature concerning the issues under investigation. Firstly, this study departs from the past literature of studying electricity service preference through grid-relevant attributes by including characteristics that are relevant to off grid RE options. An application of efficient experimental design is adopted for generating information for preference elicitation, contrary to past studies that use orthogonal designs which are not linked to the estimation models applied on the data generated from the field. The use of optimal experimental designs provides literature with more reliable estimates for consumer preferences and the cost that they can accommodate to have what they prefer. In demonstrating the social governance requirements in community-based RE microgrids, this thesis expands the literature of governing CPRs by delivering analysis of the typical requirements for achieving self-governance in a community of microgrids. An empirical link between such requirements and the observed outcomes in the field is created by this study, leading to an improvement from the largely descriptive studies that attempt to describe the governance problems in community level microgrids. Commonly cited problems of establishing such direct links emanating from endogeneity of variables is also addressed, ensuring reliability of the implied relationships between conditions for achieving cooperation or successful governance in energy commons. Lastly, we adopt an empirical approach that allows a claim to be made of the impact of small scale RE electrification interventions on welfare of households. This overcomes the potential bias from simple comparisons provided by previous studies that have attempted to demonstrate the impact of such, and providing reliable estimates that can be adopted for further analyses.

1.3 Context of the study and study sample

This study was conducted in micro hydro schemes located in four administrative Counties located in the Central part of the Republic of Kenya (Murang'a, Nyeri, Kirinyaga and Meru) within the Aberdares and Mt. Kenya water towers. Although resource survey for small hydro resource is ongoing, it is estimated by Maher et al. (2003) that Kenya has plenty of Micro and Pico hydro resource located across seven water towers namely: Aberdares; Mt. Kenya; Kerio; Nyambene; Kisii Highlands; Cherangany and Nandi Escarpment. Another estimate provided by the Ministry of Energy and Petroleum is 3000MW of a varying range of small scale hydro resource spread across 260 sites in the Kenya highlands, and only about 25 MW of this potential has been harnessed for any use (MEP, 2015). There exists adequate RE resources that can meet the energy needs of many households living in these Kenyan highlands, in an affordable and climate change-consistent electrification strategy. The Energy Act in Kenya which is under revision (now Energy Bill, 2016) allows private entities as well as groups of communities to exploit small hydro resources. Community-based renewable energy concept was introduced by the Government of Kenya in partnership with donors back in the year 2001, through the setup of two micro hydro demonstration projects in Meru and Kirinyaga Counties. The objective of this initiative was to make other communities emulate this example by setting up their own micro hydro schemes,

thus increasing renewable energy technology diffusion. It is important to note that the primary objective of a group of individuals forming such a group is to provide themselves with more affordable electricity for use in their households, motivated by the lack of connectivity to nation grid. Additional issue to note from the field is that demand for such initiatives is high even in areas with grid electrification, due to what rural consumers perceive as high grid power prices and service unreliability. Another motivation is the desire for self-empowerment, through use of locally available natural resources for local development initiatives, inspired by similar developments in agriculture, forestry and water sectors. While some projects are initiated without the support of government or external donors, others have received substantial financial and technical help from outside sources (local government development funds and external donors). What is common in all the projects is that there often seems to be a mismatch between the service that members anticipated and the end product that is delivered, with many consumers complaining about the quality of energy in addition to varying failures in collective governance within the schemes (GVEPinternational, 2014). The assumption in the initial demonstration projects was that members would be satisfied with any service delivered because they have no other source of alternating current electricity. Consumer expectations were subsequently not integrated in the initial project development stages. An assessment of such service expectations is one of the tasks in this thesis, to demonstrate that such lower bound group of electricity consumers have clear ideas regarding the type of service that can adequately satisfy their perceived needs.

Governance issues in the pioneer demonstration schemes were largely left to the beneficiary community, and did not form part of the main concern of the project development phases. This omission could have been due to excessive cooperation demonstrated by members during the initial stages of the project, driven by the urge to acquire a coveted service in their households. The idea of forming a group to exploit a local RE resource is usually initiated by a more informed (visionary) member of a community, who may then approach other members for promotion of the development initiative among the locals. Households who fall within the defined radius of the microgrid are then requested to join the scheme, subject to meeting all the proposed requirements like financial contribution as a form of expression of interest. Once such a group is formed with the intention of exploiting local micro hydro resource, members contribute allocated physical and in kind capital to the scheme in phases with strict timelines.

Some members who lose interest usually drop out across the initial phases of the project. Formal drafting of rules governing conduct within the group is continually done with modifications accompanying the progress of the project. A full set of both written and agreed upon by-laws will usually be complete by the time power generation and distribution begins, and each member assents to these rules prior to connection. The rules relate to various aspects ranging from financial, information and labor obligations, all meant to guide the day to day business in the group and sustain smooth provision of service within the microgrid. Only a subset of the original members who had expressed interest manage to meet sustain the resource demand, and they form the legitimate members of the scheme (secured by the locked in capital contribution). In the operational phase, it is apparent that a multiplicity of governance

problems emerge and the quality of regulations become more important in determining the fate of the scheme. Free-riding (shirking labor, financial and information obligations); power misuse; favoritism; poor leadership and other misconduct sets in during the operational phase of project leading to a collapse of many of these schemes. Collapse for the purpose of this study is marked by: halting of power generation indefinitely; neglected microgrid facility; stolen infrastructure and lack of direction as to how these problems should be addressed. Some few schemes escape such eventualities and continue to supply basic electricity services to their owners, and are the successfully managed cases for purposes of this study. The differences in member cooperation with the set rules or obligations and other scheme level institutional set up are suspected to be responsible for the differences in management outcomes observed across groups, and sources of such differences is among the interests of this thesis. Unlike in the energy enterprise models where investors can rely on the business returns to gauge the returns to a project, there exists almost no estimates of the energy savings or other welfare changes to the households connected to these micro hydro grids in Kenya. It is therefore hard to convince potential investors including local government agencies the importance of allocating financial/technical resources to such energy projects. Kenya now has a devolved government system, making the likelihood of financial support to such programs more likely due to reduced bureaucracy. However, these projects are often overlooked due to the belief that grid extension is the ideal solution to the energy problems facing these households. As stated before, some energy needs of rural households can be met from community-based renewable energy microgrids as acknowledged by MEP (2015). Such relevant issues regarding this model are not addressed by the current policy, perhaps because literature has rarely addressed them as well. It is the hope that the outcome in this thesis will produce useful guidelines that can fill the missing gaps in the implementation of the community ownership model of electricity generation and distribution.

The interest of this study was community-based micro hydro schemes in Kenya and the participating and non-participating households within the defined area of extension in those schemes. There did not exist any comprehensive official list of such community owned scheme for the entire country at the time of the survey for this study, or the households participating in it. The only available list of potential, currently functional and disintegrated community microgrid schemes was obtained from a list of micro hydro projects prepared by Global Village Energy Partnership (GVEP) International (see GVEP (2014)). For a particular micro hydro to qualify for this study under any of the three objectives, the installed capacity had to be less than 1 MW since this is the defined threshold of a community owned micro hydro activity in Kenya and also fits the technical definition of micro hydro in Klunne (2013).

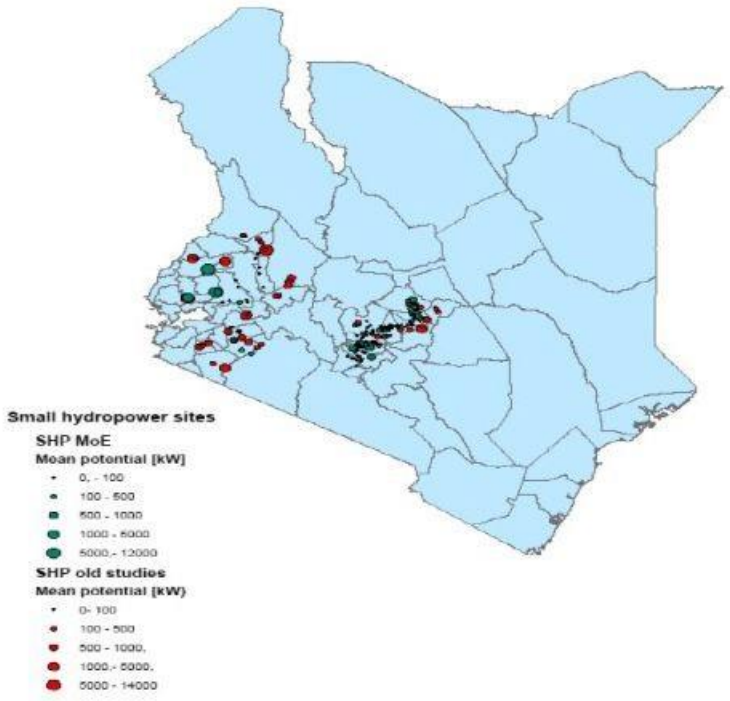
Table 1: Sample of Households in Community Micro Hydro Schemes used in Survey

County	Scheme name	total membership	per cent (1)	Interviews conducted	per cent (2)
Kirinyaga	Kiangima	76	7.3	17	4.6
Murang'a	Ngerechi	120	11.5	52	14
Murang'a	Ndiara	100	9.6	37	10
Kirinyaga	Thima	165	15.8	35	9.4
Nyeri	Kigwathi	25	2.4	7	1.8
Kirinyaga	Mungetha	60	5.7	23	6.2
Kirinyaga	Thimu	60	5.7	27	9.3
Kirinyaga	Rutui	35	3.3	14	3.7
Kirinyaga	Kathamba	50	4.8	24	6.5
Meru	Thingitho	350	33.6	133	36
Total	Total	1041	100	369	100

1-Proportion of members of micro hydro schemes who are members of that respective scheme
2-Proportion of members in our sample who come from that respective scheme

The study also limited itself to micro hydro schemes in four counties of Central Kenya (Nyeri, Kirinyaga, Murang'a and Meru). This region is indicated by the resource mapping in MEP (2015) as one of those endowed with high concentration of micro hydro sites in Kenya, and community owned micro hydro schemes that have been operational at one point in time are found in this region. It was explained earlier that this concentration is attributed to the fact that the pioneer community-based micro hydro scheme was set up by the government and donors in this region (Kirinyaga), which led to copying of the concept and technology by nearby communities. The names of the schemes that were visited for purposes of this study are listed in Table 1 above, together with their estimated membership. It is important to note that the list of member households in micro hydro schemes available in most of the instances was fairly inaccurate, and an adjustment had to be made in the field to reflect those inaccuracies; hence the over and under sampling observed in some of the cases. Random sampling was not the basis of this study, since the households or schemes of interest are only found in specific places limited by the geography of micro hydro resource, and the accepted technical radius of service for the electricity harnessed by such a scheme. It is therefore not everybody in a certain village who could be served by such a scheme, and subsequently become a potential respondent for this study. However once the target population was established for instance within a scheme, then random sampling techniques were employed to pick the households for interview at that level. The specific sampling procedure is discussed in each of the three independent papers (1, 2 and 3)

Figure 1: Micro hydro sites in Kenya



Source: Ministry of Energy and Petroleum -Kenya [MEP (2015)]

1.4 Organization of the Thesis

This thesis comprises five chapters the first of which introduces the issues of research interest, and study context. The next three chapters are devoted to three independent papers each analyzing a different aspect relating to rural electrification by use of renewable energy microgrids. The first paper (Chapter two) analyzes consumer preferences for a collection of microgrid electricity service attributes, identifying the characteristics of an acceptable service for consumers. This paper thus describes the properties of a microgrid electricity service that would meet the expectations of the participating households. Further, the monetary value that rural consumers would be willing to part with per month is also estimated, giving an indication of the prospective ranges of charges for a service comprising the desired properties. The next chapter borrows concepts of governance of common pool natural resources to study governance principles associated with favorable outcomes in management of micro hydro electricity schemes. Potential factors to explain individual cooperation are regressed against an index of self-reported cooperation with scheme rules in the first stage. Subsequently, a choice model is used to establish a link between the management outcomes observed in a scheme and some concepts of good governance of common pool resources borrowed from a list compiled by studies of natural CPRs. The fourth chapter uses quasi-experimental approach of matching techniques to compare households that are similar in all aspects but connectivity to micro hydro grid electricity. After various

tests to select the best matching technique, estimates are made of the differences in several indicators (energy spending, information access, kerosene consumption and education) between households utilizing micro hydro grid service and those without connection to any source of alternating current electricity. What follows is a series of tests for some of the assumptions made about the data applied for this estimation, to ensure robustness of the claimed impacts. The focus here is on short-term benefits that are thought to accrue to households almost as soon as they get connection to electricity, which are important indicators of an electrification investment's immediate effects. The last chapter presents a synthesis report where the findings from the three papers are reconciled to provide policy proposals pertaining to the implementation of RE microgrids in the context of study, as well as suggestions for areas of further research.

2 Paper 1: Consumer Willingness to pay for attributes of micro hydro electricity service

2.1 Introduction

The energy market in developing countries is distinct from that of developed world, with the former being characterized by a large population that is heavily reliant on dirty fuels (World Bank, 2017). This has negative implications on the welfare of this population namely: indoor air pollution; environmental degradation; fire risks and gender related inequalities. Electrification statistics show that all else given, these problems are likely to be more concentrated in the rural population as demonstrated by a marked rural-urban disparity in access rates for developing countries. According to IEA (2016) the world average electricity access rate in 2013 was 83 per cent with the urban population having a higher access rate (95 per cent) than the rural one (70 per cent). Africa had the lowest overall electricity access rate of 43 per cent with the widest disparity in urban-rural access rate (68 per cent of the urban population had access to electricity compared to only 26 per cent of their rural counterparts). Regional inequality is particularly huge given that Sub-Saharan Africa (SSA) has a rural electricity access rate of 17 per cent while North Africa region reports an impressive rural access rate of 99 per cent. Clearly, the problem of access to electricity service in the world lies in rural SSA.

There are mainly two approaches to rural electrification, with the most conventional means in Africa being extension of the national grid. However, the economics of grid extension in vast rural SSA coupled with other operational inefficiencies leads to access and affordability issues for rural households. Affordability of electricity by households in developing countries relates to not only connection but also power prices as observed by Winkler et al. (2011). Specifically, rural households in most SSA countries with access to electricity apply it for very light applications like lighting because they cannot afford the cost of intensive uses such as cooking. Such drawbacks, in the midst of abundant local renewable energy endowment has led to the consideration of decentralized renewable energy (RE)

microgrids. Off grid RE microgrids have become competitive alternatives for rural electrification as they have lower financial and environmental costs compared to main grid extensions or fossil-based solutions (Palit and Chaurey, 2011; Kaundinya et al.,2009; Williams et al.,2015). Since the use of locally available renewable energy may result in effectively cheaper energy, it could enable rural households to not only adopt but also increase their consumption of clean energy. However, Kumar et al. (2009 and United Nations Industrial Development Oorganiztion (2010) note that successful utilization of such small scale but potentially useful energy access solutions is highly limited in developing countries, due to many demand-side issues that empirical work has not addressed.

In electricity service provision, aspects such as the levels of reliability; affordability and quality of energy are important considerations that affect consumer's preference for a service. Unreliable, expensive or poor quality electricity may force some consumers back to the use of dirty fuel or lead to payment defaults especially if they feel helpless against a dominant service provider. Furthermore, although the main goal of electrification is provision of electricity service there are other important considerations if one is to deliver the true worth of this service to rural communities (Hirmer and Cruickshank, 2014). For instance, as Wustenhagen et al. (2007) notes generation and distribution in off grid RE electrification occurs adjacent to rural households in most of the cases. Subsequently, issues of local acceptability of technology, flexibility of provided service and even ownership of the electrification ventures form equally important considerations. Some motivating reasons for community ownership of RE ventures include: empowerment through income generating enterprise; development control through acceptable designs; local load management and cheaper energy prices (Walker, 2008). Inefficiencies associated with monopolistic utilities have also increased the motivation for communities to participate in local energy supply through use of renewable energy microgrids. Abdullah and Mariel (2010) found that rural consumers had a higher willingness to pay (WTP) for community provided electricity service compared to one provided by private or public utility service. Most empirical studies of consumer preferences for electricity service are largely limited to grid provided service (see Goett et al. 2000; Carlsson and Martinsson 2008; Abdullah and Mariel 2010; Gunatilake et al. 2012), creating a vacuum of knowledge with respect to consumer perceptions of attributes in other alternatives like off grid RE service. Experts in rural electrification have highlighted this discrepancy. Hirmer and Cruickshank (2014) note that there is a missing empirical assessment of end-user value of decentralized microgrid services which are now becoming popular alternatives in both developed and developing countries. The consequence is that developers of microgrids assume away some important features in the design of a project, because there is no evidence pointing to the consumer preferences in such a service. There is also a perception that such lower bound consumers will be satisfied with minimal standards due to lack of options. The consequence of such an omission is operational difficulties that come in later in the project's life, ultimately making it unsustainable for its life time. This is a real concern for some countries like Kenya where small scale local electrification projects are exempted from state regulation, giving rise to projects that deliver sub-standard services and shorter life than predicted. UNIDO (2010) estimates a 50 per cent failure rate of such projects in developing countries where many

electrification schemes were initiated for purposes of both home use and income generation through energy enterprise and technology demonstration initiatives. Empirical work examining some of the probable preferences would therefore be beneficial to overcome such omissions.

Two main approaches in electricity service literature have been adopted to obtain such information from consumers namely: revealed and stated preference approaches. The first approach involves inferring from some action that the consumer has taken in the past, how much she or he values a certain property of a service (see for example, Matsukawa and Fujii (1994); Kariuki and Allan (1996); Beenstock et al. (1997)). This approach requires an assumption that consumers will repeat their actions in the future, which may not be necessarily true. Access to ready data for such an analysis is usually not easy, particularly because it never captures the choices that the consumer had or left out. Additionally, this approach makes it impossible to study preferences for new aspects likely to be introduced in a service.

Under the second approach, the use of contingent valuation technique to assess consumer preference for a service like in Yoo and Kwak (2009) may not be suited for some specific uses. Assessing preferences for some goods or services needs the consumer to understand the properties of the goods he is buying or a service he might subscribe to. For contingent valuation, the consumer is asked to vote for single aspect of a service or a product, with less information regarding the simultaneous consequences of this choice on other useful but different characteristics of the good. It therefore becomes difficult to establish what really made the consumer make his choice, or which aspects of a service can be adjusted to match his/her expectations. This requires a different approach that can accommodate such possibilities. Discrete choice experiment permits the separation of a service into composite attributes, enabling one to identify what aspect of service drive the choices of a consumer. This also appears to be the state of the art technique in utility service studies like water (Henscher, et al., 2005 and Willis, Scarpa & Acult, 2005) and electricity (Carlsson and Martinsson, 2008; Abdullah and Mariel, 2010 among others). The limitations of studies adopting this superior approach is that they either concentrate on grid provided services (Abdullah and Mariel, 2010; Gunatilake et al., 2012) which are potentially different from microgrid service, or have been carried out in entirely different socio-economic and geographical regions making inference for purposes of off grid service outside those regions impossible. For example, empirical work on service preferences that uses samples from temperate conditions (Carlsson and Martinsson, 2008; Beenstock et al., 1998; Goett et al., 2000; Emmanouilides and Sgouromalli, 2013; Ozbafli et al., 2013) cannot be informative for populations facing tropical conditions due to extreme and non-seasonal demand for electricity services in the former. Different levels of income also limit consumer preferences for certain attributes of a service, so that what may be affordable by consumers in high income settings may be out of reach for majority of rural consumers in developing countries. Additionally, the fact that previous studies do not include attributes relating to limited electricity service means that one cannot infer if consumers would ever appreciate an off-grid service with such features yet this is a technical reality in small scale rural electrification projects. Previous electricity service

valuation studies such as Abdullah and Mariel (2010) and Gunatilake et al (2012), adopt orthogonal experimental designs. Bliemer and Rose (2011) demonstrates that such designs perform dismally in terms of the reliability and efficiency of estimates, and proposes alternative design that perform better on such parameters. The current study adopts optimal designs to overcome such limitations. Choice data collected from rural consumers of an off grid micro hydro service in a developing country is used to analyze consumer preference and willingness to pay for relevant attributes. This an extension to previous empirical work that emphasizes on grid-relevant attributes. The results will be potentially useful for electricity sub-sector regulators since they provide an insight into some of the preferred characteristics of a service that may act as a basis for setting service standards in the micro hydro grid business.

The Objectives of the Study

1. To establish relative importance of micro hydro electricity attributes to consumers
2. To estimate the marginal willingness to pay for desired attributes of micro hydro electricity service attributes

Contribution to literature

This paper contributes to the literature of rural electrification by establishing preferences of microgrid-relevant attributes among rural households, whose desires regarding off-grid electricity service are limitedly examined in literature. Some of the demand side considerations like service characteristic and affordability that should be made during design of renewable energy microgrids electrification are established, further providing a basis for similar exercise in future projects. This study departs from previous studies of electricity service preferences by adopting optimal experimental design to generate the preference elicitation scenarios. It has been demonstrated that this approach improves the estimated parameters since they come with smaller standard errors compared to those obtained from studies that use orthogonal designs. Thus, by providing literature with knowledge of the service expectations from consumers of RE microgrid electricity, the study supplies policy makers with some of the potential service standards that could be considered in regulation of such small-scale electrification projects.

Renewable energy micro grids and rural electrification

According to Goal 7 of the United Nation's Sustainable Development Goals, access to clean and affordable energy by all is a development challenge of the 21st century. Alternative interventions including RE microgrids have been proposed as part of the solution to increasing rural population's access to sustainable and affordable energy services. Although fuel-based microgrids have also been applied for this purpose (Kirubi et al.,2009), RE microgrids based on solar; hydro; wind and biomass are particularly superior alternatives due to zero fuel costs and lower environmental costs. This should translate into lower electricity costs in the long-term making them attractive for rural households who

mainly lack consistent income flows, and are therefore vulnerable to power price hikes emanating from fluctuations in global fuel prices. According to Williams et al. (2015) technology evolution has provided means of interconnecting RE microgrids to main grid sources, so that the two sources complement rather than compete with each other (see also Klunne (2013); Bracken et al. (2014)). This has changed the popular view that microgrids are only temporary solutions preceding main grid connections, and they are now classified as long-term electrification solutions.

There are several implementation models for RE microgrids with most of them operating independently of the national grid (Yadoo et al., 2011). State utilities, private entities or community ownership appear to be the three popular modes of investing in RE microgrids in literature. Public Private Partnerships are also being promoted in some countries like Rwanda, due to the realization that availability of resources and/or investment risk does not allow for purely state or private ownership of microgrids. Government's preoccupation with grid development has meant that financial resources are rarely available for small microgrid development, while donor funding remains largely inconsistent (Williams et al. (2015). This creates a room for private sector participation, which creates a conflict of interest between profit motive and provision of a social good. Community schemes have subsequently become popular and feasible models in developing countries, because they are more interested in self-provision of electricity service than profitability. Since regulators in some developing countries in Kenya are not very strict with the service standards in such self-help schemes, the usual practice is that schemes are constructed based on ad hoc or non-existent demand assessment. Subsequent gaps in expectations may lead to dissatisfaction with service and even eventual abandonment of schemes in some instances.

Electricity service provision by RE microgrids varies depending on the adopted model of delivery; available resource and the technology used. The experience in developing countries is that potential consumers are rarely consulted about their electricity service expectations, with the assumption that they will be satisfied with any service-level that is deemed by experts to be financially, economically or technically feasible. The reality in many of the cases is that local consumer expectations may depart from expert views. For instance, use of some resources may come with severely intermittent service which may not be tolerated by some customers. Furthermore, limitation of load to basic electricity use due to financial constraints like in many pico/micro hydro ventures leads to a service that is barely sufficient for most households. Elsewhere, state or private owned RE microgrids may not be received well by host communities due to lack of ownership. This may lead to insecurity of the infrastructure or resistance all together as observed by Adebayo et al. (2013). Field experiences have shown that wind turbines have been rejected due to fears of environmental changes by some communities, while limited load services are countered by illegal attempts to bypass the current limiters or system overload. Therefore, what might be technically or economically feasible from the supply side may not necessarily be appropriate from the demand side. Such incompatibilities are mainly observed in developing countries where RE microgrids are loosely regulated and implementation standards have not been well addressed. An

attempt to establish what is practically compatible service is made here through a case study of consumer preferences for attributes of a micro hydro grid service in Kenya.

Context

The current study was conducted in Mujwa village located in Meru County in the Republic of Kenya, a country which has been experimenting with RE microgrids. Specifically, community-based micro and pico hydro[4] grids have been on trial for last 12 years in several parts of Kenya. According to IEA (2016), 80 per cent of Kenya's population has no electricity connection in their households. The inequality of access pattern observed earlier on at the continental level is even worse in Kenya with rural population having an electrification rate of 7 per cent. Although electrification data is not available at the county level, the Kenya National Bureau of Statistics (KNBS) approximates[5] that 13.7 per cent of resident population in Meru County uses electricity for lighting while 77 per cent rely on kerosene. A huge disparity in rural-urban electricity access rate is also observed in this county with the urban access rate being 65 percentage points higher than the entire County average. In the vast rural setting, one observes what Lee et al. (2015) calls a rural population living 'under the grid' since there is minimal connection by households to grid electricity from central points like trading centers. These low and unequal access rate patterns have prevailed even though rural electrification efforts in Kenya have been in existence since 1973. Furthermore, there has been several changes in the electricity sub-sector to separate the generation, transmission, distribution and regulation functions in an attempt to increase the rate of electricity access. Field observation reveals that even grid-connected rural households limit electricity use to mainly lighting, phone charging and TV/Radio which can be performed by off-grid technologies like RE microgrids. This is because most rural households use cheaper firewood for the more intensive activity of cooking and heating. The role of small scale RE technologies like micro hydro has now acknowledged in the new energy policy and some County Integrated Development Plans (CIDPs).

Although Kenya's energy policy acknowledges the role that micro/pico hydro schemes play in providing cheaper and clean energy to rural households, there is little policy direction regarding implementation of the technology with fears that much regulation of the sector may scare away investors who are mainly communities. Plants with less than 1MW of installed capacity are not required to acquire a generation or transmission license, creating an initiative for exploitation of micro hydro resource by community groups living near them. The responsibility is left to community/owners to construct and maintain the plants within schemes, and this has led to informal and cheap services with respect to design, infrastructure, service delivery and tariffs (MEP, 2015). Because communities copy the technology from each other in addition to sharing general design and management models, managerial mistakes made in one scheme are usually replicated in others. Further, early Government/Donor driven demonstrations in

[4] Klunne (2013) classifications are adopted as follows: pico hydro ($< 10kW$); micro hydro ($< 300kW$); mini hydro ($< 1MW$); small hydro ($< 10MW$)

[5] These figures are based on computations done by KNBS using 2009 Kenya Population and Housing Census Data.

setting up micro hydro electricity schemes did not seek consumer opinion regarding expected or potential electricity uses or needs. The assumption here was that these rural consumers would accept whatever is given since they have no electricity in the first place. The result is that customer expectations were barely met in many schemes leading to frictions such as: violation of load limits; service outages, theft of infrastructure, safety issues, unsustainable charges and eventual collapse of electricity schemes.

Electricity sub-sector in Kenya is dominated by state-backed utilities and private companies (also known as independent power producers (IPPs)). Enlightenment and lessons from rural development projects and demonstration of community renewable energy concept by the state has generated intense desire for people to take charge of their own local development. In particular, there is a great desire by local communities to participate in renewable electricity supply resulting in establishment of many community microgrids producing power for own consumption. Although private entities have shown interest for developing and managing previously collapsed micro hydro schemes, the communities that owned them are adamant due to fear of losing control in decision making with a specific interest in tariff setting. Therefore, although public or private provision of microgrid services may seem to be economically convincing some local desires will not have been accommodated. This has important implications on scale up activity given that micro hydro resource is found in remote rural areas, where support and ownership by the community is crucial for both safety and sustainability of infrastructure. There are also other aspects that are related to consumer satisfaction with service at the household level.

The prevailing conditions of most micro hydro electricity service is an average 5 days of electricity outage per month each lasting approximately 12 hours; grid service outages in the nearest location was reported to be between 5- 7 days in a month lasting for 4-12 hours and this varies with transformer communities. The use of refurbished spare parts that break down easily and lack of expert information on the same is blamed for microgrid inefficiencies, while poor customer service by grid service provider is responsible for grid poor performance. The micro hydro grid that was the subject of this study has an installed capacity of 300 kW from the feasibility study but the actual installed capacity will be determined by financing success. Most schemes in this region have developed less capacity (ranging from 5-15 kW) than what is feasible due to poor financing, and the produced power has limited applications in the households defined in the scheme rules. The allowed appliances for use at the household level therefore vary from one microgrid scheme to another, and are entrenched in the scheme's by-laws. Micro hydro tariffs are set by owners to meet the maintenance costs, ranging between 150 to 250 Kenya shillings (1.5-2.5 USD) per month. On the other hand, the average electricity bill for a rural household applying grid (unlimited load) electricity for light uses like lighting, mobile charging and television is 500 Kenya shillings (5 USD). As is evident in the next section, consumers have different preferences and WTP for previously mentioned characteristics of electricity service. It is therefore hard to make inferences about a project in a developing country, using results obtained from developed country context.

2.2 Literature Review

Literature on the use of RE micro grids for rural electrification is currently concerned with technical aspects addressing the supply side of the service. These aspects include assessment of optimal and viable renewable energy mix plans to deliver adequate energy to the consumer (Sen and Bhattacharyya, 2014; Ngan and Tan, 2012). The general indication here is that using a single RE resource may not deliver adequate power for use in the household, due to uncertainty regarding the resource. One limitation with these studies is lack of prior information regarding the expectations and affordability of service by the target consumers. Alternative literature in provision of large utility service has dealt with such demand-side issues by interrogating consumer reactions to varying service levels. The expectation of this approach is that the answers to these questions can inform the design of microgrid services hence ensuring acceptability, sustainability and affordability of such projects. There is a variation in the type of aspects that have been studied and more importantly, the approaches that have been applied.

Reliability of electricity services is one such concern that has received immense attention from different disciplines. Within the context of power supply, reliability is described by Tinnium et al. (1994) as delivery of quality electricity to a consumer in an uninterruptible manner while at the same time ensuring that the cost of such a service is within acceptable limits. This term thus encompasses several aspects that the consumer or supplier may consider separately or jointly. Starting with service interruption, it is apparent that it is not practical to have a service devoid of any interruption (Kariuki and Allan, 1996). The issue of concern then becomes the tolerable or acceptable interruption rate depending on the cost implications on the consumer. Alongside this thinking, past activity therefore revolved around finding what is not tolerable to a consumer inferred from the incurred costs by a consumer to avoid such an interruption.

Early studies that attempted to estimate the costs of power outage to residential consumers thought of electricity as a means of facilitating leisure, and not as a means to facilitate productive activities in the households (Munasinghe, 1980). Leisure foregone as opposed to the domestic production forgone thus formed a basis for improving delivery of service. This view seems to have evolved alongside changes in development discourse, and electricity service was now considered as a basic need. The market-based estimation of the losses to households from power outages was adopted, whereby the costs that the consumer incurs to cope or mitigate outages is used as an approximation of the costs of foregone service (Kariuki and Allan, 1996; Matsukawa and Fujii, 1994; Beenstock et al., 1997), which can be used as basis for willingness to pay for better services. This approach is feasible if the researcher can observe what a consumer has done to cope or mitigate electricity service interruption. However, availability of the required data is a challenge since this approach does not allow a consumer to be indifferent or substitute other properties of service with interruption variables. This is however the reality in the field, where a majority of microgrid consumers in rural areas will only be able to connect to grid electricity in future and they do not therefore have any other backup electricity

sources at present. Specifically, rural microgrid consumers in Kenya invest in kerosene lamps and candles as backups which offer very poor services of incomparable convenience to electricity. Grid connection also requires substantial capital for most of these rural communities since they tend to be located in remote distances from the nearest point of grid access. Furthermore, looking at what a consumer has done in the past is backward-looking and doesn't guarantee the same will be replicated in the future. For these reasons, we do not consider revealed preference approach to be of much value in extracting consumer demand for certain attributes of electricity service for purposes of the current study.

Alternative consumer theory of stated preference has been adopted by few studies to infer the costs of service interruption, and this is done through stated preference techniques like contingent valuation or choice experiments. Contingent valuation is a survey based method that seeks to obtain in a direct manner, the amount that a consumer would pay for a particular good or service of interest. The method has been used in empirical work to establish consumer WTP for green attributes of electricity (Yoo and Kwak, 2009), and outage costs (Beenstock et al., 1998; Layton and Moeltner, 2005). However, applying the method limits one to a single aspect of electricity service which is not practical given that a consumer makes decision with many attributes in mind. Furthermore, the technique carries inherent biases that make the obtained WTP not very useful for policy making as demonstrated by Hausman (2012) among others. Specifically, Hanley et al (1998) cites 'yea saying' and 'part -whole 'biases which can be solved by introducing a trade-off tasks with several levels of the same product which is permissible in other techniques like choice experiments. The latter stated preference technique that is based on characteristics of goods theory (see Lancaster (1966)) and it appears to be a superior approach for studying the suitability of several attributes defining electricity service. Here, a product or a service can be broken up into different aspects/characteristics and by use of choice modeling the contribution of each characteristic to the consumer utility can be established (Manski, 1977; McFadden and Train, 2000). This approach has its own challenges the main one being hypothetical bias, and it behooves the researcher to adopt techniques that can reduce this bias as much as possible. Below is an overview of the outcomes produced by studies that adopted this approach, and their limitations which may be of use in the currently study.

Carlsson and Martinsson (2008) find that the estimated costs/inconvenience from outage of electricity service among Swedish households depends on: duration; timings and season of the year. The WTP to avoid outage increases with longer outage duration, weekend days and season of the year. Additionally, population characteristics may determine acceptable outages with city dwellers appearing to tolerate higher outages while older citizens detest outages than the average aged person (Carlsson and Martinsson, 2008). Consumers may also be more worried about outage in some seasons of the year as revealed by Ozbafli et al. (2013), making the timing attribute more important for such consumers facing temperate conditions. The samples in these two studies are drawn from developed countries and their expectations and ability to pay that cannot be compared to that rural households in developing countries. Furthermore, the willingness to pay to avoid outages may be generally higher in temperate than tropical conditions in

addition to the fact that incomes are not comparable between the two populations. Gunatilake et al. (2012) opine that timings of supply (defined as: 8 irregular hours; 12 hours; 18 hours and 24 hours of supply) are of more concern to consumers in India, where power outages are a common phenomenon. This is a unique feature in systems facing extreme stress in terms of either distribution network or installed capacity. The highest WTP in this particular study was recorded for 24 hours uninterrupted supply. This implies that consistency of electricity service is a major determinant of consumer's level of satisfaction and as Tinnium et al. (1994) highlights, if consumers cannot cope with outage plans of a service they will go for even more expensive alternatives. While studies from developed nations like Carlsson and Martinsson (2008); Ozbafli et al. (2013) are limited for our inference due to the differences in populations of survey, studies carried out in developing country (Gunatilake et al., 2012; Abdullah and Mariel,2010) comprise of users mainly connected to national grid supply. This means that those consumers face different socio-economic circumstances which sometimes inform grid electrification plans, and the priority of attributes among these consumers may also be different. Since the trade-off in attributes is responsible for the choices that we analyze, the results would not tell us much about our current service of interest (off-grid renewable service).

Consumers may possess the urge to change across service providers in liberalized markets or desire to have the presence of new players in the market where the market is highly concentrated. Electricity outages in developing countries like Kenya are particularly high due to inefficiencies of dominant utility firms. Introduction of competitors may be delayed if there is no knowledge of such a need in the market. Goett et al. (2000) demonstrates that the market responds positively to new products if they are designed to incorporate the preferences of the consumer. New entrants in the provision of electricity service must acquaint themselves with what the different end users desire, and design services that are acceptable to their target consumers. For instance, introduction of locally owned firms or private firms in power distribution in Kenya is a desired aspect by the consumers who attribute adverse service to single players in the market (Abdullah and Mariel, 2010). The possibility of having locally owned RE enterprises is real in remote rural villages, where low demand for electricity may be a disincentive to profit minded operators.

A central issue in choice surveys is the type of experimental design, due to the central role that it plays in generation of choice data. Orthogonal designs appear to be the most commonly used in applied work. Orthogonal designs aim at minimizing the correlation between the attributes so that multicollinearity is not a problem in the resultant model, and that separate effects of each attributes are estimable. Rose and Bliemer (2009) notes that for estimation purposes the data from the choice tasks is used and not that from the design. Additionally, several adjustments made to the design before the respondent is presented with respective choice tasks makes it hard to ensure that orthogonality property is maintained in the choice data. More important is the fact that orthogonality is only important for linear models, which are not relevant in the analysis of discrete choice data resulting from such an experimental design (Rose and Bliemer, 2009). Previous studies such as on the stated preferences for electricity service use versions of orthogonal designs (see Carlsson and Martinsson (2008); Abdullah and Mariel (2010); Gunatilake et al. (2012)), and

an improvement of this literature would involve using better designs. Efficient designs have been proposed as better alternatives than orthogonal designs by Yu et al. (2009); Bliemer and Rose (2010, 2011) because they yield better and efficient parameters. The former's approach seeks to minimize the standard error of the estimated parameters, through minimization of the determinant of Asymptotic Variance Co-variance (AVC) matrix and ensuring that reliable parameters are obtained from even smaller samples (Bliemer and Rose, 2011; Rose and Bliemer, 2013). Further, the reality of data collection is that respondents can only cope with a limited number of tasks and resource limitation dictating that one uses a practical (smaller) sample, but not compromising on the statistical properties of the estimates. While it is possible to control the two aspects to ensure efficiency in the case of optimal designs, the same is not possible with orthogonal designs and the researcher must resort to using other subjective rules. Other important aspects of good experimental design include avoidance of dominant alternatives in the tasks. Orthogonal designs do not always guarantee this aspect, because of the mathematical property of orthogonality that is imposed on the data and elimination of dominant cases may have to be done manually. This study departs from previous studies on stated preferences for electricity service attributes by adopting the now recommended efficient experimental design.

2.3 Methodology

Theoretical model

Choice experiments use two main building blocks (a) Lancaster's characteristic of goods theory and (b) random utility theory. The former states that an individual derives his utility from the attributes of a commodity he is consuming as opposed to merely consumption of the physical units of a good (Lancaster, 1966). A change in price can make the consumer change from one alternative to the other, due to higher utility from the combination of attributes. According to McFadden (1974) and Manski (1977), random utility theory suggests that by observing a consumer's choice we cannot tell all the predictors of his utility. Utility of a consumer i from alternative j U_{ij} is decomposed into systematic (which can be individual's characteristics and or attributes of a service) component V_{ij} and an observable (random) component ε_{ij} so that:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

The component ε_{ij} is responsible for the unobserved utility of an alternative. A rational consumer will only choose an alternative k over another one j all from a set C if he derives a higher utility from k compared to j. The probability of a consumer choosing alternative k over j all comprising of a set C can be expressed as:

$$p(k|C) = p[(U_{ik}) > (U_{ij})\forall k \neq j \quad (2)$$

This expression can also be expressed as:

$$p(k|C) = p[\left(V_{ik} - V_{ij}\right) > (\varepsilon_{ij} - \varepsilon_{ik})\forall k \neq j \quad (3)$$

In other words, a consumer will pick alternative k over j if the difference in the systematic utility of k and j exceeds the difference in the random utility of those two alternatives. The difference in the observed utility is attributed to the difference in the attributes of the alternative facing individual i, X_{ik} and her socioeconomic and demographic characteristics Z_i. The systematic part of the utility may now be redefined as linear in parameters:

$$V_{ik} = X_{ik}\gamma + Z_{ik}\delta$$

McFadden (1974) shows that a general logit framework can be used to analyze the consumer choice with the attributes of the service/good acting as the predictors.

$$p(j = k) = \frac{\exp(V_{ik})}{\sum \exp(V_{ij})} \quad (4)$$

The ratio of the coefficients of attribute j and the price can be used to recover the marginal WTP for that attribute. There have since been many theoretical advancements of this base model.

Empirical Model

Discrete choice survey exposes each individual to repeated choices comprising C alternatives, and he is instructed to choose the alternative that both suits his needs and is affordable to him. A consumer is therefore assumed to select an alternative if the combination of attributes of electricity service alternative yields the highest level of utility to him. The procedure for selecting the five attributes and their levels (See table 3 in appendix 1) is described in the next sub-section. Individual characteristics likely to influence the individual choice of alternatives like: years of schooling, income; gender and his or her household size were also included in data collection so that we have a total of m variables

that we observe in the field. The choice survey for this study included repeated choices so that the probability of a respondent picking an option in each time t is as expressed in equation 3 above.

If we assume a linear in parameters utility function, then following Carlsson and Martinsson (2008) and taking A to represent all observable data and $y_i - c_i$ as the extra monthly income that a consumer can afford to pay the energy bill; the components of utility can be expressed as:

$$U_{itk} = V_{itk} + \varepsilon_{itk} = \alpha_i' A_{itk} + \eta(y_i - c_i) + \varepsilon_{itk} \tag{5}$$

This allows us to obtain the marginal WTP as will be seen later. In the field data, α, η and ε are not observed and enter as stochastic terms. From the literature, ε_{itj} is independently and identically distributed (IID) type 1 extreme value over the individuals, rounds of choices and alternatives (McFadden, 1974; Hensher et al., 2005a). A general (multinomial/or conditional) logit model of the below form is then estimated via the maximum likelihood method.

$$p(j = k) = \frac{\exp(V_{itk})}{\sum \exp(V_{itj})} \tag{6}$$

where

$$V_{itk} = \eta bill_{itk} + \alpha_{attri} * attribute_i + \alpha_{indiv} * indivcharacteristics \tag{7}$$

Using this linear in parameters utility function, the marginal willingness to pay for attribute can be obtained by

$$\frac{\frac{\partial V_{itk}}{\partial attr_{tk}}}{\frac{\partial V_{itk}}{\partial bill_{tk}}} = \frac{\alpha_{attributei}}{\eta} \tag{8}$$

There is an extensive discussion in the literature about the shortcomings of the conditional logit model which makes it inferior for analysis of choice experiment data. Both multinomial and conditional logit models suffer from the restrictive assumption of IID error terms which does not allow for correlation of the error components of different alternatives leading to behavioral consequences of Independence of Irrelevant Alternatives (Hensher et al., 2005b). This means that the ratio of choice probabilities of two alternatives is unaffected by introduction of another attribute-based alternative to the choice set. This condition is too restrictive especially for discrete choice experiment data and may lead to over or under estimations of probabilities of choosing some alternatives. Furthermore, according to Cheng and Long (2007) the proposed test for violation of the IIA assumption may not be very helpful for applied work calling for alternative estimation strategies.

A more classical solution to this restrictive modeling is the use of a Mixed Logit Model, as explained in Hensher et al (2005b). This model is just like the conditional logit model discussed above, save for the fact that coefficients of the attributes or characteristics of the choice alternatives can vary across individuals (heterogeneity of preferences). The random parameter approach achieves this by introducing into α_i additional and stochastic components that may be correlated across alternatives and are heteroskedastic as follows:

$$\alpha_i = \vartheta + \gamma_i \tag{9}$$

where ϑ represents the population mean of the coefficient and γ_i is a random term whose distribution is dependent upon the n^{th} underlying parameter. For any γ_{ik}, the probability for choosing alternative k is still logit since the remnant error from equation 5 is IID. Thus, re-writing the utility equation gives:

$$U_{itk} = \vartheta A_{itk} + \gamma_i A_{itk} + \varepsilon_{itk} \tag{10}$$

thus with now A representing all the observed data. The conditional probability for choice k by individual i in time t now becomes:

$$prob_{ikt}(\alpha_i) = \frac{\exp(\alpha_i' a_{ikt})}{\sum \exp(\alpha_i' a_{ikt})} \tag{11}$$

This model is different from the conditional and multinomial logit in that there is an additional information we get from γ_i which influences the choice of an individual. According to Revelt and Train (1998) the unconditional probability of an individual's sequence of choices is obtained by integrating equation (10) over all α_{is} and weighting it by the probability density of α_i. This probability is now dependent upon the parameters defining the of distribution of α_i as follows:

$$prob_{ikt}(\alpha_i) = \int \frac{\exp(\alpha_i' a_{itk}}{\sum_k \exp(\alpha_i' a_{itk})} f(\alpha_i|\delta)\partial\alpha_i \tag{12}$$

where $f(\alpha_i|\delta)\partial\alpha_i$ is the density of α_i. Note that α_{is} represent each individual's tastes and we suspect that these tastes might vary across individuals. Therefore, the strategy will involve assuming certain values of ϑ and randomly drawing α from this distribution to calculate the probability of picking an alternative. The average of probability from this repetitive procedure is the simulated probability of person i_s choices and approximates the true probability with more repeated draws. Equation (12) is a ratio of two integrals meaning that the denominators cannot cancel out in the computation of the odds ratio of choosing an alternative. This therefore means that IIA is not implied in the mixed logit

model. The resultant coefficients are used to calculate the MWTP for the attributes using a different procedure[6] from equation (6) above if indeed this latter model is proven to fit the data well.

Experimental design

Key step in carrying out a choice experiment design is the determination of the attributes of concern and their levels. This study is concerned with the attributes of a micro hydroelectricity service and consultations with communities who have experiences with micro hydro power, as well as experts involved in construction and repair of the same were held in Kenya during the months of June and October, 2015. This is to ensure that the attributes and levels selected for the study are not only agreeable with sector literature, but more importantly resonate with local user considerations in addition to having the potential to influence policy in design of micro hydro electricity service in schemes. The five top attributes that resulted from this process were: monthly price to be paid for the service, the frequency of outage; the duration of an outage in hours; preferred service provider and the load quality in terms of what it can be used for at the household point. Selection of the levels for the attributes was done in consultation with the project planners or sourced from the project documentation (see table 3 in Appendix 1 for the levels). Further, the status quo levels provided in this study were obtained from the focus group discussions held in the early stages of the study. This is because offering a status quo with no attributes would mean that the respondents stay without any electricity service, and it does not reflect the correct position since there are other alternatives the consumers may get like grid electricity. The levels for status quo as shown in table 3 of the Appendix 1 follows : 5 days of outage in a month lasting for 12 hours each, private provision of service; and an unlimited power package. This study used generic alternatives (with no particular names attached to them) as an attempt to address the problem of 'yea saying' raised in section 2.2.

Once the attributes were identified, the next stage is the choice of an experimental design, since presenting the respondent with all the possible combinations of attributes is not practical. For this case, an efficient design was chosen due to its advantages highlighted in the previous sections. Constructing a D-efficient design requires use of prior values of parameters usually obtained from literature or a pilot study. Since we did not have a study that had included all the attributes of interest to our study, we used Bayesian-like priors with a basic Multinomial Logit Model to construct a design for a pilot study on some 22 respondents. This is usually a more practical option since using zero priors for the attributes suggests that we have a reasonable belief that coefficients of those attributes are zero, in which case conducting a survey would then be in vain. It was also important to block the design in order to obtain a practical

[6] This involves a process of simulation starting with an assumption regarding the distribution of the α_s and estimation of the probability of choosing an alternative. This is repeatedly done, and the average is taken as the choice probability. This also gives an estimate of the distribution parameter, δ

number of choice situations that the consumer must face. Choice experiment studies in a similar environment (see Abdullah and Mariel (2010); Otieno et al. (2011)) had respondents handling 4 choice rounds comfortably, and the same was adopted for this study (refer to an illustration of the choice card used in Figure 2 -Appendix 2). Ngene version 1.1.2 by Choicemetrics was used for generation of designs, and it was preferred due to the fact that it has a generalized platform that simultaneously accommodates most features of a good design. The objective is to get the least D-error while making sure that the scenarios make sense. The pilot design was then used to generate the choice situations for the pilot survey conducted on some 22 respondents who did not enter the main study. Subsequently, this pilot data was analyzed and the priors obtained were then used to generate the main design using the same algorithm.

Rose and Bliemer (2013) advice that contemporary sampling methods do not apply for stated choice experiments. Instead, efficiency measures that give an approximated minimum sample needed to estimate reliable parameters have been proposed in experimental design literature. These are important given the need to balance among the objectives of: obtaining significant parameters; using a manageable sample and giving rounds of choice tasks that will not lead to respondent fatigue. The S-estimate efficiency indicator available from the design platform that was used for this study indicated that a minimum sample size to get reliable parameter estimates was 50. A slightly more than double this amount of individual responses was collected to hedge for incomplete or inconsistent choices, ending up with 133 individuals choosing over 4 choice scenarios making a total of 532 effective choices for analysis.

Data collection and descriptive statistics

The target population for this study was households enlisted in a potential micro hydro power schemes in Kenya. There does not exist a comprehensive list of potential or working community micro hydro schemes in Kenya, because the government remains half committed to these projects. However, non-governmental agencies like Global Village Energy Partnership (GVEP) and Practical Action have published records of community micro hydro schemes emanating from their work which were utilized to identify an appropriate site for conducting this study. Overall, there were 12 potential projects at the time of conducting this study majority being within Mt. Kenya water tower. After careful consideration of factors such as the stage of project development; proposed generation capacity; sample size requirements, potential response rate and the attributes that were selected, the study settled on Mujwa Micro hydro power scheme in Meru County. The proposed site of the 300 kW project sits at $37^{\circ}\,42^{0}20^{00}6E\ and 0^{\circ}\,04^{0}27^{00}4S$ along River Thingitho, a perennial river flowing from the slopes of Mt. Kenya. The project is approximately 300 meters from another micro hydro power plant owned by Mujwa Catholic Mission scheme that has operated for an approximated 60 years. This scheme has approximately 350 members based on registration and records of attending regular meetings. From the official register, members were randomly picked and an impromptu visit conducted to their households using a village guide to identify the home of the selected person. After introduction and statement of the

intent of the research, the respondent (priority was given to the member[7] of the scheme) was left with one interviewer as the rest of the team moved on to the next household. Where a member was not available at the time of visit to his house, the spouse performed the choice task or another household would be picked as a replacement. Each respondent was slowly taken through four choice sets with three alternatives, and later on their socio-demographic information was solicited. A total of 135 interviews were conducted, with two being discarded due to respondent hostility. The realized sample is adequate given that the S-estimate measure of the design had indicated a minimum sample of 50 households (see Rose and Bliemer (2013) for more discussion on sample requirements for stated choice experiments). From the descriptive statistics in Table 4 of the Appendix, the mean age of the respondents is 50 years, majority of whom were males. More than half of the sample have attained primary or less education which is consistent with the national statistics. A majority of the respondents in the area are self-employed, working in their mixed farms and earning a self-reported mean income of 115 USDs per month. The latter is higher than the self-reported expenditure of 160 USDs, reflecting a common problem of conservative reporting of income by respondents. The monthly expenditure is used as the proxy for income because of two reasons: (a) it is most likely not be affected by seasonal fluctuations and therefore a favorable indicator of economic status of a household (b) it has lesser variance than income (note that there are households who reported zero income yet they have reasonable expenditure per month).

2.4 Data Analysis, Results and Discussion

The analysis is based on 532 (133*4) effective choices that 133 respondents made (n=133), with the choice of status quo alternative being avoided by all but two of the respondents (see analysis in Table 5 in Appendix 1).The experimental design used for this study provides combinations such that the respondent is forced to consider other combinations of the levels of attributes apart from what he is currently facing. There were less frequent and shorter durations in the other alternatives compared to the status quo distributed equally in the choice cards, and it is expected that reasonable consumers would seek to shift from the status quo to consider better deals. This is a potential explanation for the unpopularity of the status quo choice seen in the data.

The first step in the analysis of choice experiment models is the simple multinomial logit model (MNL), to get first impressions of the relationship between the attributes and the alternative picked (Hensher et al., 2005b). Table 6 in Appendix 1 comprises these results. An interaction term was included to check for the possibility of non-linear relationship between the attributes of outage duration and frequency, and a likelihood test showed that a model with interaction term is better than one without. While the socio-demographic variables were insignificant in predicting

[7] 'Member' here refers to the fact that the household had a person who was registered in the scheme. There was only one member per household registered in the scheme, and this was our preferred (first choice) respondent for the interview in the household. However, a spouse or another adult in the household who was familiar with the electricity service provision in the household was interviewed if our first priority (the person whose name appears in the scheme records) was not present at the time of visit to the household. Children were not interviewed in this study.

the individual's choices, the MNL suggests that individuals preferred alternatives with higher load (quantity)of electricity, community ownership and a higher cost (price) than the status quo (which had 25 watt electricity allowance and a price of Ksh 100 per month). The limitations of this model include the problematic IIA assumption, and the fact that it does not take account of the repeated choices that the individual made and this could account for the unexpected signs observed. The next step is estimation of the Conditional Logit (CL) model, taking into consideration the panel nature of the data and the results are illustrated in Table 7(a). Although alternative specific constants have no meaning in unlabeled choice experiments, they are important modeling components and were therefore included in the model. Socio-economic and demographic (SED) variables were also left out, because they were insignificant and not associated with any gain in the model fit.

As was indicated in the empirical model section, it is important to check if the data we have meets the restrictive assumptions of the conditional logit model so as to find alternative modeling approaches. In this study, the choice of the third alternative (status quo) by the respondents was almost non-existent in the data, and this led to model convergence issues while testing the IIA assumption. Eliminating the status quo alternative did not lead to a violation of the assumption, but it was not possible to check if removing the first or second alternatives would lead to the same conclusion. As a result, it was important to try a Random Parameter Logit (RPL) specification that relaxes this assumption for purposes of comparing the results. In selection of the random parameters, both McFadden and Train (2000) Lagrange Multiplier (LM) test and the t-test proposed by Brownstone (2001) were conducted. The first test indicated that the coefficients of both 40-watt package dummy and outage duration are random, while the second test indicated that coefficient of community ownership dummy is random. This is the basis of the random parameter estimation reported in Table 7(b). This estimation produced non-significant standard deviations for the parameters of the variables that were pre-determined to be randomly distributed, indicating no heterogeneity in preferences and that the use of RPL may not be necessary. Furthermore, log-likelihood ratio test was conducted to check if there is any structural gain from using the random parameter model over the simple conditional logit model. The null hypothesis could not be rejected at 5 per cent significant level, indicating that the use of a CL is sufficient for this data. As a result, the results discussed in the following section are based on the conditional logit model.

Since the utility was specified as linear in parameters, we can interpret the signs of the coefficients as indicating what aspects or attributes of microgrid electricity were preferred by the respondents in this study. Community ownership led to an alternative being preferred over another with private ownership (base), implying a higher utility to consumers if they have ownership in generation and distribution of electricity to their households. The major concern with electricity consumers in the area of study is that private owned service providers will not be accountable to the customers and they will give whatever service levels they want. These results coincide with earlier work by Abdullah and Mariel (2010) where rural consumers connected to the main grid in Western Kenya indicated that they would prefer community distributor for electricity to the state monopoly (Kenya Power). This outcome in the current study

is driven by the unpleasant experiences with Kenya Power service in the market places where the respondents get electricity services. Delays lasting for weeks in fixing problems by Kenya Power and unilateral pricing are normal and the respondents associate this with the absence of a competitor. It is also important to note that the major driving force behind many community-led micro hydro grids in Kenya is frustration with seeking grid connection and/or poor (and expensive) service when connection eventually happens.

Consumers in this study derive more utility from an alternative that delivers higher voltage to the household. Therefore, the probability of an alternative being picked is higher the more applicability it has in the household. In describing the context within which this survey was conducted, it was indicated that rural households in Kenya mainly use electricity for light uses like lighting and televisions primarily due to the cost associated with using heavy load like cooking. Micro hydro grid consumers also apply electricity for the same light tasks in the household. The respondents in this study seemed to have lesser liking for microgrid service alternatives with restricted use of electricity (limited to powering radios, lights and televisions), while at the same time choosing alternatives with lower costs. This effectively means that these consumers would wish to do more with electricity in the household (like cooking) but are willing to spend less for it than the average grid charges for an equivalent service[8]. Affordability should be defined carefully, keeping in mind that free availability of popular fuels like fuel wood may make the consumer to forego electricity since the latter has a cost. Constructing micro/pico hydro grid with limited voltage connection like in many existing schemes in Kenya may only work in the presence of other measures to stem theft, since we have established that consumer's highest interest is in unlimited voltage delivered at a cheaper price.

Service outage in a micro hydro grid is a concern for consumers as shown by the negative sign on the coefficient of the interaction term. The outage duration per day here is not significant if frequency is 0, but may be significant for other values of frequency. The negative sign on the interaction term indicates that while respondents could tolerate more hours of outage in an alternative, they would not tolerate the same alternative if it also has a higher frequency of outage with everything else given. These results mimic those of Abdullah and Mariel (2010) who found out that longer and more frequent outages generated a dis-utility to the consumer. The positive sign on the parameter of frequency of outage on its own, can be explained as willingness to accept some longer outages if community has ownership in the service provision. Consumers in the village do not use electricity throughout the day, because they are outside working in their farms (most of the respondents in this study are self-employed in their farms) and ownership of appliances such as fridges is non-existent. The farms are irrigated using gravity-delivered irrigation water, leading to almost non-existent demand for electricity in the farming undertakings. Therefore, they may be willing to do without power during

[8] The tariff setting for domestic consumers has many variable costs elements that vary with the amount of electricity consumed, in addition to having a standing charge and utility levies. However, if we ignore the investment costs for convenience of comparison, an equal quantity of electricity consumed in per month will cost more for a household utilizing grid than one using micro grid due to such extra costs.

the day if the duration is moderated as shown by the interaction term[9]. This study did not include the timing of outage, that would enable us understand why the respondents seem to appreciate longer hours of outage. Furthermore, the long outages from grid service could have made the consumers appreciate longer hours of outage now that they will have ownership of service and most likely receive an explanation for longer outages. It was also observed that there were longer outages associated with grid service in the markets, sometimes lasting for weeks instead of hours. It therefore looks reasonable that the households may be willing to accommodate longer outage but detest a combination of longer and more frequent outages.

Marginal Willingness to Pay

Marginal willingness to pay (MWTP) for the attributes of micro hydro grid attributes were estimated as the simple ratio of attribute coefficients to the cost attribute coefficient. These estimates and their confidence intervals are presented in Table 8 in the Appendix 1. Among the attributes given to the respondents of the study, load package and community ownership attracted high willingness to pay values. The highest MWTP of approximately 8.51 USD per month is what a respondent would pay to have an unlimited voltage connection at his/her house, implying that this is the most desired among the attributes of a micro hydro service. If this outcome were to be related to the design of micro hydro grids in Kenya, it would mean that a potential community provider should ideally seek to provide an unlimited voltage to the households- just like what the consumers would get under the status quo. The MWTP reduces across more limited voltage options (5.55USD for 60 watts package and 4.04 USD for 40 watts package), meaning that limited voltage packages would only be acceptable at lower charges per month. Most micro hydro schemes charge a monthly fee of less than 2.0 USD for limited voltage service, but 8.51 USD was the proposed monthly fee for an unlimited service in the scheme where this study was carried out. The MWTP for this attribute in a service implies that it is possible to charge even a higher monthly fee than is in the current proposal. There seems to be room for tariff revision, and this can be deliberated upon by the members of the scheme.

Community ownership in a microgrid attracted a MWTP of 4.2 USD per month, which exceeds the willingness to accept lower duration and frequency of outages. This means that although the model is not formally recognized by the current energy policy (see MEP (2015)), consumers are more likely to appreciate a service with unlimited voltage and outages if they own it. It was explained earlier that not having ownership increases the depth of grievances from poor service, because consumers may not be sufficiently informed about the causes of the outages frequency and duration. Lastly, consumers are willing to pay a little amount of less than one dollar (0.27) as compensation for a service offering longer and more frequent outages than the current ones (8 hours and 4 times a month respectively). Outage appears to be not much of a bother to the consumers, perhaps moderated by having ownership in a micro hydro service delivering

[9] There is little mechanization at the farm level, with small diesel machines being used for cutting fodder, while water is delivered via gravity from higher attitudes in Mt. Kenya. The major use for electricity is therefore household lighting, which can explain why the respondents seemed not to mind higher outages.

an unlimited voltage. Consumers feel that if they have ownership over the generation and distribution, outages would then be adjusted with time to fit what they would cope with in the future[10]. A cautionary note is that although the obtained figures for willingness to pay for attributes in this study may appear high particularly for the attribute of unlimited voltage, the area of study has high agro-economic potential comprising of a thriving irrigated banana and dairy farming.[11]The average monthly expenditure of the rural household in this scheme is approximately 158 USD, which is high by rural standards due to earnings from cash crops. This level of expenditure shows that the obtained MWTP for most desired properties are affordable to the average household in this scheme, and there is no need for the government to subsidize these prices.

The prices obtained here for marginal willingness to pay for attributes cannot be compared to the grid electricity charges in a straightforward manner, as one would require very precise information regarding the consumption habits. However, the general observation is that since grid electricity price is laden with many levies (main ones being water, regulator, fossil fuel cost adjustment), two comparable households spending the same units of electricity would lead to lower prices being paid by the one utilizing micro hydro grid source due to the absence of the levies. It is also important that the pricing electricity from community micro hydro grids does not full reflect all the cost elements like capital cost recovery.

2.5 Conclusion

This study sought to investigate the consumer preferences for attributes of a micro hydro grid electricity service and subsequently estimate the MWTP for those attributes. The selected attributes for this study are: frequency of outage; duration of service outage; ownership of generation and distribution; cost and power supply voltage and choice experiment based on an optimal design was carried out via a survey of 133 respondents. It was found that the data fits a conditional logit model better compared to a RPL, translating to non-existent heterogeneity in the respondent's preferences. The respondents in this study were found to have highest preferences for power supply with higher voltages, followed by ownership of generation and distribution in a microgrid, with a MWTP revealing that there is room to revise the current proposed monthly charges if a community owned entity delivers unlimited voltage to the consumers' houses is set up. A combination of long and frequent outages confers dis-utility to consumers, but they are willing to accept a negligible amount as compensation for this negative outcome implying that continuous generation

[10] This is one explanation that was received in the field, when consumers would choose alternatives with longer durations of outage.

[11] An effort was made to verify these results in the field. The researcher visited about 15 respondents and presented them with indicative prices for the attributes of their choice, while reminding them of their current financial status. These respondents would informally estimate the amount of agricultural produce they would have to sell per month to comfortably settle their electricity bill. It was also apparent that if electricity would be applicable to some agricultural activities like fodder cutting, then the possibility of meeting the financial cost of electricity would even be higher emphasizing the need for higher installed capacity.

is not a major requirement for this section of rural consumers. Further research should incorporate the timings of these outages as part of the service attributes. This is because the rural consumers in this study spend most of their day out in the farms, only retiring into their houses at night and do not have gadgets that require constant supply of electricity.

Appendix 1-1 :Tables for Paper 1

Table 2: Electricity access Data

Region/country	Electrification rate (%)	Urban rate (%)	Rural rate (%)
World	84	95	71
OECD & Transition economies	100	100	100
Developing Countries	79	92	67
Africa	45	71	28
Kenya	*20*	*60*	*7*
North Africa	99	100	99
SSA	35	63	19
Developing Asia	86	96	79
China	100	100	100
India	81	96	74
Latin America	95	98	85
Middle East	92	98	78

Source: International Energy Agency World Economic Outlook Data (2016)

Table 3: Attributes for the study and their levels

Attributes	Levels	Status Quo
Cost (in Kenya shillings per month)	150, 250,350, 450	-
Outage duration (hours per day)	2,4,6,8	12
Outage Frequency (no of times/month)	1,2,3,4	5
Ownership of the plant	community; private	Private
Household power package[12]	20 watts; 40 watts; 60 watts; unlimited voltage	Unlimited

[12] We consulted with technicians in the schemes to tell us what each of these 20; 40 or 60 watts can do in the household in terms of the applications. This is the information we gave to the respondents because we did not expect all of them to recognize what watts stand for.

Table 4: Descriptive statistics

variable	*Mean*	*Standard dev.*	*Min.*	*Max.*
years of formal schooling	8.9849	3.6962	0	19
age	50.5564	14.5500	20	80
family size	4.7481	2.0397	1	10
No of rooms	4.9399	1.7337	2	11
Total household expenditure	15975.3200	12407.53	1306	66483
Monthly self-reported income	11476.4900	21685.7	0	210,000
*n=133; choices (N)=532 (133*4)*				

characteristic		*numbers*	*percentage*
schooling levels	primary or less	308	57.89
	secondary	148	27.82
	post-secondary	76	14.29
employment status	employed	32	6.02
	self employed	484	90.98
	unemployed	16	3.01
Gender	Male	316	59.4
	Female	316	40
has schooling members	yes	412	77.44
	no	120	22.56
dwelling type	permanent structure	228	42.86
	non-permanent structure	304	57.14
environmental club membership	yes	244	45.86
	no	288	54.14
*n=133; choices (N)=532 (133*4)*			

Source: Survey data

Table 5: Choice frequencies of Micro hydro service users in Meru County-Kenya

Alternative	Frequency	Percent
Alternative1	253	48
Alternative 2	277	52
Status quo	2	-
Total	532	

Source: Survey Data

Table 6: Multinomial logit

Variable	Coefficient (stand. error)
Number of hours of outage	0.3295(0.0770) ***
Duration*Frequency	-0.1874(0.0258) ***
Number of outages in a month	0.6719(0.1563) ***
Community ownership	0.7712(0.1937) ***
Unlimited load	3.6147(0.2879) ***
60 watts	3.0936(0.2629) ***
40 watts	1.9836(0.2250) ***
Monthly cost	0.0067(0.0009) ***
Constant	-5.799(0.6306)
N	*532*
l	*-686.426*
*** 0.01; **0.05 &*0.1*	

Source: Calculation from survey data

Table 7: Conditional Logit model (and RPL)

Variable	*(a) coefficient (s.e) CL*	*(b)coefficient (s.e) RPL*
the number of hours of outage	0.1671(0.094) *	0.1636(0.1120)
Duration*Frequency	-0.0745(0.0369) **	-0.0734(0.0420) *
Number of outages in a month	0.2878(0.1941)	0.2837(0.2175)
Community ownership	1.1399(0.2387) ***	1.3025(0.3480) ***
Unlimited load quality	2.3107(0.2873) ***	2.5159(0.4055) ***
60 watts package	1.5055(0.2512) ***	1.6868(0.3672) ***
40 watts package	1.0956(0.2017) ***	1.1932(0.2558) ***
Monthly cost	-0.0027(0.0015) *	-0.0034(0.0020) ***
Alt1 const	5.5765(0.8161) ***	5.9366(1.1009) ***
Alt2 const	5.6365(0.8182) ***	6.0199(1.0303) ***
Derived standard deviations of parameter distributions		
Number of outages in a month (n)		0.0000(0.1507)
40 watts package(u)		0.0007(1.0130)
Community ownership(u)		1.7032(1.2478)
N	*532*	*532*
l	*-271.0196*	*-270.7151*
**** 0.01; **0.05 &*0.1*		

Table 8: Marginal Willingness to Pay (in Ksh.)-Delta method

attribute	*outage duration*	*duration*frequency*	*community ownership*	*unlimited load*	*60 watts*	*40 watts*
mean MWTP	*61.5873*	*(27.4587)*	*419.9455*	*851.4713*	*554.7340*	*403.7203*
CI(lower-upper)	*(47.0129-170.1877)*	*(70.8449-15.9275)*	*(67.6009-772.2902)*	*(192.2382-1895.1809)*	*(170.6804-1280.1485)*	*(83.8298-891.2703)*

* Ksh. 100 is equivalent to 1 USD

3 Paper 2: Cooperation and local institutional arrangements in management of community micro hydro schemes in Kenya

3.1 Introduction

Renewable Energy (RE) microgrids[13] have become part of modern energy solutions in both developing and developed countries. They are a source of affordable electricity for rural households who either lack access to national grid, or are financially excluded from available grid supply due to affordability issues. This is a particularly attractive option for rural SSA rural households where only 7 per cent of the population has access to electricity (IEA, 2016), despite the existence of abundant renewable energy resources. Palit and Chaurey (2011) observes that these electrification alternatives also supplement grid electrification in countries with over-loaded national grid like India, thus addressing consumer concerns about quality and sometimes affordability of electricity. Within developed world and particularly in Europe, there is increased demand for RE microgrids primarily to enhance energy security (Scarpa and Willis, 2010; Yadoo and Cruickshank, 2012). Therefore, RE microgrids should be considered as part of long term and not only transitory electrification solutions. This then makes design and operation issues facing RE microgrids in developing countries an interesting inquiry, with the aim of providing options that raise chances of successful deployment of these systems. Empirical literature has extensively looked at the optimal design for microgrids (see Hafez and Bhattacharya (2012); Sen and Bhattacharyya (2014) among others) financing mechanisms (Miller and Hope (2000); Mainali and Silveira (2011) and others) but management issues remain largely unaddressed despite their importance in ensuring sustainability of these systems.

Management practices and requirements of RE microgrid investments vary according to ownership regimes. The latter is defined on the basis of who participates and benefits from electricity generation and distribution. Walker and Devine-Wright (2008) uses two parameters to identify the different ownership structures, which gives an insight into the management challenges observed in RE electrification projects. On the one end of the spectrum are privately owned systems, best illustrated by micro generation technologies which are installed for the benefit the owner of a residence. Private individuals may also invest in a renewable energy enterprise, and sell the electricity to the local community who do not participate in the management decisions. Another popular model is community ownership comprising of individual members who jointly invest in renewable energy development to meet their local energy needs (Walker and Devine-Wright, 2008). Community Renewable Energy Scheme(CRES)[14] is a useful model for promoting RE appropriate technology diffusion and local acceptance of RE, because local people take part in siting,

[13] A micro grid is an interconnected system of local energy generation, transmission and storage usually serving a community within a defined radius. It may be connected to the national grid, or completely isolated from the same (Schnitzer et al., 2014; Williams et al.,2015)

[14] Definitions of CRES vary in literature but for the purposes of this case study, its refers to an isolated micro grid constructed through collective financial and in kind contributions by members within a defined geographical location (Nolden, 2013), who then jointly appropriate the generated electricity in their households particularly in developing countries.

management and other decisions. In developing countries this type of ownership is useful for technologies such as micro hydro whose sites are naturally located in very remote areas, that are sometimes too small to attract private investors. Accessing such sites, maintaining and securing infrastructure is costly for private enterprises given the small scale generation recoverable from such resources. Wolsink (2012) also points out that if investments are initiated by private companies there is a higher likelihood of resistance from the local community, which explains why community ownership of microgrids is very popular in rural areas of both developed and developing countries. A further impetus for this model is that energy sector liberalization in some countries accommodates local groups that seek to exploit local RE resources within their reach to provide themselves with energy for local use or sale. Because river resources are not owned by an individual, collective ownership by local community is normally the optimal ownership structure. Despite the existence of abundant micro hydro or other renewable resources in developing countries, CRES are limitedly successful partly due to management-related challenges (see Kirubi et al. (2009); Yadoo and Cruickshank (2010) & UNIDO (2010)).

The foregoing characteristics of a Community Renewable Energy Schemes (CRES) present some unique social aspects which make their management experiences more challenging than either private or public owned ventures. Ferrer-Mart´ı et al. (2012) observes that CRES are by design heavily reliant on collective participation by the owners in the aspects of design, construction and day to day management of the entire system. Further, Greacen (2004); Maier (2007); Gollwitzer et al. (2015) add that due to resource constraints, installed and generation capacity is usually limited and is appropriated on either 'flat rate' or 'package' basis with only limited appliances permitted. Although the electricity generated is 'rival' in nature, it is not possible to exclude a member from using it since they co-own the investment and are connected. There is also a temptation to 'free ride' on such a public good, especially since some resources are needed for maintenance of the infrastructure. More importantly, maintaining order in the simultaneous utilization of electricity and maintenance of infrastructure relies on individual member's adherence to agreed upon rules and regulations. Failure by members to exercise collective participation is suspected to be a possible cause for collapse of many CRES (Greacen, 2004; Maier, 2007), although no empirical study has unpacked this process. More generally, Alvial-Palavicino et al. (2011) note that renewable energy literature falls short by looking at RE technology as an isolated component of what is apparently a complete socio-ecological[15] system. The latter comprises of: ecological, social; economic; cultural, institutional and technical characteristics. As indicated before, literature largely avoids the socio-cultural and institutional aspects of CRES yet they are important determinants of outcome in such projects.

According to Wolsink (2012), renewable energy microgrids systems that are jointly owned and used by members of a community such as CRES should be considered a man-made CPR. Similar observations have been made in the field by

[15] Smith and Stirling (2010) also consider technology as one part of a socio-ecological system

Greacen (2004); Maier (2007) and most recently by Gollwitzer (2014); Gollwitzer et al. (2015). If this is true, Hardin's exposition in Hardin (2009) would lead us to conclude that the users of a CRES microgrid electricity cannot sustain order in both power use and maintenance of the system and that the schemes will be afflicted by dilapidated infrastructure due to competition for limited electricity and eventually face collapse. This in turn would mean that only ownership by public utility or a private investor can guarantee successful exploitation of RE under such circumstances. As noted earlier, these agents may not be practically suited or even interested in the case of microgrids for reasons stated elsewhere in this study. Notably, field observations by both Greacen (2004); Maier (2007) reveal instances of micro hydro grid communities in Thailand and Pakistan sustaining functional schemes through self-governance. The explanation for this phenomenon is found in counter arguments for Hardin's proposition. Wade (1987); Ostrom (1999) and others, posit that under some conditions it is possible to avert a tragic end to common pool resource system. Some exploratory studies like Maier (2007); Gollwitzer et al. (2015) attempt to identify the existence of such conditions in community microgrids but suffer from notable limitations. The three studies follow a qualitative approach, by identifying some conditions from literature on governing commons and tracing them to the conduct of business within community owned microgrids in Thailand, Pakistan and Kenya respectively. Therefore, by their design they only provide a background for quantitative work but do not link the presence or absence of some conditions to the outcome observed in those projects. Gollwitzer et al. (2015) uses fairly new and currently functional schemes to describe conduct in community microgrids in an environment where community owned microgrid trials have existed for over fifteen years (see Maher et al. (2003)). Furthermore, the use of group level analysis by such studies does not address the issue of how individual characteristics affect their participation in schemes, yet this is a recurrent theme in empirical work on collective management of CPR. Identification of such characteristics is important given that there is a disagreement in literature over how heterogeneity of users across schemes affects management outcomes in commons. In the backdrop of these limitations and gaps in existing literature, this study seeks to contribute to the study of commons and renewable energy rural electrification by identifying relevant conditions for self-governance and how they impact on observed management outcome of community micro hydro schemes.

This study contributes to the literature of governing commons through seeking evidence for the relevance of some conditions proposed in the study of other resources to energy commons. This is achieved through two objectives namely: establishing the individual characteristics that influence the level of an individual's cooperation with scheme requirements and secondly establishing how suggested conditions for managing commons relate to the observed outcome [16] in community owned microgrids. One particular interest is the role of locally devised institutional arrangements[17], in predicting the outcome observed in a scheme. A case study of micro hydro schemes in Kenya is

[16] A scheme can be functional (successful) meaning that the power generating is ongoing and infrastructure is well maintained, or can be non-functional (collapsed) implying that infrastructure has degenerated and no generation is ongoing.

[17] Throughout this text, institutional arrangements refer to the rules meant to shape the conduct of members within a scheme following definitions in Ostrom (1990); North (1990) & Heltberg (2001)

used, with the hope of expanding the empirical literature on management of CPR to other man-made resources such as electricity. Furthermore, it is anticipated that lessons that can feed into future management design and policy of CRES will be obtained from the current study. The next section gives a brief of the Kenyan experience with community-based renewable energy, most of which comprise community micro hydro schemes.

Specific study Objectives

1. Investigate the role of individual characteristics in observed cooperation with defined group requirements
2. Establish the impact of governance conditions and observed outcome in micro hydro scheme

Contribution to literature

Common pool property governance problems have mostly been discussed in published literature as relating to the formal grid network sharing, but current study demonstrates that similar problems can be identified in community-based micro grids. Although there is existing gray literature describing the common pool aspects of microgrids and how communities of users deal with them, such literature largely lacks empirical evidence making it limited for policy use. The current study overcomes that shortcoming by not only gathering information on the local governance arrangements existing in groups of microgrid users, but also goes further to link those arrangements to the observed management outcome while addressing potential econometric problems. An additional task of identifying the catalyst for increased cooperation by individuals participating in such groups marks a departure from most studies of commons which largely ignore individual-level constraints to group commitment. That way the study provides the potential points of intervention while seeking to solve governance problems, in addition to demonstrating a wider application of CPR governance principles to small scale energy infrastructure.

Management of community-based renewable energy in Kenya

Community owned microgrids in Kenya begun in Kenya in the year 2001. The first pico hydro demonstration projects were set up by the government in conjunction with development partners[18] in two communities located in the central highlands region, which had no grid access at the time Maher et al. (2003). These projects took advantage of previous groups formed by these communities to lobby for grid power connection, with the only change being that an alternative RE electrification would be provided since grid source was not forthcoming. The feasibility study, mapping and technical work was conducted by the University of Nottingham Trent, while the EU provided partial funding for

[18] The European Commission and Nottingham Trent University. There are other privately owned micro grids that are many decades old, particularly those established by missionaries, but this would require a detailed coping study dedicated to establishing the timeline of this technology in Kenya.

the infrastructure. Community members' role was to provide part of the financing, some materials and free labor at the construction site which would continue even after project was handed over to the community. Limited hydro potential was pre-allocated to households using packages with the expectation that members would only use electricity for the stipulated applications under their subscribed package. According to Maher et al. (2003) the survival of a scheme was heavily dependent upon good management practices such as: attending to technical problems as soon as possible; adhering to power use regulations; payment of bills on time and resolving conflicts in a peaceful manner. Other responsibilities that individuals in such a system had to attend to include distribution line and site maintenance mainly through contributing free labor services and finance whenever called upon. Whether or how the groups could sustain collective participation towards these important activities in the entire life of the scheme is an issue that was largely assumed away.

Following the establishment of the two pioneer schemes, other communities showed interest by initiating their own groups and seeking technical help such as plant design and feasibility studies. Thus the initial model was replicated leading to tens of schemes being established mainly in the Central Kenya highlands situated in Mt. Kenya and Aberdare catchment areas[19]. The assumptions that members would cooperate with power use rules and sustain self-governance in the pioneer schemes were also adopted by these other communities, with non-existent briefing or training of how individual commission or omission would impact on the performance of the entire scheme. The expected governance issues were left entirely to an uninformed community that had little knowledge about the opportunities and challenges of RE (pico/micro hydro) resource system they were exploiting. The result has been collapse of most schemes and vandalism of infrastructure, particularly given that grid network has since been extended to these areas. One thing that is interesting is the fact that some plants have survived this collapse and continue to provide basic electricity services to their members, with even planned future upgrades that will deliver sophisticated microgrids that can be connected to the main grid.

According to field experience, all schemes face potential problems of errant members or hostile neighbors who are a threat to the survival of the scheme. Most cited issues include but are not limited to: overuse of limited power by plugging prohibited appliances, shirking labor obligations; laxity in providing information; illegal connections within and across households as well as non-fulfillment of financial and labor obligations. These create opportunities for other problems to set in like theft of infrastructure by jealous neighbors who take opportunity of delayed line maintenance and frequently dormant generators. The latter is attributed to system overload, when members fail to adhere to power use rules or lateness in making financial contributions for repair. It is also apparent that lack of good leadership practices is a threat to survival of schemes, even where the members observe the scheme rules. However, some schemes seem to have successfully overcome some of these potential problems while others fail in almost all

[19] Pico/Micro hydro power potential is plenty in other water towers in Kenya like Nyambene hills; Mt. Elgon; Kisii highlands; Cherangany hills; Kerio, Mau and Nandi escarpments

fronts. This study makes an attempt at explaining this observed pattern, drawing inspiration from studies of CPR management which are reviewed in the subsequent section.

3.2 Literature Review

Two important seminal claims form the foundation of the extensive discourse on collective action and management of commons. Hardin (2009) uses principles in the Prisoner's Dilemma to conclude that freedom in a common would lead to degradation, since the marginal cost of individual pursuit of self-interest falls short of the benefit from such behavior. For instance, in a common grazing land self-interest leads everyone to continue adding more animals to their heard. This is because marginal benefits from an additional animal accrue to the individual while marginal costs are shared by all herders. The cumulative addition of animals by every member eventually leads to over-grazed pastures (ruining the common resource) which is a collective loss to all in such a group. This argument is also extended to other commons where there is freedom to act such as in: breeding or population, pollution and ocean resources. The ultimate solution according to this argument is to issue private rights or restricted access by external forces like the state. This is based on the fact that human beings cannot organize themselves, or enforce constraints to avoid over-exploitation in the commons. Olson (1971) reinforces this view by arguing that self-interest in an individual does not translate into collective action towards realization of common group goals. This difficulty is depicted as particularly serious in small group typical of village-level commons, while giving positive hopes for larger (no defined size) groups. Further, selective punishment whose origin is not stated is effective in ensuring compliance to group goals. These two observations are however discounted by subsequent field observations, which identified instances where groups of individuals had succeeded in maintaining orderly utilization of common resources.

Blomquist and Ostrom (1985) adapts variables from dynamic models of long-term solution to study commons dilemma by evaluating their role in management of ground water basin in Southern California. Conditions such as: providing users with information; communication among users; symmetry in resource use; monitoring use and deterrent strategies led sustained use of ground water in Los Angeles. In a similar approach, Wade (1987) challenges both the assumptions and predictions of both Hardin (2009); Olson (1971), by providing evidence for visibly self-organized systems for exploiting shared irrigation water in Indian villages. Greater chances for collective action are associated with 13 effective conditions among them: costly exclusion technology; small size of resource and user group; clearly defined boundaries of both group and resource; ease of detection and supportive state. Ostrom (1990) adopts another approach of consolidating views from case studies eventually providing eight (8) design principles associated with well governed natural resource commons. Due to the tendency for later studies to add more conditions, there arose a need to create a framework for studying commons to make studies comparable. Agrawal (2001) compiles a list of thirty-three (33) conditions from the studies by Wade (1987); Ostrom (1990); Baland and Platteau (1996), providing a basis for empirical verification of these characteristics among users of commons. Such an

application in empirical work exists for natural CPRs like forests (Gibson and Koontz (1998); Agrawal and Chhatre, 2006); fisheries (Kalikoski et al., 2002) with irrigation water being the only man-made CPR (Meinzen-Dick et al., 2002; Araral, 2009).

The first thing to note from this literature is the disagreement regarding the effects of these conditions on collective action and/or subsequent outcome in commons. The role of group size and heterogeneity is largely unresolved. Olson (1971) posits that there exists a positive effect of heterogeneity in assets (inequality) on collective action, if some highly endowed individuals in the group are willing to pay for goods to be enjoyed by the others. Conversely, deteriorated forest outcomes are found to be more likely in communities exhibiting high economic inequalities in India by Andersson and Agrawal (2011). However, the adverse outcome is lessened if a community has functional local institutional arrangements to address inequalities within a group (Andersson and Agrawal, 2011), highlighting the importance of other conditions in mediating this relationship. Further, Baland and Platteau (1999) suggests that two forces are usually at play and the net effect of group inequality is determined by which of two forces is more powerful in a specific group. Highly endowed individuals may be benefiting more from the resource thus having a higher impetus to see that the group is run successfully. To achieve this goal, they would be willing to contribute more than their fair share of responsibility in the group. On the other hand, the less endowed members may be so complacent with the lesser gain from the group and actually opt to free ride by reducing their commitment and contributions in the scheme. The bigger of these two effects determines the net effect that group inequality has on collective action (Baland and Platteau, 1999), implying that the relationship is not discernible beforehand. Where relevant, divergent cultural backgrounds among resource users may have a bearing on their collective participation. For instance, a U-shape relationship observed between caste diversity and collective forest management in India by Naidu (2009) suggests that dominance of one culture in a group may undermine participation by other minorities within the group. This calls for other supportive mechanisms like democratic conduct of business to ensure that minorities do not withdraw their support from socially diverse groups. Poteete and Ostrom (2004) suggests a positive relationship between heterogeneity and group size, all pointing out why it is important to lay out how this variable affects collective participation. Theoretically, a larger group is more likely to lead to undesirable outcome if membership is vastly spread since this brings about high transaction costs (Olson, 1971). This means that it is less likely to achieve collective participation in larger groups compared to smaller groups. However, observations of forest groups in India by Agrawal (1998) seem to indicate that indeed smaller groups are plagued with difficulties of collective action. This could suggest that homogeneity may not guaranteed even in smaller groups. The size of the group affects prospects for collective action through either dilution of individual benefits or through ability to mobilize resources. Large groups can easily raise the required financial means to pay for hiring external monitors (Agrawal and Goyal, 2001) or even capital costs in case of man-made CPRs. For rural villages comprising of mainly low income households, groups with few members may not be able to sustain collective action if there are huge capital or operation costs requirements. Further, having

too many people within a CPR may lead to minimal benefits for each participant, reducing the incentive for participation. Poteete and Ostrom (2004) provide some middle ground by proposing that medium sized groups may be better in achieving collective action in commons. More importantly, the effect of group size is mediated by institutions and other group characteristics and should thus be examined on a case by case basis (Poteete and Ostrom, 2004).

North (1990) defines institutions as rules put in place with the sole purpose of directing human conduct within an identifiable space of interaction. Formal or informal statements stipulating how individuals should conduct themselves within a micro hydro scheme can be termed as local institutional arrangements, and their effectiveness in directing smooth conduct of business reflects on their quality. Blomquist and Ostrom (1985) suggest the following to constitute good institutional arrangements in management of CPR: provision of information; immediate and constant communication; symmetry of benefits; ease of enforcement and monitoring mechanism. Ostrom (1990) gives a more clear illustration of the expected local institutional arrangements in the study of any CPR, providing a useful checklist for assessing the coverage or 'quality' of these institutions in the field. For renewable energy CPR, Maier (2007) and Gollwitzer et al. (2015) provide a description of the relevant rules derived from observing interactions within micro hydro schemes in different countries. Our emphasis is that the fact that such rules exist may not be a sufficient condition to guarantee favorable outcome, rather it is how well they achieve the intended action of directing conduct of individuals that determines the ultimate scheme outcome. Subsequently, being able to score the suitability of these local institutional arrangements is more insightful than merely performing a checklist of their existence among groups. Agrawal (2001) proposes the use of techniques such as construction of indices out of related concepts, particularly those under the 'institutional arrangements' and this is the approach taken by this study.

Although most studies examining conditions for successful utilization of CPR use group level analysis, it is important to unpack the characteristics of individuals driving the observed outcome at the group level. The reason for this is the existing debate in literature on the role that heterogeneity/homogeneity of users in management outcome of natural CPR (see Baland and Platteau, 1996; Varughese and Ostrom, 2001; Adhikari and Lovett, 2006); Gautam, 2007 and others). The first issue to note is that individuals who participate in collective action have potentially diverse characteristics. According to Varughese and Ostrom (2001), differences in socio-economic and cultural traits of individuals in groups may influence management outcomes differently in each context. For instance, while there appears to be no role for heterogeneity in predicting collective action outcome in Nepalese forest user groups, Varughese and Ostrom (2001), Adhikari and Lovett (2006) and Gautam (2007) find indeterminate effects of various heterogeneity indicators on cooperation in forest commons located in the same country. There is a notable focus on individual level characteristics and how they impact on level of participation/cooperation in a common, possibly driven by the disagreement over the impact of group homogeneity mentioned earlier. Agarwal (2009, 2010) find that the presence of women leadership increases the level of women participation in group activities and better forest

outcomes, respectively. This is particularly important for cases where one gender is more likely to interact with a resource than the other, like women happen to interact more with forests while farming or harvesting wood and food in developing countries. A contrary outcome is observed in Burkina Faso, where women's participation in forest management programs is found to be lower compared to men by Coulibaly-Lingani et al. (2011). The explanation given for this pattern is that by cultural design in developing countries, women spend most of their time attending to domestic responsibilities affording them little or no extra time to participate in forest activities.

Other characteristics like individual member's capital endowment; household size and sources of income appear to increase their participation in forest commons (Coulibaly-Lingani et al., 2011) by affecting dependency on natural resources. Incentives such as the derived personal benefits may increase an individual's participation in a common if those benefits improve his welfare. For instance, individuals harvesting larger quantity of several forest products in Nepalese villages are found to have higher participation levels (Oli and Treue, 2015) and a similar trend is found among farmers with larger irrigation plots in Uganda and South Africa (Nakano and Otsuka, 2011; Muchara et al., 2014). Higher benefits combined with other factors like higher dependence on a resource create an incentive for an individual to comply with requirements of the scheme, particularly where removal of the benefits are part of the sanctions for non-compliance. Education or being knowledgeable about the resource at hand has a potential effect on an individual participation intensity in a common. Theoretically, more educated members better understand the consequences of not meeting their group obligations and are likely to participate more to avert such results. On the other hand, more educated members may be able to exploit their peers in the group by shirking their responsibilities in the scheme while gaining from the resource (Hayo and Vollan, 2012). A positive relationship between education of an individual and cooperation has been found in studies covering grazing commons (Hayo and Vollan, 2012), while possessing more knowledge on water management is observed to increase participation rates in irrigation commons (Muchara et al., 2014). The general indication here is that heterogeneity derived from individual level socio-economic or cultural characteristics may have potentially varied impacts on personal interests on not only personal interests but also on perceived benefits and cooperation with group rules. Ultimately, the latter is critical to achieving a positive self-governance in a group. The motivation for studying such characteristics is not only for academic purposes but also for practical purposes of deriving relevant interventions in program design. Specifically, program to revive fallen schemes can be formulated with more certainty if we know the potential effect that some traits have on the ability of members to have high cooperation with scheme requirements. For community micro hydro schemes, this may involve actions or program to educate users on resource limits and role of individual actions on the general outcome of the scheme. Our main argument here is that institutions or those other conditions do not work in a vacuum but through individuals who possess different characteristics that affect their participation behavior in commons.

New developments in literature of CPR include the expansion of the concept to man-made resources. Kunneke and Finger (2009) declares energy, transport, communication and tele post infrastructures as man-made CPRs and goes

ahead to demonstrate the likely CPR problems that may manifest in either system/capacity management or interconnection. Accordingly, Wolsink (2012) while discussing distributed generation smart grids observes that local microgrids can be considered as CPR and recommends research agenda responding to attendant management challenges. Few studies like Greacen (2004); Maier (2007); Gollwitzer et al. (2015) have attempted to describe the CPR features in micro hydro schemes, but there is almost non-existent literature linking the outcome observed in CRES to the conduct of individuals and management principles. Notably, most published literature on CRES is limited to cases of sophisticated community energy projects in the United Kingdom and Europe, without addressing similar trials that have been ongoing in developing countries for decades. We maintain that its particularly important to examine the management impediments surrounding CRES in developing countries as well, since lack of information on how user communities can manage them is a leading cause of bad governance and subsequent collapse of the same. This however does not in any way discount the importance of other impediments facing these projects like financing and technology, which have been addressed widely in literature.

Greacen (2004) search for reasons behind collapse of micro hydro grids in Thailand makes the first attempt in literature to claim CPR properties of community micro hydro grids. CPR-related governance problems of the studied microgrids stemmed from appliance use patters, the power quality and equipment malfunction at the household level. However, the study prescribes a technological solution (current limiters) to align limited generated capacity with demand from households. This is not a sufficient solution, given that there must be additional monitoring and arrangements to prevent by-passing this technology in what is referred to as a 'socio-technological system'. Furthermore, the study fails to link CPR management principles to the different outcomes observed in different microgrids. Maier (2007) in a similar attempt begins an inquiry of institutions behind management of 27 community micro hydro schemes in Pakistan, by giving the CPR perspectives of a community micro hydro grid. The study observes that power produced by a micro hydro is usually limited by either the resource size or installed capacity of the generator, and households can only use the electricity with allowed appliances in the by-laws. More importantly, the resource system (micro grid) produces electricity that is rival and one person's excessive use makes it impossible for the others to use. Further, the required infrastructure maintenance requires pooled labor from members making it cheaper as opposed to sub-contracting the work. If members do not act collectively and continue to use prohibited appliances or shirking their labor/maintenance responsibilities, the system will develop malfunctions from overuse and eventually succumbing to Hardin's ruin (Maier, 2007). With this background, key informant interviews are then used to collect information on the presence or absence of CPR governance conditions in the schemes. Different rules for dealing with similar problems are found in different communities, with some schemes having collapsed because they never devised rules for dealing with some situations. Therefore, although other factors like technology, resource characteristics and external environment also contribute to collapse of plants, the study maintains that institutions have a crucial role to play in the outcome of a microgrid management. The shortcoming of this study is that it does not

have any analysis on participation at the individual level, despite the authors field experience having suggested that traits of scheme members could have a bearing on the collective ability of the whole group. Further, just like in Greacen (2004) the approach of the study does not allow the researcher to establish a clear association between conditions and the scheme outcome.

Similarly, Gollwitzer (2014) argues that since both community microgrids and irrigation systems are man-made CPRs, then an analogy between the two is useful in understanding the CPR features of a microgrid. This comparison settles for 14 conditions out of the 33 conditions proposed by Agrawal (2001) which can be used in the study of conditions for sustainably managing microgrids. Institutional variables emerge as particularly important because they are tied to socio-cultural aspects of rural electrification, that are hitherto ignored in both renewable energy and electrification literature. Overall, the study cites the relevant conditions as: all the six institutional variables; matching of appropriation to generation of resource; fairness in allocation of benefits; high dependency on resource by users; change in demand levels; low level of demand by users; appropriate leadership; heterogeneity of endowments and interests and interdependence between group members. The presence of these variables is then sought by seeking expert opinion about the operations of two functional community-based solar microgrids in Kenya. Communities in this particular study have crafted formal and informal rules of dealing with generation and appropriation problems emanating from intermittent resource (Solar and Wind). For instance, commercial customers are only allowed to use the resource during the day while households use is restricted to evenings in one of the plants. The households monitor each other, preventing power use beyond permitted levels through plugging in unauthorized appliances. Although the use of pre-paid meters is hailed in the study as a technological solution to power theft, there are other instances where households are reported to interfere with the systems in a bid to by-pass the meter or current limiters implying the need for more serious sanctions. Notably, the absence of graduated sanctions and enforcement mechanisms is attributed to the failure to remit monthly payments and budgetary problems in one of the featured schemes (Gollwitzer et al., 2015). The major weakness here follows from a replication of the qualitative strategies used by both Greacen (2004); Maier (2007), with the consequence that it is not easy to identify the contributions of any condition to the successful collective management in micro hydro schemes (see Meinzen-Dick et al., 2004 for other weaknesses of qualitative research). Furthermore, the role of heterogeneity or homogeneity among users on the management outcomes cannot be identified since no attempt was made to include households as part of the analysis. The level of analysis in studying collective action should include individuals especially if most of the activities that constitute collective group action are performed voluntarily by individuals (Meinzen-Dick et al., 2004).

Methodological approaches vary in published studies of managing commons, with both observational (qualitative) experimental and quantitative studies having different conclusions. Notably, available studies on community microgrids largely rely on qualitative evidence based on expert opinions (see Greacen, 2004; Maier, 2007; Gollwitzer et al., 2015). The potential strengths and weaknesses of this approach create room for quantitative analysis, which

may compliment such studies. Gollwitzer et al. (2015) analysis is particularly limited due the study of two fairly new and functional groups in a country that has tens of microgrids that are either functional or collapsed. The study fails to utilize some existing cases of collapsed schemes to demonstrate why their 'ruin' could be attributed to lack of some institutions/principles. Furthermore, the study has no particular outcome or collective activity of interest which can be traced across schemes making comparison to other studies difficult. The use of group level analysis is common in the all the three studies where the cases of the study double up as the unit of analysis. This makes it almost impossible to isolate the effect that a particular condition has on the management outcome observed for each group. The latter is attributed to the few existing cases of study (and the subsequent lack of degrees of freedom), but this problem may be overcome if the unit of analysis becomes the household (Agrawal, 2001). This has the additional advantage of permitting deeper understanding of the sources of heterogeneity and how they impact on CPR. The use of multivariate analysis and regression techniques, is a potential solution that can enable one to consider many collective activities as well as test the relevant variables in achieving collective action in CPRs (see Agarwal,2009 and Adhikari et al., 2014 and Muchara et al., 2014).

Thus the foregoing literature has two implications on the current study through which it can make a contribution to the literature of rural electrification and study of commons. Firstly, we are provided with a general framework for studying man-made CPR like community microgrids. Secondly, an incentive to consider quantitative approach to linking both individual and group characteristics to the observed outcome in CRES. We maintain that its particularly important to examine the management impediments surrounding CRES in developing countries as well, since lack of information on how user communities can manage them is a leading cause of bad governance subsequent collapse of the same. This however does not in any way discount the importance of other impediments facing these projects like financing and technology, which have been addressed widely in literature.

3.3 Methodology

This section explains the collective action problem in a community micro hydro, framework adopted for this study, choice of variables and their measurements, data collection and the empirical estimations.

Collective action problem in a community-based micro hydro electricity scheme

Community-based micro hydro schemes in Kenya are formed through mobilization of a group of individuals representing households living around the micro hydro resource. The common objective of such a group of individuals is to collectively construct as well as maintain power generating and distribution infrastructure which provides alternating current electricity to the members' households for domestic use. The timely contribution of money,

material and physical labor is particularly important in the operational stage of the scheme. Further the group aims to have a harmonious utilization of the limited capacity electricity once the generating and distribution infrastructure is complete, and each individual's responsibility is stated in the collectively made group rules. Some of the common rules relate to: financial and other in kind contributions; power use rules; safe guarding group property and information obligations. The assumption is that since members participate in making these rules, they will certainly cooperate with them leading to a harmonious continuity of both generation and use of power within the micro grid. This is not the case in some groups, as some schemes witness uncooperative behavior in the form of shirking labour, financial and even power utilization responsibilities while maintaining a right over use of the electricity. If most members behave like this and the rules set are not good enough, then the scheme ultimately collapses due to issues like negligence of repairs, damage to and vandalism of infrastructure resembling the tragedy described by Hardin (2009). More than half of the schemes that were at one time providing their consumers with electricity have suffered this eventuality, while others maintain their operations for longer periods. One of the explanation to this phenomenon is that there is a variation across the quality (if not type) of institutional arrangements for managing common goods in these groups, in addition to having members with different characteristics that have the potential of influencing commitment to group rules and regulations. Such arrangements include: effective sanctions; accountability of leaders; justice dispensation and appropriation of electricity. Greacen (2004) and Maher et al. (2003) observe the existence of such arrangements in communities of micro hydro users in Thailand and Pakistan, respectively.

The role of such institutional arrangements in explaining the group outcomes has been highlighted in the literature of common pool resource management, which guides the analysis in the current study. Identifying the sources of uncooperative behavior or the local institutional arrangements and other conditions associated with successful self-governance is helpful towards implementing remedial governance programs in micro hydro schemes.

Conceptual Framework

Agrawal (2001) compilation of the list of conditions for successful self-governance within commons provides a useful framework for studying management practices and their outcomes in CPRs. From these conditions, a researcher can construct variables thought to be relevant to the CPR whose outcome is the subject of research. The complete set of the proposed conditions are listed in Table 9 in Appendix, with those that are relevant in the study of micro hydro appearing in bold. The choice of these variables is informed by both field experience about the operations of community micro hydros in Kenya and descriptions of the same in other developing countries found in Greacen (2004); Maier (2007); Gollwitzer et al. (2015). From the literature review it is evident that individual level characteristics can potentially affect the outcome observed in commons, by way of affecting their interest or commitment to the responsibilities within the common user group (Lise, 2000; Dolisca et al., 2006; Coulibaly-Lingani et al., 2011). One way of demonstrating this commitment is by quantifying the cooperation of an individual with

requirements or activities within the scheme. Following this, and reflecting on the various collective activities in the studied micro hydro schemes (following discussion in Greacen, 2004; Maier, 2007; and Gollwitzer et al., 2015), it is possible to aggregate information from several related concepts to get an indication of level of cooperation with scheme requirements. These activities are equally important and a neglect of any of them is assumed to have grave consequences on the scheme.

This study also maintains that there are individual circumstances facing members of a micro hydro scheme, and they determine a member's commitment to each of these activities. The first objective analyzes several individual characteristics, to identify which ones have predictive power over the observed member cooperation from the data available for this study. Ultimately, cooperation through participation by members combined with other relevant conditions selected from the list by Agrawal (2001) is expected to drive the outcome observed in a community micro hydro scheme which is defined later. One of the most useful conditions is the presence of rules and good quality of local institutional arrangements which enable smooth conduct of business in a micro hydro power scheme. An aggregated index constructed from scores of how well these concepts aid the conduct of business in a scheme would constitute a proxy indicator of the quality of these arrangements. Such an aggregated score may then be combined with other variables and its association with the observed outcome in a scheme determined. The diagram in figure 3 of the Appendix summarizes this process.

The characteristics which are expected to influence the level of individual participation in scheme activities are mainly inspired by literature. Both Greacen (2004); Maier (2007) note that having alternative source of electricity (in this case, Alternating Current source) makes individuals to have no incentive for micro hydro sources. Specifically, Greacen (2004) states that onset of grid connectivity made most individuals to withdraw from micro hydro activities in Thailand because there was no consequence of non-compliance with scheme rules. The size of benefit from a CPR acts as a drive for commitment by members (Muchara et al., 2014), to avoid the eventuality of that benefit being withdrawn or interrupted as part of the sanction measures for non-commitment. Here, we posit that the electricity allowance per household in terms of installed watts per household can act as a motivation with more watts per household being associated with higher levels of participation or cooperation with scheme rules. Coulibaly-Lingani et al. (2011) demonstrates that people of specific gender may have higher participation than the other if by cultural design, they interact more with the CPR resource. Women in developing countries suffer more from the use of dirty and inconvenient lighting fuels (kerosene and firewood), and are more likely to appreciate micro hydro electricity and hence portray higher cooperation than men. Other factors like having trust for all peers and social capital from longer duration of membership in a group may provide an opportunity for a member to assess his position in a scheme, subsequently determining his/her commitment to activities in a micro hydro scheme. Lastly more schooling is assumed to equip an individual with a better articulation of the challenges and opportunities facing them (in this case cheaper and local sources of electricity), and so is having some training on environmental

issues.

At the scheme level in the second objective, we adopt the framework provided by Agrawal and Chhatre (2006) and the conditions of relevance to this study are as highlighted before. The exploratory analysis by Greacen (2004); Maier (2007) and Gollwitzer et al. (2015) informed selection of these variables, in combination with field observation on the conduct of groups in the location of study. The measurement of all variables used for this study is shown in table 12 in Appendix 1.

Sampling and data collection

The data for this study was collected from both operational and collapsed community owned micro hydro schemes operating in the central part of Republic of Kenya. The location of the schemes is spread between two water towers: Mt. Kenya and The Aberdare mountains[20], covering four administrative counties. The schemes were identified from a scoping study conducted by Global Village Enterprise Partnership(GVEP) International, followed by personal visits to ascertain the status of the schemes. Out of 11 such identified schemes that have been operational at one point in time, a total of nine were visited comprising of four functional schemes and 5 collapsed ones with an estimated total of 746 members. However, the true position during the actual field work was different and with some registers having been out of date, or some members who could not be traced (see Table 13 in Appendix 1) implying that the original sample size could have been over-estimated.

There were two levels of data collection namely: individual (member) and scheme(group) levels. The individual level information was collected from members who appeared in the register of both functional or collapsed plants. To obtain the number of household to interview in each scheme, a proportional calculation was done for each scheme targeting a third of the households. Subsequently, the members to be interviewed were identified using two methods:
a) where a register was available, the names were arranged in alphabetical order and then systematically picking members from the list b) where a register was not available, we would use the physical location of the households skipping those near each other or comprising of the same extended household by the use of the village/scheme guides. If the targeted member was not present during the time of visit to the household, a replacement would be made by household that is most near to that particular location. The latter was often the rule rather than the exception due to the fact that members were visited in their households for private interviews without prior warning to prevent interference with member perceptions. A questionnaire was administered by either the researcher or a trained research assistant in all the cases.

[20] Although micro hydro potential naturally occurs in most water towers in Kenya according to Maher et al. (2003) it is only in these two towers where its development has taken place because technology demonstration occurred here first

The group level information was collected from focus groups convened with the help of elders, and members invited for the discussion were selected randomly from the membership register (or sub-areas where a register was not available). This is to ensure representation of varied views in the discussions. The researcher personally conducted all the 9 focus group discussions using a scheduled questionnaire. The general characteristics pertaining to individual members within a scheme are listed in the table 14 in Appendix 1.

Empirical Strategy

The strategy for fulfilling the two objectives of this study involves estimating two equations in two stages, with the output of the first stage being absorbed as one of the explanatory variables in the second stage. From section 2 above, there is empirical evidence of a relationship between some characteristics of individuals and their cooperation with collective use and maintenance responsibilities in commons. In this study, an individual's level of cooperation is assumed to be a function of a vector of observable socio-economic characteristics X. Some of the potential variables in this vector are: education; belonging to an environmental club; scheme membership duration; trust for peers in the scheme; the energy share of household budget; incentive for electricity; potential size of benefit and the gender of a member. The choice of these characteristics is informed by studies looking at other commons as well as knowledge of the environment under which micro hydro schemes are established. A simple linear relationship between the level of co-operation and these personal characteristics is assumed to start with. From the field, we identified six crucial responsibilities expected from each member across all schemes namely: attending scheme meetings; active participation in decision making; participating in patrols to fed off thieves and vandals; reporting damages and power thefts; fulfilling free labor obligations and paying financial dues on time (summary is found in Table 10 of Appendix 1). The level of cooperation with these requirements by a member in the scheme was assessed through gathering information on how often they comply with these requirements, with those who reported as always fulfilling these responsibilities on time having higher index of cooperation. Through the use of a data reduction strategy such as Principal Component Analysis, it is possible to obtain a single score capturing overall cooperation (see Fujiie et al., 2005) and Coulibaly-Lingani et al., 2011 for similar approach).

The linear model expressing the relationship between the individual characteristics and the aggregated index of cooperation is as follows:

$$Indexpart_i(y_i) = \beta_0 + \beta_k X_i + \varepsilon_i \quad (13)$$

Where $E(\varepsilon_i) = 0; E(\varepsilon_i)^2 = \delta_\varepsilon^2 (constant); cov(x_i, \varepsilon_i) or\ E(\varepsilon|x) = 0$

where y_i is the indicator for the level of cooperation; X is a collection of k characteristics namely: education of member ($educ_i$); membership to a environmental club ($memtenur_i$); trust for all peers($trust_i$); incentive to connect

(*incentve*$_i$); size of benefit (*wattphh*$_i$); gender (*gender*$_i$); wealth possession (*landacr*$_i$) and a control for scheme *(schemecode*$_i$). The β_s are estimated using the Least Squares Estimator.

It is suspected that the variable for trust for one's peers in a micro hydro scheme may be endogenous in this model. According to Walker et al. (2010), although trust for peers in our case is a requirement for higher cooperation with scheme rules, it is also sensible to assume that having higher cooperation may also make an individual to be more trusting of all his peers in a scheme. This concept of reverse causality has the consequences that if it is indeed true for our data, then the estimated β_s are not reliable for a discussion on the central role that trust has in community energy concept. The econometric consequence is that one of the assumptions for the linear model (13) will be violated, i.e.

$$E(\varepsilon|X) \neq 0$$

Instrumental variable approach is a popular approach in such instance, if there are proper instruments M such that they are: (a) correlated with X; (b) not part of the model above and (c) orthogonal to the error ε. However, it is very hard to get a variable with these characteristics in our data, since almost everything related correlated with trust is likely to explain his cooperation. In such a case, Lewbel (2012) provides and alternative in the use of heteroskedasticity based instruments that are constructed from within the model. Denoting the two endogenous variables $Indexpart_i$ and $trust_i$ as y_1 and y_2, then the structural model can be expressed as

$$y_1 = X'\beta_1 + y_2\Gamma_1 + \varepsilon_1 \quad (14)$$

and

$$y_2 = X'\beta_2 + y_1\Gamma_2 + \varepsilon_2 \quad (15)$$

Unlike in the instrumental variable approach that relies on setting either of the $\beta_s = 0$ for identifying the structural model, Lewbel (2012) relies on restricting the correlations of the errors ε_s denoted as $\varepsilon\varepsilon'$ with the exogenous variables X. The condition for this to work is that there must be some heteroskedasticity in the original model, where the co-variance between all or a subset of X and ε_s is non-zero. According to Baum et al. (2015), some artificial instruments M are constructed from the product of the exogenous variables in the single equation (13) and its error terms ε_{is}, and their reliability (higher correlation with the endogenous variable) depends upon the greater heteroscedasticity existing between the errors of the model (13). This is the procedure that will be followed to check and address the potential endogeneity in this first estimation.

In the second stage of analysis it is hypothesized that the estimated cooperation score on individuals $\widehat{Indexpart}_i$, jointly with the quality of local institutional arrangements and other enabling conditions selected from Table 9 can explain the observed outcome in a micro hydro scheme. Agrawal (2001) recommends that correlated concepts under the subheadings in Table 11 can be combined into an index which expresses the quality or intensity of a concept such as the 'quality' of institutional arrangements for the current case. This study adopted this approach to construct an

index depicting the quality of institutional arrangements within a scheme, out of rankings by individuals of the effectiveness of those arrangements within their respective scheme. Since we do not have enough data at the group level, we replicate group level information to individuals in a group so that we have adequate degrees of freedom for our estimation. The observed collective action outcome in scheme n, denoted as s_n can only take two values, whose evolution is due to a vector of explanatory variables or what we collectively refer to as 'conditions' for management of schemes. Binary outcome models are used to estimate the probability that we observe $S = 1$ for a subject n as a function of predictor variables given as:

$$p = pr[S = 1] = F(C'\alpha) \tag{16}$$

The choice of model is determined by the assumed functional form of $F(.)$. This can be a linear probability model (LPM); logit or probit in this case. The LPM model has a shortcoming in that the predicted probabilities over-spill the 0 to 1 expected boundary, which is undesirable. The logit (assuming a logistic distribution) and probit models (assuming a normal distribution) are equivalent. The difference between the logit and probit lies in the assumed distribution assumptions underlying the transformational function $F(.)$. However, for ease of exposition we adopt the logit model since it can allow us to express the obtained coefficients as log-odds of events, and thereafter compare the results to those of a probit model. There is an expectation that the results of both the logit and probit regression are not substantially different.

Let $S_n = 1$if scheme n is functional (the scheme is generating power that is being provided to the members) and 0otherwise (dilapidated infrastructure with no generation of electricity)

If we assume that s_n takes on the value 1with a probability π_n or 0 with probability, $(1 - \pi_i)$ then S is said to follow a Bernoulli distribution expressed as:

$$Pr(S_n = s_n) = \pi_n^{s_n}(1 - \pi_n)^{(1-s_n)} \tag{17}$$

where π_n is assumed to be a linear function of a vector of observed group characteristics (or in this case conditions) C as in the conceptual framework so that:

$\pi_n = C_n'\alpha$, with α representing regression coefficients. The entire representation with the components of C can be given as:

$$\pi_n = \alpha_0 + \alpha_j C_n \tag{18}$$

C_n comprises of j predictors namely: quality of institutional arrangement *(Instindex*); the predicted score of member cooperation *indexpart*$\hat{}$; asset inequality*(inequality)*; external funding *(externalfund)*; size of group*(groupsize*); defined user boundary *(boundary*); size of resource *(resourcesize)*; monitoring mechanisms *(monitor)*; external interference *(interfere)* and social capital *(socialcapital).*

To ensure that π_n remains within the expected range of a probability ($0 to 1$), the element π_n is transformed and the subsequent transformation modeled as a linear function of the characteristics as follows:

$$Odds_n = \frac{\pi_n}{1-\pi_n} \tag{19}$$

defined as the odds ratio of the probabilities of a scheme being functional. However, this ratio can still take on any positive values and a further restriction (by taking its logarithm to get logits) ensures that the probability stays within the expected range. Thus:

$$\phi_n = logit(\pi_n) = log\left\{\frac{\pi_n}{1-\pi_n}\right\} \tag{20}$$

As the probability of a scheme being functional approaches 0, the odds ratio also approaches zero with the logit going to $-\infty$. Conversely, as the probability of a scheme being functional approaches 1 the both the odds and the logit approach $+\infty$ providing a mapping of probabilities from $0/1$ to the π_n estimated from the data. The expression for the probability of observing a functional scheme from the logit becomes:

$$\pi_n = logit^{-1}(\phi_n) = \left\{\frac{e^{\phi_n}}{1+e^{\phi_n}}\right\} \tag{21}$$

Going back to the assumption we made in in equation (16) above, then combining the exponent of the expression $logit(\pi_n) = C_n'\alpha$ and equation (18) will yield

$$\frac{\pi_n}{1-\pi_n} = exp\{C_n'\alpha\} \tag{22}$$

and from this the probability of observing a functional scheme becomes:

$$\pi_i = \frac{exp\{C_n'\alpha\}}{1+exp\{C_n'\alpha\}} \tag{23}$$

The primary interest for this study is the signs of the coefficients β_s in equation (13) and α_s in equation (23).

Additionally, the marginal effects depicting the effect of a marginal change in any one condition on the probability of successful outcome from (16) in case of a logit is

$$\partial P/\partial C_i = F'(C'\alpha_j)\alpha_j \qquad (22)$$

and from the logit, this expression becomes:

$$\partial P/\partial C_i = \frac{e^{C'\alpha_j}}{\left(1+e^{C'\alpha_j}\right)}\alpha_j \qquad (25)$$

It is expected that there might be a problem of endogeneity in equation (18) emanating from a reverse causality between the likelihood of a scheme being successful and the level of cooperation with scheme rules observed among members (and may be the quality of institutional arrangements). Lower co-operation with scheme rules may increase the probability of collapse. On the other hand, members from collapsed schemes are likely to report lower scores associated with lack of interest in the indicators of cooperation that were used in constructing the index. This may be because they have nothing to lose if the scheme is collapsing anyway, implying that signals of collapse may cause lower cooperation with ruled and regulations. It does not make much sense to assume that a reverse causality exists between the status of a scheme and the score of institutional arrangements. Given that we have a binary dependent variable and not an interval score, the state of failure in management of a scheme is not likely to be responsible of the low scores of institutional arrangements since the scheme is already collapsed (the outcome is binary), and information about the institutional arrangements was collected retrospectively. Success in a scheme cannot also be said to be responsible for better quality of institutional arrangements since there is no need for improving arrangements in an already successful scheme. However, a test of the same in the data is essential for estimation purposes only. By use of proper instruments within discrete modeling framework (instrumental variables in discrete response models) as described in Newey (1987), it is possible to test for these assumptions in our data.

The independent variables suspected to be endogenous from equation (18), can be re-written as:

$$y_{1i} = y_{2i}\zeta + Z_{1i}\Gamma + u_i \qquad (26)$$

$$y_{21} = Z_{1i}\Phi_1 + Z_{2i}\Phi_2 + v_i \qquad (27)$$

where y_{2i} is a vector of endogenous variables under the assumption being made, Z_{1i} is the vector of exogenous variables and Z_{2i} represents the relevant instrumental variables. In the data, we observe π_{1i}, based on a latent variable so that: $\pi_{1i} = 0\ if\ y_{1i} < 0$ and $\pi_{1i} = 1\ if\ y_{1i} > 0$. Following Newey (1987), a Wald Chi-square test of exogeneity

assumes that $\Gamma = 0$. Rejecting the null hypothesis therefore implies that estimates from ordinary probit (or logit) models are inconsistent, while failure to reject the null hypothesis indicates that there is no endogeneity in the data. In such a case, the probit/logit estimates are consistent.

Data reduction strategy

From the above section, two indices *Instindex* and *Indexpart* are derived (from the respective multiple but related concepts) using Principal Component Analysis (PCA). This is because both institutional arrangements and cooperation are measured using several but seemingly correlated concepts and activities respectively, and it is more useful to obtain a single measure for each of them from those multiple concepts. The variables for which data was collected from respondents and their measurements are as described in Tables 10 and 11 in appendix 1, respectively. PCA is a mathematical technique that can be used to reduce several correlated variables into fewer ones, while retaining most of the information in the prior set. The first principal component is usually taken as the best single indicator of the variation contained in the other variables (Rencher and Christensen, 2012). The coefficients of the first principal component are then used as weights together with original variables to construct a composite index. Normalization of the latter is then undertaken in both cases for ease of reference, and for use in stage two of analysis in this study.

3.4 Results and Discussion

The correlation matrix of the indicators of co-operation is shown in Panel (a) of table 15 (see appendix 1), and the correlation structure within the data is sufficient to warrant the use of PCA for dimension reduction (see the Kaiser-Meyer-Olkin statistic that was significant at 5 per cent). The first principal component with an Eigen value of 3.3947 explains approximately 57 per cent of the variation in the original variables. Following the statistical rule of retaining only those components whose Eigen values exceed 0.5, only this first component was retained for purposes of constructing this index. The resultant index is highly correlated with the original variables, which fulfils our expectation that members who reported high ratings for fulfilling their scheme responsibilities have high scores of cooperation index as follows: participation by timely meeting of one's financial obligations (0.70); providing information about misuse of plant (0.84); patrolling to fed off vandals (0.77) and participating in decision making (0.81); attending all meetings (0.62) and fulfilling labor obligations (0.58. The first four can therefore be said to be very important components of the co-operation index. Members who are more co-operative are more likely to fulfill these obligations on time. This does not suggest that attending meetings and labor contribution should not be emphasized, since this is just a check that the mathematical aggregation tool is consistent with our expectation and that the index is useful.

The regression results for implied factors that influence individual level of cooperation are posted in table 17 in

Appendix 1. Note that because our tests show that indeed the variable for trust is endogenous, we use the estimates from the model based on heteroscedasticity based instruments reported in the first column. On average, more educated members will be more cooperative controlling for other relevant factors. This type of relationship is also found in forest commons in India, Haiti and Malawi (Lise, 2000; Dolisca et al., 2006; Jumbe and Angelsen, 2007) as well in irrigation commons in South Africa (Muchara et al., 2014). The reasoning here is that more educated members are able to articulate the role that micro hydro resource can play as an affordable and local electrification solution. This result does not depend on the status of grid access, implying incentive to participate in micro hydro schemes is still high even with the option of grid electricity. Therefore, Greacen (2004) hypothesis that access to grid electricity eliminates commitment to micro hydro activities is not supported by the data in this case study, implying that arrival of grid in micro hydro communities would not eliminate interest in RE micro hydro options. Ngui et al (2011) established a behavior of 'stacking' energy sources by Kenyan households. Households who obtain grid electricity retain their solar home systems for lighting, as back up for electricity power outages and price increases emanating from fuel cost and foreign exchange fluctuation. For this case, it is plausible to think that households would still retain the micro hydro connectivity to cover themselves for volatile prices of grid electricity or frequencies of outage.

Trust for one's peers is associated with higher participation in micro hydro activities, since a member is not afflicted with suspicions of free-riding or non-cooperation by his peers. This outcome is theoretically consistent, since cooperation can only thrive in an environment with trust (see Baland and Platteau, 1996). Empirical support for such an outcome has been found in framed experiment carried out in grazing commons by Hayo and Vollan (2012). Maier (2007) also notes that trust is a fundamental element of the social organizations in Pakistan rural villages, which act the launching pad for community micro hydro schemes. Trust enhancing activities within schemes may allow individuals to feel more confident about dealing with their peers, thereby increasing their cooperation with scheme requirements. Some schemes had agreements where members are supposed to allow the 'electricity inspectors' to get into their houses to check against any illegal connections without prior announcement. Since all members had agreed to this rule, it kind of sent a signal that members were not engaging in illegal connections and there were very few reported cases of power misuse in that particular group. Other groups maintained public lists of labour and financial contributions that were read out in meetings, to ensure that all (including those in leadership positions) were making their due contributions to the group. Exchange programs between schemes may promote such trust enhancing practices from where it is present to where it is lacking.

Higher benefit in terms of more watts available for each household's use is associated with higher participation levels in a microgrid commons, holding all other things constant. This result is empirically supported for both irrigation (Muchara et al., 2014) and forest commons (Lise, 2000; Dolisca et al., 2006; Coulibaly-Lingani et al., 2011) in other developing countries. Since un-metered use is more common than metered use in the context of the current study, the guarantee of a bigger potential gain would drive members to be more committed in the scheme. Offering households

very limited electricity packages like those permitting installation of a single light bulb will mean that a household continues to use kerosene or other alternatives for lighting other rooms. The incentive to cooperate with scheme rules is little since in the event of a sanction like disconnection, there is not much difference to the household created in terms of seeking other options kerosene since they may have been using it in the first place. Lastly, its apparent that consumers with a higher demand for energy in their households demonstrate higher co-operation with scheme rules. The reason for this could be because the use of micro hydro power is a cheaper avenue for reducing dependency on costlier fuels like grid electricity or even kerosene. Members with already higher budgets (like those who pay grid electricity bills every month) would want to continuously enjoy cheaper alternatives like RE micro hydro electricity, hence the observed higher compliance levels. Thus, we do not expect respondents to lose interest in micro hydro electricity after grid extension has taken place within a scheme, in a manner described by Greacen (2004)[21]. Grid electricity cost in Kenya is high and fluctuates with changes in international oil prices, and households are advised to invest in options such as solar panels to reduce their electricity bills. Furthermore, there is high interest for micro hydro electricity even in communities that reside in areas where grid extension has taken place, with reported new scheme development activities or revival of collapsed micro hydro schemes.

The index of cooperation that was created using several variables was also replaced with each of the original variables in the columns marked 2, 3,4,5 and 6 in table 17. Overall, we can see that the significance and signs of the coefficients does not change substantially. This suggest that there is reasonable belief that the index is telling us something about the participation levels of the individuals regarding each separate aspect that was captured by these variables. The implication of using the index instead of the individual variables here is that respondents who reported high ratings of compliance with most of the scheme requirements ended up with higher scores of cooperation index. There was high correlation among the composite variables we used to compute this index (the significant KMO measure implies that it is more useful to combine the related indicators as opposed to using them separately), and the resultant index was in return highly correlated to each of the original variables. The implication of the index is that programs that focus on increasing the rate of fulfillment of each of these scheme obligations by all scheme members would result in more cooperative members. This study has highlighted some of the suggested interventions can be employed for that purpose.

In the second stage of analysis, of interest is the role that local institutional arrangements that this study identified and other conditions proposed in Agrawal (2001) play in the management outcome of a micro hydro. The first step is again to use a multivariate analysis to aggregate concepts of institutional arrangements collected from the group discussion into a score depicting the quality of these arrangements for each scheme. The last two concepts in Table 11

[21] According to behavior explained in Ngui et al. (2011), households would eventually stack all these energy sources to cover themselves particularly when grid electricity prices fluctuate due to for instance foreign exchange adjustments. Additionally, electricity has additional fixed and varying costs on top of the charge for consumption which make it costlier for households.

indicating whether rules are locally made and easily understood were dropped from the analysis, because they had zero variation across the schemes. It was reported in all schemes that members participated in making their own rules, and that these rules are easily understood by members. The score on the quality of institutions was therefore constructed from six components namely: low cost justice systems; appropriation rules that match generation; accountability of leaders to group; having graduated penalties for offenses and adjustment of rules to reflect new developments. The correlation among these variables was very high (KMO measure approaching 1) implying that combining them into one index is an efficient way of representing the concept of the quality of institutional arrangements. Still going by the statistical rule, only one component is retained and it explains more than 80 per cent of the variation in the original variables. The constructed variable is an indicator of the quality of local institutional arrangements and it enters the logit model as one of the predictors of outcome observed in a scheme. The correlation between this index and the original variables is high as follows: low cost justice system (0.93); appropriation matches power availability (0.94); leaders are accountable to members (0.92); penalties are graduated (0.71); rules are adjusted to reflect new developments (0.87) and rules are easy to enforce (0.9). This implies the has information about the original variables, and is therefore useful for this analysis.

At this point, it is important to highlight that there are variables/conditions that were initially thought to be relevant in explaining the outcome in a micro hydro scheme (see list), but it was not possible to include them in the model due to lack of variation in responses across schemes. These variables are: presence of monitoring mechanisms *(monitor)*; interference by external or local authorities *(interfere)* and social capital *(sociocapital)*. Mechanisms for monitoring the use of electricity were in place for all the schemes, the most commonly cited one being 'watching your neighbor' and 'random inspection by an appointed scheme official'. On the other hand, all schemes reported to having had no influence from external or local authorities. In addition to this limitation, there were also conditions which were present or absent in one particularly type of outcome leading to a perfect prediction. Firstly, appropriate leadership whose proxy is group rating of the management committee's ability to perform their allocated responsibilities was absent in all collapsed schemes. Leaders were described as showing less concern for the group, particularly if they acquired grid connection. However, they still lobbied hard for leadership positions in the scheme even with such disinterest. Another explanation obtained from group discussions is that leaders who are caught using electricity outside their permitted allowances influenced decision making in awarding of penalties.

The tests for the assumption of endogeneity with respect to the cooperation index and quality of institutional arrangements were rejected at 5 per cent level of significance (see tables 20 and 21 respectively in the Appendix). This means that the two variables are not endogenous for our case, and for this reason the results from the standard logit or probit model[22] presented in table 19 are adopted for interpretation purposes.

[22] The results from the logit model are not significantly different from those of the probit (see Table 19).

The probability of observing a successfully managed scheme that has not collapsed increases with higher quality of institutional arrangement put in place to manage conduct in the micro hydro. The components of this index are: simple locally devised rules that are understood by all in the group as well as easily enforceable, in addition to having leaders who are accountable for their conduct in the group and penalties that match the gravity of an offense. These conditions comprise what Ostrom (1990) terms as characteristics for long enduring institutions in governance of natural resources. While monitoring, ease of rule enforcement and graduated sanctions act as deterrent measures, having simple and locally devised rules ensures that all members understand their part of scheme contract and the consequences of infringing upon it within the schemes. It is assumed that this understanding is crucial in their judgment of whether to follow or defy the rules. These arrangements should therefore form part of the checklist for reviving collapsed schemes and particularly for the formation of new ones.

Previous objective sheds light on how some sources of heterogeneity at the individual level impact on the level of cooperation with scheme requirements, which in turn affects the likelihood of a successful outcome in a common. It is important to highlight that although there are variables that were anticipated to be theoretically important in explaining success or failure of self-governance in a scheme, but it was not possible to include them due to the nature of our data as explained above. Subsequently, a test for omitted variables bias was carried out on the chosen models for analysis. As the statistic for the test show in table 19, this problem is not manifest in our data. The logit and probit results are also not significantly different, as far as the primary concern of our study (the signs on the coefficients) are concerned.

At the group level, higher within group inequality in asset ownership is more likely to lead to successfully managed schemes. The ownership of arable land is the proxy used for an indicator of asset ownership in this study, and is suitable as land is the most commonly owned asset across the schemes. Wade, as quoted in Baland and Platteau (1996) argues that if a group has members who have higher economic means (like asset ownership in our case) than others, they tend to make more material contribution such collective efforts thereby increasing group resources. More endowed members are also opinion makers and their behavior or advice is taken seriously by the rest of the members in a scheme. In some successful schemes, it was reported that such members make voluntary personal contributions like traveling to look for technical experts to repair faults in the system, or donating trees to be used for making distribution poles. This type of effect is highlighted by Baland and Platteau (1999) and instead of opposing forces between less and more endowed members highlighted in the latter study, we actually observe a reinforcing effect where more voluntary contribution by richer members is associated with success in a scheme. More recent work in the experimental economics field by Archambault (2016) indicates that there are positive peer effects of mixing low and high voluntary contributors in micro hydro schemes in Kenya. We note however that in some unsuccessful schemes, there were complaints of members with greater local influence such as serving or retired public servants aggressively seeking leadership positions in the schemes. Once elected, they were largely uncommitted to the scheme

leadership arguably due to their household's access to grid connection. We cannot ascertain the accuracy of this argument in this study, since we find that grid connectivity does not lead to lower individual cooperation.

Larger groups are more likely to be successfully managed all else constant, contradicting popular view in Olson (1971); Wade (1987) and Baland and Platteau (1996) that successful management is more probable in small groups. The latter studies have a major shortcoming in that they do not give an indication of what is exactly meant by 'small', 'medium' or 'large' in terms of the number of members or households involved. This result is however similar to findings by Naidu (2009) for community managed forests in India. Our argument here is that since a micro hydro construction and maintenance requires more resources in terms of finances and labour, larger groups are more likely to succeed in meeting these financial and labor demands compared to smaller ones. Although the external funding seems to have no bearing on the scheme outcome, schemes with more users are more likely to succeed in lobbying for devolved government funding to finance major capital investments. The number of households participating in a micro hydro scheme ranges from 15 to 172 households and this number may not be too large to have the degenerative effect cited by Olson (1971) if there are effective proper institutional arrangements and monitoring techniques.

Schemes with defined boundaries are more likely to be successful, which is line with the theoretical and empirical evidence across other types of commons (see Wade, 1987 as an example). Successful schemes had rules identifying primary beneficiaries of the scheme and its electricity. For instance, for members with homesteads that have multiple households belonging to their sons, successful schemes had clauses in their rules permitting use of electricity in only the units belonging to the registered member. If the owners of the other households desired to use the scheme power, they have to apply and be vetted as separate members. Lastly, schemes are more likely to be successful the larger the hydro resource in terms of installed capacity. This means that controlling for factors such as group size and better institutional arrangements, investing in schemes with higher installed capacity is likely to lead to successfully managed schemes. Whenever the potential hydro resource permits, schemes should install higher generation capacities while ensuring that they have good institutional arrangements to guide conduct in the group. The local community development experts are better off working with designing projects to make sure that good institutional arrangements early on in scheme development.

3.5 Conclusion

This study borrowed concepts from studies of CPR management to identify conditions that lead to higher likelihoods of successful self-governance in a community energy common. Least squares estimator was used to study potential individual characteristics associated with higher user cooperation in selected collective activities, while a logistic

regression was used to study the association between relevant proposed conditions and observed outcome in community owned micro hydro schemes in Kenya. The results show that individuals possessing more education and trust for colleagues in addition to facing higher energy budget share register high cooperation with scheme requirements, given that they are in groups that have more electricity allowance per household. We propose that these properties must be assessed under the social analysis activities within the conduct of feasibility studies of micro hydro schemes. This would lead to identification of potential areas of support such as training or trust building activities in a scheme. The presence of some conditions proposed in literature of common pool resources management is also likely to lead to successfully managed micro hydro schemes, averting widespread collapse that is an impediment to uptake of RE for rural electrification. These conditions could thus be considered as checklists in the guidelines of developing community owned micro hydro schemes. It was also established that inequality in endowments among members may act as a catalyst for survival of schemes, if there is both higher cooperation and more importantly good institutional arrangements which have been identified here. Collectively, these results form a basis for testing the role of these conditions across a larger number of electricity schemes to overcome data limitations that we faced in this study. Replications from other countries are suggested, particularly where there is adequate data at the community level to compare the findings in this study. Checking the level of reciprocity through framed field experiments or trust games might lead to a greater understanding of the nature of trust existing among joint users of micro hydro grids.

Appendix 1-2: Tables for Paper 2

Table 9: Comprehensive list of enabling conditions by Agrawal (2001)

1. Resource system characteristics
    - **small size (RW)**
    - **well-defined boundaries (RW, EO)**
    - low levels of mobility
    - possibilities of storing benefits from the resource
    - Predictability
2. Group characteristics
    - **Small size (RW, B&P)**
    - **Clearly defined boundaries (RW, EO)**
    - Shared norms (B&P)
    - **Social capital defined by past successful experiences (RW, B&P)**
    - **Appropriate leadership (B&P)**
    - interdependence among group members (RW, B&P)
    - **Heterogeneity within group (B&P)**
    - low levels of poverty overlap: resource system and group characteristics
    - group location & resource location (RW, B&P)
    - high levels of dependence on resource system by members (RW)
    - fairness in allocation of gains from resource (B&P)
    - low levels of user demand

- Gradual change in levels of demand

3. Institutional arrangements

- **Rules are simple and easy to understand (B&P)**
- **Locally devised access and management rules (RW, EO, B&P)**
- **Ease in enforcement of rules (RW, EO, B&P)**
- **Graduated sanctions (RW, EO)**
- **low cost adjudication (EO)**
- **accountability of monitors and other officials to users (EO, B&P)**

Overlap : resource system & institutional arrangements

- matching restrictions on harvests to regeneration of resources (RW, EO)

4. External environment

- Technology

– low cost exclusion technology(RW)
– time for adaptation to new technologies related to the commons

- low level of articulation with external markets
- Gradual change in articulation with external markets
- state and group relationship

– **central government should not undermine local authority (RW, EO)**
– **Supportive external sanctioning institutions (B&P)**
– Appropriate levels of external aid to compensate users for conservation activities (B&P)
– Nested levels of appropriation, provision, enforcement and governance (EO)

The variables that are relevant for this paper are in highlighted in bold

The initials denote the contributor of principle to the list in Agrawal (2001), as follows:

B&P-Balland and Platteau

RW-Robert Wade

EO-Elinor Ostrom

Table 10: variables for cooperation index construction

Variable	description	measurement
billset	meets financial contribution	scale
freelab	meets free labor contribution	scale
infrep	providing information	scale
Patpatro	Patroling to guard plant	scale
decpat	participating in decision making	scale
meetatted	attending to scheme meetings	scale

Table 11: Variables for quality of local Institutional arrangement

Variable	Description	Measurement
lowcost	low cost justice system	binary
apprules	Appropriation rules match resource availability	binary
leaderacou	leaders are accountable to members	binary
gradpenal	graduated sanctions	binary
rules adjusted	adjustment of rules to fit new developments	binary
rulesenforce	rules are easy to enforce	binary
rules understand	rules are easy to understand	binary
rules making	are the rules locally devised	binary

Table 12: Variables and measurement

Label	Variable	measurement
Index	level of co-operation with scheme rules	index
billset	settlement of financial bills	scale
Free_labor	meeting free labour obligations	scale
infrept	providing information	scale
patpatro	participating in infrastructure patrol	scale
decpat	participating in decision making	scale
allmeet atte	attending meetings	binary
yrseducation	education acquired	years
enviclub	membership to an environment club	binary
memtenu	duration of membership in the scheme	years
trustall	trust of peers	binary
Eexpratio	energy share in house budget	ratio
Incentive	having another main source of electricity	binary
Wattsper	the watts available for each household	watts/household
Gender	gender of member	binary
landacr	the size of arable land owned	acres
schemecode	scheme name	binary
Insti index	quality of institutional arrangement	index
just cost	cost of justice in time	binary
apprule match	appropriation rules match to generation	binary
leader _account	leader accountability	binary
gradu penalties	graduated penalties	binary
rules adjusted	adjustment of rules to reflect developments	binary
enforce ease	ease of enforcing rules	binary
expe partindex	predicted participation level	index
asset ineqy	level of asset inequality	index
ext funding	external funding	binary
group size	size of the group	number of members
boundary users	defined boundary of users	binary
resource size	size of resource	installed kilowatts
Social capital	if members meet in other different groups	binary

Table 13: Sample: Target vs Realized

Scheme name	total membership	expected sample	realized sample
Kiangima	76	22	17
Ngerechi	120	50	52
Ndiara	100	37	37
Thima	165	50	35
Kigwathi	25	7	7
Mungetha	60	20	23
Thimu	60	20	27
Rutui	35	11	14
Kathamba	50	15	24
Total	746	232	236

Table 14: Mean characteristics at group level

scheme	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Status	*0*	*0*	*1*	*1*	*0*	*1*	*1*	*0*	*0*
age	*55.9285*	*54.2500*	*53.5882*	*62.7143*	*49.65217*	*62.2973*	*51.2692*	*52.6*	*55.5926*
yrseducation	*8.7857*	*10.8750*	*9.7059*	*7.5714*	*8.5217*	*6.8378*	*8.1731*	*8.5143*	*9.6296*
yrs in village	*43.8571*	*42.75*	*41.7059*	*58.1429*	*35.6087*	*51.1351*	*37.1923*	*36.6571*	*48.4074*
landacr	*1.4643*	*1.1746*	*1.2959*	*1.5928*	*0.8349*	*2.1301*	*2.6904*	*1.3952*	*1.8852*
income	*23598.93*	*16683.82*	*17209.82*	*10152.14*	*22707.09*	*17976.82*	*24546.95*	*17835.11*	*19467.7*
imputed inco	*10371.43*	*13962.5*	*15074.53*	*4428.571*	*14621.74*	*15190.54*	*13956.62*	*11451.43*	*13944.44*
Eexpratio	*0.0496*	*0.0792*	*0.1087*	*0.1087*	*0.0965*	*0.0825*	*0.0788*	*0.0721*	*0.0871*
Group level information									
gender ratio	*0.20*	*0.44*	*0.50*	*0.00*	*0.22*	*0.14*	*0.33*	*0.31*	*0.28*
group age(yrs)	*10*	*12*	*5*	*10*	*0.7*	*7*	*9*	*10*	*1*
resource size(kw)	*3*	*1.1*	*11*	*1*	*10*	*11*	*5*	*2.2*	*2*
group size	*76*	*150*	*70*	*150*	*25*	*60*	*60*	*15*	*172*
ins index	*0.84*	*0.13*	*1*	*0*	*1*	*1*	*1*	*0*	*0.53*
Part_ level	*0.81*	*0.65*	*0.80*	*0.82*	*0.51*	*0.77*	*0.85*	*0.53*	*0.46*
mean insti index=0.67; mean part level=0.68									

Source: Survey Data

Table 15: Correlation matrix of the variables used for indices construction.

Panel (a): Variables for Index of Cooperation					
	billset	*freelab*	*infrep*	*patpatro*	*decpat*
billset	*1*				
freelab	*0.5326****	*1*			
infrep	*0.5179****	*0.3961****	*1*		
patpatro	*0.3771****	*0.3089****	*0.4793****	*1*	
decpat	*0.5154****	*0.4371****	*0.6098****	*0.4879****	*1*
meetatte	*0.6461****	*0.5229****	*0.4813****	*0.3097****	*0.5082****
Panel (b): Variables for Index of local Institutional Arrangements					
	just_cost	*apprule_mat*	*leader_*	*gradu_*	*rules_*
*just_*	*1*				
*apprule_*	*0.7726****	*1*			
*leader_*	*1.0000****	*0.7706****	*1*		
*gradu_*	*0.4712****	*0.7971****	*0.4712****	*1*	
*rules_*	*0.6841****	*0.8855****	*0.6841****	*0.7058****	*1*
Enforce_ease	*1.0000****	*0.7766****	*1.0000****	*0.4712****	*0.6841****
*****significant at 1%*					

The variables are highly correlated which means that aggregating them into a single index is useful

Table 16: Correlation matrix of variables- OLS

	index	education~	memb_	duration~	Trust~	energy share	grid conn	incentive	gender
Index	1	1							
educ_	0.0850								
envi_	0.1808***	-0.0728	1						
memb_	0.3162***	-0.0460	0.1024	1					
Trust	0.4317***	-0.0533	0.0822	0.2358***	1				
energy_	0.0736***	-0.0118	-0.1102	-0.0483	-0.0363	1			
incen_	0.2873***	-0.1917***	0.0998	0.3080***	0.2021***	-0.0480	1		
watts_	0.1155	-0.0916	-0.0570	-0.0826	0.0975	0.0223	-0.0312	1	
gender	-0.0946	-0.3212***	0.0145	0.1031	0.0071	0.0634	0.1025	-0.1084	1
Asset_	0.0902	-0.0592	0.2465***	0.0807	0.0558	-0.0230	-0.0043	-0.1039	0.0059
***Significant at 1%									

Source: Survey Data

Table 17: Factors influencing individual cooperation levels in scheme activities-OLS

Variable	***1-Coefficients (S.E) IV***	*1(2)-Coefficients (S.E)*	*3-Coefficients (S.E)*	*4-Coefficients (S.E)*	*5-Coefficients (S.E)*
Education level(years)	***0.1127(0.0398)*** ***	*0.1128(0.0437)* ***	*-0.0002(0.0128)*	*0-.0007(0 .01114)*	*.0602294(0.01590)****
Membership to an environmental club	***0.6278(0.4154)***	*0.6215(0.4307)*	*0.1521 (0.1206)*	*0.1443(0 .10446)*	*.1073396(0.1490)*
Duration of membership in scheme	***0.0998(0.0822)***	*0.0969(0.0852)*	*0.0028(0.0222)*	*0.0082(0.019246*	*.0277419(0.0274)*
trust for peers	***2.4907(0.6162)*** ***	*2.6742(0.6275)* ***	*0.5777(0.1651)****	*0.7451(0.14302)****	*.6145475(0.2040)****
energy share in household budget	***5.3970(1.9631)*** ***	*5.4181(2.0304)* ***	*0.1651(0.73041)**	*1.3396(.63255)****	*.9213306 (0.9025)*
incentive (grid connection)	***0.6888(0.5850)***	*0.6830(0.6075)*	*0.1497(0.15752)*	*0.1341(0.1364)*	*1665906 (0.1946)*
watts/household	***0.0194(0.0056)*** ***	*0.0191(0.0059)* ***	*0.0063(0.0018)****	*0.0079(0. .0016)*	*.0087491(0.0023)****
Gender (male)	***-0.4898(0.3995)***	*-0.4917(0.4145)*	*-0.1608 (0.1155)*	*-0.1242(0. .10010)*	*-.0226043(0.1428)*
Asset ownership (arable land acreage)	***-0.0191(0.0784)***	*-0.0189(0.0813)*	*0.0002(0.02990)*	*-0.0078(0.0259)*	*-.0106585(0.0369)*
Scheme1	***1.3858(1.0942)***	*1.3700(1.1390)*	*0.5425 (0.2721)***	*-0.3110(0.2357)*	*.2881025(0.3362)*
Scheme2	***0.5155(0.7241)***	*0.4904(1.7515)*	*-0.1435(0.2864)*	*-0.177(0. .2480)*	*.196139(0.3538)*
Scheme3	***2.7515(1.0222)*** ***	*2.7126(1.0620)* ***	*0.5741(0. .3798)*	*0.0395(0 .3290)*	*.7947192(0.4694)**
Scheme4	***-2.3000(0.7725)*** ***	*2.2477 (0.7994)* ***	*-0.9725 (0.2615)****	*-0.3633(0.2264)*	*-1.147361(0.3231)****
Scheme5	***0.1650(0.7369)***	*0.1524 (0.7651)*	*-0.3378(0.2425)*	*-0.3579(0.2100)**	*-.310744(0.2996)*
Scheme6	***3.2244(1.0661)*** ***	*3.2028(1.1103)* ***	*0.5865(0.2830)***	*-0.1494(.24514)*	*1.220766(0.3497)****
Scheme7	***0.3617(1.0755)***	*0.3604 (1.1193)*	*0.3997(0.29077)*	*-0.4671(.25181)**	*.2468122 (0. .3592)*
k	***2.1218(0.9591)*** **	*2.0101 (1.000)* ***	*1.027 (0.2822)****	*1.8832(.24440)****	*-.368832 (0.3487)*
n	***236***	*236*	*236*	*236*	*236*
r2 [adj]	***41.65%***	*37.65%*	*20.82%*	*17.16%*	*33.8%*
Kleibergen-Paap LM Statistics	***60.604(p-value=0.00)***				
Hansen Statistic of overidentification	***24.69 (p-value=.04)***				

3-dependent = the frequency of settling bills on time; *4-dependent=frequency of meeting labor obligations*; *5-dependent=information provision*. The fact that the results in 1 and 1(2) resemble those in other columns suggest that the index has useful information that came from the separate variables that make up this index.

Table 17: Factors influencing individual cooperation levels in scheme activities-OLS (Continued)

Variable	***1-Coefficients (S.E) IV***	*1(2)-Coefficients (S.E)*	*6-Coefficients (S.E)*	*7-Coefficient(S.E)*
Education level(years)	***0.1127(0.0398) ******	*0.1128(0.0437) ****	*.0313935(0.0180)**	*0.0313(0.0180)**
Membership to an environmental club	***0.6278(0.4154)***	*0.6215(0.4307)*	*.0995(0.1695)*	*0.0995(0.1695)*
Duration of membership in scheme	***0.0998(0.0822)***	*0.0969(0.0852)*	*.0074(0.0312)*	*0.0074(0.0312)*
trust for peers	***2.4907(0.6162) ******	*2.6742(0.6275) ****	*.4393(0.2321)**	*0.4393 (.2321)**
energy share in household budget	***5.3970(1.9631) ******	*5.4181(2.0304) ****	*1.7610(1.0264)**	*1.7610 (1.026)**
incentive (grid connection)	***0.6888(0.5850)***	*0.6830(0.6075)*	*.2351 (0.2213)*	*0.2351 (0.2213)*
watts/household	***0.0194(0.0056) ******	*0.0191(0.0059) ****	*.00320(0.0026)*	*0.0032 (0.0026)*
Gender (male)	***-0.4898(0.3995)***	*-0.4917(0.4145)*	*-.2006(0.1624)*	*-0.2006(0.1624)*
Asset ownership (arable land acreage)	***-0.0191(0.0784)***	*-0.0189(0.0813)*	*-.0239(.0420)*	*-0.0239(0.0420)*
Scheme1	***1.3858(1.0942)***	*1.3700(1.1390)*	*.4185(0.3824)*	*0.4185(0.3824)*
Scheme2	***0.5155(0.7241)***	*0.4904(1.7515)*	*.1837(0.4025)*	*0.1837(0.4025)*
Scheme3	***2.7515(1.0222) ******	*2.7126(1.0620) ****	*.7255(0.5338)*	*0.7255(0.5338)*
Scheme4	***-2.3000(0.7725) ******	*2.2477 (0.7994) ****	*-.0997(0.3675)*	*-0.0997(0.3675)*
Scheme5	***0.1650(0.7369)***	*0.1524 (0.7651)*	*1.0031(0.3407)****	*1.0031(0.3407)****
Scheme6	***3.2244(1.0661) ******	*3.2028(1.1103) ****	*1.2609(0.3978)****	*1.2609(0.3978)****
Scheme7	***0.3617(1.0755)***	*0.3604 (1.1193)*	*.4931(0.4086)*	*.4931(0.4086)*
k	***2.1218(0.9591) *****	*2.0101 (1.000) ****	*-.3525 (0.3966)*	*-0.3525(0.3966)*
n	***236***	*236*	*236*	*236*
r2 [adj]	***41.65%***	*37.65%*	*20.54%*	*20.54%*
Kleibergen-Paap LM Statistics	***60.604(p-value=0.00)***			
Hansen Statistic of overidentification	***24.69 (p-value=.04)***			

6-dependent variable=participation in patrolling plant infrastructure. The fact that the results in 1 and 1(2) resemble those in other columns suggest that the index has useful information that came from the separate variables that make up this index.

Table18: Correlation matrix of the variables-logit model

	outcome	*insti index*	*part index*	*asset ineq*	*ext _fund*	*grop _size*	*boud _user*	*resou _size*
outcome	*1*							
insti index	*0.6176*	*1*						
Parti index	*0.7248*	*0.4650*	*1*					
asset ineq	*0.064*	*-0.4732*	*0.1014*	*1*				
Ext fund	*0.3368*	*0.1568*	*0.2075*	*0.2763*	*1*			
grop size	*-0.1693*	*-0.2221*	*-0.1177*	*-0.0224*	*-0.6305*	*1*		
boud user	*-0.4796*	*-0.3847*	*-0.6316*	*-0.0883*	*-0.2498*	*-0.0532*	*1*	
resou size	*0.5342*	*0.7561*	*0.2567*	*-0.4206*	*0.4348*	*-0.4422*	*-0.0902*	*1*

Source: Survey Data

Table 19: Predictors of successful management of a scheme

Variable	*logit-coefficients (s.e.)*	*m.e. (at means)1*	*Probit-coefficients (s.e.)*	*m.e. (at means)*
Institutional ind	*1.7185(0.8479) ** *	*0.4289(0.2130) ** *	*0.9709(0.4332) ** *	*0.3867(0.1730) ** *
Participation ind	*3.2920(0.6390) *** *	*0.8215(0.1614) *** *	*1.8390(0.3255) *** *	*0.7324(0.1300) *** *
Asset inequality	*50.3164(11.3953) *** *	*12.5573(2.7656) *** *	*27.8460(5.9480) *** *	*11.0898(2.3035) *** *
group size	*0.0516(0.0130) *** *	*0.0129(0.0032) *** *	*0.0289(0.0069) *** *	*0.0115(0.0027) *** *
Boundary of users	*8.0891(2.2962) *** *	*2.0188(0.5721) *** *	*4.5101(1.2009) *** *	*1.7961(0.4744) *** *
Resource size	*1.3165(0.2909) *** *	*0.3286(0.0703) *** *	*0.7294(0.11486) *** *	*0.2905(0.0575) *** *
k	*-69.0423(13.2489) *** *		*-38.4335(6.1927) *** *	
log-likelihood	*-24.1533*		*-23.6546*	
Pseudo R^2	*0.8522*		*0.8522*	
Pregibon link test statistics	*0.0301 (0.0425)*		*0.06837(0 .0767)*	

**, ***significant at 5% and 1% respectively

Replacing the components of the Institutional quality index with the variables that make up this index in the logit model led to results that largely resemble the above. This means that the index has some useful information even at that aggregated level.

Table 20: Probit model under the assumptions of endogeneity (Institutional arrangement quality) with external funding as an instrument

Variable	*ivprobit coefficients (s.e.)*
(scheme outcome is the dependent variable)	
Institutional ind	*0.7830 (1.1179)*
Participation ind	*1.8414 (0.3251) ****
Asset inequality	*26.6442 (9.2905) ****
group size	*0.0287 (0.0071) ****
Boundary of users	*4.3583 (1.5122) ****
Resource size	*0.7433 (0.1559) ****
k	*-37.6412 (8.5584) ****
relationship between institutional quality index (Institutional indx) and instruments)	
Participation ind	*0.0646 (0.0197) ****
Asset inequality	*-1.9252 (0.5952) ****
group size	*-0.0016 (0.0009) ***
Boundary of users	*-0.6397 (0.0902) ****
Resource size	*0.1876 (0.0125) ****
external funding	*-0.69 47(0.1322) ***
k	*1.8118 (0.3163) ****
k	*5.6201 (1.0312) ****
log-likelihood	*—188.0197*
athrho	*0.1039(0.5616)*
note: the statistic for Wald test of exogeneity (anthro) is not significant at 5 per cent	
, ** ,*significant at 10%, 5% and 1% respectively*	

Table 21: Probit model under the assumptions of endogeneity (cooperation index) with church attendance as an instrument

Variable	*ivprobit coeffic(s.e.)*
Participation ind	*0.4747(0.9939)*
Institutional ind	*0.9954 (0.3775) ****
Asset inequality	*19.2039 (11.3337) **
group size	*0.0147 (0.0137)*
Boundary of users	*1.3780 (2.4143)*
Resource size	*0.3979 (0.3294)*
k	*-18.0234(18.1620)*
relationship between (Participation ind) and instruments	
Institutional ind	*0.9194 (0.1941) ****
Asset inequality	*7.5131 (1.7560) ****
group size	*-0.0017(0.0024)*
Boundary of users	*-2.0825 (0.2516) ****
Resource size	*-0.0093 (0.0478)*
church attendance	*-0.4720 (0.2679) **
k	*5.6204(1.027) ****
log-likelihood	*-466.7826*
athrho	*1.2592 (1.0054)*
note: the statistic for Wald test of exogeneity is not significant at 5 per cent	
** ,**, ***significant at 10%, 5% and 1% respectively*	

4 Paper 3: Impact of micro hydro electricity access on household welfare indicators

4.1 Introduction

International Energy Agency estimates that 1.2 Billion people in the world had no electricity access as of 2014 (IEA, 2016). Slightly more than half of these people are in Sub-Saharan Africa (SSA), making electricity access a particularly pressing development problem in this region. Consequently, there have been concerted efforts to direct more infrastructure spending to rural electrification (RE) mainly through grid extension and other alternatives like renewable energy microgrids. For instance, the World Bank is currently running several lending programs for rural electrification in developing countries. Although not widely deployed in SSA before, microgrids are now important in deploying renewable energy in remote rural areas where grid extension is uneconomical (Munuswamy et al., 2011). Among the many advantages of microgrids over national grid is the higher energy efficiency, due to the fact that energy generation occurs near the consumers (Abu-Sharkh et al., 2006). Such systems are useful means of energy conservation practices because they reduce demand on grid provided electricity (Casillas and Kammen, 2011). The main justification for these rural electrification interventions is based on a hypothesis that access to electricity can lead to improved health, education, gender equality and economic outcomes. Bernard (2010) observes that in the face of current resource shortages and competing budgetary needs, it is important to account for rural electrification spending on improvement of human living standards. This is the entry point for academic literature that sets to obtain the independent impact of rural electrification of several claimed outcomes.

Barnes and Binswanger (1986) note that RE projects take long to materialize in addition to the fact that rural households may take long to make the connection or adoption decision. Consequently, the socio-economic benefits may take long to show up even if a lot of unrecoverable resources have already been spent. Methodological difficulties are apparent in literature given that the most suitable methods of establishing impact like Randomized Control Trials (RCTs) may not be easily applicable. This is because electrification projects in developing countries are mostly subsidized, and the fact that isolating treatment and control groups in electrification of poor households may raise ethical challenges. In spite of these difficulties, attempts have been made in literature to quantify the changes that occur to grid electricity consumers. Increased income is established by (Khandker et al., 2012, 2013) but this may only be a localized impact as shown by other studies like (Bensch et al., 2011). Thus it is not a guarantee that households in all electrified geographical regions will get an income gain attributable to electrification. Other studies like Dinkelman (2011) have established an increase in employment that is purely attributable to electrification. Additionally, gender equality objectives may also be achieved if availability of electricity eases household chores that

mainly tend to tie women down like cooking with collected firewood (Dinkelman, 2011). However, this impact may not occur in countries where electricity is expensive and households limit their use of electricity to only light uses (Madubansi and Shackleton, 2006). Educational gains from rural electrification can only be established in samples comprising of school going population, and even so the proxy used for education gain is study hours which may not translate into improved academic performance. Bensch et al. (2011) find non-robust evidence for increased study time for primary school kids in rural Rwanda, while Matinga and Annegarn (2013) claim that access to electricity may paradoxically reduce the study time as children divert study time to electricity powered entertainment activities. This indicates that a case by case assessment of electrification intervention impacts may be particularly necessary. Renewable energy microgrids may deliver services that are slightly different from grid services, and it is not justifiable to assume that the impacts on the users are like those grid consumers. For instance, rural electrification through solar or micro grids cannot lead to shifts in cooking fuel since such electrical loads is rarely met from such projects. Income earning opportunities for households can only be possible if the available electricity can be used for operating machines for home-based enterprises. Grid electricity comes with unlimited capacity capable of all these applications.

There is a general hypothesis that access to electricity leads to elimination of dirty fuels, driven mainly by the replacement of kerosene lamp and open fires with electric bulbs. Madubansi and Shackleton (2006) find that electrification led to increased fuel wood use in households, although the approach in the study does not control for other changes to a particular household over time. Even so, we cannot entirely dismiss such an outcome given that rural households may not afford the cost of cooking with electricity. The obvious thing in the literature is that electricity can affect different aspects of human welfare, all of which are agreeably important. More importantly, it is apparent that the impact of electrification is context dependent and a claim of an impact in one instance does not guarantee the same outcome elsewhere. In particular, since off grid renewable electrification solutions are potentially different from grid services in terms of quality (Terrado et al., 2008), it is clear that expectations from such installations are more likely to be modest but all the same useful. Households using limited electricity may not be able to achieve goals like changing the cooking fuel, since such load is not admissible in solar or other such off-grid solutions. Heavy applications such in agriculture or industry may also not be reasonable to expect with electrification services that deliver limited electricity to households.

While electrification impacts resulting from grid electrification dominate empirical literature, (see Bernard (2010); Dinkelman (2011); Khandker et al. (2012, 2013)) there exists a vacuum of empirical evidence for the impacts of alternative off grid rural electrification. In particular, off grid renewable energy is often justified on the grounds that it leads to improvements of human welfare such as provision of convenient, affordable and clean electricity. Whether this hypothesis is maintained remains an empirical question because the few studies that claim such impact do not solve for self-selection bias into connectivity (see for instance Madubansi and Shackleton, 2007; Komatsu et al., 2011; Mondal and Klein, 2011; Matinga and Annegarn, 2013). Moreover, evidence from ex-ante evaluation like Bensch et al.

(2012) may not form a useful reference point for impact of limited capacity electrification interventions, since they use comparison households which are connected to grid supply. The current study aims to contribute to ongoing debate of deploying renewable energy electrification by using observational data and a consistent estimation technique that can permit attribution of electrification to outcomes.

Objective of the study

The objective here is to establish the impact of micro hydro grid connectivity to selected indicators of household welfare namely: kerosene consumption; energy expenditure as a ratio of household spending; cost of recharging mobile phone batteries; the hours of night light utilization and study duration for schooling children.

Contribution to literature

The main contribution of this study is application of an econometric technique that can permit a claim of an impact of microgrid electrification, in a field where impact assessment largely focuses on grid-based electrification in developing countries. Existing studies examining impact of small scale electrification projects compare only the before and after access conditions, without adjusting for other simultaneous changes that occurred to the connected households in the course of accessing connectivity to their households. Matching techniques are used to create comparable units, and the estimated impacts subjected to various robustness checks. The study focuses on changes that accrue to a household almost immediately after electrification, thereby providing estimates of the short-term benefits from RE microgrid electrification. This is because of the data accessible by the study, and does not in any way dismiss the potential long term benefits that such electrification models can deliver to participating households.

Micro Hydro Electricity and rural electrification in Kenya

Although there have been ongoing rural electrification investments in Kenya, serious state focus on rural electrification can be traced back in 2003 in the advent of a political regime change. Several changes in the Electricity sub-sector culminated into adjustments in the Energy Act and a Sessional Paper on Energy that recommended separating of generation and distribution functions, as well as introduction of energy sector regulator in 2006. Other players have been introduced through review of the energy sector policy and regulations. The function of rural electrification is the responsibility of the Rural Electrification Authority (REA), while power generation and distribution is left to Kenya Electricity Generation Company and Kenya Power and Lighting Company, respectively. Responsibilities for renewable energy development are spread across actors in the energy sector with the Government's role being largely facilitation through policy. Despite this type of institutional set up, electricity access continues to be a development challenge with only 7 per cent of the rural population having access to electricity (IEA, 2016).

The use of off grid renewable energy technologies like microgrids like based on solar, wind and water has been adopted by individuals, communities and institutions as alternative RE mechanisms in Kenya. These are mainly practiced by private individuals (like solar home systems or individual microgrids) or communities (micro solar/hydro grids) to either meet their primary energy needs or supplement own energy sources. Community owned micro hydro grids were initiated when two demonstration projects were set up by the Government of Kenya in conjunction with development partners (United Nations Development Programme and Practical Action) in the year 2000. Two communities were mobilized to set up micro hydro grids that would later act as demonstration points for other groups. What followed was a long trial period and demand for this alternative electrification remains high even in places that have grid presence, although state support for such local electrification projects has declined over time. The latter has not diminished the interest of community-based projects with at least 10 proposals lined up for potential funding, while others are at various stages of development.

Once a community decided to exploit local micro hydro potential a scheme would be established, and participating households within the radius of a micro hydro would be required to register on a first come basis. Communal manual work and contribution of building materials and money form part of the mandatory contributions throughout the phases of constructing the power plants and distribution lines. Only those who have fulfilled all the labor and financial obligations are eligible for connection of power into the households in several phases. Because of financial and or technical limitations, most community micro hydro grids in Kenya are designed to provide basic electricity services to member households ranging from lighting to powering small appliances like television. As a result of this limited use, one would not expect outcomes associated with heavy use of electricity like cooking or heating. An interesting observation is that households connected to the grid in these rural areas limit electricity use to the similar light uses due to affordability and availability other cheaper alternatives. Nevertheless, it is important to isolate the claimed impact of microgrid electrification in literature since they informed the investment decision in the first place. This study seeks to establish such impact using observational data collected from participating and non-participating households within community-based micro hydro schemes.

4.2 Literature Review

Impact evaluation studies for electrification and other infrastructure projects have only become popular recently, following accountability concerns by donor community (Bernard, 2010). In response to this, empirical work on impact evaluation for project intervention grew rapidly after Paris Declaration on Aid effectiveness. The existing studies on the impact evaluation of rural electrification can be separated into two types: those that use mainly attributions to claim impact and those which put emphasis on addressing endogeneity (participation bias) while seeking causal impact. The first lot of studies collect post-electrification data to describe how a community looks like after

electrification, or compare outcomes based on whether one has electricity or not. The limitation with these studies is that the claimed benefits such as extended night activity and clean indoor air cannot be attributed to electricity access only, since the environment under which they are isolating impact is not controlled for other influences. This weakness is addressed by studies that create experimental atmosphere or try to mimic one, which permits a claim of causal impact of electrification. Both studies are reviewed here with this setting in mind.

The most obvious way of telling that a household has benefited from electrification is through extended night activity, due to availability of more quality and efficient lighting (Bensch et al., 2011). Most studies assume away this impact which may not be achieved if electrification is accompanied by poor service like extreme outages. Bensch et al. (2011) finds that connected households in Rwanda report more light hours per day compared to their counterparts who are not connected. The measure used here does not account for the fact that more light hours from use of for instance tin lamps is actually a non-desirable outcome due to the associated pollution. It may be worthwhile to look at other ways of capturing increased use of lighting in the household from electrification, since demand for lighting during the day is very little for rural households. For instance the use of either kerosene or firewood for lighting is costly to the household and inconvenient due to smoke, and it is reasonable to expect that cheaper and cleaner option like micro hydro electricity would be associated with more use of light at night. Thus comparing the night time light hours may be more useful as opposed to looking at whole day light usage.

Reduced consumption of dirty fuels like kerosene and fuel wood is a common justification for rural electrification, but the outcome from empirical work is contentious. Dinkelman (2011) found that households take up of electric cooking and lighting led to reduced use of firewood over a six-year period (1996-2001) of rural electrification in South Africa's Kwa Zulu Natal Province. However, Madubansi and Shackleton (2007) contends that in some communities of Bushbuckridge within South Africa, fuel wood use did not decrease in the aftermath of rural electrification carried out between 1991 and 2002. Elsewhere, Vietnamese households reported huge reductions in kerosene lighting after only two years of electrification in a country with a fairly high grid reliability (Khandker et al., 2013). If electricity supply comes with frequent power outages, electrified households end up spending the same amount on kerosene as those who are not electrified as found by Khandker et al. (2012) in Bangladesh. Complete elimination of kerosene in the household due to electrification is also possible, as illustrated by the introduction of Solar Home Systems (SHSs) in Bangladesh (Mondal and Klein, 2011). This happens when households become so accustomed to clean indoor air after electrification, that they find it inconceivable to return back to kerosene use and experience its smoke. Elsewhere, Bernard (2010) observes that although rural households desire to use electricity for activities such as cooking, a combination of cost/affordability ensures that cheaper options like firewood eventually prevail. Thus, health gains from electrification such as those demonstrated by Rollin et al. (2004) among South African households may not be achieved unless rural electrification is accompanied by programs disseminating cleaner household fuel alternatives.

One can safely predict that rural electrification can only reduce rather than eliminate the use of dirty fuels in the household.

Economic gains from electricity access in rural areas accrue from increased productivity in home enterprises or intensification of agricultural activity. In Vietnam, adoption of electric water pumps was observed to have replaced manual irrigation leading to increased agricultural income (Khandker et al., 2013). Electric water pumps enable farmers to irrigate larger acreages of land with little spending on labour, and this may translate into higher earnings if markets are accessible. Bensch et al. (2011) find that electrified houses have slightly more income in Rwanda. This outcome is from an ex-ante evaluation under the assumption that hypothetically connected households would reap the same benefits as those already connected. However, Matinga and Annegarn (2013) cautions against such assumptions that lead to generalizations in impact evaluation work. The study notes that income gains from electrification are largely dependent on pre-existing conditions or simultaneous interventions which are rarely captured in observational data, and this is responsible for the varying outcomes in literature. For instance, if electricity service is of limited capacity or comes with poor service then the probability of zero income gain is even higher. Alongside this reasoning Rao (2013) finds that although electrification led to higher incomes in Indian villages, those households with better quality of supply had even higher income gains. This resonates with our earlier claim about expected gains with limited capacity rural electrification. Other conditions like markets and level of economic activity determine the potential income gain. Bernard (2010) observes that in SSA rural settings, there is limited employment opportunity exacerbated by lack of market for goods that are produced by home enterprises. Electrification may lead to increased productivity of micro enterprises such as that described by Jacobson (2007); Kirubi et al. (2009) in Kenya, but income gains may not be realized due to market bottlenecks. Obermaier et al. (2012) advises that for electrification programs to be successful, they must be integrated into the greater rural development strategy. Twin objectives of increasing access as well as increasing electricity consumption through other facilitation programs must be met in addition to simultaneously implementing other non-electrification programs. These other supporting programs may take time to implement, giving long lead times for income gains to be observed after electrification. Khandker et al. (2009) found that in Bangladesh, income gains from electrification increased with duration of electricity exposure but at a decreasing rate (based on the squared term for duration electrification). Income thus seems to be one of those benefits that can be accessed only in the long term after and electrification intervention.

Gender-based roles are common in developing countries cultural settings, and they may have a bearing on who gains most from electrification within a household. For instance, women spend time collecting firewood for family use and introduction of electricity may reduce the demand for firewood subsequently freeing up some of their time. This additional time may be translated into increased labour market participation by women, as observed in South African rural households by Dinkelman (2011). Most rural households however continue to use firewood and charcoal for cooking even after electrification, with an enormous 80 per cent of rural electricity consumption devoted to lighting

and television (see K¨ohlin et al. (2011)). The inability to pay for more units of electricity, cultural cooking habits or simply inability of delivered quality of electricity to be applied to some uses may mean that expecting such gender-related outcome may be farfetched in developing countries. Results for educational gains from electrification are mixed. Although electricity avails quality light for reading in the evening, Matinga and Annegarn (2013) notes that children may reduce their daytime study hours by taking up television watching or playing games. Thus there is no direct link between electrification and education outcomes because more often than not, there is no long-term data to indicate if the changes in study patterns actually translate into education outcomes. In an interesting case, school enrollment rates and average years of schooling in India increased for girls over 17 years of rural electrification while no change was observed for boys (Van de Walle et al., 2013). In Bangladesh, Khandker et al. (2009) find that electrification led to an increase in both study hours and school completion rates with boys appearing to have gained more than girls. Within each gender, education gains from electrification were higher in households with more land. This implies that more resources (like capital) may lead to higher gains from electrification because they possess higher ability to pay for other services. Any rural electrification program must be accompanied by other development efforts to ensure that everybody has a chance of receiving some benefits from access to electricity.

In addition to the above contradicting outcomes from rural electrification, a major concern in empirical work is methodological approaches mainly driven by endogeneity/sample selection problems and data availability. Households that are naturally flexible and hardworking are more likely to self-select into connection, and this means that they are likely to have better outcomes than their rigid or less determined counterparts even in the absence of electrification. Additionally, placement of rural electrification projects is usually biased towards areas with higher economic potential due to concerns about project returns. Studies vary in their econometric approaches that allow a claim about causality. More importantly, data availability dictates the choice of method particularly where evaluation is not a component of rural electrification programs. Propensity score matching as used by Khandker et al. (2009); Bensch et al. (2011) seems more appropriate in the absence of before and after connection data, with the major challenge being finding proper and adequate comparison units. The use of geographical instrumental variables on the other hand is gaining popularity in literature, making it a feasible approach whenever such data is available. Dinkelman (2011) uses community gradient in a study of communes distributed in South Africa's province of KwaZulu-Natal to establish the labour market gains from electrification, while the distance from nearest connectivity point in India is used as an instrument for endogenous electricity access (Khandker et al., 2009). In special cases where data spanning two time periods is available, adopting panel fixed effects can control for selection problems, in addition to identifying long term benefits of electrification. Such data is missing in most instances for small scale projects. Notably, published literature that has looked at that scale of electrification (Kirubi et al., 2009; Komatsu et al., 2011) adopt approaches that cannot support causality and claimed impacts need to be re-assessed using more robust approaches. Furthermore, since return-based targeting that is popular with grid electrification is rarely the motivation

behind village microgrids-therefore one needs to be conservative with the choice of outcome selection for impact analysis (Matinga and Annegarn, 2013).

Overall, literature provides some lessons on potential benefits of both grid and off grid rural electrification. Its apparent that the quality of electricity delivered to a household determines what power can be used for, and thus the consequent gains. Because most studies that claim causal impacts consider grid electrification, they do not offer much lessons for small projects which deliver limited capacity electrification. There are nevertheless expected benefits from such projects, whose evidence forms the goal of this study. Considering data challenges raised above, the next section looks at a feasible strategy that can allow us to identify such impacts.

4.3 Methodology

This section addresses the econometric procedures to deal with endogeneity of household connection to a village micro hydro grid, which will then allow for a claim of impact. The problem of impact evaluation is explained, leading to a choice of method appropriate for the current study. The data used for the study is then described, followed by the estimation procedures

Theory of impact evaluation and propensity score matching

According to Caliendo and Kopeinig (2008), the mainstay of any impact evaluation exercise is establishing how a treated individual would look like if they never got the particular intervention or the 'treatment effect'. The latter is the causal effect of a binary event on an outcome of interest to a researcher. The Roy-Rubin framework provides an approach for defining this causal inference problem with the main components being: treatment (connection) status; potential outcomes (on kerosene spending, battery charging expenses and light usage at night) and the subjects (households). Following exposition of this model in Caliendo and Kopeinig (2008), consider the treatment indicator D and the subject i, so that the treatment indicator of a subject is denoted by D_i. D_i assumes a value of 1 if subject *i* (*where* $i = 1,2,3, \dots, K$) was exposed to the treatment and a value of 0 if the subject has not been exposed to treatment. Defining Y_i as the potential outcome of the subject, then $Y_i(D_i)$denotes the potential outcome of a subject *i* from its treatment status.

The treatment effect t_i is the difference between the outcome of an individual with treatment and without treatment i.e.

$$t_i = Y_i(D = 1) - Y_i(D = 0) \tag{28}$$

Obtaining this value requires us to observe the same individual i under the two states, so that we compute the individual treatment effect on the treated (ATT)[23]. This is impossible because the treatment cannot be removed from the subject once given, so an average treatment effect based on the population of interest is used as an approximation as follows:

$$t_{att} = E(t|D = 1) = E[Y(1)|D = 1] - E[Y(0)|D = 1] \tag{29}$$

where $E[Y(0)|D = 1]$ is the counterfactual or the outcome of a treated subject if he or she had not received the treatment. However, the component $E[Y(0)|D = 1]$ is still not recoverable and this is what leads to a counterfactual problem.

For experimental studies like the randomized control trials, using $E[Y(0)|D = 0]$ as an alternative provides valid estimates of treatment effect since randomizing subjects into treatment and control groups ensures that there is no self-selection into the treatment. However, the same cannot be said in the absence of randomization. This is because there are factors that could be affecting both treatment and outcome simultaneously, so that the outcome variable would still be different for the two groups even if treatment was not administered in the first place. This is one source of identification problem in evaluation work. The 'self-selection bias' can be illustrated by rearranging the expression for ATT as:

$$E[Y(1)|D = 1] - E[Y(0)|D = 0] = t_{ATT} + E[Y(0)|D = 1] - E[Y(0)|D = 0] \tag{30}$$

An unbiased treatment effect on the treated can only be obtained if the 'selection bias' term amounts to nil as follows:

$$E[Y(0)|D = 1] - E[Y(0)|D = 0] = 0 \tag{31}$$

Experimental studies ensure that the difference between the counterfactual terms for treated subjects and the observed outcome for control subjects is zero. In the absence of randomized control trials, there are methods of impact evaluation that employ techniques to reduce these differences. Depending on data availability, several statistical techniques can be used to reduce this bias namely: regression methods; Instrumental variables; Propensity score matching-based methods.

[23] Although ATT is the most commonly used measure, another possible measure is the ATE (average treatment effect)

Propensity Score Matching (PSM) Method

According to Rosenbaum and Rubin (1983) a propensity score $\Pr(D = 1|X)$ is the predicted probability of assignment to the treatment ($D = 1$) conditional on a vector of observables, X. Since X is a balancing score, it allows us to group subjects into treatment ($D = 1$)and control ($D = 0$) such that we can derive sensible comparisons between them. Balancing scores are a function of the observable characteristics and it has been shown that if treatment is ignorable (or unconfounded)[24] given X then it is also ignorable given $\Pr(X)$ (see proof in Rosenbaum and Rubin (1983)). Comparing mean outcomes of treatment and control subjects at each value of score yields unbiased treatment effect. For small samples the propensity score is estimated using a probit or logit model. The resultant propensities can then be applied differently to adjust observations such that comparison is possible in three major steps: creating matched samples from the control subjects; constructing sub-classes of similar units and comparing the impacts within those sub-categories to come up with the differences. Subject to the availability of adequate control units, matching is more practical and popular in studies than the other two methods highlighted in the previous sub-section.

The first step in carrying out PSM is to estimate the scores using a choice model, and obtain the predicted probability of a subject receiving treatment conditional on *X.* Given that two conditions of treatment (ignorability and overlap) are met, the average treatment effect on the treated subjects using PSM is expressed as:

$$t_{ATT(PSM)} = E_{(pr(X)|D=1)}\{E[Y(1)|D = 1, \Pr(X) - E(Y0)|D = 0, \Pr(X)]\} \quad (32)$$

Where $E_{(pr(X)|D=1)}$ is the distribution of the subject's propensity score, that is used as a weight of the difference between the outcome of the treated and untreated subjects within the region of overlap. But first is a statement of the link between the treatment and the expected outcomes.

Change mechanism

The change mechanism is basically what follows any electrification program. Once a micro hydro electricity potential is taken up by a community for development, some households join the scheme and subsequently contribute the relevant financial and labor obligations. The harnessed electricity is then connected to households who have fulfilled the contributory obligations while others drop out of the scheme or do not join the scheme in the first place. In a previous section, it was highlighted that micro hydro electricity has limited applications in the household level.

[24] Treatment ignorability/unconfoundedness is one of the conditions for using PSM. It states that if we obtain a set of observable characteristics that are independent of treatment assignment, then outcome is independent of treatment assignment (see Caliendo and Kopeinig, 2008). The other requirement for PSM is the overlap condition, $0 < Pr(D = 1|X) < 1$, which requires that subjects with the same characteristics have a positive probability of being in both treatment and control groups.

Therefore, it would be reasonable to expect outcomes that are associated with the use of low voltage items in the household that comprises of mainly lighting and small appliances.

Kerosene is the primary source of lighting in 68.93 per cent of Kenyan households, and the prevalence of kerosene lighting is higher in rural areas compared to urban areas [25]. Ngui et al. (2011) highlight that while kerosene is mainly used for cooking in poor urban households, its main use in the rural household is lighting. The first use of electricity in a household is to replace kerosene as a primary lighting fuel. The expectation here is that households connected to microgrids have a lower average consumption of kerosene in terms of both the physical quantities and spending. Kenya is a net importer of crude oil products and the fluctuations in the price of these products affect households using kerosene as a primary energy source directly. This is the reason behind the controversial subsidy on kerosene in Kenya, and it would be interesting to establish if microgrid electrification reduces kerosene consumption.

Secondly, Bensch et al. (2011) propose that the number of lighting hours is an important indicator of the impact of any electrification project, as it is a primary indicator of the level of service take up. The expectation here is that connected households experience more light hours (for our case we choose to limit ourselves to hours of light during the night) than those not connected, because the latter have to limit the use of more expensive kerosene fuel.

School going children would also be expected to increase their evening study time, due to availability of electricity. Lastly, ability to use information & communication appliances like radios, televisions and mobile phones is more enhanced if there is power connectivity in the household. High spending on recharging the batteries for use with these devices is likely to impede their utilization, and this has a negative effect on the household (Komatsu et al., 2011). If there is electricity connection in the household, there is less spending on re-chargeable batteries and this extends the time of use of the devices. This also means that the device can be used whenever the owner needs it. Table 22 in Appendix 1 summarizes the outcomes of interest for this study, and their measurements.

Empirical strategy

Data collection

This exercise involved comparing outcomes of households that are connected to community microgrids to those with no connection to micro hydro scheme electricity service. There was no comprehensive list of micro hydro schemes in Kenya by the time we conducted this study. For identification of projects that would consist of connected households, we used a list of functional projects from a recent scoping study on micro hydro electricity use in Kenya spread over three counties in central Kenya: Muranga; Nyeri and Kirinyaga. Unfortunately, there were plants that were listed as functional but generation had stopped more than two years ago. Thus, all schemes were visited by the researcher before classifying them as functional or non-functional with regard to production and distribution of electricity.

[25] see data at: www.opendata.go.ke/Distribution-and-Consumption/Main-Lighting-Energy-Sources-averaged-to-Counties

Because of the limited number of connected households that were found, it was important to interview all the connected households in every scheme. A total of 77 connected households were available for interview spread across four functional schemes, while some fifteen household heads could not be interviewed because they were not present during the time of the survey. There were few households that had grid-connectivity, and this remained switched off at the mains, for fear of expensive bills. Scheme electricity was the main source of electricity for these households.

There were both connected households and those that are not connected within the defined radius of service for a micro hydro scheme. The location of these households is random, since there is not settlement plan related to the presence or absence of the micro hydro scheme. The households had already been established there before the schemes came up, for reasons not related to electricity connection. These unconnected households provided good potential matches for those that are in the same location but connected, since they face fairly similar conditions such as agricultural potential and cultural settings. Due to the technical requirements for micro hydro electricity generation, all the schemes in this study were located in very similar geographical and climatic zones (in rural areas, near water towers, similar agricultural potential and in highland climatic conditions), and we can safely conclude that both control and treated households face near similar geo-economic opportunities. The control households were randomly picked from the pool of non-connected households within this pre-defined radius of a micro hydro scheme that was provided by the scheme chairmen. This involved visiting every third unconnected household, while avoiding those units that were in the same compound. The reason for this is that household decisions could have been easily shared because related households live in proximity to each other. Following this procedure, a total of 190 control households that had no electricity connection were interviewed.

Estimating the propensity scores

For estimating the propensity scores Caliendo and Kopeinig (2008); Zhao (2008) among others indicate that there is no foundation for discriminating between the logit or probit specifications. This is because if the unconfoundedness condition is met, the estimated impacts from the two models are very similar. The choice of covariates in the connection status model was informed by advice in Garrido et al. (2014); Bensch et al. (2011); Caliendo and Kopeinig (2008). Generally, variables that are thought to influence both treatment and outcome should be included, while leaving out those that may be influenced by treatment itself. Economic theory, intuition based on the knowledge of research area and past research should form the criteria of choosing variables. This study relied on the first two criteria and the following observable characteristics were proposed to predict the connection decision for purposes of estimating the propensity score.

X = {*household size; gender of household; employment status; having received environmental training; type of dwelling; kerosene price; monthly income and age of household*}

The probability that a household is connected to a micro hydro electricity is $E(Y = 1$ and is a linear function of X as follows:

$$\mathrm{E(Y = 1)} = \Pr[Y = 1|X] = \alpha X_i \tag{33}$$

Where α denotes the regression coefficients. For a binary outcome model (logit for this case), this is a non-linear model and $F = \sum \alpha X_i$ is the cumulative density function of the logistic distribution. The probability of connection is given by:

$$\Pr[\mathrm{y = 1|X}] = \frac{\exp(F)}{1+\exp(F)} \tag{34}$$

and the propensity score estimated is obtained from the predicted probability based on model (33).

Earlier in this section, it was highlighted that one of the conditions for estimation of ATT is the presence of overlap or common support region in data. This will ensure that subjects with the same propensity scores (based on a set of characteristics) have a chance of either being connected to the micro hydro grid or not. The best way to demonstrate the existence is through visualization using density plots.

Matching quality

Once the propensity scores have been estimated, the next step involves stratification so as to make sure that in each stratum both treated and control subjects have 'similar' propensity score. A propensity score from section 4.3 is actually a balancing score, because it makes objects with near similar characteristics achieve near equal propensity of receiving treatment. This implies that within specified strata of propensity scores, the treated and control subjects should be having the same distribution of observed covariates. According to (Austin, 2011) one way of ensuring that the model for estimating the propensity scores was well specified is to ascertain whether the distribution of the covariates for the two groups is similar within the matched sample (i.e. same strata). Therefore, in a set of matched subjects the probabilities of being in either treatment category are equal, that is:

$$pr(D = 1|X) = pr(D = 0|X) \tag{35}$$

The distribution of the treated and control subjects' propensity scores before matching is illustrated in panels (b) and (c) of Figure 5 (Appendix 2). Several methods have been proposed in literature to check to balancing quality after matching (Austin, 2011). The use of standardized differences in means seems to be superior and was adopted by this study. The standardized differences in means for a continuous variable is calculated as given below:

$$d = \frac{(\bar{x}_{treatment} - \bar{x}_{control})}{\sqrt{\frac{s^2_{treatment} + s^2_{control}}{2}}} \tag{34}$$

while that of a binary outcome variable is given as:

$$d = \frac{(\hat{p}_{treatment} - \hat{p}_{control}}{\sqrt{\frac{\hat{p}_{treatment}(1-\hat{p}_{treatment}) + \hat{p}_{control}(1-\hat{p}_{control})}{2}}} \tag{35}$$

where *d* is the "standardized percentage bias".

The one thing that is clear in literature is that it is difficult to expect balance in all the covariates, and there is no standard for tolerable imbalance. However, it is erroneous to claim an impact if you have 'bad' matches (see Garrido et al. (2014); Austin (2011) among others). Other methods like the use of t-tests and model fit measures have been discredited due to a disconnect between their major assumptions and the purpose for which propensity scores are estimated.

Choice of matching methods

The general framework for PSM estimator for Average Treatment Effect (ATT) was shown in section 4.3. Once a balanced propensity score is obtained, a matching method with which to use the propensity scores is chosen. Several matching estimators work by comparing the outcomes of the connected households to that of households which are not connected. The matching techniques vary according the following: handling the common support requirement; defining the appropriate distance between two comparison subjects (neighbors) and the weighting of each comparison unit (Caliendo and Kopeinig, 2008). The choice of a method depends the data available, and involves a 'bias-efficiency' trade off. Two methods were adopted for this study based on the type of data available to us, namely: Kernel and nearest neighbor matching. Following is a brief description of each one of them.

Kernel Matching

The study chose the kernel matching as the base comparison model, given the limitations of getting too many observations as controls in the sample. This technique allocates a weight to each control within a pre-defined range (bandwidth) depending on how 'close' that subject is to the treated subject. Therefore, control subjects who are closer to the treated ones in terms of propensity scores are allocated more weight than those who are distant. A band width of 0.06 was used based on literature since it is optimal in the trade-off between efficiency and bias. For robustness checks, lower (0.04) and higher (0.06) bandwidths were also be considered. The downside of kernel matching is that it can introduce a bias, while improving on efficiency. To overcome this, estimation is limited to the common support region and we use nearest neighbor estimator which is inefficient but introduces less bias as a 'robustness' check (see Caliendo and Kopeinig (2008) for efficiency bias trade-off classifications).

Nearest Neighbor (NN) matching

This estimator involves picking 1: *k* treated and control subjects who have smallest propensity score difference. The matched controls can be replaced back in the reservoir of control units and used as matches for another treated unit, and this estimator is called 'NN with replacement'. The use of replacement is adopted for this study because it improves the quality of matching (Caliendo and Kopeinig, 2008), given the limited number of control observations that we have. We also use calipers to safeguard against poor matches in instances where the nearest neighbor may be too distant from its treated counterpart in terms of propensity score (Garrido et al., 2014).

Sensitivity Analysis

From sub-section 4.3, the assumption of unconfoundedness was adapted to allow us to use the matching framework. This means that we can observe all the covariates that affect both assignment into the connection status and outcomes of interest. However, this may not be potentially true and according to Caliendo and Kopeinig (2008) matching estimators such as those adopted by this study may not be robust to such an eventuality. Rosenbaum (2002) provides a model of sensitivity analysis against this 'hidden bias' based on a parameter that indicates the extent of deviation from random assignment of objects to treatment. A 'hidden bias' is said to be present if two households *i* and *j* with similar observable characteristics *X* have different chances of connecting to the micro hydro service, denoted as θ. Rosenbaum (2002) relates the odds ratio of such two households to a parameter, Γ, representing the effect of the observable characteristics on the selection into connection decision as follows:

$$\frac{1}{\Gamma} =\leq \frac{\theta_i(1-\theta_j)}{\theta_j(1-\theta_i)} \leq \Gamma \forall i,j \tag{36}$$

For the classical case of randomization this parameter takes the value of 1. If the value of this parameter increases by a certain factor (γ) of let's say 0.2 then the odds of these two similar households being connected could differ, so that now *i* is more likely to be connected than *j* by a factor of 1.2 despite the two households appearing to be similar to us based on *X*. This difference is attributed to the observable factors (γ can therefore be termed as the reaction of the connection status to changes in some observable characteristics). Effectively, the test allows us to determine how strongly observable covariates must affect the selection into treatment to a point of compromising the consequences of the matching. Results are said to be sensitive if an increase in γ makes the inference different from that obtained while assuming that $\gamma = 0$ (that is no 'hidden bias'). Insensitive results imply that a very big γ is required to alter the base inference.

4.4 Results

The treated and control subjects are similar in only 5 out of ten characteristics. From this outcome, we conclude that it is important to address the fact that these two groups have other potential differences apart from the treatment status. The differences in the outcome variables between the two groups based on naive t-tests is also shown below in table 23 in the Appendix 1.

Propensity Score Estimation Model

Table 24 in Appendix 1 presents the results of this model. The results for naïve regression of this same models are presented in the other panels of the table 24 (b), for purposes of illustrating how the results would have looked like if we ignored the issue of endogeneity in connection status. From the logit results, having a male household head and a non-permanent living structure is associated with a lower probability of a household being connected to a micro hydro grid service its apparent that the size, quantity of farmland holding, having piped water connection and age are not relevant in explaining the treatment status of the households in the sample. However, they have theoretical relevance to connection status and their inclusion into the model did not result into adverse matching quality. The goal of the logit estimation in this case is to obtain propensity scores for matching as opposed to offering a structural explanation of the connection decision. A propensity score was therefore estimated from the predicted probability of connection given by this model, and used to select comparison subjects in next stage. The distribution of the propensity scores between the connected and unconnected households is shown in panel (a) of figure 5 in Appendix 2. A stratification of the propensity scores was then done, with the optimal number of blocks suitable for the data determined as 5 within the common support. The overall indication was that the balancing property was satisfied.

Region of common support and Matching quality

The propensity score was used for matching using two methods: Kernel and NN matching. The specifications which gave the best matching quality in terms of both mean and median standardized differences in covariates were kernel (Epanechnikov) with a band width of 0.06 and NN with two neighbors and caliper of 0.25. There were no reported bad matches and the Rubin's r (this test is based on the standardized differences) was within the expected range for good matches, and the region of common support under the two matching approaches is illustrated in panels (b) and (c) in figure 5 (Appendix 2). The estimated impacts based on the estimated ATTs within the region of common support are discussed in the next section.

Treatment effect using kernel matching

Significant effects of electrification through microgrids were found for the quantity of kerosene consumed per month, the spending on charging mobile phone batteries per month and the number of hours that children dedicate to studies in the evening. There is no significant difference in both the hours of light at night and radio entertainment between connected and non-connected households. The results were robust to changes in bandwidth changes as well as to use of nearest neighbor matching with several calipers. No bad matches were reported by the standardized difference of means ratios. The sensitivity analysis was implemented using a code provided by Gangl et al. (2004), and the implication from the test is that obtained impacts are insensitive to changes in the assumption we made on unconfoundedness (see result in tables 26 and 28 in Appendix 1). Therefore, the matching gives us a fair indication of what is happening in the sample. For interpretation purposes, we focus on the results in panel (a) of table 25 (Appendix 1) and the rest of the panels in tables 25 and 27 are kept for checking the robustness of results to changes in some of the matching parameters.

The treatment effect is significant for only three outcomes: the physical quantity of kerosene consumed per week, the expenditure incurred on cell phone battery recharging and the number of hours that kids study in the evening. However, there is no difference between connected and unconnected households in terms of: the proportion of spending on kerosene, the number of night light hours and the length of time that radios are utilized in the households. Following section gives a contextual interpretation of the significantly different outcomes observed between the two groups

While households which are not connected to the microgrid consume about 2.8 liters of kerosene per month, the connected households consume about 1.3 liters giving a difference of approximately 1.5 that is reported in column (a) in table 25. The explanation for the 1.3 liters of kerosene consumed by the connected households is due to frequent repairs or breakdowns that were reported in most plants, which delay due to reporting failures or tardiness in contributing money for attending to repairs. Therefore, these households are forced to purchase kerosene as a contingency during service outages. No household in our ample was found to be using kerosene for cooking, thus we cannot attribute the utilization of kerosene by electrified households to cooking. More important is the fact that even with such breakdowns, connected households still manage to consume almost half the amount of kerosene consumed by the unconnected ones. Although connection status does not seem to have an effect on the share of household income that is allocated to kerosene purchases, it certainly implies that if we assume all households use kerosene with the same device (e.g. the popular tin lamps) then connected households face less kerosene-based pollution. The results thus support the justification for off grid rural electrification on the basis that they can lead to reduction or eventual elimination of kerosene use in the household (see Jacobson, 2007 and Komatsu et al., 2011). Komatsu et al. (2011) also found that as a result of electrification via Solar Home Systems (SHS) in Bangladesh rural villages, 95 per cent of

the households eliminated the use of kerosene in their households. Thus with interventions such as adoption of re-chargeable torches for power back up and/or enhanced infrastructure that reduces frequency of repairs, it is possible to eliminate use of kerosene in the households utilizing micro hydro services in Kenya. Unlike in Khandker et al. (2012), we did not find significant reduction in kerosene spending due to electrification. However, this was not the same for some energy-related spending like charging of mobile phone batteries.

Households that are not connected to microgrids spend approximately 0.92 USD[26] more per month on recharging their mobile phones batteries, compared to those who are connected to microgrids. The treated households spend almost nothing (this is because their reported mobile expense is below Ksh. 10, which is the minimum cost of charging a cell phone battery) to charge their mobile phones per week, while those who are not connected spend approximately Ksh. 30 per week for the same. This also means that mobile phone owners who live in non-connected households are more likely to face communication and other mobile service access inconveniences because of lack of reliable electricity to recharge their devices. If they do not have cash to pay for recharge at some other place, then the inconveniences are even higher. There are similar findings by Komatsu et al (2011) who found that in Bangladesh, households that had adopted Solar Home Systems (SHS) electrification had the ease of charging their mobile phones at home without any extra financial costs.

Finally, school children in households that are connected to micro hydro electricity were found to be devoting shorter time to evening study compared to those who did not have micro hydro electricity connection to their household. While the average study period for those in connected homes is 1.35 hours, those in unconnected households study for 2.06 hours. This contrasts findings from empirical work in Vietnam by Khandker et al (2013), but coincides with ethnographic findings in South Africa by Matinga and Annegarn (2013). The latter observes that once electricity is available in the households, children are also likely to take up other activities like TV or Radio entertainment made possible by access to electricity instead of studying. Therefore, at first glance the expectation of increased studying due to electrification may not always be supported in some research contexts.

4.5 Conclusion

The main task in this study was to isolate the impact of rural electrification by use of micro hydro schemes on selected aspects of household welfare identified as: kerosene consumption, education, access to communication and information and availability of extended light hours at night. Observational data was used from connected and unconnected households in Kenya where micro hydro projects have been implemented on trial basis for over 10 years. Both kernel and nearest neighbor matching techniques were used and the quality of matching assessed, where no bad

[26] 1 USD was equivalent to Ksh. 100 at the time of data collection

matches were reported and the results were insensitive to assumptions of the analytical method used. Significant impact of electrification was found for three outcomes namely: monthly consumption of kerosene, the number of evening study hours for kids and monthly mobile phone recharging expense. Although micro hydro service that is currently offered provides limited voltage, they deliver significant improvement in aspects of household welfare. If the service provision is enhanced, they can lead to elimination of kerosene lighting in the household and associated health and safety dangers. Access to communication and other mobile phone based-benefits due to availability of electricity accrue to households due to almost lower costs of recharging batteries. Availability of electricity may also reduce the time allocated to studies due to take up of entertainment activities. Therefore, it is not entirely true that electrification may lead to increased home study time which is in turn expected to lead to better education outcomes. Other social support programs in a sector like education are required to foster the utilization of electricity for evening study, or even time allocation between entertainment and studying. However, further studies tracking other education outcomes are important for this particular case, since the current study did not collect data on extended indicators of schooling progress like scores and enrollment. Another interesting aspect would be to compare the same outcomes for off-grid and grid electrified households, given that grid connected households in developing countries' households limit their use of electricity to basic applications similar to those met by off-grid means. Grid extension to households conducting very limited use of electricity may not make much economic sense particularly for remotely located rural households, with low income and therefore limited electrical loads.

5 Synthesis and Conclusion

5.1 Summary of findings

This thesis sought to address limitations facing the wide-scale adoption of RE microgrids for rural electrification of communities by exploiting local renewable energy resources. Although developing countries are endowed with such resources located in remote areas, preoccupation with grid-based solutions to rural electrification has led to large proportions of rural population remaining without access to modern energy in developing countries like Kenya. The use of RE-based microgrids like micro hydro schemes is now being considered as an option, due to proximity to rural households or ability to extend access to clean energy without further strain on overloaded national grids. The abundance of RE resources like wind, solar and water also makes such solutions attractive when it comes to sustainability consideration which are now a major concern in the modern development agenda. The low adoption rate of these electrification alternative raises scholarly interest, to investigate the impeding barriers and propose methods of overcoming them. Three issues appear to be particularly outstanding in literature of rural electrification by way of using RE microgrids in developing countries.

Centralized energy planning and top down approach to energy problems has been observed to lead to neglect of target consumer preferences in service project planning. It is apparent that some investments may deliver services that do not meet the expectations of the targeted consumers. This leads to issues of concern to consumers of these services among them: frequency of service interruptions; quantity of electricity that may not be compatible with basic household energy needs; and even preferences of service providers. The characteristics of the expected electricity service by target consumers are barely interrogated in literature, yet it a practical reality that consumers may have different expectations than what the project delivers. A first natural step to gaining support for such an energy project is to assess what is desirable from the point of the consumers, to inform the plan of action for satisfying those needs. However, supply side considerations seem to dominate the literature of rural electrification. Subsequently, some services hardly meet desired standards of the targeted users leading to low interest and even abandonment of such services.

Secondly, community-based electrification initiatives are becoming popular in rural communities due to abundance of renewable energy resources in remote rural area. There is also an emphasis on participatory development in renewable energy technology diffusion and emphasis on local ownership to allow for greater acceptance of technology. Such models are important for participatory development goals, but come with extra challenges of attaining local self-governance in the utilization of both electricity and overall infrastructure which led to the second issue of inquiry for this study. Ensuring successful outcomes requires governance structures and supporting programs that are established in chapter two of this study. Thirdly, attracting any investment (financial or technical) into such RE schemes is highly dependent upon demonstrating benefits that are attributable to such an intervention. Lack of such

evidence could be partly blamed for the excessive emphasis on grid electrification by governments of developing countries, since the impacts of large scale grid electrification are widely cited and not in doubt. This study generated such evidence, by producing estimates that can be used in the analysis of rural electrification alternatives and in accounting for such investments.

The foregoing three issues constitute current barriers to successful deployment of renewable energy. This study sought to contribute to the literature of rural electrification, by carrying out an analysis in search for (a) consumer-preferred components of a service, (b) avenues of increasing participation and enabling self-governance in community micro hydro grids and (c) the attributable impacts of community-based RE microgrid electrification. The first such analysis in chapter two investigates the desirability of some selected characteristics of microgrid electricity service packages, using preference elicitation techniques and a discrete choice models. The results from this analysis imply that contrary to what most microgrids provide, consumers prefer a service that delivers unlimited electricity into their households. The highest marginal value is derived from this characteristic, with a monthly marginal willingness to pay of approximately 8.5 USD. There is consistency in the preference for higher amounts of electricity, in that the results show a decline in the monthly willingness to pay for such services for packages offering lower amounts of electricity. Specifically, consumers are willing to pay 5.4 USD for 60 watts and even a lower amount of 4 USD for 40 watts package every month. This effectively means that delivering a micro hydro service that permits very limited use in terms of what one can perform using such electrical energy is a disappointment to the consumers. As further results will demonstrate, such limited power is one of the attributable reasons to lower participation by members of a community micro hydro grid providing such a service. Whenever a renewable energy resource permits, planning for high installed capacity should be prioritized and accompanying capital requirement should be provided from sources such as government or donor financing. Public-Private Partnerships (PPPs) may also be considered for future[27] upgrades or new projects, because it could deliver high quality technology. The terms of engagements like the level and extent of community participation still need be carefully considered, as it can be a source of tension between the community and PPP entities. Channels for advancing consumer complaints and addressing the same must be clear under PPP, because one of the motivations for establishing community micro grids to supplement grid electricity is frustrations with public utility. Consumer rights in Kenya exist, but enforcing them against the only distribution utility is often not practical for rural consumers who have no alternative in the first place.

Apparently, whatever source of financing is used to provide such high quantity of electricity should not jeopardize community ownership of the scheme. This is because our results from the second analysis show that having ownership and the accompanying control over power generation and distribution activities is a desirable characteristic for these consumers. We have established that consumers are willing to pay an estimated 4.2 USDs for a service that they have

[27] PPPs could be considered for micro hydro schemes that may want to undergo such transformation of formalization.

ownership stake in. Effectively, this tells us that rural consumers of RE microgrid services derive some intrinsic value from participating in renewable energy electrification ventures. Subsequently, the current emphasis on private (or government) ownership may not sufficiently address the development needs of the electricity consumers. The additional challenges that may come with this participatory model have also been addressed by this study, meaning that with a few interventions, it is possible to have successful service delivery through community owned RE micro hydro grids. There are community owned schemes that have currently succeeded to upgrade into a sophisticated renewable energy enterprise of megawatt scale[28], casting doubt into the belief that such community enterprises are not feasible in the energy sector. Although consumers seem bothered by longer and more frequent power outages, the willingness to pay to avoid the same is a mere 0.2 USD per month. Our explanation is that outage itself may not seem to be much of a bother for rural consumers, but a further probe incorporating timings of schedule for outage or maintenance activities that lead to such outages is needed. Notably, members of rural households spend most of their time outdoors tending to farming activities with very little activity inside the households. It is therefore possible that specific timings of outages are more useful way of looking at the reaction to outages, than simply asking the respondents about the duration and frequency of electricity service outage.

The findings in chapter two clearly show a preference for community ownership in micro hydro grid electricity service delivery. Subsequently, governance problems become a considerable barrier to smooth conduct of business, forming the subject of our analysis in the third paper of this study. Energy infrastructure governance problems are often discussed in the context of large cross-national grids, but similar problems lead to failed self-governance and ultimate collapse of micro hydro schemes. This study went further to investigate the personal circumstances that may potentially encourage or discourage individual commitment to a community owned micro hydro electricity scheme, and subsequently establishes necessary conditions attributed to successful self-governance in a community micro hydro scheme. The link between the quality of locally designed institutional arrangements that guide conduct of group business is also established, by borrowing concepts and relationships from the literature on governing CPRs. The results show that members who are more educated portray higher cooperation with scheme requirements (comprising of financial, information, labor, meeting attendance and decision making obligations). This is attributed to awareness of the role that renewable energy can play in meeting certain household energy needs. Proper preparation of the participants of a micro hydro scheme in terms of educating them on the benefits and responsibilities associated with such a joint undertaking is important, in order to capture and sustain their interest during the life of the RE scheme. Households facing higher energy budgets and deriving larger benefits in terms of electricity allowance per household tend to be more cooperative, and this is attributed to greater changes in certain aspects of their welfare

[28] Sustainable Energy for Africa (SEFA) managed by Africa Development Bank (AfDB) extended a grant of US$ 992 000 to Mutunguru Hydro Power Project, which is one of the two community owned micro hydro power schemes that have successfully graduated into formal power companies. Their foundation is the type of schemes featured by this thesis.

that were estimated in chapter four. The results also show that joint community development projects need to have members who trust each other, because it fosters greater cooperation with rules and obligations by members. Members who trust all their peers in such a group have no uncertainty of being short-changed into contributing more than their fair share of resources and work in the scheme, and will not need to retaliate by shirking their contributory efforts. This then highlights the importance of trust building activities, particularly in community projects where members are of different ethnicity or possess other sources of social divisions.

The role of locally devised institutional arrangements in enabling successful self-governance in an energy common like a community microgrid is also highlighted in the second part of chapter three. Good quality of institutional arrangements comprising of: non-costly justice, graduated penalties, accountability of leaders, appropriation of electricity that is matched to generation capacity and adjustment of rules to suit new demands is paramount to survival of schemes. There are however other additional requirements with even larger marginal effects on the probability of getting a successfully run micro hydro. Schemes with more members and higher cooperation ratings; disparity in asset ownership, larger installed capacities and clearly marked boundaries of the microgrid users have higher probabilities of achieving self-governance and avoiding collapse. Inequality in assets ownership is not a threat to the continued operation of micro hydro schemes, as groups comprising poor and rich households do not face inequality-related problems that lead to disintegration. This is supported by observations in the experimental studies of peer effects of increased voluntary contributions from mixing high and low contributors. Thus having very rich members in a scheme who also happen to be high contributors can rally the rest of the group towards high voluntary contribution.

The presence of clear boundaries defining who can utilize the electricity and related infrastructure is likely to prevent illegal connections in multiple households that sometimes bring about an overload in the grid. From chapter two, it was highlighted that consumers prefer services that deliver more electricity at the household point, which is in turn capable of several applications by the user. This is supported by the result that higher installed capacity in a scheme increases the probability of sustained generation and distribution activities. This can be attributed to fact that members are motivated to keep enjoying the benefits derived from satisfactory quantity of power delivered to their households. The potential benefits enjoyed by households include improvements in some aspects of welfare, which were verified in chapter four of the thesis.

The impacts of microgrid electrification is the third issue of interest in this thesis, the motivation being that most studies concerned with the impact of non-grid electrification alternatives do not control for simultaneous changes to the subjects. By use of matching techniques, it was established that households connected to micro hydro electricity in Kenya spend an approximated 1.5 liters less of kerosene for lighting in their households. This may have wider implications when other repercussions of use of kerosene in the household like health due to related emissions are considered. The differences would be much higher if the micro hydro systems were reliable in terms of lesser break downs particularly at night, to a point of completely eliminating the use of kerosene in the households. There is also a

small but significant difference in the amount of expenditure that is allocated to recharging of mobile phone batteries in connected households. Connected households have almost zero monthly expenditure on this item, while those in non-connected households spend on average 0.92 USD to have their mobile phones charged elsewhere. These two outcomes imply that despite some of the projects delivering very limited electricity (for instance limiting the number of bulbs that one can install in the household) and having intermittent supply, there are notable welfare changes between consumers of micro hydro electricity service and those without access to any electricity at all. In particular, micro hydro electricity can meet the primary electricity needs of rural households like provision of clean and providing convenient lighting. The fact that mobile phones in connected households can be charged in the confines of the house implies that members of such households do not experience limited access to mobile telephone services ranging from communication to money transfer, all else given. However, the much claimed increase in the night study periods for school children is not supported by the data in this study. In contrast, schooling children in connected households actually spend less time on evening studies (by an estimated half an hour) compared to those in households having no electricity connection. This is a possibility if children become preoccupied with other electricity-aided entertainment in the household as a result of electrification, and education programs creating such an awareness may be important to improve schooling outcomes. That apart, this study recommends further analysis that uses additional long term indicators of education outcomes like scores to establish the wider implication of microgrid electrification on education related outcomes.

5.2 Policy implication of the findings

There are several policy implications that can derived from the findings of this thesis. These would partly address the barriers against successful deployment of RE micro hydro grids, and we believe some lessons are applicable to community-based microgrids like those utilizing solar energy. Community-based micro hydro schemes operate outside the legal threshold for procuring generation and distribution licenses, if the installed capacity does not exceed 1Megawatt. The reason for such lack of strict regulation is to spare innovative groups from the state bureaucracies associated with obtaining such permits, therefore encouraging an increase in such investments in rural areas. Unfortunately, this also means that service standards may be compromised leading to sub-standard electricity services at the local implementation level. From the outcome in chapter two, it makes sense to bring them back into the regulation pool but evaluating them as a separate group to avoid the lengthy procedures that larger investments have to undergo. This may help in inculcating better practices in the field thereby improving service delivery. It is useful for the regulator (Energy Regulatory Commission- ERC) to demand a requirement for an assessment of consumer electricity service expectations as part of the feasibility study of such projects, in addition to inspecting the final service delivered to ensure that it meets the expectations highlighted at the beginning. For instance, where delivery of unlimited capacity is impossible due to resource limitation then the household needs that can be fulfilled from the anticipated service must be made known to the consumer or member well before they commit themselves. Members

who sign up for such a service will then be aware of the limits and capability of the expected service, to avoid stretching the infrastructure beyond its limits. Secondly, since adequate assessment of hydro resource and possible installed capacity is done at the feasibility stages of such projects, technical emphasis should be placed on exploiting the entire capacity so as to increase the power allocation per each participating household. Some schemes install very small fraction of the potential generating capacity due to lack of financial capital, since bigger capacities take longer time to develop and require more capital resources. Larger installed capacity may also attract capital from state or non-state actors, due to the larger scale of operation and potentially larger benefits to the users.

We have established a demand for community ownership of micro hydro grids from the results, implying that more community owned micro grid should be expected to come up in the future. The current energy regulations give room for community ownership of microgrid to operate as a 'private entity' but leans towards formal means of addressing potential management challenges facing such enterprises, that are used by formal private companies. This is because such problems afflicting these schemes are often not within the purview of the regulator, and solutions to the same have not been found. The governance challenges facing these schemes are have therefore been left to the groups themselves to solve, yet members do not have expertise on group dynamics affecting the energy infrastructure. This explains the widespread collapse of community micro hydro schemes in Kenya.

The Ministry of Energy could utilize its RE centers regional framework to remotely assist such groups with the relevant governance and managerial principles that will lead to inculcation of conducive environment for group operations. Some basic good governance elements are suggested based on the analysis in paper 2, ranging from investing in individual level improvements like education forums to assisted institutional set ups. Such support is important to ensure longevity of projects that have been shown to have the potential of reducing kerosene consumption and some energy expenses in rural households (in paper 3). Moreover, well governed projects are more likely to secure funding for upgrade of their RE microgrid enterprise into Megawatt scale projects like have happened in isolated schemes in Kenya. Even if capital and technology were availed to such groups, failure to include good governance programs to accompany such finance and capital may lead to waste of resources if the projects disintegrate. PPPs should also be considered as avenues for access to funding and up to date technology, but with a caveat that there must adequate participation from the beneficiary community if the electricity that is generated is mean for local distribution[29].

With an understanding that both capital and financial resources available for extending to such projects are limited, we recommend prioritizing larger groups of members who are faced with high energy budget. This is because they have higher propensity to cooperate with rules and regulations driven by the higher incentives and benefits received

[29] It is important to note that PPPs may not be an ideal arrangement for such small-scale projects as micro hydro scheme, due to the low load demand in rural households given their profit motives. The sites are also located in remote rural areas, where they interact with the lives of the communities around (especially other community projects like farming; water and forestry). There is growing resistance of renewable energy projects in such settings in Kenya, with a wind project having been called off due to resistance from local farmers in Kinangop, Nyadarua County.

from such schemes. Ultimately, such a group has higher chances of collectively sustaining micro hydro operations. For micro hydro schemes the mean group size was 70 users, so that groups exceeding this size may qualify for such assistance assuming they fulfill all other requirements. Education programs demonstrating the opportunity of cheap and affordable electricity from renewable energy exploitation are important in sustaining individual interest in community renewable energy investments. Micro hydro electricity is mostly used to fulfill similar energy needs to those that grid connected households apply to grid electricity (lighting and powering low voltage household appliances like radios, televisions and charging mobile phones). Consumers do not however know about the intrinsic value of using RE electricity to achieve these same purposes, since there is a prevailing low number of years of exposure to formal education that is a potential source of such knowledge. Further, participating members should be equipped with knowledge of the potential of economic opportunities in the energy carbon markets if only to capture and sustain their interest and commitment to such ventures.

This study has demonstrated that even amid frequent service interruption and governance related problems facing such schemes, households achieve significant savings on kerosene consumption and cell phone charging expenses. There is also the convenience of not having to travel long distances to purchase kerosene or charge mobile phones, or even the health benefit of avoiding kerosene fumes from lamps. Packaging such information in educative forums may could assist households in estimating the monetary savings from micro grid electrification, particularly given that RE tariffs are always below the general grid electricity tariff. This is important in Kenya and other developing countries, where there has been a prevalence of perception among users that such light household electricity demand can only be met from the national grid extension. Micro hydro sources and other decentralized RE sources are widely viewed as inferior options, due to ignorance and government pre-occupation with grid-based solutions. Another empowerment agenda is trying to demonstrate to individuals the link between their personal actions and the overall group objective. It was noted that most members in collapsed groups could not link their individual actions to the negative group outcome. These actions specifically relate to: timely fulfillment of financial obligations; devotion to allocated manual work; providing information on faults and breakages; importance of patrolling the scheme infrastructure to fed off vandals; the need for active participation in decision making and attending meetings without failure. Some individuals hope some commitment from others except themselves is adequate to keep the scheme functional.

Group exchange programs are potential learning platforms about effective institutional arrangements and this may be considered by the state or other facilitators through organizing group social exchange tours. All groups face similar potential governance challenges, but it is clear that some have been able to overcome those problems using locally devised arrangements. Just the way the technology diffusion occurred by setting up initial demonstration points, good management practices can also be emulated across schemes if such interaction is facilitated. For instance, members from worse performing schemes can adopt and adapt practices on certain aspects of institutional arrangements, by

physically interacting with members from a scheme that has overcome such challenge. From chapter three, there are specific arrangements comprising of: making justice cheap and quick to obtain; methods of matching electricity distribution to generation capacity; how to improve accountability of leaders; matching penalties to offenses; gradual adjustment of rules and how to ensure easy enforcement of rules. Designing quality institutional arrangements is an art that can be passed across groups, with adaptation to fit the local circumstances. Community RE microgrids are gaining popularity in new regions in Kenya, while some micro hydro schemes are now graduating into formal energy companies. This is a perfect opportunity for the department of RE to consider facilitating a national forum of community RE operators to act as a point of exchange of ideas and comparison of performances. Such has been done in other sub-sectors like agriculture, forestry, fisheries and livestock through community associations.

Finally, the results in chapter four provide a basis for further technical and social support for community-based microgrids by the government of Kenya. Community ownership of micro hydro is not only an important channel for reducing resistance to RE technology, but it is a form of empowerment since it allows people to determine solutions to their own problems. Soft regulation and capital support of community-based RE micro grids can ensure that quality standards are met, therefore sufficiently meeting primary electricity needs of rural households without the need to further expand the national grid. The use of kerosene for lighting can be eliminated leading to safer and more healthy environment for rural households, particularly for children and women who study or do house chores using kerosene lamps for more hours at night. Enlightening the locals on opportunities that connectivity to such microgrid presents is also important, to ensure that expectations from electrification are met. An example would be school programs emphasizing allocation of time by students or even providing training on home-based small enterprises possible with extended availability of lighting in the evening.

5.3 Suggested areas of further research

Rural consumers spend most of their day outdoors working in their farms, and this is a potential explanation to near indifference in the duration and frequency outage attributes obtained in chapter two. A more interesting perspective would be to look at the reactions to specified timings of the outages, so that it can inform the optimal timings of power distribution and when to schedule major maintenance routine in a way that is not displeasing to the consumers. Secondly, it is important to understand the levels of trust relationships in a scheme. The use of framed field experiments to verify potential of reciprocation could be useful in assessing the role of nontechnical solutions to non-cooperation within a scheme. Extending the scope by including other renewable energy microgrids like community solar is also a proposed extension to this study, so as to generate more evidence for governance requirements to sustain operations in CRES. This study limited itself to the immediate impacts of RE microgrid rural electrification. Studies that trace electrified and non-electrified household for longer periods could be important in verifying some

long term impacts such as education achievements or income improvements. It would be interesting to estimate the impacts that this study considered, but for households with grid connection in Kenya to verify if the two fulfill similar needs to a household. This is because most of the electricity energy needs for rural households can be met from using RE microgrids, but emphasis continues to be placed on grid electrification which is uneconomical in remotely located rural dwellings. Finally, we also recognize that among off grid RE technologies, Micro hydro is viewed as superior in terms of reliability. It may be therefore important to carry out more impact assessments particularly for solar microgrids.

Appendix1-3- Tables for Paper 3

Table 22: Outcomes of interest

Outcome	Measurement
Kerosene consumption per month	liters
Kerosene budget share	ratio
Kerosene energy budget share	ratio
cell phone battery recharge/week	Kenya Shillings
Radio use	hours the radio is used per day
Kids evening study time	hours

Table 23: Differences in the covariates before matching

variable	*t/z value*
household size	*0.0578*
Gender male	*3.4921****
size of arable land	*-2.6584****
piped water connection	*-1.2543*
Religion Protestant	*-0.1572*
received environmental training	*-3.1565****
Dwelling not permanent	*4.7468****
kerosene cost/litre (Ksh)	*-0.4165*
log income household	*-4.2166****
age of head	*-2.6880****
years of education	*-0.9337*
****indicate significant mean difference at 1%*	

Table 24 (a) : Logit results (treated as the dependent variable)

variable	*Coefficient (S.E)*
household size	*0.0126(0.0935)*
Gender(male)	*-1.0504(0.3467) ****
Arable land	*0.05280(0.0865)*
Piped water present	*0.0553(0.3773)*
environmental training(yes)	*1.1555(0.3766) ****
dwelling(non-permanent)	*-1.2965(0.0.3600) ****
Kerosene cost/litre (Ksh)	*0.0222(0.0152)*
monthly income (log)	*0.6445(0.1835) ****
age (head)	*-0.0024(0.0724)*
age(head) squared	*0.0002(0.0006)*
no of years in school	*-0.0206(0.0423)*
religion	*0.0665(0.3290)*
k	*-8.5593(0.2.9985) ****
LR chi-square (12)	*65.82*
n	*267*
****Significant at 1%*	

Table 24(b) Naïve Regression

	Share of kerosene expenditure in energy budget	Physical consumption of kerosene in liters per month	Kids study hours	Mobile phone recharging cost	Night light hours	Share of kerosene expenditure in household monthly budget	Duration of radio use in a household
Treated(D=1)	*-0.0628441*	*-1.458929***	*-.348506*	*-24.48824***	*-.0901869*	*-.0042953*	*.1501879*
household size	0.0024549	.2347184**	.2932365**	1.767004	-.035125	-.0004477	.1605117
Gender(male)	0.0559232	-.0521598	-.2752196	-5.976015	-.161545	.0040185	-.2449557
Arable land	0.0040933	.0006729	.0654025	-.0747607	.140495	-.0003605	-.0627393
Piped water present	-0.0511294	-.5311659*	-.1993111	-4.473489	-.1717192	-.0076998**	.1675696
environmental training(yes)	-0.0793706*	-.2983379	.3377692	9.295664*	-.654048*	-.0049086*	-.8645319***
dwelling(non-permanent)	0.0194716	-.6170066*	-.1493446	-6.44442	-.2781416	-.0007385	-.2717329
monthly income (log)	-0.0311671*	-.1503291	-.0361287	-1.024557	.1158561	-.0022539***	.1424919
age (head)	0.0149566***	-.011837	.1087858**	-2.685003**	-.0533175	-.0001274	.0270649
age(head) squared	-0.0001148	.0001442	-.0010401**	.0217149**	.0004348	2.43e-06	-.000144
no of years in school	0.0005903	-.0222054	.0626664**	.3031101	.0404713	-3.50e-06	.1265202*
Religion (protestants)	-0.0385324	-.0886825	-.1112844	-4.834935	-.0537297	-.0030961	.3519142
k	.1482461	4.728612**	-2.097109	113.0504**	3.767615	.046326**	1.497069

Table 25: Impact: Kernel (epanechnikov) results

outcome variable	**(a) Base (bwidth=0.06)**	(b) K(bwidth=0.04)	(c) K(bwidth=0.08)
kerosene demand in litres	**-1.4941 (0.3064) *** **	-1.4680(0.3431) ***	-1.4846(0.3209) *
hh budget share of kerosene	**-0.0048 (0.0035)**	-0.0046(0.0031)	-0.0046(0.0031)
energy budget share of kerosene	**-0.0573(0.0487)**	0.056(0.0475)	-0.0585(0.0449)
night light hours	**-0.2629(0.5076)**	-0.2803(0.5186)	-0.2705(0.5020)
Cell phone charging expenditure/wk	**-23.2364(4.6132) *** **	-23.3831(4.6722) ***	-23.6174(4.3087) ***
radio hours	**-0.4735(0.7258)**	-0.3476(0.6966)	-0.2979(0.6806)
Kids study hours	**-0.7110(0.3289) ** **	-0.6960(0.3146) **	-0.6622(0.3200) **

*** denotes significance at 1% ; **denotes significance at 5%; (bootstrap standard errors)

Table 26: Sensitivity Analysis: Kernel (epanechnikov)

Gamma (γ)	sig (+)	Sig (-)	t-hat(+)	t-hat(-)
kerosene consumption per week				
1	1.2e-07	1.2e-07	-1.7838	-1.7838
1.1	1.7e-08	6.7e-07	-1.8436	-1.7220
1.2	2.5e-09	2.9e-06	-1.8972	-1.6576
1.3	3.7e-10	9.7e-06	-1.9506	-1.5838
1.4	5.4e-11	2.8e-05	-1.9936	-1.5120
1.5	8.0e-12	6.9e-05	-2.0358	-1.4566
cellphone charging expenditure/wk				
1	5.2e-11	5.2e-11	-28.5036	-28.5036
1.1	4.8e-12	4.6e-10	-28.6894	-28.2332
1.2	4.5e-13	2.8e-09	-28.8812	-28.0465
1.3	4.1e-14	1.3e-08	-29.0378	-27.8327
1.4	3.9e-15	4.9e-08	-29.2279	-27.6458
1.5	3.3e-16	1.5e-07	-29.3610	-30.8688
Kids study hours				
1	5.7e-4	5.7e-4	-0.8344	-1.3365
1.1	1.6e-4	1.8e-4	-0.9059	-0.7587
1.2	4.4e-5	4.6e-3	-1.0349	-0.6567
1.3	1.2e-5	0.01	-1.1016	-0.6
1.4	3.2e-06	0.0182	-1.1839	-0.5601
1.5	8.3e-07	0.0768	-1.2477	-0.4930

gamma-log odds of differential assignment due to unobserved factors Γ
sig(+) - upper bound significance level sig(-) - lower bound significance level t-hat(+) - upper bound Hodges-Lehmann point estimate t-hat(U-) - lower bound Hodges-Lehmann point estimate
**the lower bound confidence intervals are not reported but also show insensitivity of the obtained impacts.*

Table 27: Impact: Nearest Neighbor (NN) matching results

outcome variable	(a) NN(1); c=0.25	**(b)NN(2); c=(0.25)**
kerosene demand in litres	-1.6089 (0.3989) ***	**-1.4214(0.3930) *** **
hh budget share of kerosene	-0.0038(0.0034)	**-0.0028(0.0031)**
energy budget share of kerosene	-0.0402(0.0535)	**-0.0491(0.0517)**
night light hours	-0.4107(0.5115)	**-0.4869(0.4945)**
Cell phone charging expe/wk	-29.0725(7.3445) ***	**-23.2319(6.7314) *** **
radio hours	-0.3051(0.6783)	**-0.1435(0.7203)**
Kids study hours	-0.7290(0.3608) ***	**-0.7971(0.3367) *** **

*** denotes significance at 1%

__Changing the caliper to 0.2 did not make any major difference for the 2 neighbors case

Table 28: Sensitivity Analysis: Nearest Neighbor matching (1) ;(2) c=0.25 and c=0.2

Gamma(γ)	sig (+)	Sig (-)	t-hat(+)	t-hat(-)
kerosene consumption per wk				
1	9.8e-09	9.8e-09	-1.75	-1.75
1.1	1.2e-09	6.4e-0.8	-1.8333	-1.6964
1.2	1.6e-10	3.1e-07	-1.8975	-1.6146
1.3	2.0e-11	1.2e-06	-1.9583	-1.5531
1.4	2.5e-12	3.7e-06	-2	-1.5
1.5	3.1e-13	9.8e-06	-2.0417	-1.4542
:ellphone charging expenditure/wk				
1	2.6e-10	2.6e-10	-25	-25
1.1	2.6e-11	2.0e-09	-25	-25
1.2	2.7e-12	1.1e-08	-27.5	-22.5
1.3	2.8e-13	5.0e-08	-27.5	-22.5
1.4	2.9e-14	1.7e-07	-27.5	-20
1.5	3.3e-16	5.2e-0.7	-30	-20
Kids study hours				
1	2.6e-4	2.6e-4	-1	-1.5
1.1	6.9e-5	8.9e-4	-1	-0.875
1.2	1.7e-5	0.0024	-1.25	-0.825
1.3	4.4e-06	0.0054	-1.25	-0.75
1.4	1.1e-06	0.011	-1.25	-0.75
1.5	1.1e-06	0.019	-1.375	-0.625

gamma-log odds of differential assignment due to unobserved factors Γ
sig(+) - upper bound significance level sig(-) - lower bound significance level t-hat(+) - upper bound Hodges-Lehmann point estimate t-hat(U-) - lower bound Hodges-Lehmann point estimate
**the lower bound confidence intervals are not reported but also show insensitivity of the obtained impacts.*

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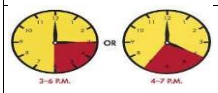
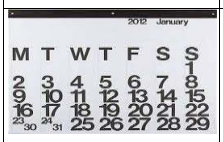
Appendix 2-Figures

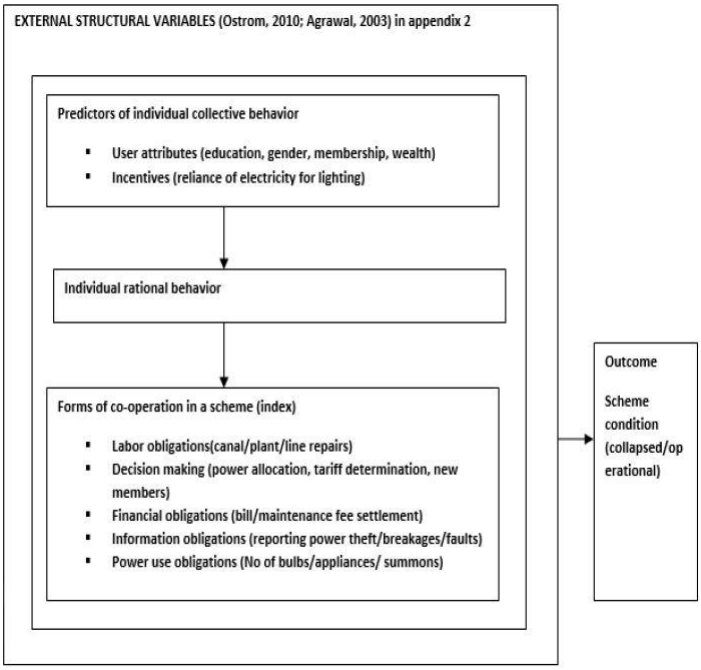
Figure 2: Example of a choice card[30]

BLOCK____4___ CHOICE CARD NUMBER_____2_____ ____

ATTRIBUTE	Explantaion	ALTERNATIVE A	ALTERNATIVE B
	**Duration of planned power outage**	8 HOURS	2 HOURS
	**Number of days in a month of planned power outage**	3 HOURS	2 HOURS
	**Community or private owned and managed**	PRIVATE OWNED	COMMUNITY OWNED
	**The uses to which power can be utilized in the house**	UNLIMITED DOMESTIC USE	• 4 CFLS • RADIO • TV+DVD □
BILL TO PAY PER MONTH IN KENYA SHILLINGS		150/=	300/=
Which option would you choose and can afford?		**A. Alt A** **B. Alt B** **C. None-status quo(remain the way I am)**	

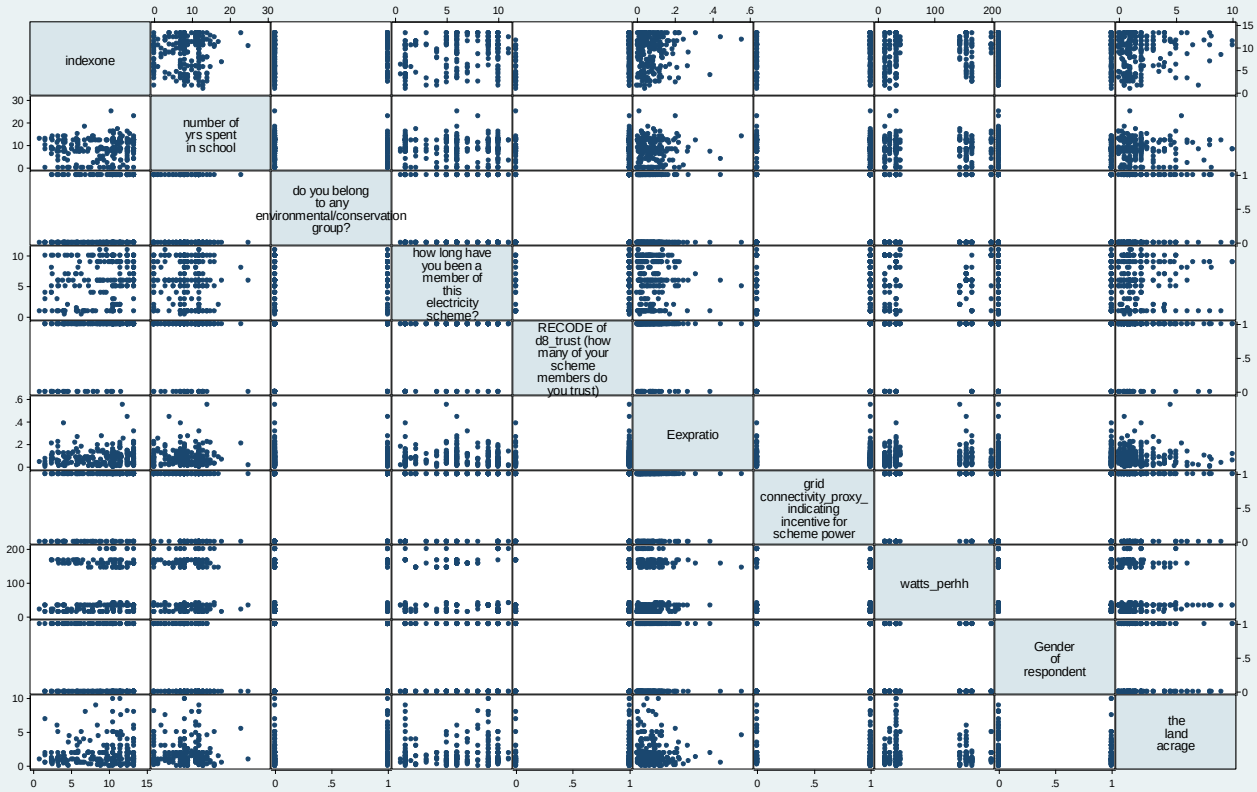
[30] While a technician or an academic may understand what 30, or 50 watts means, this has no meaning to the respondent. However, technicians in the field were consulted to give an indication of the activities that may be supported by 30 or 50 Watts packages in the household participating in the scheme. This is the information that is presented in the choice card and we took time to explain this to our respondents in the field.

Figure 3: Conceptual framework: Individual Characteristics and Group Variables



Adapted from Ostrom (2010)

Figure 4: Scatter Plot of Residuals



source:Own data

Figure 5: Residual Plot

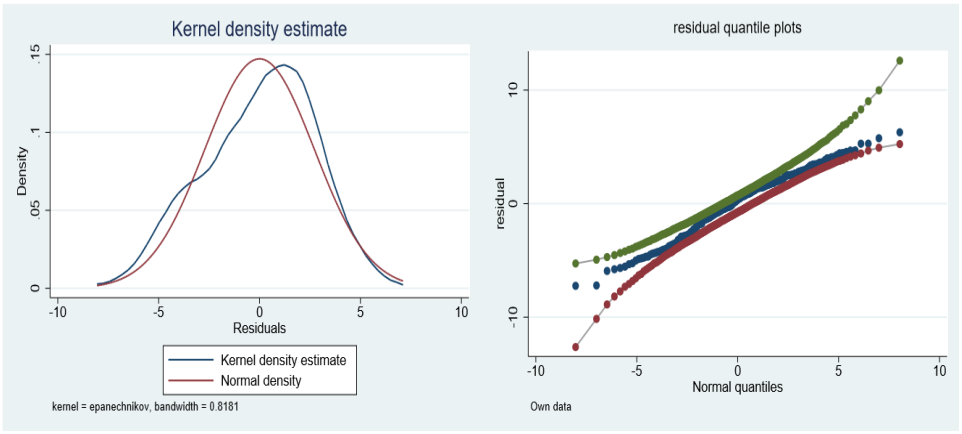
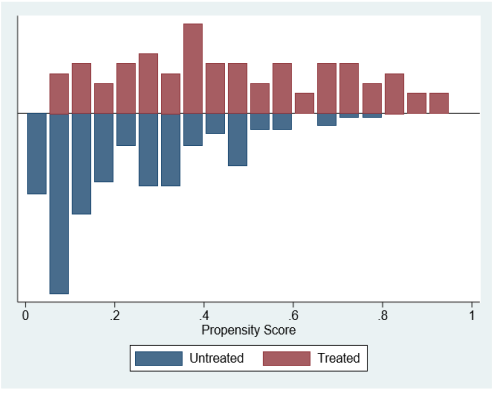
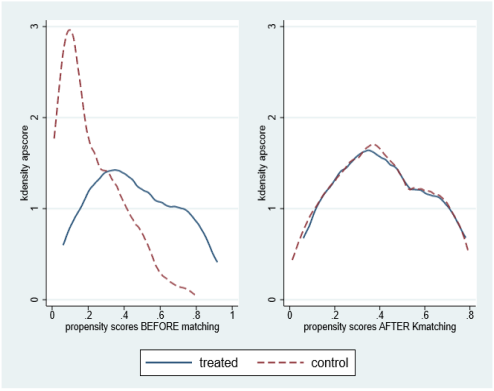


Figure 6: Propensity Score Imbalance before Matching & Region of common support (Kernel and NN-Matching)

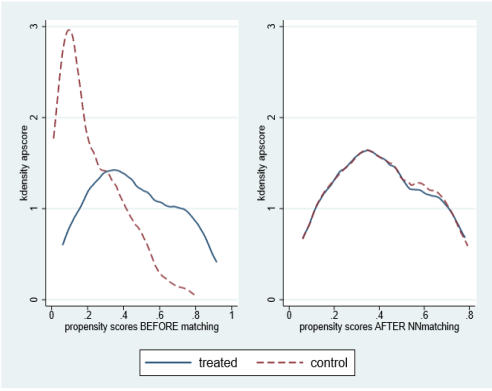
(a)



(b)



(c)



Appendix 3-Study Survey Instruments

No.

QUESTIONNAIRE FOR HOUSEHOLD CHOICE OF ELECTRICITY GENERATION

(TO BE ADMINSTERED TO HOUSEHOLDS IN POTENTIAL MICRO HYDRO PROJECT SCHEMES IN KENYA)

Name of enumerator…….

Date……

Start time……End time……

INTRODUCTION

This questionnaire is part of research being conducted by **Ms. Mary Karumba**, a doctoral researcher at the University of Cape Town, and this research has been approved by the Commerce Faculty Ethics in Research committee. Additionally, the relevant authorization has been obtained from the Kenya National Council for Science and Technology.

The researcher is interested in uncovering society's value for important attributes of electricity service that will be explained to you in a short while. The purpose of this questionnaire is to collect information from individuals faced with the potential of electricity supply from small scale hydroelectric plants. We would appreciate if you would spare some 25 minutes of your time to give us your honest opinion about the attributes of this potential electricity service. The information collected is purely for

research purposes and will be treated with high confidentiality. Your participation in this research is voluntary and you can withdraw from the research at any time. This questionnaire will be administered by the researcher or trained research assistants, and should you have any question regarding the research, please feel free to ask the researcher who is here with us.

SECTION A: HOUSEHOLD DETAILS

A-1) COUNTY_____

A-2) DISTRICT_____

A-3) SUBLOCATION: _____

A-4) NAME OF PROPOSED SCHEME_____

A-5) PROPOSED CAPACITY _____

A-6) CHAIRMAN: (Name and mobile number please)

A-7) RESPONDENT'S FIRST NAME (only for purposes of follow up if need be)

A-8) PHYSICAL LOCATION OF THE HOUSEHOLD

Household code			
Point	**Longitude**	**Latitude**	**Time of day hh:mm:ss**
a) Electricity plant*			
b) Nearest transformer*			

c) Nearest Market*			
d) Household*			

Section B: Knowledge of renewable electricity and its implications on environment

B-1) The following are used for electricity generation in Kenya. Do you think each is good or bad for the society and why?

a) Diesel

0-Good 1-Bad 2-Don't know

Explain_____

b) Water

0-Good 1-Bad 2-Don't Know

Explain_____

c) Sun (solar energy)

0-Good 1-Bad 2-Don't Know

Explain_____

d) Wind

0-Good 1- Bad 2-Don't know

Explain_____

e) Geothermal energy

0-Good 1-Bad 2) Don't know

B-2) When it comes to provision of electricity service, what is the **<u>most important</u>** consideration for you? Tick

a) The connection cost (capital cost for connecting you to electricity)

b) The monthly cost of electricity (what bill you pay at the end of month)

c) The load quality (what you can do with the electricity in the house)

d) The frequency of power cuts (number of planned power cuts in per month)

e) The length of time that power takes to resume during planned power cuts.

f) Having ownership and responsibility over generation and transmission infrastructure

g) **All of the above**

B-3) Apart from the most important consideration you have given in (B-2) above, how do you rank **other attributes**? (Indicate the order here).

1.

2.

3.

SECTION C: Choice of alternatives

C-3) Attribute briefing by interviewer

IMAGINE your house is currently without electricity connection. You can get your household connected to small scale hydroelectricity from two alternatives that vary in the service attributes as follows:

Firstly-Community ownership

- 0-No ownership
- 1- Ownership

For one alternative households own, manage and repair/maintain the electricity generation and supply infrastructure through a registered community association at a local small hydro site. On the other alternative, the generation and transmission is owned by a private developer, and households have no ownership, management or repair/maintenance responsibility.

Secondly-Home electricity packages: What the electricity can be used for

- ***20 Watts*** (you will be able to use **2 CFLs; radio; mobile charging**)-code 3
- ***40 Watts*** (you will be able to use **3 CFLs plus radio, TV and mobile charging**)-code 2
- ***60 watts*** (you can use **more lights and connect more light appliances)- code 1**
- ***unlimited watts (you can connect any and as many appliances as possible in your household)- code 0***

Third, the frequency of planned electricity outages (those you will be informed of)

- 1 day a month
- 2 days a month
- 3 days a month
- 4 days a month

Fourth, the duration of planned outage per day (the number of hours it will take for electricity supply to come back during a planned outage

- 2 hours
- 4 hours
- 6 hours
- 8 hours

Lastly-Monthly bills: Ksh. 100; Ksh. 150; Ksh. 200 and 450

Now I will present to you three options to choose from on each round. Two of the three options are based on the differences in the attributes of electricity service I have explained to you. The third option is choosing to **stay without small hydroelectricity service to your house**. You are requested to choose only **ONE** of the three alternatives each round which is most suitable for your household. There **is no right or wrong answer** (**only your opinion matters**). Please pay attention to the associated monthly bill of the alternative you choose, and **make sure that**

you can afford to pay this monthly bill out of your current household budget.

Round	Choice set presented	Alternative picked A, B, C
1		
2		
3		
4		

Section D: Follow up for those picking "status quo" alternative consistently

D-1) I noticed that you chose the 'status quo' alternative for all the times you were asked to select a choice. What is the reason(s) for your choice?

(Tick /write the reason given)

a) I cannot afford to pay for any of those options

b) I will get electricity from other options (name them_____

c) I believe electricity should be provided free by the government

d) Any other (please specify)_____ D-2: for those choosing **status quo:**

a) What is your current source of electricity?

0-no electricity 1-KPLC 2-Home solar 3-Generator

b) How many days in a month of electricity outage do you suffer from your current source?

_____days in a month

c) How many hours does an electric outage take from your current source?

_____hrs

d) What bill do you pay at the end of month on average from your current source? Ksh. _____

_____

SECTION E: Socio-demographic information of respondent

E-1) Gender of respondent (member)

0-male 1-female

E-2) Employment Status:

0-employed 1- self employed 2-unemployed

E-3) What is the average **net income** for your household from your work/Business/farming per month?

	Source	**Estimated amount/month**
A	Salaries and wages	
B	Other business income	
C	Farming income	
D	Grant or transfers	

E-5) Highest education level achieved

0-None 1-Primary 2-Secondary 3-College 4-University

E-5-1) Approximate Number of years in school _____yrs

E-6) Age _____yrs

E-7) Do you belong to any community environmental /Conservation group?

0-Yes 1-No

E-8) How many people are you in your household (those you share meals/ a roof with)? _____

E-9) If you have **MULTIPLE** households in your home, how many are they?

_____

E-10) What is the type of your dwelling according to construction materials?

0-Permanent (cemented floor and stone walls)

1- Semi-permanent (only floor Cemented; or stone/brick walls only)

2-Temporary (wooden structures; grass thatch; mud walls)

E-10-1) What is the number of rooms in your dwelling?_____

E-11) What is **your** approximate household expenditure **per month/per year**?

a) Food/groceries_____

b) Fuel

	Type	**Amount/month (specified lasting period)**
b-1	Wood/charcoal	
b-2	Kerosene	
b-3	Cooking Gas (LPG)	
b-4	Charging (lamps; batteries)	
b-5	Dry cells/candles	

c) School fees/supplies_____

d) Animal feeds/farm inputs_____

e) Medical (*or insurance thereof*)_____

f) Clothing_____

E-12) FOR THOSE WITH ELECTRICITY CONNECTION-What are your THREE main uses of electricity in their order of importance to you?

*(*INDICATE TOP THREE IN ORDER OF IMPORTANCE)

Key: 0-lighting; 1-radio/TV; 2-mobile charging; 3-farming; 4-cooking (fill in the code)

a) _____

b) _____

c) _____

E-12-1) indicate any other uses of electricity that you might consider

a) _____

b) _____

c) _____

E-13) If you **DO NOT** have electricity connection in your household right now, and you get connected in the future, what would you mainly use the electricity for?

*(*INDICATE TOP THREE IN ORDER OF IMPORTANCE)

Key: 0-lighting; 1-radio/TV; 2-mobile charging; 3-farming; 4-cooking (fill in the code)

a) _____

b) _____

c) _____

E-13-1) indicate any other uses of electricity that you might consider

a) _____

b) _____

c) _____

The researcher is very grateful for your participation and time in this study. We will share with you the outcome of this research.

No.

QUESTIONNAIRE FOR FOCUS GROUPS (COMMUNITY –LEVEL)

INTRODUCTION

This questionnaire is part of research being conducted by **Ms. Mary Karumba**, a doctoral researcher at the University of Cape Town, and this research has been approved by the Commerce Faculty Ethics in Research committee. Additionally, the relevant authorization has been obtained from the Kenya National Council for Science and Technology.

The research is interested in the design and management of small scale hydro energy for electrification of rural households. We would appreciate if you could spare some of your time to participate in this research as a respondent, by providing us with information about your electricity scheme. Your participation in this research is voluntary and you can withdraw from the research at any time.

The purpose of this questionnaire is to collect information from both active and inactive groups that own mini hydroelectricity schemes in Kenya. The information collected is purely for research purposes and will be treated with high confidentiality. This questionnaire will be administered to a group of scheme members by the researcher with the assistance of a trained assistant. Should you have any questions about the research, please feel free to ask the researcher who is here with us.

Start time _____End time_____

SECTION A: GROUP IDENTIFICATION DETAILS

A-1: NAME OF GROUP_____

A-2: COUNTY_____

A-3: LOCATION_____

A-4: SUB-LOCATION_____

A-5: CHAIRMAN (name and mobile number please for follow up only)

_____

A-6: PLANT and SCHEME DETAILS

a		Year group was established	
b		Year electricity was first generated	
c		Initial Plant capacity (kW/MW)	
	c1	For how long did this capacity last?	
d		Current Plant capacity (kW/MW)	
	d1	For how long has this capacity lasted?	
e		Total Cost of original system (Ksh.)	
e-1		Turbine cost	
e-2		Generator cost	
e-3		Construction costs (except free labor)	
e-4		The number of members at start	
e-5		The total contribution per member for initial project	
e-6		Total cost of **current/upgraded** project (Ksh.)	

e-7		Turbine cost	
e-8		Generator cost	
e-9		Construction costs(except free labor)	
e-10		The number of members at upgrade	
e-11		Total contribution per member for current upgrade	
F		Cost of Land (if any)	
G		External financial assistance (tick appropriately) 1) CDF -__Ksh_____ 2) MoE/REA-___Ksh_____ 3) Donor -_____Ksh_____ 4) Others (specify)	
G5		What the financial assistance for initial project or the upgrade?	1) Initial project 2) Upgrade 3) both
G6		Have you ever got a loan from a bank?	0-no 1-yes
G7		If yes in G6 above, what was the amount?	Ksh.
h		Did you receive any external technical assistance?	0-no 1-yes
	h1	Please tick the nature of external assistance 1) Plant design 2) Machinery donation/fabrications	

		3) Feasibility studies	
	h2	Organization which provided technical assistance was	0-non-government 1-government
i		No. of days of free labor contribution by members	
j		Total no. of years of generating electricity (up to date where applicable)	
	k1	No. of Households connected at the start	
	k2	No. of Households connected at the start	
l		Are you currently generating power?	0-No 1-Yes
m		Electric power pricing (bills/packages) write here	Ksh.
n		Total group collections per month (bills and fees)	Ksh.
o		Average expenditure per month (repairs; wages e.t.c)	Ksh.

p		Is/was the group registered? (indicate registration with what authorities) a)_____ b)_____ c)_____ d)_____	

A-7: Number of members

a) At start _____b) **Current**_____ Current membership structure

c) Connected to power (No.)	d) Not connected (No.)	e)Total(No)
M F	M F	M F

A-8: Any reasons for exit of members from scheme?

_____
_____
_____
_____

A-8-1: Once a member exits a group, is **re-admission** allowed in your laws?

0-Yes 1-No

A- 8-2: What are the conditions for **re-admission** of a member into the group? (write down)

_____

_____

_____

_____

SECTION B: GROUP ACTIVITIES

B-1: Is your scheme active currently? 0-No 1-Yes

B-2: Are you generating power from your plant? 0-No 1-Yes

B-3: If **NO** in (B-2) above, whats the main reason why the scheme inactive? (*Tick what is mentioned and briefly write the explanation given*)

	Reason	**Brief explanation**
1	Financial problems	
2	External meddling by administration/politicians/Sects	
3	Internal group wrangles	
4	Withdrawal by most members	
5	Vandalism/theft of infrastructure	
6	Misappropriation of finances	
7	Little or no water (drying up of rivers)	
8	Any other reason (specify)	

B-3-1: Are there plans to restart the generation in the near future?

0-Yes 1-No

B-4: Are you currently doing any plant/line construction/expansion/maintenance?

0-No 1-Yes

B-5: What is the required full monetary contribution of a member in 'good standing'? Ksh._____

B-6: How many members have paid the required full monetary contribution (in B-3 above)?

…….out of……

B-7: How do you/did schedule your group meetings?

0-Planned regular (e.g: Monthly, Weekly) 1-When need arises B-7-1: if you have/had regular meetings how frequent are they?

0-weekly 1-fortnightly 2-monthly 3-other (indicate)_____ B-7-2: How are members informed of a meeting?

1) written notice/letter
2) Word of mouth
3) Mobile phone call/SMS

B-8: On average, how would you rate the meeting attendance?

0-Excellent (all members attend) 1-Most members attend

2-Fair (only a few attend) 3-poor (quorum is never met)

B-8-1: on average, _____out of _____members will attend a meeting.

SECTION C: GROUP INSTITUTIONS

Group laws on conduct and use of power

C-1: Do/did you have group constitution/by-laws?

0-Yes 1-No

C-2: Do/did you have specific laws/rules on power use? 0-No 1-yes

List a few *(write down)*

1) Meeting attendance 0-no 1-yes

2) Resource/power appropriation 0-no 1-yes

3) Bill payment 0-no 1-yes

4) Conflict resolution 0-no 1-yes

5) New member recruitment 0-no 1-yes

C-2-1) Are ALL those rules written down formally?

0-No 1-yes 2-some

C-3: Where did the laws (including the group constitution) come from?

0- Inherited from outside the group

1- Members in the group made them

2- group leaders made them

3- Do not know

C-4: How do/did you make laws/pass decisions in group meetings?

0-Secret voting 1-Acclamation (show of hands/ shout approvals) 2-

Anyother (specify)_____ C-5:

How easy are the rules to understand?

0-Very easy 1-average 3-difficult 4-Very difficult

C-6: How many people here understand all the rules of power use and group by laws? (by show of hands)

_____out of_____

C-7: Do/did you have a **scheme management committee**?

0-Yes 1-No

C-7-1: The number of committee members

a) Male (Number)	b) Female(Number)	c) Total(Number)

C-7-2: How did this committee come about?

0-Appointment 1-Elected 2) volunteering

C-7-2a: If you elected the committee, how did you vote?

0-One member one vote 1-Acclamation 2- Other (specify)
……

C-7-2b: If they were appointed, who did the vetting?

0-all members 1-some group members 2- Non group members

C-7-3: Please list the functions of this Management committee in this group

_____
_____
_____
_____
_____
_____
_____
_____
_____

C-7-4: Is/was there any form of compensation/remuneration for this committee for their service to the community?

0-Yes 1-No 2-Don't know

C-8: Is everyone who is/was serving in the management committee a bona fide member of the scheme?

0-No 1-Yes 2-Don't know

C-8-1: For how long does the committee serve before being replaced, according to your rules?

_____

C-8-2: How many times have (did) you replace (d) the management committee?

_____

C-10: How would you rate the performance of the management committee? Give a score ranging from 0-4 (0 is poorest while 4 is excellent).

0-very poor 1-poor 2-satisfactory/average 3-good 4 -Excellent

	Aspect	**Score (see rating)**
a	Representing the **GROUP** **(in community development issues)**	
b	Safeguarding the group resources (plant; contributions)	
c	Lobbying for group benefits (e.g. finances; technical assistance;	
d	Accountability of their actions to group	
e	Transparency in financial matters	
f	Adherence to group power use rules	
g	Maintaining peaceful conduct in the group	

C-11: Do/did you have a president/leader/chairman of the group?

0-Yes 1-No

C-11-1: How did he become your leader? (*Tick what is mentioned*)

0-Elected by the committee

1-Appointed by the committee

2-Elected by the group members

3-Appointed by the group members

4-Vount

5-Other means (specify)

C-11-2: Do you pay the management committee members as a group?

0-Yes 1-No

C-11-3: Can you re-elect members to the management committee?

0-Yes 1-No

Conflict resolution Mechanism

C-12: Do/did you face any form of disagreements in your group? 0-Yes 1-No

C-13: If Yes, above, what specific disagreements do/did you face, and how often?
Use this Key: 0-Always 1 -Most times 2-Few 3-Rarely

	Source of disagreement	**Frequency**
a	Decision making	

b	Free labor contribution rules	
c	Land contribution	
d	Power use regulations	
e	Power rationing scheduleswhen power is limited	
f	Money (bills, fees)	

C-14: Do/did you have a conflict resolution committee/sitting? 0-Yes 1-No

C-14-1: How would you rate the group conflict resolution mechanism in resolving the specific conflicts within the group (use given score)

0-Conflicts not resolved 1-partly resolved 2- conflict fully resolved

	Source of disagreement	**Score out of 5 (0-conflicts not resolved; 2-conflicts fully resolved)**
a	Decision making	
b	Free labor contribution rules	
c	Land contribution	
d	Power use regulations	
e	Power rationing scheduleswhen power is limited	
f	Money (bills, fees)	
g	Overall group conflict resolution	

C-15: Do you think there is/was favoritism in conflict resolution? 0-Yes 1-No

Explain briefly

_____
_____
_____
_____

Group monitoring systems

C-16: Do you have ways of monitoring whether the power use rules are/were being followed?

0-Yes 1-No

C-16-1: What are some of the ways for ensuring power use rules are adhered to?

_____
_____
_____
_____
_____

C-17: Indicate how often laws are/were broken in the group

Use this key [0-Always 1-Mostly 2-Few times 3-Rarely 4-Never]

	Aspect of law Broken	**Frequency**
a	Power use	
b	Labor contribution	
c	Bill payt	
d	Meeting attendance	
e	Other(specify)	

C-17-1: What are the specific power use rules that are broken **most** of the times?

0- Use of high voltage (unauthorized) appliances

1- Unauthorized power connections

2- Exceeding the allowed bulbs

3- Illegal trade using scheme power

C-18: Do/did you have existing arrangements of penalizing those who break the rules?

1-0-No Yes

C-18-1: Is/was there a special committee which sits to summon, discuss and allocate penalties to offenders?

1-0-No Yes

C-18-2: Please list some of the offenses and their associated penalties

Offence	Brief description of penalty (e.g.) monetary amount; public apologies; free labor contribution e.t.c
a.	
b.	
c.	
d.	
e	
f	
g	

C-19: Do you think these penalties are **fair** enough to deter people from breaking the rules?

0-No 0-Yes

C-20: How costly is the group justice system-in terms of the money paid to access it?

0-Costless 1-Affordable 3-Very expensive (unaffordable)

C-20-1: How would you rate the time take justice delivery by the committee (if it's there)?

0-very slow 1-delayed 3-fast

C-21: Do you think the group justice system is effective in deterring potential offenders from within the group? 0-No 1-Yes

C-22: Do you seek external justice (from the chief/courts) with respect to errant members/non members (if internal solution is not possible)

0-Yes 1-No

C-23: Do you receive any support from the EXTERNAL justice systems to your group (chief, courts)?

0-Yes 1-No

C-24: Do EXTERNAL authorities/systems meddle with your group activities-by undermining the group members/authority?

0-Yes 1-No

C-24-1: Please explain briefly how the meddle

1) _____

2) _____

3) _____

4)

C-25: Have some of you participated jointly with others in another community development projects apart from this one ? 0-Yes 1-No

C- 25-1: Have these other community projects you are jointly participating failed or succeeded?

0-failed 1-succeded

D- **Design principles status (***Ask in past tense for collapsed schemes***)**

	Principle	Status (no, yes or uncertain)
a	1) Is there a clear boundary of those who should benefit from the mini hydro scheme power you have harnessed	0-No 1-Yes 2-uncertain
	2) Is there a defined way of establishing who should benefit from the harnessed mini hydroelectricity?	0-No 1-Yes 2-uncertain
b	1) Do the appropriation rules for power match the availability of generated power throughout the year?	0-No 1-Yes 2-uncertain
	2) When there is a shortage of water (dry spells), is the distribution of electricity adjusted to make sure the little is used equitably by all members?	0-No 1-Yes 2-uncertain
c	1) Has a need to adjust your scheme rules ever risen? 2) Did the whole group participate in adjustment of the rules to reflect new developments in the group?	0-No 1-Yes 2-uncertain 0-No 1-Yes 2-uncertain

d	1) Does the local authority (chief, police, and cooperative development officials, other…….) recognize your group rules? 2) Have you been coerced into changing some of your rules by local authority (Chief,	0-No 1-Yes 2-uncertain

	police and cooperative development officials any other…….)	0-No 1-Yes 2-uncertain
e	1) Have you developed systems for members to monitor each other's behavior (like use of power in the household) 2) Is action taken for members who are reported to have flouted scheme rules by their colleagues?	0-No 1-Yes 2-uncertain 0-No 1-Yes 2-uncertain
f	1) Are there different punishments? Sanctions for different levels of offences in the group? 2) Do you have only one penalty for whichever offense by a group member?	0-No 1-Yes 2-uncertain 0-No 1-Yes 2-uncertain
g	1) Do you incur costs to resolve disputes amongst group members	0-No 1-Yes If yes, how much (e.g. _____
	2) How much time lapses between a dispute reporting and resolution	Days_____ Months_____

	3) How long did the longest standing dispute resolution take?	_____(*fill in unit...days; months, weeks)*
h	1) Does your group participate in any umbrella body for small hydro scheme owners?	0-No 1-Yes 2-uncertain
	2) Do you interact with other groups using the water upstream or downstream (like	0-No 1-Yes
	laying down the rules for amount of water abstraction)?	2-uncertain
	3) If (Yes) above, are the interactions formal (legalized) or basic understanding between the groups?	0-Formal 1-Informal (based on mutual understanding) 2-Both

THE RESEARCHER IS VERY MUCH APPRECIATIVE OF THE TIME YOU HAVE TAKEN TO ANSWER THESE QUESTIONS, AND THE OUTPUT OF THE RESEARCH WILL BE SHARED WITH YOU ONCE COMPLETE.

No.

QUESTIONNAIRE FOR a) **SCHEME MEMBERS (ACTIVE AND INACTIVE SCHEMES)** b) **NON-MEMBERS WITH NO ELECTRICITY (AC)**

Name of enumerator…….

Date……

Start time……End time……

INTRODUCTION

This questionnaire is part of research being conducted by **Ms. Mary Karumba**, a doctoral researcher at the University of Cape Town, and this research has been approved by the Commerce Faculty Ethics in Research committee. Additionally, the relevant authorization has been obtained from the Kenya National Council for Science and Technology

This research is interested in the group participation dynamics and impact of community small scale hydroelectricity on participating households. We would appreciate if you could spare your twenty or so minutes to participate in this research as a respondent, by providing us with information about your household and use of energy. Your participation in this research is voluntary and you can withdraw from the research at any time. The information collected by this research is purely for research purposes and will be treated with high confidentiality. This questionnaire will be administered to you by the researcher or trained research assistants, and

should you have any question regarding the research please feel free to ask the researcher who is here with us.

SECTION A: HOUSEHOLD DETAILS

A-1) COUNTY_____

A-2) SUB-COUNTY_____

A-3) LOCATION_____

A-4) SUB-LOCATION_____

A-5) CHAIRMAN'S NAME *(for scheme*)

_____

A-6) SCHEME NAME (*if household is in a scheme*)

_____

A-7) PHYSICAL LOCATION of the household (ask whether the household is within the 'design radius' of small hydro power plant site?)

0-Within an SHP site 1-Off an SHP site

A-8) PHYSICAL LOCATION OF THE HOUSEHOLD

Household code			
Point	**Longitude**	**Latitude**	**Time of day hh:mm:ss**
Electricity plant*			
Nearest transformer*			
Nearest Market*			

Household*			

SECTION B: MEMBER INFORMATION

B-1) Name of member (*optional - for follow up cases if need arises)*

B-1-1) Are you among the PIONEER members of this small hydro scheme (**those who started the scheme**? 0-Yes 1-No

B-1-2) For how long have you lived in this village? _____yrs

B-2) Gender: 0-male 1-female

B-3) Employment status:

0-employed 1- self-employed 2-unemployed

B-3-1) Are you employed on permanent or casual (temporary) basis?

0-Permanent 1-Temporary

B-4) Education:

0-None 1-Primary 2-Secondary 3-College 4-University

B-4-1) (Please indicate the approximate years in spent schooling) _____Yrs.

B-5) Religion: 0-Catholic 1-Protestant 2-Muslim 3-Other B-5-1) How many times do you attend your respective church in a MONTH? _____

B-6) Age (yrs) _____

*If the respondent **COMPLETELY** refuses to give the exact age, ask for indicative age range of 5 yrs e.g. 20-24; 25-29; 30-34; 35-39;*

B-7) Do you belong to any Community Environmental /Conservation group?

0-No 1-Yes

B-7-1) Specify if Yes in B-8 above_____

B-7-2) Have you ever received any training/education on environment issues (planting trees, soil conservation, renewable energy)?

0-No 1-Yes

B-8) How many people are in your household (meaning you cook the same meals and share a living space)? (Total **number**)_____

a) Primary school-going Kids	b) Secondary/collegeschool going Students	c) Adults

---

B-9) Do you own the house and land you reside in or you have rented it?

0-Rented 1-owned

B-10) Land acreage_____ acres B-11)

What is the type of the household dwelling?

0-Permanent (stone walls & cemented floor)

1-Semi permanent (cement/ floor & wooden walls)

2-Temporary (earth floor & wooden/mud walls; thatch)

B-12) Number of rooms in your MAIN living house _____rooms.

SECTION C: HOUSEHOLD ENERGY USE

C-1) Does your house have electricity connection? 0-No 1-Yes

C-2) If yes in (C-1) above, what is the **main** source of electricity?

0-Grid (paid to KPLC) 1-Scheme 2-Solar

C-2-1) **Before** your house got connected to the scheme electricity, did you have any source of electricity *(like solar or grid)?*

0-No 1-Yes

C-2-2) If Yes in C-2-1 above please specify the source of **electricity**

0-Grid 1-Solar 2-fuel generator

C-2-3) For how long have you been/were you connected to scheme power? _____(yrs or months)

C-3) What is the MAIN source of energy for **LIGHTING** in your household?

0-Electricity 1-Kerosene 2-Solar 3-Firewood 4-Rechargable lamps

5- Candles 6-other_____

C-3-1) If Kerosene is your MAIN source of lighting energy, what type of lamp do you use it with?

0-Hurricane lamp 1-Tin lamp 2-pressure lamp

C-4) What other source of energy apart from the **MAIN** one (in C-3 above) do you use for **LIGHTING**? (list)

0-Electricity 1-Kerosene 2-Solar 3-Firewood 4- Rechargeable lamps

5-candles 6-Other (specify_____)

C-4-1) If you use kerosene for lighting in your house, which type of lamp do you use?

0-Hurricane lamp 1-Tin lamp 2-pressure lamp

C-5) What is the MAIN source of energy for **COOKING** in your household?

0-Wood/charcoal/Dung 1-Kerosene 2-LPG 3-Biogas 4-Electricity

C-5-1: If you use wood as MAIN source of cooking energy, do you have a chimney in your kitchen?

0-No 1-Yes

C- 5-2: If you use wood as MAIN source of cooking energy, do you have a **wood saving stove** in your kitchen?

0-No 1-Yes

C-5-3) Before you got connected to scheme electricity, what is the MAIN fuel that you were using for cooking?

0-Wood/charcoal 1-Kerosene 2-LPG 3-Biogas 4-Electricity

C-6) HOUSEHOLD ENERGY BUDGET

How much do you spend on each household energy item per MONTH?

(*For *LPG, indic,ate for how long a certain quantity is used, and for how much the respondent purchases it: e.g 6kg cylinder, used for 4 months, bought for Ksh3,000…same for any other applicable fuel)*

Fuel	**Ksh/MONTH**	**Units/no of chnarges**	**Price/unit/charge**
1) Electricity bills			
2) Lamps recharging			
3) LPG*			
4) Batteries			
5) Bat Recharge			
6) Kerosene			
7) charcoal			
8) Firewood			

C-7) What is your average **household expenditure** per **month**?

(**NOTE:** *if you are told for instance that they spend Ksh. 40,000 on fees per term, indicate under school fees or respective item as Ksh 40,000/term for 2 terms per year)*

Ksh._____

	Item	**Amount (Ksh/month)**
1	Food and groceries and small house supplies *(Do not include energy expenditure here)*	
2	Subsistence farm inputs/livestock feeds	
3	School fees and supplies	
4	Wages for domestic labor	
5	Water& phone (airtime) bills	
6	Clothing &Apparels	
7	Health(insurance)	
8		
9		
10		

C-8) Indicate the MAIN use of electricity in bmyour household

0-Lighting 1-Cooking 2-Farming (pump/cutting fodder) 3-TV/radio/DVD

4-Mobile phone charging 5-others (specify_____)

C-8-1) indicate other uses of electricity in the household

0-Lighting 1-Cooking 2-Farming (pump/cutting fodder) 3-TV/radio/DVD

4-mobile phone charging 5-Others (specify)

C-8-2) (For those without electricity connection) imagine you got electricity connection today, what would you mainly use electricity for in your household?

0-Lighting 1-Cooking 2-Farming (pump/cutting fodder) 3-TV/radio/DVD

4-mobile phone charging 5-Others (specify)

C-8-3) Apart from the application in (C-8-2 above) what other uses would you use electricity for (*List in order of their most likely use*)

1_____
_
2_____
_
3_____
_
4_____
5_____

C-9) Please provide an estimate of your **household** disposable income from employment and other income generating activities:

	Source	**Estimated amount per month**
1	Salaries (wages) for all employed members living in household	
2	Income from self-employment (business)	
3	Income from farming	
4	Grants/transfers	
5		
6		

SECTION D: PARTICIPATION IN ELECTRICITY SCHEME

D-1) How long have you been a member of this electricity generation scheme? _____yrs

D-2) How often do/did you attend the electricity scheme meetings?

0-Hardly 1-rarely 2-mostly 3-always

D-3) How often are you able to settle your scheme bills/contributions **on time**?

0-Hardly 1-rarely 2-mostly 3-always

D-4) How often do/did you fulfill your **FREE** labor obligations to the scheme?

0-Hardly 1-rarely 2-mostly 3-always

D-4-1) Indicate how many days out of the REQUIRED you meet/met your labor obligations_____ out of required_____ D-5) Did/do you contribute any materials (poles, equipment) to the scheme?

0-No 1-Yes

D-6) Do/did you report all noted theft/destruction of scheme property?

0-Never 1-rarely 2-mostly 3-always

D-6-1) Do you participate in night patrols/watch of the scheme infrastructure?

0-Never 1-rarely 2-mostly 3-always

D-6-2) How often do you participate in decision making at scheme meetings

0-Never 1-rarely 2-mostly 3-always

D-7) How many times were you (have you been) summoned for contravening scheme rules?

_____

D-8) How many of your scheme members do/did you trust?

0-None 1-few 2-most 3-all of them

D-8) Apart from electricity benefits, how else do you benefit from scheme membership*? List the benefits as mentioned*

……1……
……2……
……3……
……4……
……5……

……6……

……7……

D-9) Are/were you in any other development project together with other members of the electricity scheme?

0-No 1-Yesb

SECTION E: IMPACTS OF ELECTRICITY ON THE HOUSEHOLD

E-1) What apparatus do you **MAINLY** use for lighting in your house?

0-Tin lamp 1-hurricane lamp 2-electric bulb 3-solar lamp

4-Candles 5-Rechargable lamp 5-Any other

E-1-1) **If you use electricity** for lighting how many electric bulbs do you have in your house? _____ Bulbs

E-1-2) What is the power output of those bulbs (*you can ask to read off from the bulb if respondent doesn't know*)

_____watts

E-2) How do you find the quality of light you get from the **apparatus**?

0-Poor 1-Fair 2-Good 3-Very good

E-3-2) What time do people often retire to sleep in your family? _____

E-3-3) How many rooms do you light using each of the following apparatus in your house every night and for how long?

	Apparatus	***Number of rooms lit***	***Hours of use per night***
a)	Electric bulb		
b)	Hurricane lamp		

c)	Pressure lamp		
d)	Rechargeable torch		
e)	Tin lamp		
f)	Other (specify)		

E-4) How long do children use the lighting for studying per night?

_____hours each night

E-4-1) what apparatus do the studying kids use most of the time?

0-Tin lamp 1-hurricane lamp 2-electric bulb 3-solar lamp

4-Candles 5-Rechargable lamp 5-Any other E-5-

1) Do you own a television set?

0-Yes 1-No

E-5-2) For how many hours do you watch the TV in your house on average per day? _____hrs E-5-3) What powers your TV?

0-rechargable batteries 1-Soalr PV 2-electric power (AC mains) E-5-4) Do you own a Radio set?

0-Yes 1-No

E-5-5) For how many hours do listen to radio in your house on average per day?

_____hrs

E-5-6) What powers your radio set?

0-rechargable batteries 1-Soalr PV 2-electric power (AC mains) E-5-7) Do you own a DVD/VCD player?

0-Yes 1-No

E-5-8) For how many hours do you use the DVD/VCD in your house on average per day? _____hrs E-5-9) What powers your DVD/VCD player?

0-rechargable batteries 1-Soalr PV 2-electric power (AC mains) E-6) Do you own a mobile phone?

0-No 1-Yes

E-6-1) Are you able to have your mobile phone batteries charged always?

0-No 1-Yes

E-6-2) Do you recharge your mobile phone batteries at home or you pay to have it

charged somewhere else?

0-home charging 1-charge elsewhere (at a fee) 2 -Charge elsewhere for free E-6-2) Approximately how much do you (would you) spend per week to have your mobile phone charged? Ksh. _____

E-7) Do you and/or members of your family get eye/respiratory system ailments?

0-No 1-Yes

E-7-1) On average how many of your family members (you included) will get the above ailments in your family per period?-Tick and indicate the frequency

(e.g. two times in a month; four times in a year)

a) Eye infections	**b) Respiratory infections**
Number	Number

E-7-2) How many members go to hospital/clinic to seek treatment of such ailments?

a) Eye	**b) Respiratory**
Number	Number

Section F: Asset Index

	Indicator	
1	Arable Land ownership(Acres)	_____
2	Owns a motorcycle	-No 1-Yes
3	Owns a bicycle	-No 1-Yes

4	Owns a car	0-No	1-Yes
5	Value of livestock		
6	Dwelling permanent?	-No	1-Yes
7	Piped drinking water connection?	0-No	1-Yes

Thank you very much for the cooperation, once more this information will be used purely for research purposes.

No.

QUESTIONNAIRE FOR HOUSEHOLD CHOICE OF ELECTRICITY GENERATION

(TO BE ADMINSTERED TO HOUSEHOLDS IN POTENTIAL MICRO HYDRO PROJECT SCHEMES IN KENYA)

Name of enumerator…….

Date……

Start time……End time……

INTRODUCTION

This questionnaire is part of research being conducted by **Ms. Mary Karumba**, a doctoral researcher at the University of Cape Town, and this research has been approved by the Commerce Faculty Ethics in Research committee. Additionally, the relevant authorization has been obtained from the Kenya National Council for Science and Technology.

The researcher is interested in uncovering society's value for important attributes of electricity service that will be explained to you in a short while. The purpose of this questionnaire is to collect information from individuals faced with the potential of electricity supply from small scale hydroelectric plants. We would appreciate if you would spare some 25 minutes of your time to give us your honest opinion about the attributes of this potential electricity service. The information collected is purely for

research purposes and will be treated with high confidentiality. Your participation in this research is voluntary and you can withdraw from the research at any time. This questionnaire will be administered by the researcher or trained research assistants, and should you have any question regarding the research, please feel free to ask the researcher who is here with us.

SECTION A: HOUSEHOLD DETAILS

A-1) COUNTY_____

A-2) DISTRICT_____

A-3) SUBLOCATION: _____

A-4) NAME OF PROPOSED SCHEME_____

A-5) PROPOSED CAPACITY _____

A-6) CHAIRMAN: (Name and mobile number please)

A-7) RESPONDENT'S FIRST NAME (only for purposes of follow up if need be)

A-8) PHYSICAL LOCATION OF THE HOUSEHOLD

Household code			
Point	**Longitude**	**Latitude**	**Time of day hh:mm:ss**
a) Electricity plant*			
b) Nearest transformer*			

c) Nearest Market*			
d) Household*			

Section B: Knowledge of renewable electricity and its implications on environment

B-1) The following are used for electricity generation in Kenya. Do you think each is good or bad for the society and why?

a) Diesel

0-Good 1-Bad 2-Don't know

Explain_____

b) Water

0-Good 1-Bad 2-Don't Know

Explain_____

c) Sun (solar energy)

0-Good 1-Bad 2-Don't Know

Explain_____

d) Wind

0-Good 1- Bad 2-Don't know

Explain_____

e) Geothermal energy

0-Good 1-Bad 2) Don't know

B-2) When it comes to provision of electricity service, what is the **<u>most important</u>** consideration for you? Tick

a) The connection cost (capital cost for connecting you to electricity)

b) The monthly cost of electricity (what bill you pay at the end of month)

c) The load quality (what you can do with the electricity in the house)

d) The frequency of power cuts (number of planned power cuts in per month)

e) The length of time that power takes to resume during planned power cuts.

f) Having ownership and responsibility over generation and transmission infrastructure

g) **All of the above**

B-3) Apart from the most important consideration you have given in (B-2) above, how do you rank **other attributes**? (Indicate the order here).

1.

2.

3.

SECTION C: Choice of alternatives

C-3) Attribute briefing by interviewer

IMAGINE your house is currently without electricity connection. You can get your household connected to small scale hydroelectricity from two alternatives that vary in the service attributes as follows:

Firstly-Community ownership

- 0-No ownership
- 1- Ownership

For one alternative households own, manage and repair/maintain the electricity generation and supply infrastructure through a registered community association at a local small hydro site. On the other alternative, the generation and transmission is owned by a private developer, and households have no ownership, management or repair/maintenance responsibility.

Secondly-Home electricity packages: What the electricity can be used for

- ***20 Watts*** (you will be able to use **2 CFLs; radio; mobile charging**)-code 3
- ***40 Watts*** (you will be able to use **3 CFLs plus radio, TV and mobile charging**)-code 2
- ***60 watts*** (you can use **more lights and connect more light appliances)-code 1**
- ***unlimited watts (you can connect any and as many appliances as possible in your household)- code 0***

Third, the frequency of planned electricity outages (those you will be informed of)

- 1 day a month
- 2 days a month
- 3 days a month
- 4 days a month

Fourth, the duration of planned outage per day (the number of hours it will take for electricity supply to come back during a planned outage

- 2 hours
- 4 hours
- 6 hours
- 8 hours

Lastly-Monthly bills: Ksh. 100; Ksh. 150; Ksh. 200 and 450

Now I will present to you three options to choose from on each round. Two of the three options are based on the differences in the attributes of electricity service I have explained to you. The third option is choosing to **stay without small hydroelectricity service to your house**. You are requested to choose only **ONE** of the three alternatives each round which is most suitable for your household. There **is no right or wrong answer** (**only your opinion matters**). Please pay attention to the associated monthly bill of the alternative you choose, and **make sure that**

you can afford to pay this monthly bill out of your current household budget.

Round	Choice set presented	Alternative picked A, B, C
1		
2		
3		
4		

Section D: Follow up for those picking "status quo" alternative consistently

D-1) I noticed that you chose the 'status quo' alternative for all the times you were asked to select a choice. What is the reason(s) for your choice?

(Tick /write the reason given)

a) I cannot afford to pay for any of those options

b) I will get electricity from other options (name them_____

c) I believe electricity should be provided free by the government

d) Any other (please specify)_____ D-2: for those choosing **status quo:**

a) What is your current source of electricity?

0-no electricity 1-KPLC 2-Home solar 3-Generator

b) How many days in a month of electricity outage do you suffer from your current source?

_____days in a month

c) How many hours does an electric outage take from your current source?

_____hrs

d) What bill do you pay at the end of month on average from your current source? Ksh. _____

_____

SECTION E: Socio-demographic information of respondent

E-1) Gender of respondent (member)

0-male 1-female

E-2) Employment Status:

0-employed 1- self employed 2-unemployed

E-3) What is the average **net income** for your household from your work/Business/farming per month?

	Source	**Estimated amount/month**
A	Salaries and wages	
B	Other business income	
C	Farming income	
D	Grant or transfers	

E-5) Highest education level achieved

0-None 1-Primary 2-Secondary 3-College 4-University

E-5-1) Approximate Number of years in school _____yrs

E-6) Age _____yrs

E-7) Do you belong to any community environmental /Conservation group?

0-Yes 1-No

E-8) How many people are you in your household (those you share meals/ a roof with)? _____

E-9) If you have **MULTIPLE** households in your home, how many are they?

_____

E-10) What is the type of your dwelling according to construction materials?

0-Permanent (cemented floor and stone walls)

1- Semi-permanent (only floor Cemented; or stone/brick walls only)

2-Temporary (wooden structures; grass thatch; mud walls)

E-10-1) What is the number of rooms in your dwelling?_____

E-11) What is **your** approximate household expenditure **per month/per year**?

a) Food/groceries_____

b) Fuel

	Type	**Amount/month (specified lasting period)**
b-1	Wood/charcoal	
b-2	Kerosene	
b-3	Cooking Gas (LPG)	
b-4	Charging (lamps; batteries)	
b-5	Dry cells/candles	

c) School fees/supplies_____

d) Animal feeds/farm inputs_____

e) Medical (*or insurance thereof*)_____

f) Clothing_____

E-12) FOR THOSE WITH ELECTRICITY CONNECTION-What are your THREE main uses of electricity in their order of importance to you?

(INDICATE TOP THREE IN ORDER OF IMPORTANCE)
Key: 0-lighting; 1-radio/TV; 2-mobile charging; 3-farming; 4-cooking (fill in the code)

a) _____

b) _____

c) _____

E-12-1) indicate any other uses of electricity that you might consider

a) _____

b) _____

c) _____

E-13) If you **DO NOT** have electricity connection in your household right now, and you get connected in the future, what would you mainly use the electricity for?

(INDICATE TOP THREE IN ORDER OF IMPORTANCE)

Key: 0-lighting; 1-radio/TV; 2-mobile charging; 3-farming; 4-cooking (fill in the code)

a) _____

b) _____

c) _____

E-13-1) indicate any other uses of electricity that you might consider

a) _____

b) _____

c) _____

The researcher is very grateful for your participation and time in this study. We will share with you the outcome of this research.