An Evaluation of Rural Electrification Using a Sustainability Assessment Framework: The Case of Kenya

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持続可能性評価フレームワークを使用した農村電化の評価ーケニアを事例としてー

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Abstract

This research is driven by the concept of human survivability studies, an academic approach that incorporates insights from multiple disciplines in an effort to resolve complex and diversified social issues and challenges which undermine the well-being of humanity. Academic research is thus undertaken to produce results which can make a contribution to the betterment of society by improving long term social welfare. This research addresses issues of poverty, inequality and climate change resilience in rural communities of Sub-Saharan Africa. Energy access through the mechanism of rural electrification is recognized as the potential solution for these societal challenges, and promoting socio-economic development in rural communities. It is thus consequently determined through revisions of energy investment data and various other enabling factors that undertaking a rural electrification case study in Kenya would be ideal for assembling valuable information and data for observation and analysis. In this rural electrification case study, various electrification activities are assessed using a sustainability framework (consisting of five dimensions, namely technical, social, economic, environmental and institutional), in order to evaluate the sustainability of an electrification project, and to determine the degree to which the project has contributed to the socio-economic development of a rural community. Questionnaires are used to collect data during semi-structured interviews conducted with electrification project managers and consumers. The collected data is then converted into scores which are accumulated to display the performance of the electrification projects in each of the five dimensions of the sustainability assessment framework. Six electrification projects are assessed in this case study, including national grid extension to previously disconnected households, three mini-grid installations, and solar home systems sold by two separate private companies. Results of this assessment encourage the formation of partnership with the private sector as a key policy action for promote socio-economic development in rural Kenya, achieve universal electrification access, and enabling sustainable development. This case study was conducted in various locations across rural Kenya in the months of September and October of 2017 and 2019.

Key words – survivability studies, sustainable development, energy policy, renewable energy, sustainability assessment, poverty, inequality, climate change

Abbreviations

IEA – International Energy Agency

IRENA – International Renewable Energy Agency

MDG – Millennium Development Goal

PPP – Public-Private Partnerships

SDG – Sustainable Development Goal

SHS – Solar Home System

SSA – Sub-Saharan Africa

TICAD – Tokyo International Conference on African Development

UN – United Nations

UNDP – United Nations Development Programme

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Introduction

This research uses a sustainability assessment framework in order to study the performance of various rural electrification projects in Kenya on the spectrum of sustainable development. Given sustainability has become a global term of paramount importance in all sustainable development related activity, a sustainability assessment framework, constructed by the author, was used as a tool to evaluate rural electrification projects. The quantitative and qualitative data that is obtained from the field surveys are considered in the exploration of policy solutions which enhance socio-economic development of local communities through rural electrification. The results of this research will also enable the successful and effective implementation of future rural electrification projects.

Various concepts have been reviewed before this research could develop into its final form. The relevant concepts will be discussed in detail in the paper, to create context for the case study conducted in Kenya, and to obtain study results that can have a positive impact on the well-being of rural communities in developing countries. This research has the objective of policy formulation which promotes socio-economic development in Sub-Saharan Africa. It is motivated and inspired by a desire to promote human survivability; and contribute to human survivability studies, a nascent, multidisciplinary academic field.

I. Human Survivability Studies

"Human survivability studies" is a new, issue-oriented academic field incorporating insights from multiple disciplines in efforts to contribute to the resolution of complex global issues which undermine the well-being of society. Kawai et al. (2015) discuss the concept, its novelty and necessity to fundamentally "avoid extinction" of all living organisms including mankind. The authors derive the necessity of such an academic approach from a noticeable independent development of various academic disciplines. Such development leads to narrow approaches in addressing societal issues, making the challenge of resolving them even greater. The concept is therefore founded on the importance of reversing this trend of academic individualization and segmentation by embracing trans-disciplinary research to expand research scopes in studying social challenges. Survivability studies is proposed as the solution to such segmentation, uniting various disciplines in order to search for ways to ultimately extend the existence of the global community, and acquire wisdom needed to avoid crises that may come in the future. My research, therefore, based on these premises, has the principal objective of playing a contributing role in resolving societal issues, with human survivability studies being a driver for the development of this paper.

II. Poverty, Inequality, Climate Change

Having established the aforementioned orientation of this research, it is recognized that this paper orients itself in the overarching academic discipline of development economics, and therefore addresses related societal issues namely poverty, inequality and climate change. These societal challenges are consequentially the supplementary drivers of this research. Poverty in this research is defined (borrowing the concept in Maslow's hierarchy; Maslow 1943; see Figure A) as the inability of an individual to consistently obtain or maintain basic human needs for survival, which include oxygen, food, water, shelter, and clothing.

Figure A – Maslow's hierarchy

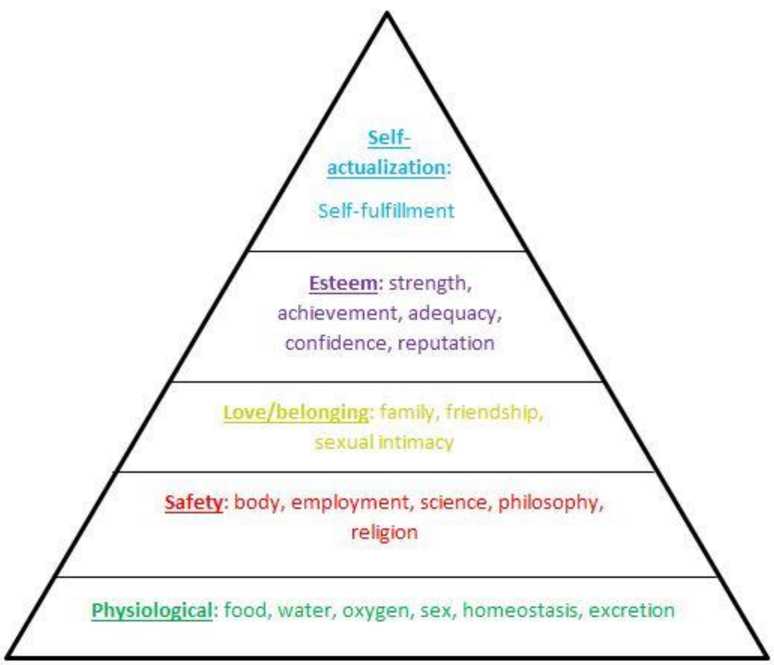
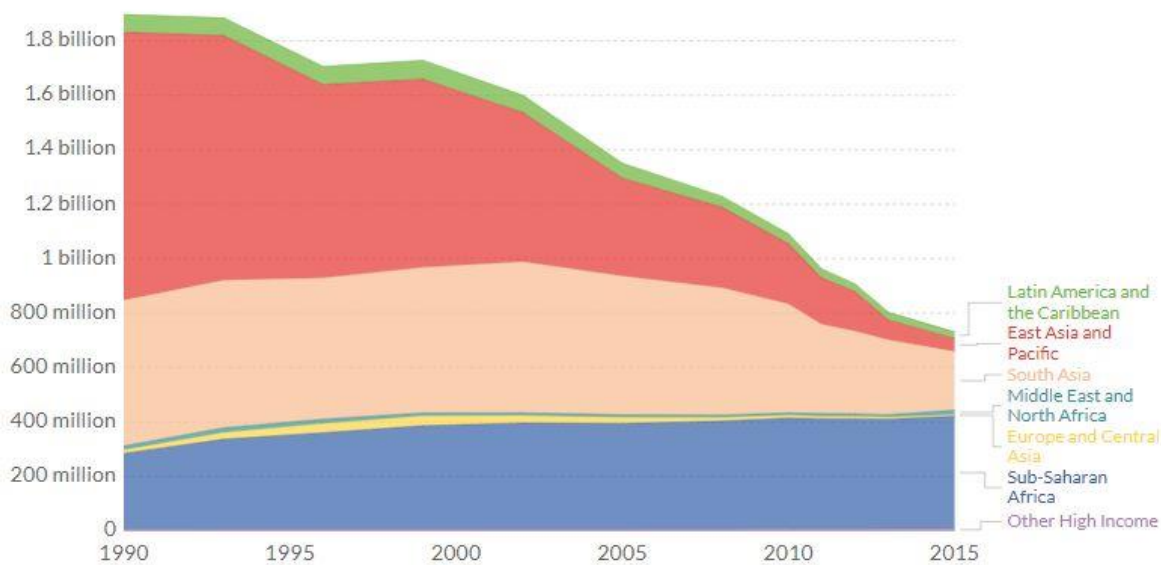


*Diagram constructed by author based on Maslow (1943) "A Theory of Human Motivation"

Economic inequality in this research employed the definition provided by OECD: "the difference in how assets, wealth, or income are distributed among individuals and/or populations". It is also described as the gap between rich and poor, income inequality, wealth disparity, wealth and income differences, or the wealth". Such conditions of poverty and economic inequality are known to be more prevalent in developing countries. In turn, an impoverished population with limited access to the resources necessary for poverty alleviation is more susceptible to climate change caused by anthropogenic activity (industrialization and economic development).

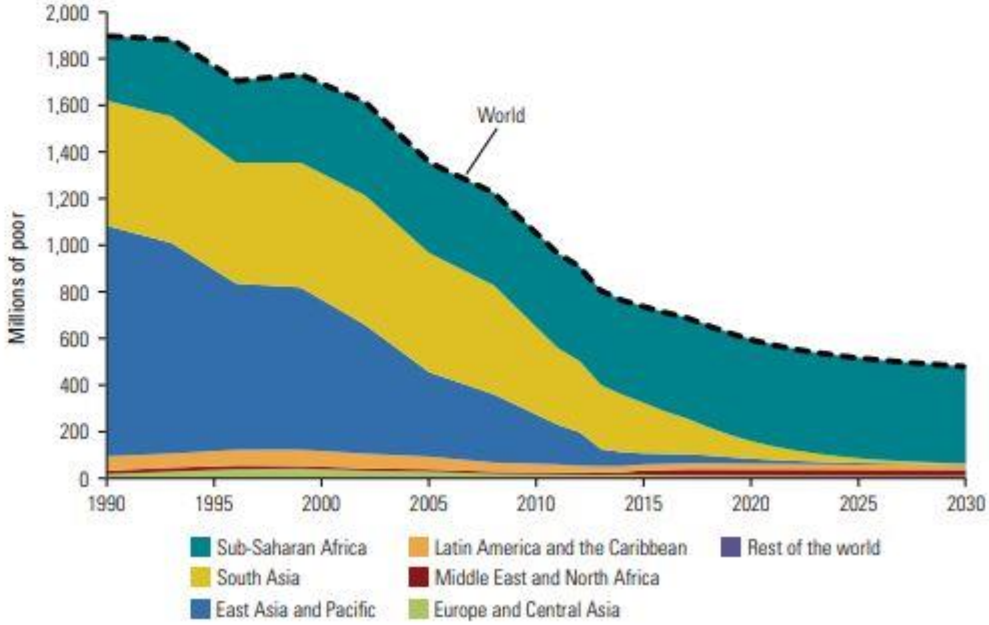
Regarding the aforementioned societal challenges, various sets of relevant data and statistics provided by the World Bank and other institutions, along with various sets of academic literature, have established that issues of poverty prevail most prominently in Sub-Saharan Africa (SSA) (see Figures B and C). However, SSA is a developing region known to have experienced strong economic development over the past decade (UNECA 2019), which raises questions about how poverty levels in absolute terms have remained relatively high. Economic inequality in this research is considered a primary culprit for this circumstance (World Bank 1990; Beegle et al 2016; Bigsten and Fosu 2004; Mwabu and Thorbecke 2004; Fosu 2003).

Figure B – Population living in extreme poverty (below $1.90/day)



Source: PovcalNet (World Bank) *retrieved online*: https://ourworldindata.org/extreme-poverty

Figure C – Population living in extreme poverty (projections to 2030 included)



Source: *Poverty and Shared Prosperity 2018, World Bank.* web:
https://openknowledge.worldbank.org/bitstream/handle/10986/30418/9781464813306.pdf

Additional literature has also shown that economic inequality in countries of this region can be attributed to multiple factors, primarily urban bias (economic activities favoring urban areas), leaving rural areas more vulnerable to the negative effects of climate change, such as reduced agricultural productivity, which affects rural household incomes (Sala-i-Martin 1997; Alagidede, Adu, Frimpong 2015; Lanzafame 2014).

III. Sustainable Development – Energy Access – Rural electrification

Hence, it has become of paramount importance to consider solutions which promote socio-economic development in this region to overcome the societal challenges. Given the concepts introduced in formulating this academic research, this research considers the use of renewable energy for rural electrification developing nations. The concept which is addressed by the first and second targets of the 7th Sustainable Development Goal (SDG7) set by the United Nations (United Nations General Assembly 2015, pg. 15; see Figure D); which stipulate that by 2030, access to affordable, reliable and modern energy services must be ensured, and that the share of renewable energy in the global energy mix must be substantially increased.

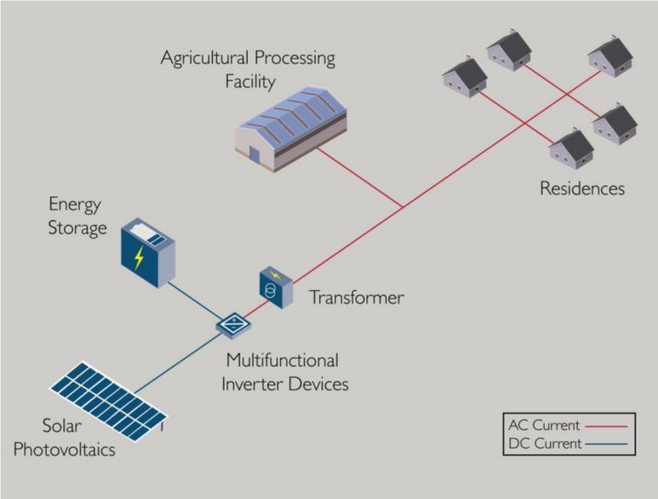
Figure D – Sustainable Development Goals

Source: United Nations – Sustainable Development Goals 2015

Sustainable development is most notably defined in the Brundtland Report as social, economic and environmental development that meets the needs of the present without compromising the ability of future generations to meet their own needs (such a concept can thus be seen as closely related to the premise of human survivability studies). A key driver of sustainable development, energy access is recognized as an important driver of socio-economic development (a concept with a greater focus on social and economic development). Multiple academic papers (see Chapter 2) have also come to this same conclusion regarding energy access, making universal energy access a globally recognized fundamental enabler of sustainable development.

The 7th sustainable development goal on energy access places a great emphasis on the use of renewable energy, in order to minimize the effects of anthropogenic climate change, and thus promote the sustainable development that is needed in this modern age of globalization and exponential technological advancement. To promote modern energy access, and contribute to the attainment of the sustainable development goals established by the United Nations, several rural electrification methods have been employed in rural areas to promote energy access, including national grid extension, mini-grids (to serve small towns or villages, example illustrated in Figure E) or stand-alone system installations (exclusively for individual households or businesses, illustrated in Figure F). However, while maximum power supply capacity is different for each method, these rural electrification projects also differ in their ability to contribute to sustainable development.

Figure E – Mini-grid illustration



Source: National Association of Regulatory Utility Commissioners (NARUC). *Web*: https://www.naruc.org/international/where-we-work/global-initiatives/minigrids/

Figure F – Stand-Alone Electrification System illustration

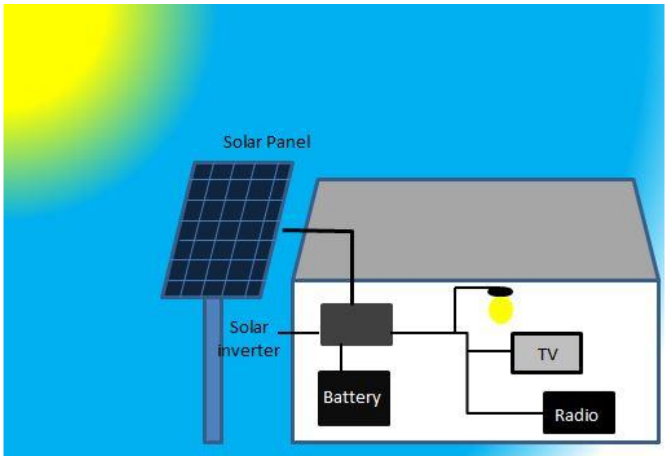


*Diagram developed by author

Therefore, in this research, it is first recognized that the developing region of SSA is one which faces various societal challenges (poverty, inequality, and climate change) despite experiencing strong economic development. It is also revealed through an examination of secondary data that energy poverty, a lack of access to modern energy services, is prevalent in the region (see Chapter 1). The recognition of energy as a key driver of sustainable development gears this research for an exploration of the effects that energy access has had in especially rural areas of developing countries. Rural communities in the developing world were considered not only because of their limited access to modern energy (as illustrated by recent data), but also due to their greater vulnerability to the consequences of poverty, inequality, and climate change. Moreover, the impact of modern energy access provision was certain to be more notable in areas that have experienced energy poverty. A sustainability assessment framework is used, to evaluate the electrification methods that are employed, and to determine strategies which enhance the sustainable development of rural areas in developing countries.

IV. Kenya

Located in East Africa, Kenya is a country with a population of approximately 50 million, in which Swahili and English are the spoken languages by the majority of the population. The population is concentrated primarily in the central and western parts of the country, where ground elevation above sea level reaches up to 2000 meters. As details in Chapters 1 and Chapter 2 will illustrate, Kenya was recognized and chosen as an ideal site for undertaking this research; given its institutional, geographic, and private energy market circumstances which not only created major potential nationwide for renewable energy production, but substantiates the country's history of achievements in renewable energy production. Kenya is unique case due to its primary reliance on renewable energy for electricity generation (see Figure G). Figure G illustrates power generation in Kenya, which has predominantly been through the use of hydropower and geothermal energy sources. Oil is an imported source of energy, and has seen its share in the Kenyan energy mix grow in the past few decades.

Figure G – Kenya Electricity Generation by source

**Energy source, top to bottom*: Oil, Biofuels, Hydro, Geothermal, Solar (40GWh in 2017), Wind (48GWh in 2017). *Source*: International Energy Agency (2019)

Additionally, Kenya has a rapidly transforming energy sector, with the country continuing to successfully expand electricity access in rural and urban areas, in conjunction with private sector actors. Such expansion is illustrated in Figure G with the incremental growth of solar PV. Regarding rural electrification, recent data reveals the rural electrification rate in Kenya has increased from 16% to 68% from 2015 to 2017. Moner-Girona et al (2019) cite the former figure, while IEA (2018) cite the latter (see Appendix A). This makes Kenyan case one in which sufficient data regarding this energy transition and rural electrification can be obtained and studied, to draw lessons and conclusions which can be applied in future efforts to transform the energy sector of other developing economies.

V. Research Question

Given the aforementioned topics of discussion for this research, one main research question drives the development of this paper. The question inquires: "What are the impacts on communities in rural Kenya of grid and off-grid electrification?" It explores rural electrification experiences, and how rural communities have benefitted from rural electrification in Kenya. This question assembles quantitative and qualitative data to produce a comprehensive assessment of the energy transition that has taken place in rural Kenya.

VI. Research Objectives

The principal research question establishes two main objectives in this paper. The first objective is as previously mentioned, the formulation of a framework that will enable an assessment of grid and off-grid electrification in rural Kenya. Given the context that has formulated this research, this framework should incorporate social, economic, and environmental dimensions of sustainable development to assess the rural electrification projects in the way they have promoted sustainable development. The second objective of this research is to determine based on answers to the research question, the policy recommendations that should be implemented for promoting electricity access which is compatible with sustainable development in rural communities in Kenya.

VII. Methodology and scope

This research focuses on grid and off-grid rural electrification. Mini-grids and stand-alone solar PV projects were chosen for the off-grid electrification projects, due to their ability to reach the most remote locations in rural Kenya. Chapter 4 in this paper will discuss in depth the methodology employed in order to answer the research question (the field survey itself, designed based on the sustainability assessment framework developed by the author, used to conduct interviews with managers and consumers of various electrification projects in multiple sites across rural Kenya). The development of the methodology for the field survey necessitated in Chapter 3 a review of the literature regarding assessments of rural electrification projects, in order to enable the author to construct an appropriate framework for the field survey. Regarding policy, further exploration of the literature was also undertaken, to understand those which can be most effective for promoting sustainable development in rural Kenya. This exploration of policy for sustainable development was also conducted through interviews with stakeholders in the energy sector, interviews with consumers, and through the results of the assessment of the various rural electrification projects based on data collected in questionnaires prepared for the interviews. A total of 135 households were interviewed in the months of September and October in 2017 and 2019. The research question, along with the altruistic initiative of tackling the issues of poverty, inequality, and climate change, are the guiding interrelated principles, concepts and ideas which enable this research work to unfold and make the writing of this PhD dissertation possible.

VIII. Research Contribution

This research will address renewable energy policy for rural communities in SSA. In more specific terms, this research develops a case study on rural electrification strategy in Kenya, especially with renewable energy (solar PV); and explores the impacts of various rural electrification projects on the livelihood and well-being of these communities. A sustainability assessment framework, constructed by the author, takes various aspects of rural electrification into consideration and is used to conduct this comparison of rural electrification projects, which can be apples and pears in nature. This unique methodology is employed to gather the quantitative and qualitative data which help to answer the research question. The examination of the impacts of these projects precedes the exploration of effective electrification strategies in rural Kenya for socio-economic development promotion. The results of this assessment, through the employment of the framework, can then facilitate renewable energy policy discussions for rural electrification in other developing countries, and such discussions ultimately help to tackle the challenges of climate change, poverty and inequality in developing nations, especially in Sub-Saharan Africa. This research, therefore, draws upon lessons that can be learned in the Kenyan case study to ensure future rural electrification projects can be successful in improving the quality of life of households in rural Kenya and in other parts of Sub-Saharan Africa. As chapters 3 and 4 in this paper will illustrate, the use of the sustainability assessment framework in order to undertake this research in Kenya is the originality that separates this paper from previous studies, especially given the limited number of studies that have been performed employing this methodology.

IX. Paper Outline

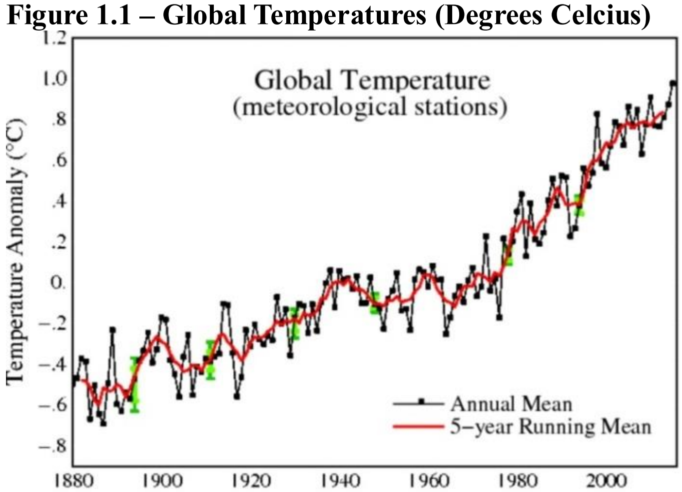
Various sets of literature were reviewed which lead to the development of the sustainability assessment framework and its application in a case study of rural Kenya for this research, and they, along with the methodology, will be discussed in detail in this paper. This PhD dissertation is organized in a logical sequence. Part One, which contains three chapters, will be the literature review which leads to the development of the framework. The first chapter of this paper will introduce and discuss literature and data regarding renewable energy, energy access and rural electrification. The second chapter will focus on the energy transition that has occurred in Kenya, with a review of the literature related to energy access, rural electrification, and renewable energy production potential. This chapter will explore several enablers for renewable energy production and rural electrification in Kenya, and will draw details from discussions that have been held with experts and key stakeholders in the Kenyan energy sector, which are principal actors in the energy transition. The third chapter will then discuss literature regarding the assessment of various rural electrification activities that have been completed. The remaining chapters of this paper, which all belong in the second part of the paper, will discuss the development of the sustainability assessment framework (based on findings from the literature in the third chapter), its implementation in a case study for rural Kenya, and case study results. The policy implications of the research findings are discussed at the end of the paper in Chapter 6, which is then followed by the paper's conclusion section.

Chapter 1: Energy Access and Rural Electrification

1.1 Energy Access – Clean and Affordable

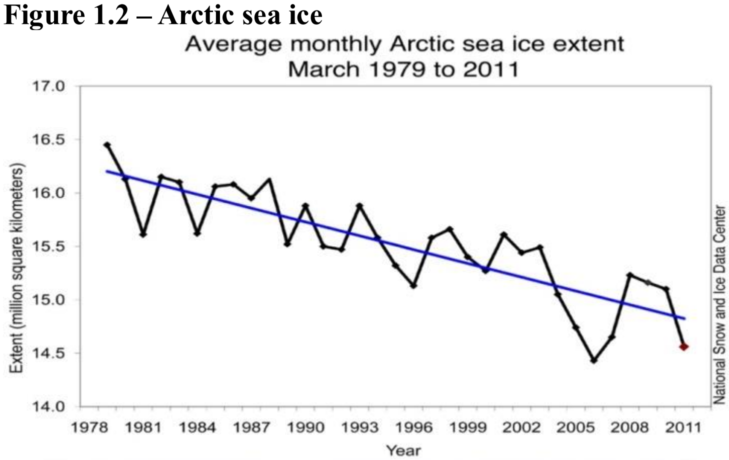
As previously mentioned, energy is considered an indispensable resource not only for the eradication of poverty but also for enabling socio-economic development. Energy has played its essential role in enabling economic development in various nations around the world to take place, with the consumption of fossil fuels for producing electricity driving various industries. It is therefore of paramount importance that universal access to modern energy is attained. However, conventional energy consumption patterns are affecting the global climate, with the increase in carbon emissions over the past century causing global temperatures to rise, ice caps to melt, and sea levels to consequently increase (see figures 1.1, 1.2, 1.3).

Figure 1.1 – Global Temperatures (Degrees Celcius)



Source: National Aeronautics and Space Administration (NASA)

Figure 1.2 – Arctic sea ice



Source: National Snow and Ice Data Center

Figure 1.3 – Global Sea level

Source: National Aeronautics and Space Administration (NASA)

During the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, energy, through Agenda 21, was discussed, highlighting the fact that its consumption and production patterns were unsustainable; that emphasis should be placed on the implementation and transmission of cleaner energy technologies; and that the role of alternative energy sources needed to be expanded and developed further (United Nations, 1992). Fossil fuels have been the traditional source for energy in the industrial world. As mentioned, they are producing carbon emissions which are effectively changing the global climate, and their reserves are also being depleted in such a way that future generations may be forced to more desperately innovate and develop efficient alternatives before the traditional energy resources are fully exhausted. To therefore facilitate future generations' maintenance and improvement of their standard of living, it was globally recognized in 1992 that cleaner, more sustainable forms of energy needed to be considered for sustained economic development and fundamentally for the long-term survival of mankind. Fossil fuels cannot be considered sustainable nor clean, since their consumption is harmful to the environment, and because they cannot be replaced after use.

1.2 Clean Energy vs Renewable Energy

Various forms of clean energy can be considered. However, with climate change becoming a greater concern, a clear distinction must be made between a few categories of energy; clean energy and renewable energy. Clean energy refers to sources of energy that meet energy demand, without having significant impacts on the environment. It is a category of energy sources with varying characteristics. Examples of such sources of clean energy include nuclear power, and coal with carbon capture and storage (CCS). However, nuclear power and CCS rely on more immediately finite resources, namely uranium and coal respectively. It must also be noted that these clean forms of energy can have damaging effects on the environment if accidents occur during production processes. Potential for carbon emissions are still possible in the development of CCS, while radioactive waste from nuclear energy production can also cause irreversible damage to surrounding living organisms. Famous instances in which of radioactive waste affected organisms include the Chernobyl disaster of 1986, and the Fukushima nuclear power plant explosion in 2011. Given the aforementioned possible pollutive effects of carbon emissions, and risk for irreversible damage to living organisms caused by radioactive wastes produced from nuclear power generation, the sustained exploitation of these sources of energy undermine the long-term well-being of humankind.

Renewable energy, on the other hand, inherits all of the characteristics that define clean energy. The distinction that is made between the two forms of energy, however, is that renewable energy has a much lower carbon footprint (in most instances, carbon emissions are non-existent after development/installation), and therefore help to prevent further significant changes from being made to the climate. These energy sources are more also more rapidly replenished on a human timescale. Sources of such renewable energy include sunlight, wind, geothermal heat, biomass and water (tides, waves, and rain for hydropower). Hence, in order to ensure sustainable development and the long-term well-being of mankind, renewable energy sources can be taken into consideration as an important mechanism for promoting this form of development.

1.3 Renewable Energy Sources

1.3.1 Solar

Renewable energy can be produced from various sources that are naturally available in abundance in the environment. The natural resources include sunlight, water, wind, geothermal heat, and biomass. Use of such natural resources facilitates achieving the global objective of meeting present-day needs without compromising the ability of future generations to meet their energy resource needs by focusing on these long-term, clean and sustainable alternatives. REN21 (2016) and Heal (2009) provide a significant amount of information regarding renewable energy sources currently in use.

Sunlight is considered the most abundantly available energy source of all renewables, with solar power systems lasting at least 10 years. It is converted into electricity using photovoltaic (PV) cells, or concentrated solar power (Heal 2009). However, the resources required to manufacture the photovoltaic cell panels that help convert the sun’s rays into electricity are scarcely available, which may compromise the potential for long-term mass production of electricity-generating solar systems. It has also been noted that solar power is an intermittent source (with a need for storage), often times meaning supplemental energy sources are needed in areas with less exposure to sunlight: so solar power on its own in certain conditions may not be sufficient to meet consumption demand consistently. Like other forms of renewable energy, solar energy requires a large initial investment, but incurs no fuel costs after installation, and operation and maintenance costs are relatively low.

The levelized cost of electricity, or LCOE (price at which electricity would have to be sold for a production facility to breakeven over its lifetime, as defined by Geoffrey Heal [2009]) for utility-scale solar PV prices fell almost 60% from 2010 to 2015, with the most competitive price falling as low as $0.08/kWh, much cheaper than the cost of fossil fuel consumption in the price range of $0.045/kWh to $0.14/kWh (REN21, 2016). Heal (2009) had also written that costs for solar PV can be expected to match the price for fossil fuels between 2015 and 2020. More recent data provided by the International Renewable Energy Agency reveals the average LCOE of solar PV has indeed continued to fall, from $0.37/kWh in 2010 to $0.09/kWh in 2018 (IRENA 2018).

Prices for stand-alone solar home systems installed in households vary depending on power manufacturing costs, power capacity and consumer demand. Stand-alone solar home systems enable households to significantly reduce or completely eliminate their dependence on the national electricity grid. While such stand-alone solar power generators are also typically considered expensive for households, this initial investment for the installation of the system is in certain cases a one-time payment which virtually pays for the lifespan of the generator. Households typically would never have to pay electrical bills for the solar power produced from their generators, but they may settle with making monthly payments (for instance via installments) if the solar home system was bought under long-term payment plans. In low income households, stand-alone solar home systems are the main products that unable households unconnected to the national grid to attain electricity access

1.3.2 Renewable Energy Sources - Wind

Wind is another natural resource used to produce electricity. Wind energy is divided into two categories; on-shore wind and off-shore wind, with off-shore wind energy referring to energy produced from turbines near beaches on water, while on-shore wind energy refers to windmills built on mainland territories. Off-shore wind is known globally to be more expensive than on-shore wind energy sources, given this aspect of the wind energy industry is relatively new. Hence, technologies at the disposal of the off-shore wind energy industry require further development (REN21, 2016). Meanwhile, on-shore wind energy is considered one of the more affordable sources of renewable energy.

Recent data reveals the global installation cost for onshore wind has fallen from $1913/kW in 2010 to $1,497/kW in 2018, and the levelized cost of electricity (lcoe) falling from $0.08/kWh to $0.06/kWh with the help of technological and manufacturing progress made in this energy sector (IRENA 2018). Small wind turbines are also stand-alone on-shore wind energy solutions that households can consider to produce their own clean power. This possibility remains a luxurious consideration for the average household, given that the size of the small wind turbines vary from being 3.7 to 7.6 meters in diameter, depending on the power demand of the household.

The windmills are known to have relatively high output capacities, but are disruptive to surrounding ecosystems, especially with the extensive amount of land required for their construction, the perceived negative impact on birds, and negative visual impact (Klain, Satterfield, Sinner, Ellis and Chan 2018); however, this negative impact on the environment is considered negligible. Wind energy however does still face a few challenges. In addition to high initial investment requirements, like solar power, ongoing maintenance costs also need to be covered in order to operate these wind mills effectively, raising questions of affordability. Finally, power output is also intermittent, fluctuating depending on winds in the area, making it an unfavorable power source in certain geographic locations. The height of the windmill also affects the power output capacity, with greater heights increasing power output capacity of windmills, which can increase costs for households looking to buy small wind generators. Despite the aforementioned challenges, wind energy is considered to be one of the most mature forms of renewable energy technology.

1.3.3 Renewable Energy Sources - Biomass

Biomass, another natural resource that can be used as fuel to produce energy, consists of materials such as lumber, forest debris, specific crops (ex. sugarcane), manure, and waste residues. With waste being constantly available from various activities, renewable energy production through biomass sources can continue indefinitely. Biomass is one of the most widely used sources of energy in developing countries, due to its abundance in supply, especially with the use of wood fuel and charcoal for lighting and cooking (Rosillo-Calle 2016). Biomass energy sources, like wind, are also competitively priced, with weighed average LCOE ranging from $0.08/kWh to $0.05/kWh in the previous decade (IRENA 2018).

Biomass sources, like many other renewable sources, have geographic limitations. In order to reduce costs which can rise due to transportation activities, it is most cost efficient for biomass sources to be consumed near the location in which they are initially gathered. Biomass sources can also be air pollutants, thus can adverse effects on health. Sources of biomass energy can emit nitrogen oxide, and in some cases fossil fuels are needed to convert sources of biomass energy to energy. Therefore, biomass sources seem to be scarce compared to other forms of renewables. Carbon emissions resulting from the use of biomass are inevitable in certain cases, sparking discussions on the need to increase greenhouse gas savings (Rosillo-Calle 2016). There is also therefore the debate regarding the question of biomass being a renewable energy source, with strong arguments being made for and against its continued use. Considering challenges such as deforestation, for example, the consumption and replenishment of the wood fuels needed would be a time consuming cycle. This is an argument about resource depletion, caused by the inefficient use of biomass sources. Inefficiencies may also lead to carbon dioxide emission that can exceed emissions from the exploitation of conventional fossil fuels like coal, oil, and natural gas. This discussion raises the question of whether biomass can be considered a viable and sustainable source of energy for long-term energy production, making the adoption of biomass as a renewable energy source a controversial resolution.

1.3.4 Renewable Energy Sources - Geothermal

Geothermal energy sources are found beneath the Earth's surface (Heal 2009), in the form of heat that can be extracted from shallow ground, steam, hot rocks, and magma. Wells are drilled into underground reservoirs to generate electricity, and heat pump systems consisting of a heat pump, ductwork (air delivery system), and a heat exchanger (system of underground pipes), tap into the Earth's shallow ground in order to heat and cool buildings. Geothermal power plants require steam to generate electricity, and supply this energy to a power grid. On land, geothermal energy sources have very few geographic limitations when taking into consideration the possibility of using magma (available everywhere, and in abundance) as a potential heat source. However the technology for exploiting magma has not yet been developed, thus geographically restricting geothermal energy production to areas where underground steam is available. Global weighed average LCOE for geothermal power in 2015 was \$0.08/kWh, a competitive cost in the renewable energy sector (REN21, 2016). IRENA (2018) reveals this value fluctuating from \$0.05/kWh to

$0.08/kWh. Like most sources of renewables, initial investment costs for geothermal is high, with operation costs being significantly reduced to manageable levels after installation.

1.3.5 Renewable Energy Sources - Hydro

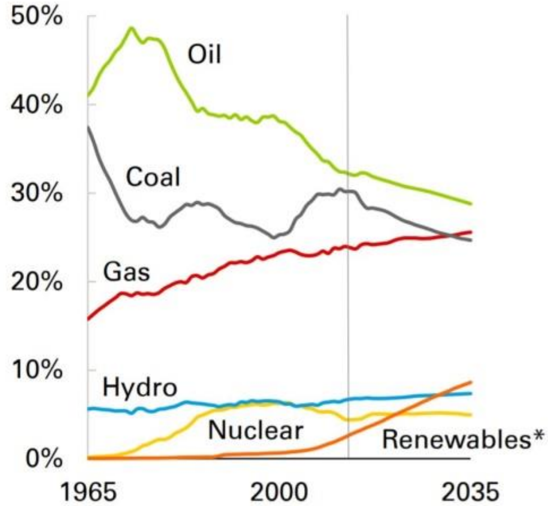
Hydropower is a renewable energy form that is generated by using water flows in rivers in order to operationalize generators that produce electricity. It is considered an extremely attractive renewable energy technology due to its low cost, the flexibility it can provide to the grid (IRENA 2018). Unlike solar and wind energy sources, power output is also more easily regulated to meet demand. This renewable energy source can also be produced at varying scales. Global average LCOE for hydropower was the cheapest of all other renewables, ranging from $0.03/kWh to $0.05/kWh, making it the most competitively priced renewable energy source. Large scale hydropower, produced from dams, and small hydro, which can serve a community or household.

However, there is controversy regarding the sustainability of large-scale hydropower, due to its greater negative impacts on river ecosystems (Bakken, Sundt, Ruud, and Harby 2012); and its role in causing deforestation, community displacement, altering livelihoods, and affecting water quality (Moran, Lopez, Moore, Muller, and Hyndman 2018). Hence, in terms of the discussion regarding the promotion of sustainable development, the consensus is small-hydro is the more renewable, sustainable energy source.

1.4 Global energy consumption

BP reveals data illustrating the primary sources of energy across the globe over the past 5 decades. Figure 1.4 below illustrates the global energy consumption patterns.

Figure 1.4 – Share of primary energy



Source: BP Energy Outlook – 2016 Edition – Outlook to 2035. pg. 80

Oil, coal, and gas have dominated the shares of energy consumption throughout this time. However oil and coal have seen their percentage in the global primary energy mix decline, due in particular to the growing percentages of gas, renewables and nuclear energy. BP projects shares of oil and coal in the energy mix will continue to fall, while renewables continue to become a greater primary source of energy in the global energy mix.

1.5 SSA Energy Consumption

Regarding energy consumption in Africa, however (as briefly mentioned in the introduction section of this paper), there are several factors that cause and maintain economic inequalities which complicate the ability of a larger portion of a population to benefit from the economic growth that is being experienced in a country. SSA has not yet achieved universal access, and at present urban areas of African countries have much higher electrification rates than rural areas. A single, most prominent cause of such economic inequality is difficult to isolate and identify. The literature has identified various causes for these inequalities. Nevertheless, given the majority of the poor living in Africa are in rural areas, it can be argued that the economic growth being experienced in many African countries are focused in urban areas, which suggest the existence of an urban bias (economic development activity concentrated in and favoring urban areas).

Bigsten and Fosu (2004) discuss the need to address microeconomic constraints to enhance the effectiveness of macroeconomic reform, explaining how macroeconomic and structural imbalances in the early 1980s led African countries to enter structural adjustment programs. Despite these efforts, per capita incomes stagnated, and poverty levels remained high. Mwabu and Thorbecke (2004) explore the question of why development in rural areas in SSA has been poor, concluding that an urban bias in policy making has been a factor. This bias has contributed to poor rural infrastructure, which leads to a host of additional economic development challenges, such as poorly functioning (or simply missing) markets. Bates (1981) proposes the political process being a culprit for the theoretically existing bias. Fosu (2003) writes about how unstable political processes (inconsistent, corruptible) in many countries in Africa led to the maintenance of policies which penalize exports that are produced by those who work in rural areas, giving an example of overvalued exchange rates favoring cheaper imports which are consumed by urban dwellers. Additional explanations for the inequalities include limited human capital (in terms of skilled labor), geographical distances (the remoteness of the settlements of various rural communities), and tribal conflict (based on interviews conducted during the field survey). There are therefore multiple factors which have contributed to existing inequalities in SSA, which in turn has led to poor (and lower) rural electrification rates in most countries in SSA (see Figure 1.5).

Figure 1.5 – Electricity access in Africa 2017

Source: IEA, *World Energy Outlook-2018*

Electricity Access in Africa

	Rate of access						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2017	2017	2017	2017
Africa	**35%**	**39%**	**43%**	**52%**	**74%**	**36%**	**603**
Sub-Saharan Africa	**23%**	**28%**	**32%**	**43%**	**67%**	**28%**	**602**

The data in Figure 1.5 for 2017 electrification reveals that on average, 52% of the total population of SSA has access to electricity. It has also been determined that within this electrified portion of SSA, 67% of those electrified are situated in urban areas, while 28% are in rural areas. This trend of greater electricity access in urban areas than in rural areas is observable for every country in Sub Saharan Africa, except for Seychelles and Mauritius, both island countries. In Seychelles, electrification rates are at 99% in both urban and rural areas, while Mauritius has successfully achieved 100% electrification for its population (see Appendix A). However, for all other countries in SSA, electrification rates are higher in urban areas, implying a smaller portion of a country's population is benefitting from economic development activities.

Energy consumption in SSA is dominated by the use of traditional biomass, used almost exclusively in rural areas (Figure 1.6).

Figure 1.6 – Use of traditional biomass in Africa 2017

Source: IEA, *World Energy Outlook-2018*

Access to Clean Cooking, Summary by Region

	People without access to clean cooking				Population without access	Population relying on biomass
					(million)	
	2000	2005	2010	2017	2017	2017
Africa	76%	74%	73%	71%	895	825
Sub-Saharan Africa	90%	89%	87%	84%	893	824

The forms of traditional biomass used include firewood, charcoal, manure and crop residues. These sources are typically used inefficiently, leading to resource depletion and health problems due to indoor air pollution from cooking and lighting. Such biomass sources also lead to emissions of greenhouses gases due to poor combustion. These emissions are thought to contribute to the global warming derived from anthropogenic activities. However, since biomass use is highly correlated with people's income levels, living habits, gender roles and village structures, it is a source of energy that has essentially been ingrained in the culture of people in rural communities in SSA that use biomass. It is therefore an energy consumption pattern that is difficult to change, without disrupting the social stability such changes in energy sources may bring. This raises a question regarding the viability and social sustainability of changing social structures, not only to protect the environment, but also the rural communities that will be directly affected by changes in the climate. Figure 1.6 reveals in SSA 84% of the population in the region uses biomass sources for energy consumption. Data from the IEA's 2018 World Economic Outlook report reveals that Botswana, Cape Verde, Seychelles, Gabon, Mauritius and South Africa are the countries in which a majority of the population relies on other sources of energy for cooking (see Appendix B).

1.6 Rural Electrification

Given the aforementioned energy consumption patterns in SSA, there is a clear demand for additional, modern energy services, and various systems for rural electrification should be considered. There are three methods that prevail when considering the electrification of rural areas in SSA. They include the extension of the national grid, installation of a mini-grid, and dissemination of stand-alone power systems (for one household). The author has been able to visit and observe the function of each of the rural electrification methods during the field survey for this research. These rural electrification methods will be discussed in this section of the chapter.

The national grid is the infrastructure that provides electricity to all other forms of infrastructure in an economy. It can be considered the bloodstream, a primary enabler of modern economic activity, capable of supplying electricity from various sources, including renewables. A system of power lines (and towers which suspend them) transmit electricity nationwide; and streetlights, urban centers (entire cities), and households that are connected to them are provided with electricity needed for various daily socio-economic activities. This method of electrification is capable of supplying electricity nationwide, however as shown in the cases of countries in SSA, not all households are connected to the national grid, so grid extension can be necessary in order to achieve 100% electrification. However, this electrification method faces a few challenges in SSA with regards to extension. Costs can be typically high, especially in developing countries, where low-income households are located in distant, remote locations in rural areas. These households are also typically either unable to afford these services, or do not have the energy demand which necessitates incurring the high costs for grid extension. Other factors can also sometimes prevent further national grid extension, such as areas where deforestation or construction over national parks and wildlife sanctuaries is prohibited by law, forcing policy makers and other stakeholders that are part of the rural electrification effort to consider alternative strategies to access these areas to provide electricity services (Chaurey, Ranganathan, Mohanty 2004).

Nevertheless, when households are connected to the national grid, electricity services are generally stable and able to meet all energy demands. However it must be noted that in certain areas in SSA, unplanned power outages can last a few minutes to several days or weeks, inconveniencing households and various businesses that depend on these electricity services to proceed with daily economic activities. Households in rural areas that connect to these power lines for the first time are typically required to pay an initial connection fee, before making monthly payments for electricity services. These monthly fees will vary depending on the amount of electricity consumed in that time frame, and will therefore be expensive for low-income households, businesses, and institutions in certain cases, and very affordable for others.

Mini-grids, like the national grid, consist of a power station, connected to power lines carrying the electricity produced at the power station (that are suspended on poles). However, they are only capable of supplying electricity to a small community, village, or town. The benefit of having mini-grids installed in certain areas is to provide energy access to remote locations that are too distant from the national grid to consider national grid extension economically viable. Like the national grid, mini-grids can be powered using various sources, including renewables, and are thus not only capable of contributing to the improvement of socio-economic standards of the connected community: they contribute to the reduction in dependence on finite natural resources which when used and consumed have adverse effects on the surrounding environment and climate. Mini-grids are therefore a popular solution worldwide for providing clean, affordable energy services to remote rural areas, and their installation has been completed by various organizations such as private enterprises, development assistance agencies, and governments. Appropriate installation models enable mini-grids to be integrated with the national grid in the future, helping mini-grid owners (community, or business) sell electricity produced by the mini-grid power station to the national grid. The major drawback for mini-grids, however, is that they are in fact only capable of serving small communities. This entails that decisions have to be made by the aforementioned stakeholders regarding the *ideal location* in which these mini-grids are installed based on various criteria; especially economic, geographic and regulatory conditions. This decision making procedure therefore disadvantages remote locations that are not considered viable for mini-grid installation. Hence, mini-grid installations alone may be unable to fully provide energy access in rural areas.

Hence, there are rural areas in which the actualization of national grid extension and mini-grid installations proves to be a challenge. Such areas can obtain access to energy through small, stand-alone power systems. These systems are suited for individual households, businesses and institutions that require access to energy, or require a back-up power system in case of power outages. Such forms of access to energy for households already exist, with the use of traditional biomass sources for cooking and lighting, as mentioned in the previous section of this chapter. Diesel generators, solar PV systems, micro hydropower systems, and wind turbines also all help constitute various stand-alone power systems (some being renewable). However, the installation of these systems in rural areas of SSA can be expensive for consumers, and in certain cases geographically unviable due to their location (ex. location of consumers can sometimes make micro hydropower systems an impossible solution). Wind turbines for individual rural households can also be costly when taking into consideration the lower income levels of the rural population. Solar PV systems and diesel power generators, however, are more flexible in their ability to match the price range of rural consumers, due to their ability to vary in size and capacity, and are more flexible in their ability to reach any remote location in rural areas of SSA. Hence, in SSA in particular, solar PV systems and diesel power generators may be ideal solutions for off-grid electrification. While private enterprises can be heavily involved in the selling and installation of these systems in rural areas, governments have also undertaken projects to distribute small solar panels to villages in rural areas for simple purposes such as lighting, and mobile phone charging, and like some private enterprises, have assessed the socio-economic benefits that these systems provide to households, businesses, and communities.

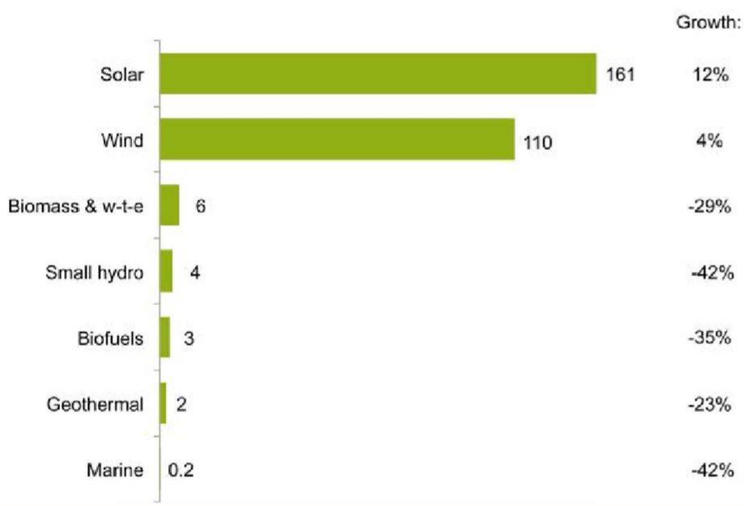
The complimentary nature of the aforementioned rural electrification options to contribute universal energy access is evident. Electricity supply capacity for larger electrification systems are evidently greater than those of smaller systems, and therefore may have greater socio-economic impacts on rural areas, if any. Such impact possibilities have helped establish the research question for this dissertation, and are explored further in this research with the field study conducted in Kenya and a review of the rural electrification literature in Chapter 3. These electrification methods are also recognized as having the potential to contribute to the resolution in SSA of the societal challenges of poverty, inequality, and climate change, an observation which is agreed upon by a majority of the academic literature that has addressed this topic.

However, an ideal research setting and location needed to be established for this research question to be answered. Countries worldwide have already undertaken the process of rural electrification using various mechanisms which fall into the three electrification method categories mentioned in this section of the paper. Hence, a brief review of energy investment trends globally was conducted to identify a potential ideal setting in SSA to further develop this research. Following this identification process, a case study can then be developed in this setting which can supply sufficient data to find answers for the research question that has been posed, and to attain the research objectives that have been set in the introduction of this PhD dissertation. The following section therefore undertakes this brief review in order to identify the ideal direction for this research to take.

1.7 Energy investment trends

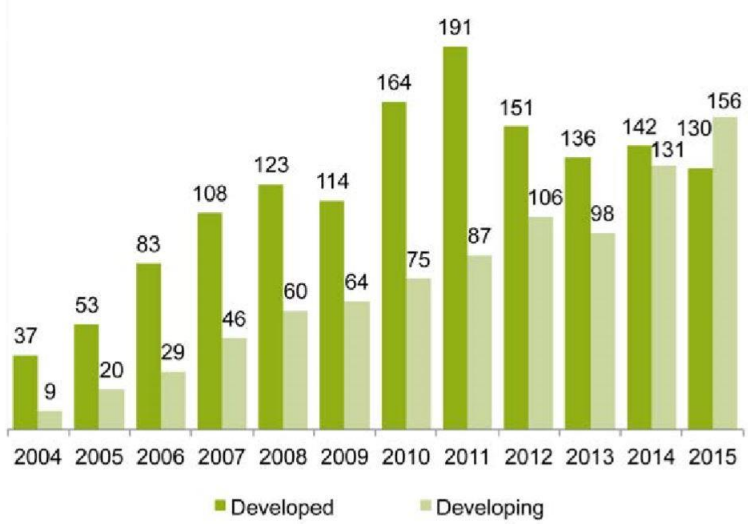
The Global Trends in Renewable Energy Investments 2016 Report (UNEP 2016) will be used in order to discuss investment trends in renewables in this section. The report reveals a new record was set for global investment in renewable energy in 2015, excluding large hydro-electric projects. Approximately $285.9 billion were invested, beating the 2011 record of $278.billion. These investments help to enable the growth of renewables in the global energy mix, contributing to the objective of enabling the entire global population to eventually have access to clean electricity. Global investment in renewable power capacity was $265.8 billion, which is double the allocation for new coal and gas generation (approximately $130 billion), preventing the emission of almost 1.5 gigatons of carbon dioxide in 2015. In addition to these investments, the cost of renewable energy generation has continued to fall, especially for solar PV (in accordance with other pieces of literature). Solar power has seen a 12% increase in renewable energy investment, the highest percentage change amongst all renewables (see Figure 1.7).

Figure 1.7 – Global New Investment in Renewable Energy



Source: UNEP, Bloomberg New Energy Finance

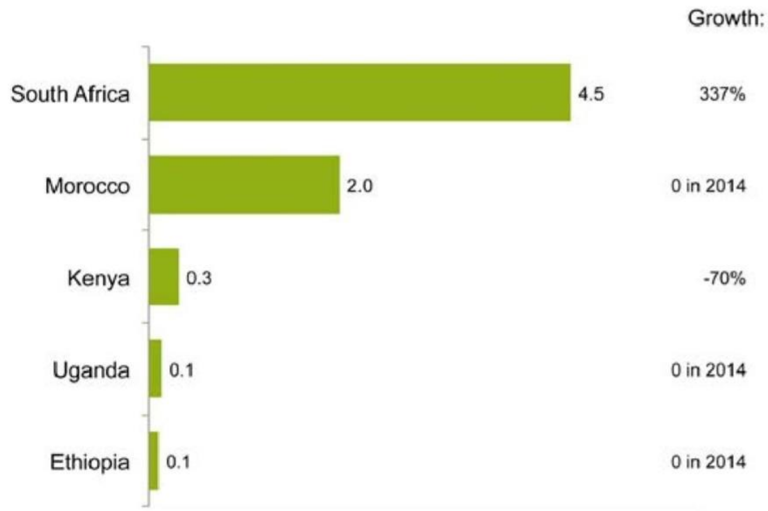
Figure 1.8 - Global New Investment in Renewable Energy: Developed vs Developing Countries



Source: UNEP, Bloomberg New Energy Finance

Figure 1.8 illustrates annual growth in investments in renewables from 2004 to 2015, with developing countries in particular seeing a steady increase in new investments. In Sub-Saharan Africa (excluding South Africa), Kenya is the country with the highest amount of asset finance for renewable energy (financing for renewable energy production), even though $316 million in 2015 is a disappointment compared to the $1.1 billion in financing received for renewables in 2014 (Figure 1.9).

Figure 1.9 – Asset Finance in Renewable energy in Africa by Country 2015



Source: UNEP, Bloomberg New Energy Finance

However, with renewable energy markets in Kenya and many other African countries having vast potential with its growing population (and the inevitable growth in demand for energy as a result), natural resources in sunshine, wind, biomass and geothermal, these investments can be expected to steadily grow over the next decade. Further examination of the Kenyan case (see Chapter 2) has revealed Kenya as an early mover in the dissemination of small-scale solar PV systems, and a country with historic achievements in renewable energy production.

1.8 Conclusion – Bridging the key concepts

This chapter acted as a background section, supplementing the introduction section in bridging the key concepts related to this research, to form the context which enabled this PhD research. Poverty is a challenge that threatens the survival of mankind. This challenge especially prevails in rural communities in SSA, which represent a majority of the population in the region. Due to various causes of economic inequalities, rural communities are facing various challenges and barriers that complicate their ability to improve their well-being and quality of life. Hence, several approaches can be considered in order to determine how the resilience and survivability of mankind, especially in rural communities, can be preserved. In light of this challenge, among many others facing the globe, the United Nations established as mentioned in the Introduction 17 sustainable development goals which focus on developing and improving three global dimensions (economic, social, environment) for sustainable development to be successful. Since this research looks to focus on eliminating the challenges that face survival (poverty, inequality, and climate change), rural electrification appears to be the ideal process to develop the resilience necessary for long-term societal well-being in rural communities.

Energy is considered a mechanism of paramount importance for the economic and social development of any region, and has been a key mechanism for development throughout the entire Industrial Age of civilization. Coupled with advancements in technology and growth in popularity of renewable energy sources (leading to increases in investments in such energy sources as well), energy has also become an instrument for stabilizing and reducing carbon emissions, in order to prevent these emissions from having significant effects on the climate, thus ultimately improving the survivability of people living in rural communities. Can renewable energy therefore be a solution for overcoming the challenges rural communities face? Africa is a region of the globe with enormous potential in renewable energy production and consumption due to its natural endowments in sunlight, wind, geothermal and biomass energy sources, along with a rapidly growing population. Solar PV is a technology that has attracted increasing levels of investments and financing globally, and Kenya is the leading country in SSA in financing for renewables. The aforementioned ideas raised some prominent questions. What is Kenya doing to attract renewable investment? How has the renewable energy transition taken place in Kenya? Will solar energy be a future dominant source of electricity in the Kenyan energy mix? These are all questions that are further explored under the umbrella of the main research question.

However, in this research, the focus is primarily on resilience, and on the survivability of mankind. Since Kenya is an early mover in national electrification, especially with renewable energy sources such as small scale solar PV, Kenya was identified as the ideal site for forming a case study and performing several field surveys. It can be certain that plenty of electrification had already taken place in rural areas through different mechanisms, therefore raising questions regarding their significance locally, nationally, and in terms of the socio-economic development of rural areas.

Chapter 2: Energy Transition and Rural Electrification in Kenya

While there are many countries in SSA that could have been selected for this research, Kenya is a country undergoing a significant energy transition. The nation has been an early mover in the dissemination of renewables and off-grid rural electrification, creating a field study setting in which sufficient quantitative and qualitative data can be gathered to answer the research question of this paper. Moreover, Kenya leading all developing countries in SSA in renewable energy asset financing reveals that Kenya has been able to create an appropriate environment in the region for renewable energy production (as seen in Figure 1.9, Chapter 1). Thus, this chapter will discuss the development of the Kenyan energy sector, namely the enabling factors making Kenya a leading country in renewable energy transition (by referencing important documents, articles, and statistical data). This chapter will also illustrate how rural electrification has been able to occur throughout (and as a result of) this energy transition, explore the rural electrification methods that have been employed, and discuss the challenges which were faced (based on secondary literature, and interviews with stakeholders conducted during the field survey of September and October of 2019) in undergoing this energy transition.

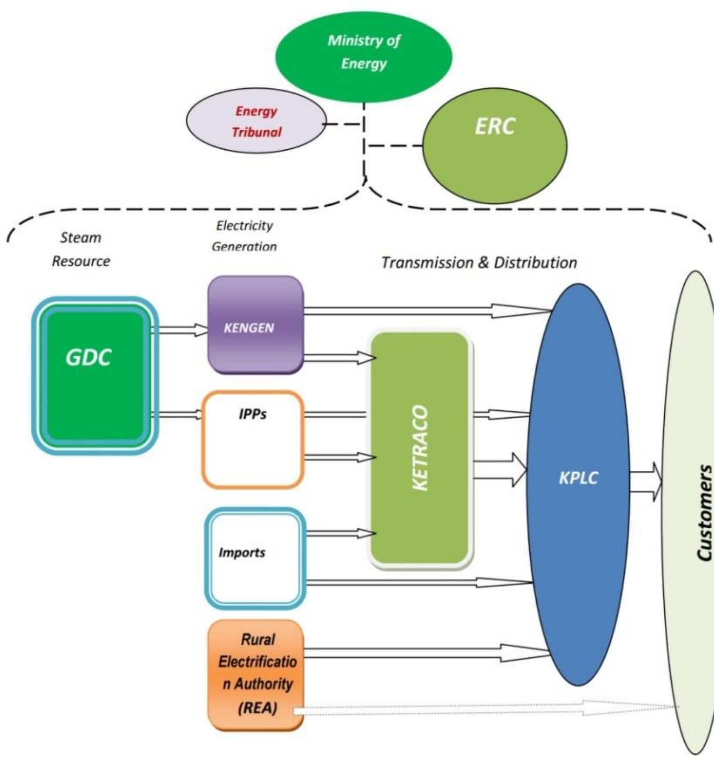
2.1 Enabling Environment - Institutions

Institutions in Kenya have led the energy transition in Kenya. Throughout the past few decades, the Ministry of Energy and Petroleum (MoEP) in Kenya was the principal institution that implements policies which create an enabling environment for the growth of the energy sector. This institution considers access to competitively-priced, safe, and sustainable energy as essential for being able to provide a high quality of life to all citizens in a clean and secure environment. In addition to energy policy implementation, MoEP is also involved in the regulation, security and conservation of energy; the development of hydropower and geothermal energy industries; renewable energy promotion and development, the rural electrification programme, and mobilizing financial resources for the public sector (Ministry of Energy 2018).

The institutional structure beneath the MoEP comprised of the Energy Regulatory Commission (ERC), Rural Electrification Authority (REA), and the Energy Tribunal, originally created under the 2006 Energy Act enacted by the Parliament of Kenya (Republic of Kenya 2006), to consolidate the nation's energy sector. The ERC regulates all energy subsectors; protects stakeholder interests to ensure reasonable returns on investment for developers; regulates licensing;

approves power purchase agreements (PPA) between Kenya Power (KPLC) and power generators; and reviews and adjusts tariffs for consumers and independent power producers (IPPs). The REA mobilizes funds to support rural electrification, finances rural electrification project preparation studies, recommends suitable policies to government, and implements rural electrification through grid extension and off-grid systems (Ministry of Energy 2018). Given REA's mandate, the REA is an example of the effort necessary for the elimination of the urban bias that exists in developing countries in SSA (which negatively hampers rural development) by focusing on projects which directly increase energy access in rural areas. Figure 2.1 illustrates the entire institutional structure for Kenya's energy industry over the past decade, headed by MoEP.

Figure 2.1 – Energy Sector Institutional Framework, Kenya



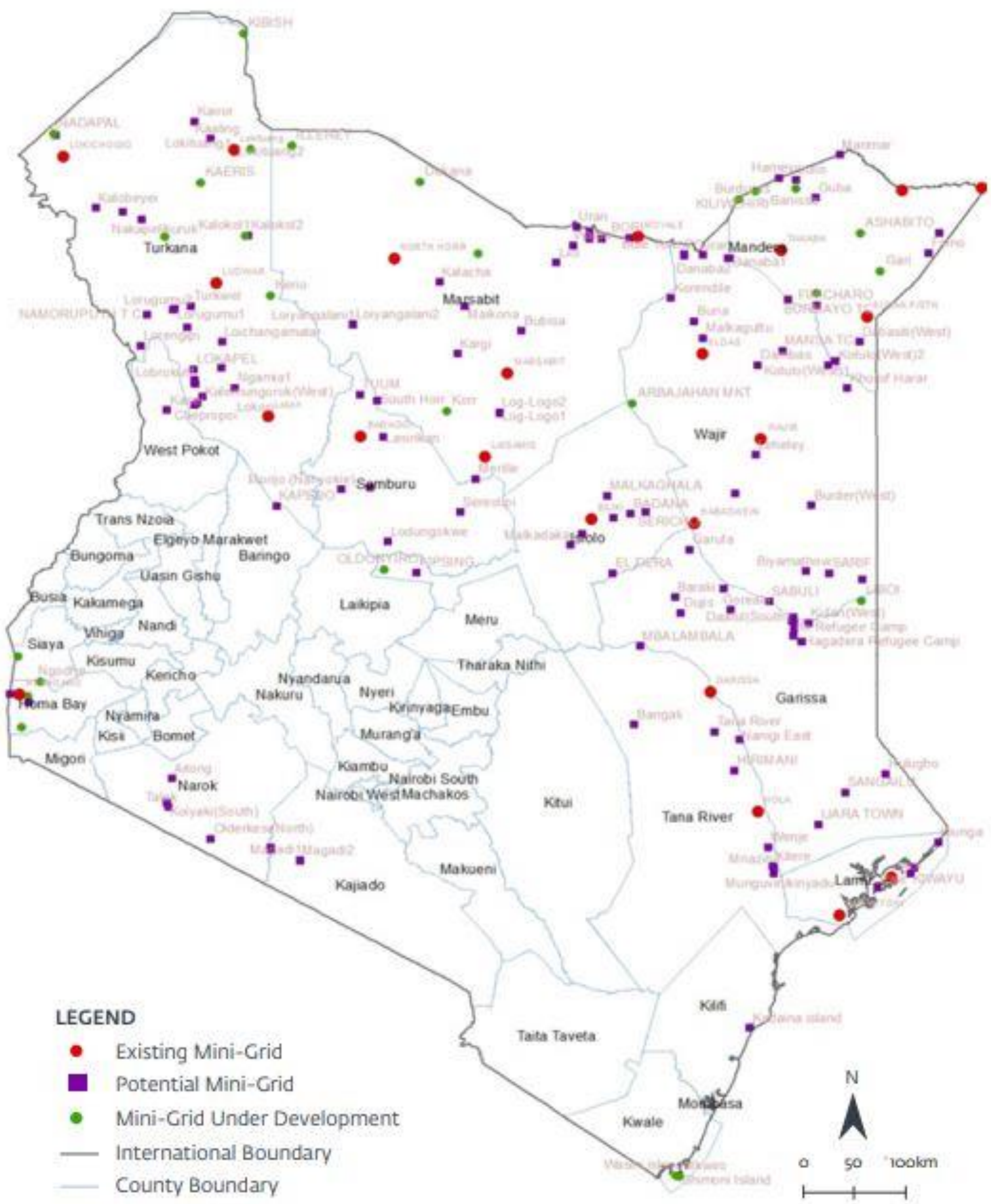
Source: Ministry of Energy and Petroleum (MoEP) (Kenya)

Kenya Power (KPLC) is the state-owned utility company in charge of the transmission and distribution of electricity nationwide via the national grid to its consumers, and has been making progress connecting consumers in all areas. The MoEP has five Directorates; Petroleum Energy, Geo-Exploration, Renewable Energy, Electrical Power, and General Administration and Support

Services, which facilitate the delivery of its mandate. The Geothermal Development Company (GDC), government-owned as in the case of KPLC, focuses on the development of steam fields and selling steam for electricity generation to the Kenya Electricity Generating Company PLC (also known as KenGen), IPPs and private investors. KenGen is the leading power generating company in Kenya, focusing on the delivery of clean energy to the power transmission and distribution entities in the energy sector. KenGen's generation capacity mix currently consists of hydropower (818MW), geothermal energy (534 MW), Thermal (254 MW) and Wind (26MW). The Kenya Electricity Transmission Company (KETRACO), is also government owned and is mandated to plan, design, build and maintain high voltage electricity transmission lines and substations. KPLC then undertakes the transmission and distribution of electricity to end consumers. The Energy Tribunal was the judicial branch of the Kenyan Energy sector which heard and determined appeals brought against decision that were made by the ERC. IPPs, institutions, or private investors who were not satisfied with certain regulations were therefore able to state their case to the Energy Tribunal, before a decision is made regarding the regulation in question. This organizational structure creates in Kenya the necessary institutional and legal environment for the development of the energy sector, including for renewable and clean energy.

The government of Kenya has implemented several regulations and initiatives to support the development of its clean energy industry. Kenya's Least Cost Power Development plan, a 20-year rolling power generation and transmission plan established in March 2011, for instance, looks to open plants, and undertake projects to generate new power capacity from clean energy sources such as geothermal, nuclear, and water (hydropower) (original document superseded). The rolling plan has been updated and is currently titled the "Updated Least Cost Power Development Plan 2017-2037" (Republic of Kenya 2018). The REA has actively undertaking projects to electrify public facilities (such as schools and health clinics) with stand-alone solar home systems, and households and communities across remote locations in rural Kenya with mini-grids; hence playing its mandated role in the energy sector to contribute to Kenya's original national objective of achieving 100% electrification by 2030. The institution has also been involved in the development of off-grid diesel mini-grids in areas of commercial and strategic importance, with 7 of the 14 mini-grids recently having solar and wind energy introduced into the mini-grids, providing further modern energy access services to households, schools, and community centers (Mini-Grid Policy Toolkit – Case Study – Kenya). Additional potential mini-grid sites have been identified (see Figure 2.2) in the 2018 Kenyan National Electrification Strategy (KNES 2018), in which accelerated electrification efforts are expected to enable Kenya to attain universal access to electricity by 2022. Additionally, in order to achieve this universal access by 2022, the Ministry of Energy estimates that $2.75 billion in investment will be required over the next five years, with $2.3 billion of public investment being made in grid and mini-grid expansion (with the support of donor-financing) and $458 million of private investment in solar home systems.

Figure 2.2 – Existing mini-grids and potential mini-grid sites



Source: Kenya National Electrification Strategy 2018 (KNES)

The 2015 Energy Bill, passed by the Parliament of Kenya, established the Renewable Energy Resource Advisory Committee, an inter-ministerial committee that advises on developing criteria for the allocation of renewable energy resources, licensing of renewable energy resource areas, water tower management, and renewable energy management and development (Energy Regulatory Commission, 2015). The same bill also determined that the national energy policy will be reviewed every five years to remain abreast with trends in the energy industry.

In addition to the aforementioned enabling factors, the feed-in-tariff implemented by the government of Kenya in January 2010 was introduced to promote the investment in renewable electricity generation, reduce administrative and transaction costs, and encourage private investors. The feed-in-tariff has been periodically reviewed, with Figure 2.3 illustrating current tariffs for renewable energy projects producing up to 10 MW and above 10 MW of electricity (IEA 2016).

Figure 2.3 – Kenya 2nd revision of Feed-in Tariff for Renewable Energy

	Duration	Installed capacity (MW)	Standard FiT (USD $/kWh)	Percentage Escalable portion of the Tariff	Max. capacity (MW)
Wind	20 years	0.5 – 10	0.11	12%	10
Hydro		0.5	0.105	8%	10
		10	0.0825		
Biomass		0.5 – 10	0.10	15%	10
Biogas		0.2 - 10	0.10	15%	10
Solar (grid)		0.5 – 10	0.12	8%	10
Solar (off-grid)		0.5 – 10	0.20	8%	1

	Duration	Installed capacity (MW)	Standard FiT (USD $/kWh)	Percentage Escalable portion of the Tariff	Max. Cumulative capacity (MW)
Wind	20 years	10.1-50	0.11	12%	500
Geothermal		35-70	0.088	20% for first 12 years and 15% after	500
Hydropower		10.1-20	0.0825	8%	200
Biomass		10.1-40	0.10	15%	200
Solar (Grid)		10.1-40	0.12	12%	100

Source: IEA (2016) - https://www.iea.org/policies/5635-2nd-revision-of-feed-in-tariffs-for-renewable-energy

Under feed-in-tariffs, eligible generators or contributors of electricity (from renewable energy sources) to the national grid, are paid a cost-based price (in reference to the cost for producing energy from a specific source, which varies from one source to another) for the amount of power supplied to the grid (see Figure 2.3). These generators may include households, farmers, energy companies and private investors. The supply to the national grid is made possible with "net metering". For instance, if a household uses solar PV to consume electricity, and the amount of power available exceeds consumption at the end of a power consumption cycle (one month, for example), the surplus electricity is "sold" to the national grid. Such settings have the potential to make Kenya a leader in SSA in investments in renewable energy, contributing to making Kenya an ideal location for the development of this research. As Figure 2.3 illustrates, the highest maximum feed-in-tariff level in Kenya is for electricity generators of off-grid solar PV, and those that contribute to the grid using solar power. This creates a greater incentive for businesses, private investors, and households to focus on using solar sources to potentially generate additional income. The feed-in-tariffs in Kenya can therefore be considered an enabler for the dissemination of renewable energy, including solar energy.

Beyond activities that were undertaken by the REA, and the application of the feed-in-tariff, the Kenyan governmental has also expressed interest in contributing to an increase in the dissemination of solar power in the national energy mix through off-grid technologies (even though solar PV is recognized as a private market driven phenomenon, with its uptake being encouraged). The project, titled the Kenya Off-Grid Solar Access Project (KOSAP, founded by the Ministry of Energy and funded by the World Bank), was proposed in March 2017 to increase energy access in underserved areas in Kenya with solar mini-grids and stand-alone solar home systems. It can hence be seen that the Government of Kenya looks to work to resolve issues of energy access in the nation.

2.1.1 Enabling environment – Institutional transition

The aforementioned institutions and initiatives in the energy sector were created with the establishment of the aforementioned 2006 Energy Act. The transition that has occurred over the past decade is due to the institutional structure that was formulated with this Energy Act. On March 14th 2019, the 2006 Energy Act was superseded by the 2019 Energy Act, to reconfigure the existing institutional structure of the energy sector in Kenya. Notable changes include The Energy Regulatory Commission (ERC) becoming the Energy and Petroleum Regulatory Authority (EPRA), and the Rural Electrification Authority has become the Rural Electrification and Renewable Energy Corporation (REREC). Each institution has its updated set of established mandates, and it remains to be seen how these adjustments will affect the energy sector in Kenya. In the case of REREC, as revealed through interviews while conducting a field survey in September 2019, the new organization acquired the responsibility from KPLC for the management of mini-grids and their installations. Among many of the provisions outlined in the 2019 Energy Act, net metering is a new provision that has also been included, enabling end consumers to feed electricity to the grid. Nevertheless, based on various developments in the energy sector, a streamlining of the institutional structure was the main objective of the establishment of the 2019 Energy Act.

2.2 Enabling environment - Geography

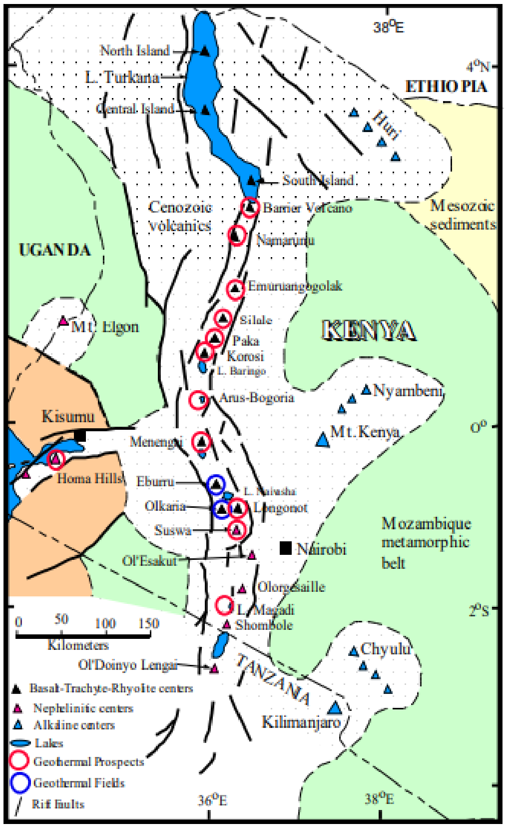
Kenya also has a considerable geographic enabler. Firstly, it is a country with limited fossil fuels at its disposal, with Figure 2.4 illustrating that a majority of the energy supplied from fossil fuels are imported. This reliance on imported fossil fuel has a negative effect on net exports, a disincentive for relying on fossil fuel for energy supply. However, the country has much greater capacity for supplying energy through geothermal sources (see Figures 2.7 and 2.8), especially from the Great Rift Valley where several potential sites for geothermal energy production have been identified (see Figure 2.5), enabling the nation to have more cost-effective and renewable options for power supply. Thus Kenya as a country primarily relies on renewables sources of energy for power supply, an observation that was also illustrated in Figure G in the Introduction section of this dissertation.

Figure 2.4 – Fossil Fuel Power Supply (Kenya)

Source	**Domestic Production (kt)**	**Imports**
Coal	0	533
Natural Gas	0	0
Crude Oil	0	597
Liquefied petroleum gases	13	137
Motor gasoline	76	828
Aviation gasoline	0	2
Jet kerosene	102	427
Other kerosene	45	253
Gas/diesel	163	1615
Fuel oil	194	194

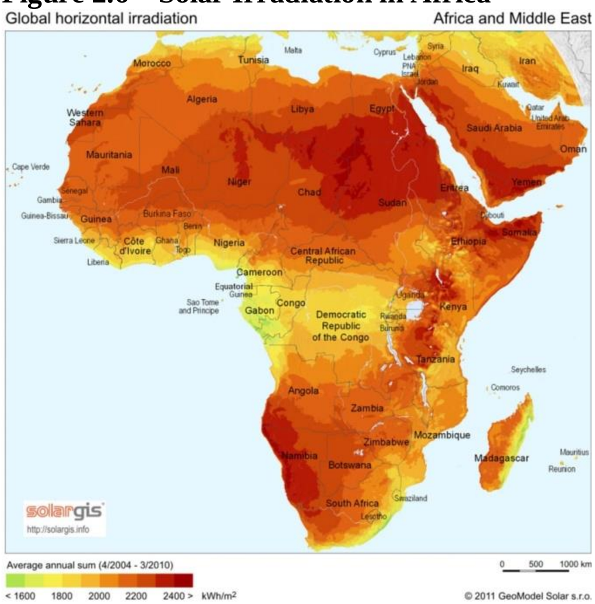
Source: IEA (2014)

Figure 2.5 – Geothermal sites in Great Rift Valley



Source: Least Cost Power Development Plan 2017-2037 (updated in June 2018)

Figure 2.6 – Solar Irradiation in Africa



Source: http://www.hotspotenergy.com/DC-air-conditioner/solar-map-africa-middle-east.php

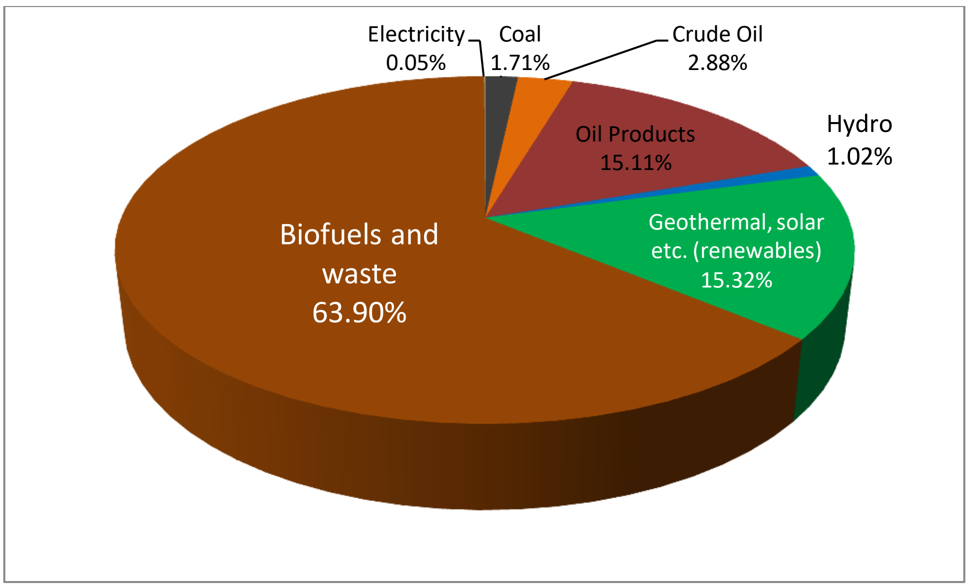
Secondly, the map of Africa illustrated in Figure 2.6 illustrates the country's other geographic enabler for renewable energy production in more detail. The map of Africa displayed in this figure is depicted with solar irradiation levels all across the continent. The figure reveals several countries in particular that receive more sunlight than other countries in SSA, including Kenya. This graph demonstrates the potential in Kenya for solar energy technology development and production. In 2010, solar energy covered up less than 1% of Kenya's national energy mix given its uptake in the form of off-grid solar home system in rural areas (with typically lower generation capacity) (Lay, Ondraczek, Stoever 2012). Since this time, multiple companies, entrepreneurs (solar PV technicians), and government have entered the solar PV market, enabling its continued growth in rural areas. This healthy competition can help improve the quality of solar products, with households being given a variety of solar PV options to consider. This incentivizes private market players to improve the quality of their solar PV products to be able to sell, which in turn enables the private solar PV market to grow. The subsequent growth in popularity of solar energy solutions will increase the share of solar PV in the Kenyan energy mix. Rural households subsequently become the main beneficiaries of this market development.

2.3 Current Energy Profile

The most recent data provided by the IEA's World Energy Outlook 2018 (see Appendix A) reveals 73% of the total Kenyan population has been electrified. In terms of urban and rural electrification, the same report shows the urban and rural electrification is at 90% and 68% respectively. Figure 2.7 illustrates the most recent energy profile available for Kenya, while Figure 2.8 illustrates the country's current electricity production mix (International Energy Agency 2019). The heavy reliance on traditional biomass and waste can be seen in figure 2.7 a typical situation for rural communities in developing countries in SSA. It can also be seen that Kenya relies more heavily on renewable sources for energy supply, rather than for coal, given its globally recognized renewable energy production potential.

Figure 2.7 – 2017 Kenya Energy Profile

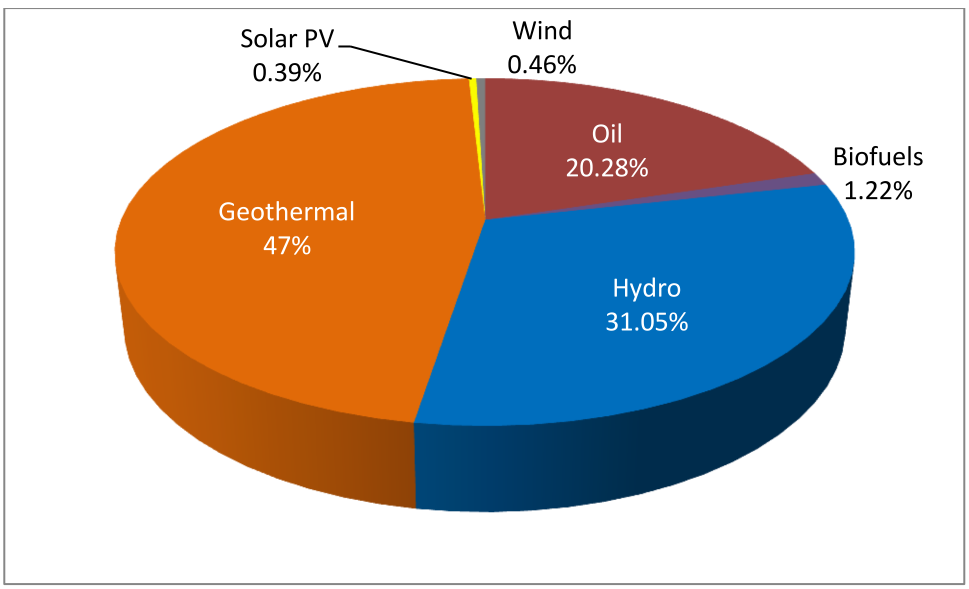
Source	Total Primary Energy Supply (ktoe)
Coal	463
Crude Oil	780
Oil Products	4086
Natural gas	0
Nuclear	0
Hydro	276
Geothermal, solar etc. (renewables)	4143
Biofuels and waste	17281
Electricity	13
Heat	0



Source: International Energy Agency (2019)

Figure 2.8 - 2017 Kenya Electricity Generation Profile

Source	Electricity Generation (GWh)
Coal	0
Oil	2094
Natural gas	0
Biofuels	126
Waste	0
Nuclear	0
Hydro	3206
Geothermal	4810
Solar PV	40
Solar thermal	0
Wind	48
Tide	0
Other	0



Source: International Energy Agency (2019)

Figure 2.8 demonstrates Kenya's development of its geothermal energy sources, in addition to hydropower production. It can also be seen that solar PV currently makes up a very small (but growing) percentage of the national electricity production mix. The statistics in figure 2.8 accurately reflect the Kenyan government's focus on the development of their geothermal and hydro power production facilities to this point, despite vast potential for solar PV production.

2.4 Energy Transition and Rural Electrification – Additional Enablers

The aforementioned information regarding the enabling physical environment, institutional framework, institutional initiatives, and energy consumption patterns in Kenya help to illustrate how rural electrification has been able to take place in Kenya and in certain ways how the solar PV market has been able to develop. Nevertheless, there are additional drivers which have also helped to drive this solar market in rural areas, where households primarily rely on solar PV for modern energy access. The household solar PV market in Kenya, as demonstrated in the literature, has been driven by the development of the private sector. Acker and Kammen (1996) attribute the opening and development of the private sector for solar PV to the oil shocks of 1973-74. The shocks led to considerations for alternative, reliable and fiscally predictable energy sources (to avoid the effect of future "shocks"). Acker and Kammen then subsequently refer to the activities of Harold Burris in 1984 as playing a pivotal role in the ignition of the market. Ockwell and Byrne (2016) refer to an interview with Mark Hankins held in 2007 (in which Harold Burris is also mentioned) detailing the specific activities which may have led to the creation of the private PV market. Harold Burris was an engineer who promoted solar PV systems, and his encounter with Mike Hankins, a former Peace Corps volunteer (volunteer at the time of their encounter), played this decisive role in igniting the solar PV market in rural communities in Kenya. In their encounter, Hankins revealed in their conversation that the Karamugi Harambee Secondary School was considering electrification with a diesel generator and that created an opportunity for Burris to discuss the solar PV system as a more affordable alternative. Further discussions led to the eventual installation of a PV system at the school, which quickly attracted interest from other teachers and members of the surrounding community. This interest led to the purchase of PV systems for their own homes, sparking the household solar PV market. In addition to these developments, Burris and Hankins initiated solar PV technology training programs with international support, for graduates of polytechnic schools, which included the installation of PV systems in several secondary schools (Acker and Kammen 1996). These training programs also helped to spark interest among people in surrounding communities.

Another factor which has driven the penetration for solar PV in rural communities in Kenya is the demand for electricity for television, radio, mobile phone charging, and lighting. Since a small percentage of the rural population was electrified, there was the opportunity for market penetration with solar PV. Solar PV has demonstrated its ability to meet immediate electricity needs in rural areas, with many communities being situated at great distances from the national power grid.

Should the power grid eventually reach these distant communities as Kenya works to achieve 100% electrification, electricity costs would be more expensive for locals than using solar PV, and secondly would be a higher cost burden for government given low energy demand in these areas. A third driver for PV systems is that these remote areas are very dark during the night, and as discovered in the case study for this research, the visibility of electric light raises the curiosity of neighbors and people living in the surrounding area. There is therefore an unintentional showcasing of the features of PV systems by system owners, raising awareness of the availability of the technology for generating electricity, consequently growing demand in the area.

Many subsequent socio-economic benefits of owning solar home systems were discussed during interviews with consumers in rural areas, including the ability to open new businesses, children studying for longer hours, reduced or eliminated reliance on kerosene lighting, and increased frequency of social gatherings for various purposes. A majority of these benefits have been confirmed in secondary sources, clarifying how small-scale solar PV systems became an attractive option for rural households (Acker and Kammen 1996; Hankins et. al 1997; Jacobsen 2007).

Lighting Africa, a World Bank led initiative to promote universal access has also played a role in making the private solar PV market in Kenya one of the most attractive markets in Africa. Starting in 2009, consumer education campaigns were conducted to raise awareness and demand, support was provided through business development services to private sector companies looking to enter the market, and technicians were trained across Kenya before being connected to product manufacturers and distributors to offer post-sale maintenance support. These activities enabled a dramatic increase of 200% in the up-take of solar PV by 2013. The efforts of Lighting Africa in Kenya have enabled 10 million households to meet basic electricity needs with quality ensured solar PV products (lanterns for lighting).

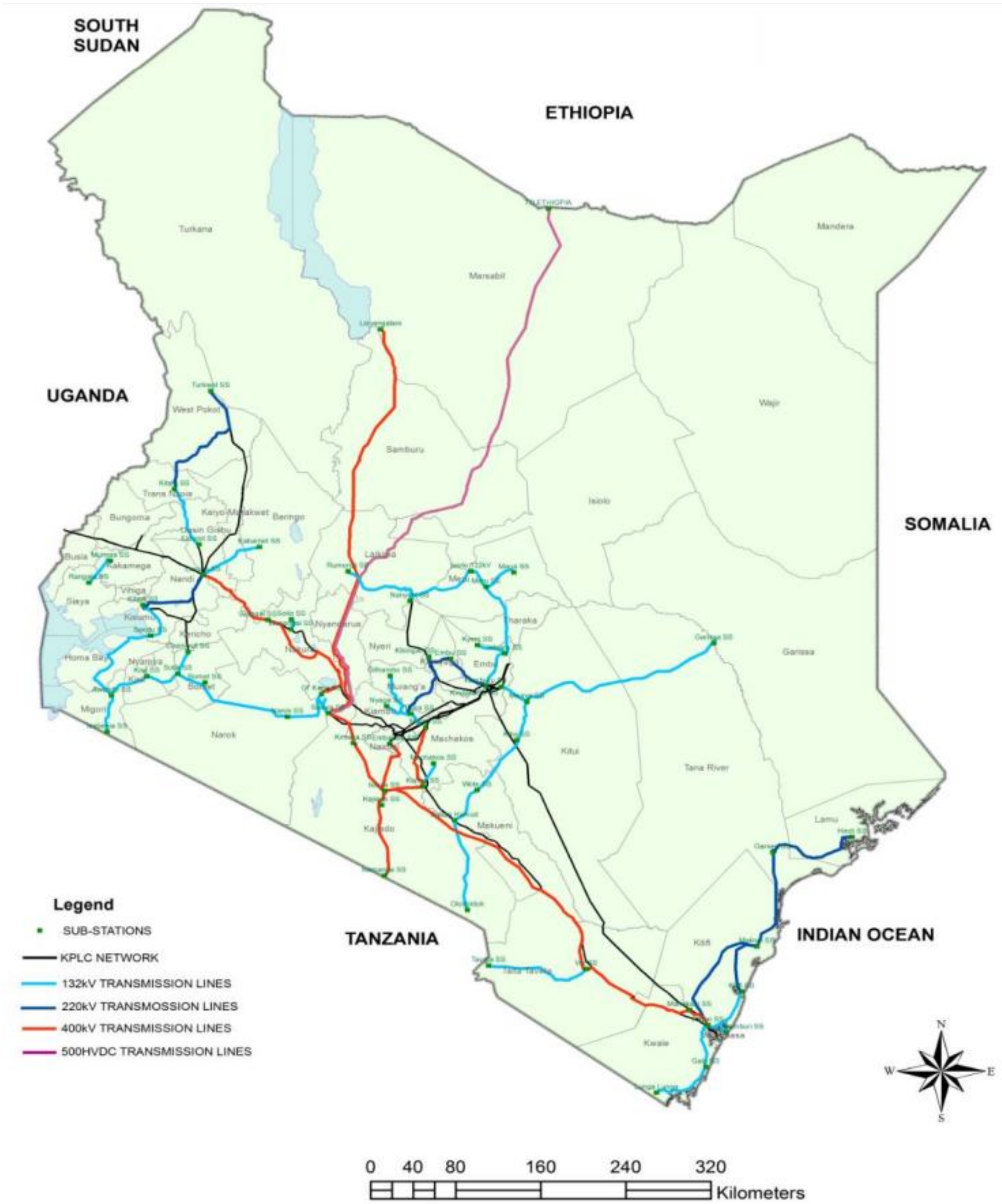
There have therefore been many enablers of rural electrification throughout the energy transition in Kenya. The main actor has particularly been the private sector in rural areas, as the literature demonstrated. Today, the solar PV market is a competitive industry with various enterprises and entrepreneurs situated all over Kenya developing, selling and installing stand-alone solar home systems to households in rural communities. One final driver for solar PV for the foreseeable future is its declining cost. Solar PV is expected to become the most affordable energy option by 2030, which will help costs match the purchasing power of households in rural communities, making PV systems an even greater attraction for potential consumers in rural areas.

2.5 Challenges in Energy Transition and Rural Electrification

While there have been many enablers of the energy transition in Kenya, such transition has not occurred without its challenges. Kenya is a unique case in the energy transition. A majority of countries typically need to adjust their energy source, from those that are harmful for the global environment (fossil fuels), to cleaner, more sustainable sources. In the Kenyan case, however, fossil fuels are imported, with the country relying heavily on hydropower, geothermal energy, and biofuels for energy production. The energy sector has also been streamlined to facilitate the energy transition, and complement the transition that had already been taking place in rural areas. Nevertheless, interviews with stakeholders including in the Kenyan energy sector, along with secondary sources, have revealed some of the challenges and barriers which remain in enabling this renewable energy transition, some of which are the very factors which have facilitated the energy transition.

Geography, for instance, while being an enabler for promoting energy production via renewables (especially given Kenya's greater reliance on renewables for production), has also posed a challenge for attaining universal access in Kenya. The majority of the Kenyan population is concentrated in the central and western areas of the country, with the rest of the country occupied by smaller, more dispersed populations (Ondraczek 2013). Additionally, there is the need to attain universal access while protecting the environment. This makes grid extension a less viable solution than mini-grids or stand-alone systems, for instance, for expanding current energy infrastructure and for promoting energy access in remote areas. The challenge, therefore, also lies in decision-making regarding appropriate solutions for attaining universal access, mobilizing the necessary finances for promoting energy access in rural Kenya, and in ensuring that these energy solutions are affordable for consumers living in these remote areas. The Government of Kenya nevertheless has plans in place (and in motion) to extend the grid to remote areas (see Figure 2.9). Electricity transmission lines have grown by 19.2% in 2017, with total circuit length reaching 213,700 kilometers from 49,818 kilometers in 2013. The government of Kenya has also implemented as previously mentioned several initiatives to promote rural electrification through solar home systems and mini-grids as previously mentioned (REA activities and KOSAP) to overcome this challenge, but it remains to be seen if on-ground experiences influence future legislation, help to create partnerships with private sector companies or development assistance institutions to overcome this barrier to attaining universal access.

Figure 2.9 – Kenyan National Grid 2020



Source: Least Cost Power Development Plan 2017-2037 (updated in June 2018)

Affordability has also been a challenge, with high costs of obtaining systems which provide modern energy access pricing out a majority of people living in rural communities. To overcome this challenge, the off-grid energy sector has turned to pay-as-you go systems and installment payment plans for rural consumers, facilitating financial accessibility to modern off-grid rural electrification services (Sanyal, Prins, Visco, and Pinchot 2016). Grid connected households also use the pay-as-you-go systems to pay for the modern energy services.

Marketing is also an additional challenge, given the small scale of operations of solar PV businesses, and the challenge that freelance technicians face in finding new potential clients without referrals. The limited marketing, in turn, minimizes consumer awareness of the availability of more modern energy services. Since the private sector has primarily relied on word-of-mouth for the development of the market, dispersed populations have less opportunity to attain these services without being contacted. Moreover, if these households were contacted, trust may also become an additional issue, given energy services in the past were provided with sub-standard products (Da Silva, Batte, Ronoh, and Ouma 2014), causing market spoilage. While conducting the field survey with sales representatives in Kisumu, the author was able to observe the persistent effort of the SHS company employee in identifying potential clients as he distributed flyers, engaged with prospective clients, and arranged future appointments in between household interviews. It has also often been the case that surrounding neighbors notice the availability of electricity at night in typically dark locations, creating additional inquiries regarding the availability of modern energy services, thus additional opportunities to sell solar home systems.

Institutions in Kenya have also proved to be a barrier in promoting the energy transition. Since the institutional structure of the Kenyan energy sector has experienced a period of transition, there have been difficulties experienced in understanding the regulatory environment for private sector companies looking to establish operations in rural Kenya. Additionally, while there has been interest in the dissemination of solar PV systems, there has been a greater focus on the development of hydro and geothermal energy production projects. Solar PV was encouraged and promoted more as a possibility, and proposed as a principal solution for dispersed households in rural areas. There was therefore limited government activity in rural electrification, beyond recent KPLC proposals, projects undertaken by the Rural Electrification Authority (now REREC), the tentative introduction of solar PV to energy production in mini-grids, and the spread of solar PV through businesses and independent entrepreneurs. Although solar PV has only recently garnered greater attention from the government, the current national energy policy and strategy for achieving the Kenya Vision 2030 of 100% electrification is likely to occur more significantly through other sources, including geothermal, wind, and hydropower.

Discussions held during interviews conducted with multiple stakeholders including UN Habitat, the Ministry of Energy, KPLC and REREC confirmed many of the aforementioned challenges, namely the high cost of investing in mini-grids and renewable energy, product quality being below national standards set by the ERC (now EPRA), and regulations for renewable energy investment. Additional challenges specified during visits include the need for local capacity development, the availability of spare parts required for system maintenance, duty-tax regulations, disposability at the end of the life-cycle of a system, uninformed consumption leading to system malfunction. It has also been recognized that tribal conflicts can complicate the possibility of connecting mini-grids located in separate communities to each other in the future.

2.6 Rural Electrification in Kenya

As mentioned, Kenya's solar energy market has operated for over several decades, with limited government regulation especially due to its growth in rural areas. It is believed according to the literature that early use of solar PV in Kenya dates back to the late 1970s, or early 1980s, for limited applications. Ondraczek (2011) confirms that the Kenyan government, international donors, and development agencies in the 1980s began to include solar energy in their projects for the provision of electricity for various social uses in off-grid areas, including lighting, water pumping, and vaccine refrigeration. During this period of increasing use of solar PV, businesses and entrepreneurs (technicians, including Harold Burris and his small company, Solar Shamba, founded in 1984) began to establish offices or agents in Kenya in anticipation of the development of PV markets in developing countries.

This time span of the growth of the private solar PV market is an ideal timeframe to measure impacts and significance on various aspects of the daily lives of the rural population in Kenya. Various initiatives undertaken by the Kenyan government to enable the energy transition in rural communities, and many challenges had to be overcome in this process. The energy transition that has occurred in Kenya, including in rural Kenya, makes electrification significance studies possible.

A set of secondary research questions can be posed given the understanding of the Kenyan energy sector and the energy transition that has taken place. What happened on the field during this transition? Has this transition been successful? How can the various initiatives for promoting energy transition and rural electrification in particular be deemed a success? How to evaluate the performances of the various electrification projects that have been implemented in Kenya? How can rural electrification projects in Kenya be assessed? Similar questions have been asked in previous studies (including the research question of this paper), and the field surveys were conducted in different countries in the past. Such studies will be reviewed in the following chapter of this paper, to explore how rural electrification projects can be assessed.

2.7 Concluding Observations

This chapter has helped to illustrate how rural electrification has been able to occur in Kenya throughout the country's renewable energy transition. Institutional, geographic, and market enablers have facilitated rural electrification activities throughout the country. It is also therefore clear that several studies regarding rural electrification in Kenya have been conducted, and an increasing number of consumers from different rural areas have been able to gain access to modern energy services in the past few years. Given the aforementioned information regarding rural electrification in Kenya, we consider how these details fit in the academic framework of human survivability studies that has been established for this research.

Through the lens of a solution-oriented academic approach, the research question introduced in the Introduction section of this paper, and the following sub-questions posed in this chapter are the questions to be considered. Thus, the following chapter of this paper reviews literature regarding various studies regarding rural electrification activities and how these electrification activities have been evaluated. This review will not only help to find answers for the aforementioned research questions, but help contribute to the development of the case study that was conducted in this research for rural Kenya.

Chapter 3: Rural Electrification Assessment Literature Review

In previous sections of this paper, the concept of human survivability studies was introduced as a solution oriented academic endeavor for the service and betterment of society. Some societal challenges were also discussed (poverty, economic inequality, and climate change) using academic literature and secondary data, and the scope of this academic research was defined (rural electrification impacts in Kenya, especially with solar PV). This section of the paper maintains this research scope by exploring how, in light of the aforementioned topics discussed in this paper, various rural electrification methods can contribute to the socio-economic development of surrounding rural communities.

Energy is considered essential for sustainable development and improving human, social, economic, and environmental conditions, especially in the developing world (Kaygusz 2012). Thus, various electrification systems have been employed in rural areas. Results and levels of effectiveness have varied as well, and several assessment methods have been used to study these electrification systems. This chapter will therefore review these different assessment methods, identify study gaps, and establish the rural electrification assessment framework which best fits the scope and orientation of this research. Assessment studies have been conducted by members of the academic community and the implicated stakeholders in rural electrification projects. Such studies in the literature I organize into 3 main categories; techno-economic assessment studies, impact evaluation studies, and sustainability assessment studies.

3.1 Techno-economic assessment studies

The literature grouped into the system-specific evaluation studies category consists of extensive discussions and assessments of the technology used for rural electrification (especially via renewable sources described in the first chapter of this paper) and sustainable development, evaluating their technical, economic, environmental viability, and performance after installation. These studies also often compare multiple electrification systems which can be considered for installation to promote sustainable development in rural communities. Such studies can be likened to a display of electrification technology options (and their components) for rural electrification currently available for use with renewable energy sources, for the promotion of sustainable development in rural communities. The emphasis placed on this form of literature is the *potential* for the discussed technology to promote sustainable development. The concept of promoting sustainable development or socio-economic development is not addressed in this set of academic evaluation studies.

These system-specific evaluation studies have been conducted for all electrification systems which employ renewable energy resources. Pappas, Karakosta, Marinakis, and Psarras (2012) for instance detail the technologies that have been developed for the provision of electricity via renewable energy sources (namely solar, wind, and biomass). Economic, environmental, political and social dimensions are proposed in this paper to compare the electricity-generating technologies developed from renewables. Output capacity of each technology is detailed, along with their various costs. Negative environmental impacts are also detailed (greenhouse gas emissions [GHG] and nuclear waste), while the political and social dimensions focus more on proliferation and public acceptance respectively. The quantitative and qualitative data produced led the authors to the conclusion that, since there is no clear most viable renewable energy technology solution, the adoption of such technology largely depends on the energy needs and policies of the country considering disseminating such technologies. Heal (2009) also extensively discusses the various renewable energy technology options available, detailing their cost, viability and potential. In addition to solar, wind, and biomass, renewable energy technologies developed from geothermal, hydro, and coal (carbon capture and storage, also referred to as CCS) are evaluated.

In another study, Mukerjee (2007) highlights the importance of using energy efficient appliances, referring to light emitting diodes (LED) and compact fluorescent lamps (CFL) used in pico-solar systems (primarily for lighting and mobile phone charging) in order to maximize the lifespan of the product, and minimize the frequency of system failures. Such lamps also help to avoid greenhouse gas emissions by being a stronger lighting alternative for consumers than the traditional kerosene lamps. In this comparative study, LED-based lanterns were found to be cheaper, while CFL-based lamps can provide more illumination at minimum power.

Krauter (2004) proposes the manufacturer assembles components of SHS such as the charge controller, support structure, inverter, wiring, and PV module in order to ease installation and reduce costs and failures. Mashelenia and Carelseb (1997) emphasize the importance of using intelligent charge controllers for stand-alone solar home systems to improve system efficiency and protect storage batteries, given such measures would help to increase the life-span of the SHS, thus making them a more viable option for increasing energy access. Kahn (2008) concludes; in an effort to illustrate the viability of the dissemination of solar energy, that solar PV electricity transmitted near load centers at a sufficiently large scale helps to avoid expensive incremental transmission costs that would be created by the construction of new and long power lines required for unfortunately low capacity energy generation. Shaahid and El-Amin (2009) evaluate the techno-economic viability of hybrid stand-alone photovoltaic-diesel battery power systems in Saudi Arabia. Several benefits of this hybrid system are highlighted, including maximized diesel efficiency with minimal maintenance, reduction in carbon emissions by 24%, and high utilization of PV generation. This illustrates the viability of hybrid systems to mitigate for intermittency concerns that are addressed with PV-only electrification technologies.

Literature regarding various electrification technologies available for deployment and resulting promotion of socio-economic development are available in abundance. As mentioned, information gathered and conclusions drawn from these studies help to illustrate the *potential* that these electrification technologies have for promoting energy access in rural communities. They also illustrate the *feasibility* of their dissemination. Nevertheless, the important observation made in this portion of system-specific evaluation literature is that such findings remain an illustration of *potential* for effective rural electrification. In certain cases, such potential seem to have inspired the development of feasibility studies and planning models which employ quantitative research methodologies to determine ideal cost-effective grid-extension strategies and determine the best locations for future off-grid electrification project deployment (Parshall et al. 2009; Christofides 1989; Kanagawa and Nakata 2008; Hernández-Escobedo et al. 2017). Project implementing institutions that are outside the academic community, including development assistance agencies, governments, and private companies are also known to undertake such feasibility studies based on economic viability to determine ideal sites for electrification project deployment.

As previously mentioned, members of the academic community and institutions or companies in the private sector that deploy various rural electrification projects have also conducted post-installation evaluation studies, focusing on system performance. A post-installation evaluation study of a SHS and street lighting system installed in 1988 in Sukatani, Indonesia revealed that while failure rates were high, villagers expressed positive opinions regarding the systems, being satisfied with system performance (Reinders et al. 1999). Survey studies also revealed that several components of the SHS had changed during this time, including the lamps and batteries being replaced with cheaper ones that were locally produced. Low energy consumption was cited as the reason why the original 100 Ah (ampere hour) batteries were replaced with 70 Ah batteries. The Indonesian case thus illustrates the importance of evaluating energy demand to minimize production costs, and such measures should be taken before decisions are made regarding electrification system deployment (many decision makers nowadays already take such measures to insure supply is actually meeting local demand). Nevertheless, it must be noted in this study that while battery sized had decreased, a 45% increase in average electricity consumption had been noted. It was also found in this case study that 40% of SHS users in Sukatani indirectly demonstrated interest in future grid connection.

In Mexico, 555 lead-acid batteries (87% of the sample size) taken from domestic PV lighting systems were evaluated for performance (Huacuz et al. 1995). While these car-type batteries performed reasonably well over 0-3 years, technical, environmental and socio-cultural factors in the immediate surroundings of the batteries were thought to potentially have a negative influence on the batteries. Undersized storage capacity and improper operation and maintenance practices (due to lack of proper user training), were recognized as a technical and socio-cultural factors causing a rapid decrease in battery performance, resulting in user disappointment in solar PV for rural electrification. Unavailability of spare batteries locally was also identified as a critical issue for the sustainability of the PV electrification project. A more recent study highlights the effect that shading and staining can have on overall energy loss for single module SHS in Africa (Ubisse and Sebitosi, 20009). The paper proposes that manufacturers reconsider current module designs given the inevitability of shadowing (shadows/shade).

The studies shared in this section are samples of papers available in abundance evaluating various technologies for rural electrification and sustainable development. As mentioned, some studies assess their viability, while others focus on system performance on-site. This portion of the literature therefore focuses primarily on the ability of the technology to perform in rural settings. It can be certain that proper operation of the systems will help contribute to continued socio-economic development in rural areas. While the systems show promise for promoting socio-economic development in rural areas, there is no direct mention of the effect of the systems in rural communities (except in a few rare cases where user satisfaction is addressed). These aspects of rural electrification project studies are more directly addressed in the two other categories of rural electrification assessment literature mentioned in this chapter.

3.2 Impact Evaluation Studies

Academic literature grouped into the impact evaluation studies more directly focus on the impact that the installation of the electrification technologies have had on the consumer. These impacts are measured quantitatively and qualitatively, and such studies are also available in abundance. The literature evidently has shown that such studies have been conducted all over the world, with different renewable energy sources, technologies, and infrastructure. The impacts of mini-grid installations have also been discussed, along with national grid connection impacts. However, given this scope of this dissertation, this section will especially review pertinent studies that have been conducted in Kenya.

Acker and Kammen (1996) conducted their survey in Kenya in 1994, interviewing 40 owners of solar PV systems, discovering that many owners had gone beyond their financial means to acquire the systems, and that some systems were even owned in households that were located close enough to the national grid to make owning solar PV systems more expensive. Survey respondents also most commonly stated that the principal benefit of PV and why it was chosen over other sources was that it is the least expensive energy solution when compared to grid extension or diesel generators, demonstrating that economic factors (cost of solar PV compared to other energy alternatives) have enabled PV dissemination in Kenya. Other benefits cited by respondents include the improved quality of light, one-time payment for electricity (at purchase), health benefits (from avoiding diesel generators and kerosene lamps), the convenience of PV (simple switch for lights compared to lighting a lantern or starting a generator; simple maintenance), and the reduced frequency of journeys to buy fuel or recharge lead-acid batteries. Another consideration is that with blackouts being common, along with periodic kerosene shortages (temporarily unable to afford/replenish kerosene lamps), photovoltaics were considered a more reliable energy source. Given the benefits cited by respondents, Acker and Kammen conclude that PV systems have been able to spread in Kenya due to being a more immediate and economical energy alternative for households. Respondents also revealed that solar PV systems have a few drawbacks, including their inability to supply enough power during rainy seasons (the principal drawback according to respondents), or their inability to supply enough power for cooking or ironing. Other drawbacks reported include the initial cost to install the system, and the shortened lifespans of the solar PV systems (due to inefficient use of their batteries by system owners by exceeding the recommended discharging limit of 20% before recharge).

Conclusions from the survey conducted by Hankins, Omondi and Scherpenzeel (1997) were that savings from the purchase of solar PV systems were made by eliminating expenses necessary for kerosene and dry cell batteries. This survey, funded by the Energy Sector Management Assistance Program (ESMAP), a global multi-donor technical assistance trust fund administered by the World Bank, covered 410 households across 12 districts in Kenya. Average savings were approximately 10 USD per month, and 8.55 USD per month for those with systems smaller than 15 W. Other results of the survey were found to be similar to those of Acker and Kammen. However, with the sample size being significantly larger, greater detail of the Kenyan solar PV market could be observed, making it possible for Hankins et al (1997) to present detailed recommendations for actors in this market, which include government, donors, industry, financial institutions, non-governmental organizations (NGOs), and research organizations. The general assessment of the solar PV market in Kenya is that the market is a private sector phenomenon, given its growth originating in the household sector. Emphasis was placed on the need for supportive national and international policy, capacity building, financing schemes, better and impartial information, and smaller engineered PV systems to improve affordability.

Jacobson conducted numerous surveys, assessments, and analyses of the solar PV market in Kenya throughout the past decade, covering both the supply and demand sides of the market. For the demand side of the market, surveys conducted in 2003 and 2004 provided insight into the dynamics of electricity use in the household, the demand side of the solar PV market (Jacobson 2007). Even though 15 systems were surveyed, detailed information was gathered regarding appliance use, combined with household activity observations and interviews, in order to illustrate the complex realities of electricity consumption patterns in the household. Jacobson found that for small solar PV system owners (less than 25Wp), TV dominated electricity consumption (54%) and kitchens were low on priorities when deciding where to install lights in the home. Lights dominated electricity consumption for larger systems (61%), with TV accounting for one-third of power consumption. Jacobson also discusses solar electrification and the social significance of solar power dissemination in rural communities (Jacobson 2007). In this discussion, he finds that demand for solar PV systems are driven by middle class purchasing power; electric lights from PV play a modest but significant role in supporting income generation activities; and a substantial role played by PV systems in supporting evening time studying for children. A survey conducted by the author in 2003 is also referenced in this paper, revealing 32% of the 76 households surveyed used lights for income generation or work-related activities, and smaller percentages reporting work-related uses of television and radios with solar PV. Overall, 48% of the households in this 2003 sample reported work related activity supported by the use of solar electricity. Solar power in rural Kenya was found in this paper to be primarily used for television and radio. Jacobson adds to his conclusions that solar PV dissemination has contributed to increased rural-urban connectivity than to poverty alleviation or sustainable development, believing that it is crucial to avoid focusing primarily on technology and markets to address such issues that were shaped by social and political processes.

The impact evaluation papers mentioned are some of the papers that focus on impacts of PV electrification in rural Kenya. It is recognized, that impacts of rural electrification (regardless of technology) deployed in various areas all across the globe have been evaluated. They looked to determine how they have affected the lives of the beneficiaries, namely households and businesses, and how they contribute to rural development. Cabraal et al. (2005) were able to illustrate how provision of education and electricity can yield higher household income than education without electricity. A study conducted by the World Bank revealed that access to electricity was strongly associated with high educational achievement in the Phillipines (ESMAP 2003). Electricity provision is also known to provide access to information (through television) that is valuable to women regarding health and family planning (IEG 2008). Information and communication tools deployed as a result of electricity access also help to fight and prevent the spread of pandemics such as HIV and malaria. Kirubi et al. (2009) also demonstrated in their study how access to electricity in the village of Mpeketoni in Kenya has enabled the use of electric tools in small-medium enterprises, which increased productivity per worker. They were also able to confirm, through interviews with teachers, parents, that academic performance had measurable improved following electrification. Case study results, including those shared in this set of academic literature, are consistent across this portion of the literature in terms of impacts on business/institution operations, impacts on the household (health, income, education), and overall impacts on communities. As with *system-specific evaluation studies*, the impact studies have also been conducted beyond the realm of academia, to determine the results of various rural electrification projects, extract lessons that can be learned and applied to future projects.

3.3 Sustainability Assessment studies

The literature regarding rural electrification assessment studies categorized as sustainability assessment studies in this paper focuses on the sustainability of a rural electrification project, along with the contribution of the project to socio-economic development. Studies in this class of literature combine the ideas discussed in system-specific evaluation studies and impact evaluation studies. Projects evaluated in sustainability assessment studies include stand-alone system and/or mini-grids installation, and national grid connections. However, very few studies have actually been conducted using this approach in studying rural electrification. Ilskog (2008) pioneers this concept with a proposal of a set of 39 indicators that can be used for rural electrification assessment. The indicators are arranged into five dimensions, namely the technical, economic, social, environmental, and institutional dimensions. The framework was essentially proposed as a globally acceptable method for evaluating various rural electrification projects to determine their effect on the sustainable development of a rural community. In the author's own words, the framework is proposed as a method for "comparing apples and pears", within the context of the sustainable development of the communities that gain access to modern energy services. Data collection would consist of gathering quantitative and qualitative information regarding the various indicators proposed, in order to then be able to assess the performance of various rural electrification projects. This very author also notes that no studies in the literature are using this approach in assessing rural electrification, and thus undertakes a case study using this proposed sustainability framework (Ilskog and Kjellström 2008). Following the work of this author, a few research papers (notably recent ones) employ a similar methodology in order to assess the sustainability of an electrification project. Hence their papers will also be briefly discussed in this section.

Hong and Abe (2012) deviate most from the proposed sustainability framework. The sustainability assessment study was conducted in the Philippines focusing on the Pangan-An Island solar mini-grid that was financed for installation back in 1999. As is the case with many studies regarding rural electrification, the study focused primarily on the techno-economic and socio-economic aspects of this project. Overall, the project faced several sustainability challenges, including the lack of impact on consumer income, and reduced financial viability of the project due to the inability of many low income residents to pay the monthly costs. This resulted in decreased power prices (which in turn would make the mini-grid financially unsustainable), and other questionable management decisions. Nevertheless, users were satisfied with the project and have experienced positive effects on their welfare through better lighting for education, and television and radio usage. As for the technical dimension of this project, challenges leading to a decrease in efficiency of mini-grid operations forced users to return to conventional power sources. The authors also additionally used multiple correspondence analysis (MCA) to identify user attributes which would help to better determine electricity consumption behaviors, finding that users with higher income and education levels were greater consumers of electricity provided by this solar mini-grid. This analysis helps to develop appropriate capacity and pricing mechanisms that can be more suitable for the community and hence promote substantial socio-economic development. Nevertheless, there was little discussion regarding sustainable development or socio-economic development of the rural community in this paper.

There is also a greater focus on the sustainability of the hybrid mini-grid (solar and wind) that was installed in Lucingweni Village in South Africa in the assessment conducted by Brent and Rogers (2010). These authors employ a sustainability assessment framework which comprise of dimensions similar to those proposed by Ilskog. However, the terminologies of these dimensions are slightly different, with ecology replacing *environment*, sociology replacing *social*. The indicators the authors use are also quite different, since the framework itself is actually contextualized the case of this mini-grid in South Africa. Using this framework, it is determined the mini-grid was deemed unsustainable due to issues of trust, affordability, uncertain productivity returns, and lack of resilience of the technological systems to social, economic and institutional influences. The writers conclude that national grid extension is required for the promotion of sustainable development in South Africa.

Susanto and Smits (2010) employ an assessment framework that is locally adapted in order to evaluate the technical and economic aspects of multiple off-grid rural electrification technologies that have been deployed in Laos PDR. The authors use 5 indicators to assess the off-grid technologies in their framework and make their objective evaluations for each technology using these indicators (assessment scores in this study were determined as "low", "medium", or "high" by the authors). The authors use the result of their assessments in order to make appropriate policy recommendations to improve technological performances of off-grid electrification technologies in Laos.

Bhandari, Saptalena and Kusch (2018) also present a sustainability assessment framework. The framework consists of 4 dimensions, namely social, economic, environmental, and technical. Multiple indicators are used in this assessment, which were developed with the help of discussions held with multiple stakeholders in an electrification project. As in the case with Brent and Rodgers, Bhandari et. al (2018) develop a framework that is unique for the micro hydropower plant that was assessed in Mahadevsthan, located in the Dhading District of Nepal. A scoring system is employed (1 to 5) in order to determine the final assessment for each dimension, with 5 being the highest possible score.

Yadoo and Cruickshank (2012) closely employ a sustainability framework based on the indicators and dimensions proposed by Ilskog (2008a). Additional indicators were developed in this case study based on prior on-field experiences. Each indicator in this case study is given a value of either 0, 0.5, or 1 point depending on whether the indicator was unmet, partially met or completely met. After undertaking field studies visiting hydro mini-grids in Nepal, Peru, and Kenya, scores were produced for each mini-grid indicating their impact on the socio-economic development of each implicated community. The Nepalese mini-grid obtained the highest scores, while the Kenyan hybrid mini-grid obtained the lowest scores, due to insufficient financing preventing technicians from investing in higher cost components and undertaking higher quality repairs. Given these technical challenges in the Kenyan case, it was difficult for the hydro mini-grid to have notable development impacts in Thiba. The authors then produce policy recommendations, suggesting further promotion of mini-grids, improving regulatory frameworks and developing innovative financing mechanisms to encourage private sector investments. The work of the authors conducting sustainability assessments are summarized in Table 3.1 below.

Table 3.1 – Summary table of sustainability assessment studies

Authors	**Hong and Abe (2012)**	**Brent and Rogers (2010)**	**Yadoo and Cruickshank (2012)**	**Ilskog and Kjellström (2008)**	**Susanto and Smits (2010)**	**Bhandari et. al. (2018)**
Project assessed	Solar Mini-grid	Hybrid Mini-grid	3 Hydro Mini-grids	Grid; 3 Mini-grids; Various Solar Home System installations	Multiple off-grid technologies	Micro hydropower plant
Assessment focus	Sustainability of energy provision service	Sustainability of energy provision service; and local community impacts	Sustainability of energy provision service, and local community impacts	Sustainability of energy provision service, and *some* local community impacts	Off-grid electrification technologies: their economic and technical aspects	Hydropower plant sustainability
Project Location(s)	Pang-An Island, The Philippines	Lucingweni village, South Africa	Nepal, Peru, Kenya	Tanzania, Kenya, Zambia	Laos PDR	Mahadevsthan, Dhading District, Nepal
Energy source	Solar PV	Wind, Solar PV	Hydro	Diesel, Hydro, Solar PV	Solar PV, Hydro, Diesel	Hydro
Assessment Dimensions used	Techno-economic Socio-economic	Economic Institutional Ecology Sociology Technology	Technical Economic Social Environmental Institutional	Technical Economic Social Environmental Institutional	Technical Economic	Technical Economic Environmental Social
Number of indicators used	0	20	43	31	5	54
Indicator origin/formulation	N/A	Millennium Development Goals (MDGs)	MDGs; Ilskog (2008); On-field experiences	Previous studies; data accessibility through tests	N/A	Sustainability dimensions (based on literature), stakeholder discussions
Assessment Result/Conclusions	The mini-grid had minimal socio-economic impact	Project deemed unsustainable	Highest dimension scores - Nepal Lowest dimension scores - Kenya	Not Applicable - Sustainability score comparisons	Not Applicable - Technology viability comparisons	Scores produced for each assessment dimension. *Social dimension* obtained highest score

3.4 Literature observations and study gap

This chapter organized rural electrification studies into three categories. The academic papers in the first set primarily discuss the economic and technical viability of various renewable energy system technologies, and their performances in rural areas where they are installed. This assessment method focuses on a technology's potential and ability to perform, along with the actual performance of the systems. Academic papers in the second set discuss in greater detail the impact that these electrification technologies have had on households, businesses and rural communities. Economic, social, and environmental benefits are recorded in this evaluation, revealing how the systems have affected the welfare of the user and the surrounding rural community.

The third set of academic papers is a smaller set, due to the novelty of the approach in assessing rural electrification projects. These few papers combine various aspects of an electrification project. It can even be seen that these papers combine the assessment approaches of the first and second set of academic papers discussed in this chapter. This combination contributes to the creation of a holistic framework that can be used to undertake a sustainability assessment for rural electrification projects. It must also be noted that the research conducted in this set of literature tend to contextualize their sustainability assessment frameworks, using some different indicators in order to better capture specific conditions of a particular project.

Given this assessment approach is a more recent one according to the literature, few studies have employed a similar methodology in order to undertake rural electrification assessments. There is therefore an opportunity to contribute to this unique set of literature (referred to as the "third set" in this chapter) by adopting this holistic, sustainability assessment framework to undertake a rural electrification assessment study in unique rural settings and circumstances. In the case of this dissertation, therefore, such a contextualized framework was adopted to assess several rural electrification activities in Kenya.

The adoption of this sustainability framework is valuable not only to contribute to a growing set of academic literature, but to be able to draw conclusions that help to better serve society. The framework very much matches the concept of human survivability studies as well, undertaking a holistic, multi-faceted approach in evaluating how electrification is contributing to socio-economic development in rural areas. Applicable on a case by case basis, this framework can be used to contribute to energy policy formulation which promotes socio-economic development in rural areas of countries around the world that aim to achieve 100% electrification. Thus, given the aforementioned observations and study gaps, I look to employ a similar methodology in my work.

The following chapter details the sustainability assessment framework employed to undertake an assessment of several rural electrification projects in Kenya.

Chapter 4 – Kenyan Case Study: Methodology

As discussed in the previous chapter, Ilskog (2008) introduces a framework which essentially is proposed as a method for "comparing apples and pears" within the context of the socio-economic development of rural communities that gain access to modern energy services. The reasoning behind the viability of using this framework to undertake such an assessment is that key decision makers, especially policy makers, have to make their resolutions based on the comparison of apples and pears at various points along the decision making process, while in often cases being distant from the location in which an electrification project has been implemented. It is therefore suggested that a new evaluation method, the one proposed by Ilskog, is used to handle these implications. Many authors have accordingly adopted a similar approach in assessing electrification projects. As mentioned, most of the sustainability assessment frameworks in the literature use adapted indicators to more accurately reflect the local context of the projects under evaluation. However, very few have examined multiple electrification projects in their assessment. Only the works of Ilskog and Kjellström (2008) and Yadoo and Cruickshank (2012) compare multiple electrification projects.

This research also therefore employs a methodology in which multiple electrification projects completed in rural Kenya are evaluated using a contextualized sustainability assessment framework. This methodology distinguishes itself from previous studies by focusing on multiple electrification projects in a specific country, with a focus on the promotion of socio-economic development, while past studies conducted these assessments examining single projects, or by comparing projects in different countries. In this case study, six electrification projects in Kenya are chosen for evaluation. The projects fit into one of the three technologies used for rural electrification: grid extension, mini-grids, and stand-alone systems.

This case study of rural Kenya addresses the performance of rural electrification projects in the context of promoting socio-economic development. The electrification projects assessed include; (1) grid extension by the government owned utility company, Kenya Power (KPLC), (2) a hybrid solar-diesel mini-grid operated by KPLC, (3) a second hybrid solar-diesel mini-grid installed by a development assistance organization (which worked in collaboration with local government), (4) a solar mini-grid installed by Powerhive, a multinational enterprise company, and solar home systems being installed in rural areas by (5) Gennex Solar, and (6) SunKing, two multinational companies in the private sector.

4.1 Sustainability Assessment Framework Formulation

This research employed a sustainability assessment framework in order to undertake the case study in rural Kenya. Sustainable development, as discussed in the introduction of this paper, is defined as development which meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Commission 1987). The United Nations have concretized this concept of sustainable development with the establishment of 17 sustainable development goals which focus on social, economic and environmental dimensions of development (United Nations General Assembly 2015). Accordingly, the framework introduced in Chapter 3 consists of social, economic and environmental dimensions, and a set of indicators in each dimension used to evaluate a rural electrification project. While the definition of sustainable development requires the analysis of the impact projects to include the dimension of time or how this impact develops over time the framework used in this dissertation provides a snapshot of the impact of rural electrification at a specific point of time (i.e. the time when the field study was implemented).

In order to promote sustainable development through energy access, the literature has illustrated the need for strong institutions to operate them and the need for viable technologies. This entails that the sustainability assessment framework not only addresses the promotion of sustainable development of a specific community, it must also take into account the sustainability of a rural electrification project, which is ensured by strong institutions and reliable technology. Promoting social, economic, and environmental development through energy access is therefore not possible without taking into consideration the technical and institutional dimensions of an electrification project, due to the fundamental role they play in enabling sustainable development to take ever place. It is therefore with this rationale that the technical and institutional dimensions are included in the sustainability framework as indispensable factors in assessing the performance of rural electrification projects.

Thus, the sustainable assessment framework discussed in Chapter 3 consists of several dimensions containing multiple indicators in each dimension, which is used to evaluate a rural electrification project based on a scoring system. Higher scores produced by the framework typically indicated greater project sustainability, greater promotion of socio-economic development, and greater contribution to sustainable development. A review of the literature which employed these frameworks preceded the development of the framework used in this case study.

The literature showed that frameworks used in the past were contextualized in order to more directly address the circumstances and local conditions surrounding a rural electrification project. The objectives of these studies also varied, which influenced the final forms of the frameworks used, and the methodology employed. Given these observations regarding the literature in the previous chapter, the author revised the frameworks of the closely related studies in order to determine how the framework for the Kenyan case study would be formulated.

The objective of this research has been the promotion of sustainable development in rural communities through rural electrification, especially with solar energy. Consequently, the framework that was to be formulated had to directly reflect this objective. However, in order to avoid bias in its formulation, the author established the original framework proposed by Ilskog (2008); and the selection of the indicators for the framework were mainly based on those proposed by Ilskog (and used by other authors) which directly address socio-economic development (see influential indicators highlighted among the indicators used in previous studies in Table 4.1). Given the variety of methodologies employed based on the framework proposed by Ilskog, some authors opted to use more descriptive indicators in their assessment frameworks, demonstrating a decision to consider qualitative aspects of the impacts of rural electrification projects.

Table 4.1 – Sustainability Assessment Framework of Previous Studies

	Brent and Rodgers (2010)	Ilskog (2008)	Yadoo and Cruickshank (2012)	Bhandari et al (2018)	Susanto and Smits (2010)
	Dimensions used Economic Institutional Ecology Sociology Technology	**Dimensions used** Technical Economic Social Environmental Institutional	**Dimensions used** Technical Economic Social Environmental Institutional	**Dimensions used** Social Economic Environmental Technical	**Dimensions used** Technical Economic
(T)	**Increased productivity**	-Efficiency -Conformance with national standards -Technical losses -**Compatibility with future grid service** -Availability of support infrastructure -Daily operation service **-Availability of services**	**-Reliable; little disruption** -Demand capacity met -Efficient; low technical losses **-Compatible with future grid service** -Support infrastructure -Good maintenance **- Advance notice for blackouts** **-Safe to use and operate**	-Serviceability performance of energy supply -Load factor -Plant factor(downtime) -Maintenance program quality -Quality of power -Capacity factor -Machinery efficiency -Grid efficiency and expansion possibility -Program of asset upgrades - Possibility for upgrading/expansion -Replication of program in nearby villages	-Technology complexity -Local capacity
(Econ)	-PPP -Gini -Health -Education -Access to basic services -Positive ROI for energy **-Affordability**	**-Profitability** -Costs for operation and maintenance -Cost for capital and installation -Profit re-investment -Tariff lag **-Share of electricity consumed by businesses** **-Share of households using electricity for income-generating activities** **-Business development** -Number of electricity service organizations in the area	**-Affordable** **-Break-even** -Profitable excl. capital costs -Profitable incl. capital costs -Profits re-invested -Local industries use electricity **-Micro-enterprises use electricity** **-Improved agricultural activities** **-Local employment opportunities increase** **-Micro-enterprise profits have increased**	- Loan % of funding - Grand % of funding - Payback period - Life cycle costs - Repair and maintenance costs - Villager's monetary contribution - Work on MHP activities (sweat equity) - Salary levels of employees/operator of MHP -Official salary agreement **- General income increase per household** **-Employment opportunity** **-No. of new income-generating activities** - change in number of local enterprises	-Capital costs -Operating costs -Strength of the supply chain
(Env)	-Biological community diversity -Soil type maintenance (fertility) -Available natural energy resource	**-Share of renewable energy in production** -Emissions of CO_2 from production **-Replaced lighting** **-Replaced cooking source**	**-Low carbon source** **-Replaced dirty lighting sources** **-Replaced dirty cooking sources** -Displaced energy sources for powering equipment on diesel -Adverse environmental impacts occurred but rectified	- Compliance with legislation - level of interference with fish population and other aquatic species - interruption of river continuum, inverse to quality of fish bypass system - Share of water taken from the river - Landscape - Noise emissions from powerhouse - Erosion - Sedimentation	

			-Community awareness of environmental issues and environmental surroundings improved	- Fossil fuels avoided - Rate of deforestation - Flood protection	
(S)	**-Jobs (ability to get food)** **-Nutrition** **-Life expectancy** **-Literacy**	**-Health centers and schools with electricity** -Street lights in area (total) -Share of public places and specialized businesses where TV/telecomm provided -Micro-credit possibilities available for electricity connection -Primary education % -Electricity access % -Electricity access distributed by income group -Subsidies for electricity -% economically active children	-Used in schools -Improved education -Used in health centers **-Improved healthcare** -Used in community center -Existence of street lights **-Telecomm improvements** -Reduced women's burden - Micro-credit possibilities available for electricity services -All households who want it have access to electricity service	- Training of local community members and operators - Sense of ownership - Self-governability - Self-sufficiency - Equality **-Resettlement or disturbance of living space** - Share of household income spent on electricity - Gold access - Ease of grid connection **- Safety of electricity use** - Access to improved medical supply **- Risk of respiratory diseases** - Working conditions of operator **- Electrical service reliability** **- Electrical service quality** **- Satisfaction of management** **- Satisfaction with costs** **- Perceived change in quality of life** - Improved teaching by use of electricity **- Extended study hours** **- Electricity use for communication purposes** - Internet users (per 100 people) **- Computer usage %**	
(I)	-Allocation and control of resources -Legal protections for controls -Access to credit -Post Kyoto CO_2 eq. targets - Access to basic resources	**-% of staff with appropriate education** -Degree of local ownership -Number of shareholders -% of women in staff and management -Staff turnover in organization -Number of years in business **- Share of non-technical losses/default rate** **- Level of satisfaction** - Auditing of financial papers on yearly basis	-Service management organization is efficient, effective -Local capacity for organization and management improved -High sense of responsibility for system by managers -High degree of stakeholder participation if desired -Greater empowerment for women through involvement in the electricity system **-Low level of non-technical losses or payment default** **-Users are satisfied with electricity service** -Transparent financial accounts are kept -There is an effective channel through which complaints about the service can be made		

**Table constructed by author*
***Highlighted indicators are those which influenced the sustainability assessment framework for the Kenyan case study*
**** T – Technical; Econ – Economic; Env – Environmental; S – Social; I – Institutional*

Moreover, based on preliminary field visits conducted in 2016 for the formulation of the methodology of this research, and the implications of indicators used in previous studies, the author established 2 additional indicators (*social activities* and *accessibility for reporting*) unique to this Kenyan case study. This was done not only to achieve research objectives through qualitative and quantitative data collection, but also to recognize the unique rural electrification experience in Kenya. Thus, in addition to the author's examination of similar studies, the constructed framework for the Kenyan case study was contextualized (as was the case with previous studies) to better reflect local circumstances and experiences. Table 4.2 illustrates the framework that was developed, based on the aforementioned influences of its formulation. As proposed by Ilskog, the framework employs 5 dimensions of an electrification project, namely the technical, economic, social, environmental and institutional dimensions.

Table 4.2 – Sustainability Assessment Framework

Technical	**Economic**	**Social**	**Environmental**	**Institutional**
- Service reliability - Service availability (expertise) - Demand capacity met - Safety	- Profitability - Affordability - Income - Employment - Micro-enterprise connection	- Education - Health - Social Activities -Telecommunication improvement	**- Renewable source** - Replaced kerosene - Replaced wood/charcoal	- Satisfaction - Default rate - Staff education level - Accessibility for issue reporting

**Table constructed by author*

In this assessment framework, the technical dimension focuses on the technical performance of an electrification project. This specifically refers to the ability of the project to effectively provide services and satisfy demand where modern energy access was attained. Hence, *reliability* (minimal disruptions of service), *demand capacity met*, *service availability* (speed of maintenance operations) and *safety* were the indicators that were employed in the dimension.

The economic dimension assesses the economic impact of the project in the household and surrounding rural area, and its listed indicators are used to assess this impact. *Profitability* is an indicator in the economic dimension which reflects cost recovery for a rural electrification project, and thus addresses a project's financial sustainability. *Affordability* addresses the ability of consumers to pay for the modern energy services provided. *Income* refers to the impact that a rural electrification project has had on income, which can be positive, negative, or neutral. The *employment* indicator looks to determine if new employment opportunities were created as a result of rural electrification, and *micro-enterprise connection* explores if rural electrification projects served to small-medium enterprises.

The social dimension of the framework focuses on the impact that modern energy access has had on various aspects of the daily lives of the people living in rural Kenya. *Education* focuses on impacts on study hours of the children, *health* focuses on the impact a project has had on the physical health of consumers connected to modern energy services, and *social activities* is a primarily qualitative indicator which looks to explore additional social activities that have been made possible as a result of rural electrification (such as increased frequency of social gatherings, or the formation of new friendships/relationships).

The environmental dimension focuses on how well the project has been able to reduce dependence on finite natural resources, especially the use of traditional biomass for energy production, which in many cases have harmful effects on overall health, the climate, and the immediate natural environment. Such sources of traditional biomass include kerosene for lighting, and firewood or charcoal for cooking. The environmental dimension in this framework, therefore, focuses on the minimization of pollution and resource depletion. Thus, the framework in this case study looks to determine if a rural electrification project relies on a renewable energy source (*renewable source*), and if they replaced the traditional biomass for energy consumption (*replaced kerosene, replaced wood/charcoal*).

The institutional dimension, finally, as defined by Ilskog, looks to determine the ability of an organization to facilitate the general performance of an electrification project. There is hence in this dimension a focus on the long-term project maintenance, which is of paramount importance in order to determine if the provision of modern energy services by any organization can be sustained, which thus entails sustained socio-economic development. *Satisfaction*, by definition, assesses the degree of success of a rural electrification project in catering to the needs of their consumers. Higher satisfaction levels entail consumer retention, which enables business to continue to generate revenue. *Default rate* refers to instances in which a consumer has been unable to afford a specific payment for the energy service (through the pay-as-you-go model or installments). High default rates indicate that the institution responsible for a rural electrification project is not. *Staff education level* assesses the expertise and quality of the people operating a rural electrification project, and is a more subjective indicator which is scored by the author. *Accessibility in for issue reporting*, similar to *service availability*, refers to the ease with which consumers can reach a key contact that can resolve a particular issue. This indicator thus refers to the process undertaken before the decision is made by the institution to dispatch a technician to resolve any technical challenges.

4.2 Data collection

Two questionnaires were designed (one for managers and one for consumers) to obtain qualitative and quantitative data regarding the aforementioned rural electrification projects (see Appendix C and D). Some of the questions formulated were directly related to the indicators employed in the sustainability assessment framework. The answers provided by interviewees to these questions were to then be recorded, and converted into a score. For response to an indicator-related question, a score of either 0, 0.5 or 1 was given. A response to an indicator-related question was scored 0 if it revealed a lack of socio-economic promotion, consistent with discussions about rural electrification in secondary data and academic literature. A score of 0.5 was given if a response either revealed neutral impact, minimal impact, or whether an aspect of rural electrification project could be improved. A score of 1 was given for any response that illustrated socio-economic promotion, sustainable development, and project sustainability. Such responses would be typically consistent with the literature which discusses the benefits of modern energy access provision. Upon completion of interviews with multiple households and the managers of an electrification project, the scores would be aggregated to illustrate the degree to which each project promoted sustainable development in their communities. The qualitative data obtained through these interviews are also reflected in the final scores to be obtained for each project, but also complement them by contextualizing the scores that were obtained. This combination of quantitative and qualitative data were to be used to fully assess the rural electrification projects in Kenya, developing a deepened understanding of rural electrification experiences in the country to draw the appropriate conclusions for this research.

The field surveys for this case study were conducted in the months of September and October in 2017 and 2019. Various locations across central and western Kenya, areas which are most densely populated in the country, were targeted and visited for data collection through semi-structured interviews. The areas visited were Nairobi, Machakos, Talek, Narok, Kisii, Homa Bay, Mfangano Island, Kisumu, Siaya, Eldoret, and Nakuru. Households connected to these electrification services were contacted for interviews to discuss their experiences. Interviews were also planned with managers and operators of each electrification project, in order to gather additional complimentary details which contribute to establishing a proper context with which the gathered household data can be interpreted. English is spoken nationwide in Kenya. However, an interpreter was also involved in interviewing activities to ensure information can be shared accurately. Figure 4.1 illustrates the locations in which interviews were conducted. These selected areas, as mentioned are known to be the most densely populated regions in Kenya, and were therefore were chosen to facilitate data collection in various neighborhoods. Two questionnaires (see Appendices C and D) were prepared for completion during interviews regarding the aforementioned dimensions of electrification, to capture data related to the indicators in the assessment framework. A total of 120 households were visited for interviews (2 households decided to abandon the interview); 26 were connected for the first time to the national grid, 15 households were connected to the hybrid mini-grid by KPLC in Mfangano Island, 8 were connected to the hybrid mini-grid installed by the development assistance organization, and 31 to the solar mini-grid by Powerhive. Interviews were conducted with 13 households that owned solar homes systems sold by Gennex, and 27 households that owned solar home systems sold by SunKing. A principal manager of each a rural electrification project in this assessment (who in certain cases invited a colleague) was also interviewed (6 managers in total). Questionnaires were used by the author to record information shared during these semi-structured discussions and in field visits. Interviews with government officials, scholars and a representative of an international organization were also conducted to gain a deepened understanding of the Kenyan energy sector.

Figure 4.1 – Field survey sites, Kenya

**Field survey interview sites marked and circled in red.*

Chapter 5 - Kenyan Case Study: Results and Discussion

The sustainability assessment framework employed for the Kenyan case study was used to determine the principal objective of this research; evaluate the impact of several rural electrification projects in Kenya, and formulate policy recommendations for rural electrification compatible with sustainable development, based on field research findings. The framework reveals 3 important details, captured quantitatively and qualitatively, regarding the rural electrification projects assessed and how they ultimately affect the consumer. Firstly, it reveals the socio-economic impact that the project has had on a community. Secondly, it enables an evaluation of the sustainability of the project: the ability of the project to maintain and continue its modern energy services over an extended period of time (the duration of the life cycle of its technologies). Third, the framework ultimately reveals how each project has contributed to sustainable development.

This chapter details the results of the employment of the sustainability assessment framework for the field surveys conducted in the months of September and October in 2017 and in 2019. Notable observations made by the author during the field survey will also be discussed, in addition to details shared during interviews with managers. Unique experiences and perspectives shared by consumers will also be incorporated in the field survey result discussion.

Interviews conducted with rural households recently connected to Kenya Power's national grid were located in the outskirts of the cities of Homa Bay, Kisumu, Eldoret, and Nakuru. Households located in Siaya, a primarily rural county situated in Western Kenya, were also visited for interviews with people that were connected to the national grid. The hybrid solar-diesel mini-grid installed in the town of Talek in Masaai Mara was constructed by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), a German organization that focuses on development aid, in collaboration with local Kenyan Government. The solar mini-grid that installed in Ogembo, a village located in Kisii County, was built by Powerhive, an American private company which focuses on promoting energy access in rural homes and businesses all around the world. A third mini-grid, constructed by KPLC, was visited in Mfangano Island to assess its performance in the off-grid community situated on the island. Finally, the solar home systems sold to off-grid households were installed by Gennex and SunKing. An interpreter was also present during interviews to translate from Swahili to English when necessary.

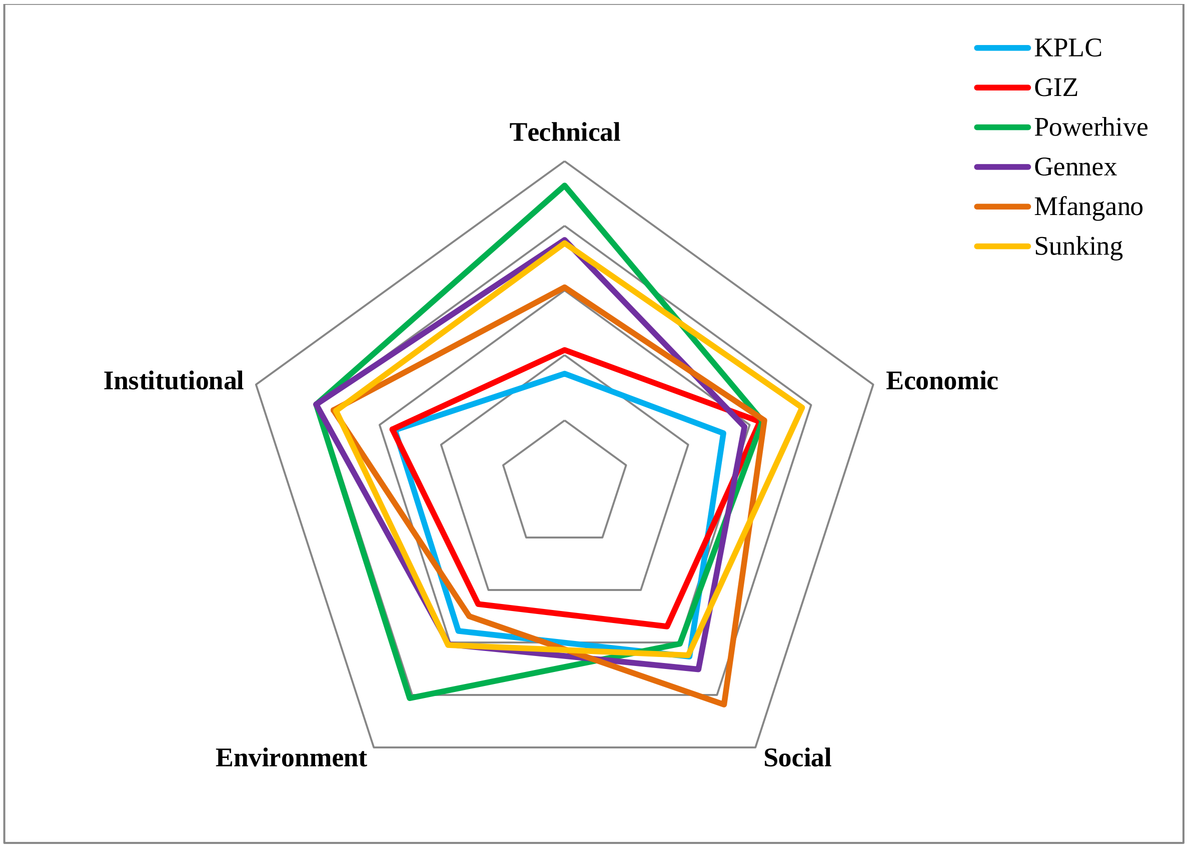
Figures 5.1 and 5.2 illustrate the results of the field survey that was conducted in rural Kenya. The results illustrate degrees to which electrification activities have had socio-economic impacts, promoted sustainable development, and the sustainability of the project. While Figure 5.1 illustrates the scores produced after aggregating the scores from the questionnaires for each project, Figure 5.2 depicts these same results in a web diagram, to visually illustrate the degree to which projects have contributed to the socio-economic development of their immediate and surrounding rural areas.

Table 5.1 – Sustainability Assessment Scores

	Grid	GIZ	Powerhive	Mfangano	Gennex	SunKing
Technical	**0.34**	0.42	**0.92**	0.61	0.76	0.74
Economic	**0.52**	0.63	0.64	0.65	0.58	**0.77**
Social	0.65	**0.54**	0.60	**0.84**	0.70	0.65
Environment	0.56	**0.45**	**0.81**	0.50	0.56	0.61
Institutional	**0.55**	0.56	**0.81**	0.75	0.80	0.74

*Highest dimension score in **green**, lowest in **red**
**Table constructed by author based on data collected during interviews and in questionnaires

Figure 5.2 – Sustainability Assessment Web Diagram



*Radar diagram constructed by author based on data collected during interviews and in questionnaires

5.1 Result observations

In this research, while it was important to produce quantitative figures in order to illustrate the results of this case study, it was of paramount importance not only to be able to gather qualitative details regarding modern energy access experiences for these rural households to give greater meaning to the scores produced (thus contextualizing and facilitating their interpretation), but also for creating a snapshot of the impact of rural electrification on rural communities in Kenya. One common theme that emerged in every discussion that was held during this field study is that every household made periodic payments using M-PESA, a very popular mobile phone based money transfer service that is used for various expenses, including the payment of utility bills. This payment method has proved to be an especially convenient solution which saves time and money on existing alternative energy-related expenses for these households. Nevertheless, due to economic or personal circumstances, some households reported skipping several payments.

The results in this case study reveal that Powerhive, Gennex, SunKing (the companies in the private sector), along with the KPLC mini-grid in Mfangano Island, obtained the higher scores in the sustainability assessment. While the interviewed households connected to the hybrid solar-diesel mini-grid constructed by GIZ were fewer in number compared to the other electrification projects, notable visual and response patterns while undertaking the site visit in Talek led to a general set of expectations regarding the sort of data that would be obtained from any additional household interview. Information collected while visiting these households (regarding electrification impacts) became redundant in nature (as with the case during interviews with customers of other electrification projects), which facilitated this research's employment of the qualitative approach for gathering information regarding modern energy access experiences via semi-structured interviews.

Moreover, unlike the case of GIZ, the initial pattern of responses in Mfangano, for instance, were much more indicative of positive socio-economic impacts, which by default enabled the mini-grid scores to be higher for Mfangano, even if the number of households interviewed in Mfangano were equal to the number interviewed in Talek. This entails that a substantial number of additional households in Talek would have had to consistently make comments more indicative of socio-economic promotion in order to enhance the sustainability assessment scores of the GIZ project to levels on par with those of the better performers; a scenario that is unlikely given the circumstances described during interviews with its managers, and the circumstances discovered during the field survey in Talek. Thus, while supplemental interviews in Talek would have enhanced the robustness of the assessment scores obtained, its influence on conclusions regarding this research would have been minimal.

In this research, the additional focus on establishing the *rationale* (from deep learning of modern energy access experiences through semi-structured interviews with managers and consumers) which *resulted* in these scores was of paramount importance to affirm the validity of the scores. Hence, this case study employed a quantitative and qualitative research design in order to obtain a holistic set of information and data regarding off-grid electrification experiences in Kenya. Given the results of the methodology employed, it may be postulated that energy access being realized with mini-grids and energy access provided by the private sector best promote socio-economic development in rural areas.

5.2 Case Study Findings

5.2.1 Kenya Power Grid Extension

As discussed in Chapter 2, Kenya Power (KPLC) is the national utility company in charge of nationwide electricity provision through the national grid to its customers. As revealed during interviews with managers at Kenya Power, the utility company operates under the national government, and therefore undertakes projects that are established by government. The institution then sends an invoice to the Kenyan government, which reimburses the costs incurred by KPLC in completing a designated project. This collaboration was said to have been established in 1971, the year in which the contract between KPLC and the Kenyan government was signed. Since costs of certain projects can also be substantial, it was also noted during the managerial interview that delays can be experienced in KPLC's reimbursement for its activities from government. Energy demand is known to have grown consistently, warranting the need to upscale energy generation, and extend the grid into previously unconnected areas. However, such efforts have experienced some challenges, including the challenge of delivering energy through poor infrastructure, limited peace and stability in certain areas of the country (although such a challenge has now been overcome), and local capacity for system operation (managers reported that high levels of insecurity that existed led to the displacement of capable operators). Consumers in rural Kenya that are connected to the grid follow a token system, in which households pay for a specific amount of electricity (through M-PESA) to be delivered to their homes. Thus, household typically pay for the amount of electricity it can afford. Periodic payments made for grid energy services from KPLC are therefore inconsistent, ranging from 2-3 days at a time in lower income households to several weeks in middle income households. These periodic payments are made through the token system to ensure continued provision of modern energy in the household.

During the field survey in various parts of rural Kenya, several consistent trends were noted in responses provided by households connected to Kenya Power. Firstly, households reported high income levels, which help to better understand KPLC's economic dimension score. Employment activities for most of these households are conducted outside of the home, so the economic dimension obtaining the lowest assessment score among all projects assessed was expected, since households that connect to the national grid are typically households that are able to better afford these services. Rural households that look to be connected to the grid are expected to pay an initial connection fee of approximately 13,000 Kenyan Shillings (approx. $130), which prices out many of the lower income households in rural areas. Income impacts were therefore reported to be unnoticeable, or positive primarily on the basis of money being saved since Kerosene lamp and fuel purchases were no longer necessary.

Secondly, technical operations of the national grid in rural areas have proven to be problematic for many households. Consumers reported power outages which last several hours to several days, inevitably creating inconveniences which cause overall satisfaction levels with KPLC electrification to be lower than those of other electrification projects. Many households expressed concern regarding the reliability of KPLC electrification services, and shared a desire to consider complementary electrification options such as solar home systems for backup. One household which operates a cosmetics business in the outskirts of Eldoret reported circumstances similar to a power surge which took place after a power outage which lasted several hours. The power surge had devastating consequences on most of the business owner's electrical appliances, which either burned or exploded, causing the owner to incur costs related to damage repair and replacement of several electrical appliances. This raises safety concerns which were also addressed by another household head that was interviewed, who reported questionable infrastructural designs in connecting households in the area to the national grid (an observation which echoes the limited local capacity mentioned by the managers interviewed at KPLC). Such circumstances, in addition to the long power outages in rural areas leading to moderate to low consumer satisfaction negatively affected KPLC's assessment score in the technical and institutional dimensions. A notable observation regarding grid operation is the issue of power outages potentially lasting weeks in remote areas, while urban areas typically experience such outages for several minutes. There is therefore an inequality that exists in energy distribution by the national grid, with rural (and lower income) households paying for energy services that have proved to be unreliable. Such findings have contributed to KPLC being the poorest performer in the assessment.

Nevertheless, households shared positive opinions and feedback regarding KPLC. The households that were interviewed expressed general satisfaction and pride for the organization's progress over several years, and use this basis to express optimism for KPLC’s future. It interviewees generally believed that the benefits provided by KPLC’s service outweigh the negatives aspects of grid extension. Hence, while KPLC was the poorest performer in this sustainability assessment case study, public perceptions of Kenya Power seemed to be positive, with hopes of further service improvements to become noticeable in the future. Nonetheless, the national grid connects to households that are able to afford their services, hence minimizing the socio-economic impact that national grid connection can have in rural areas. This circumstance, which is typically an economic barrier, contributes to the economic inequalities which exist in energy access activities. KPLC, nevertheless, as revealed by managers, currently has in incubation various system reinforcement projects, grid extension plans, and mini-grid installation projects which demonstrate that the institution recognizes the current challenges being faced and can be expected to become an important promoter of socio-economic development in Kenya.

5.2.2 GIZ

The hybrid solar-diesel mini-grid was installed back in 2015 by GIZ, in collaboration with the local government. The operations of the mini-grid were then transferred to PowerGen, a local energy service provider. A manager from PowerGen was thus also part of interview discussions regarding this hybrid mini-grid. The mini-grid was installed with a capacity of 50kW, with 80% of this capacity being generated from solar PV panels.

Talek town is a commercial town in Masaai Mara. Countless businesses are located in this town, with business owners actually living inside their businesses, or in a separate room right where the business is operated. Given this visual pattern, it was no surprise that, regardless of the small number of interviewed households, the economic dimension of the GIZ mini-grid obtained the highest dimension score in its sustainability assessment. Households almost unanimously reported positive impacts on income due to direct effects on employment activities, given their businesses are able to operate for longer hours in the evenings. GIZ managers also revealed during the interview that while conducting their own post-installation socio-economic impact assessment, 125 new jobs were created along with the foundation of 40 new businesses.

However, such growth in energy demand has led to the mini-grid being unable to satisfy energy demand. Managers reported instances in which operations of the mini-grid were suspended for several hours in order to economize operations, and consumers had also reported power outages which lasted for a similar period of time. Paying for the mini-grid services has also proved to be a challenge for consumers, causing strained relationships with the service providers, especially after fee increases were announced while service reliability had declined. Managers had also mentioned customer care as a challenge that had to be overcome after mini-grid installation. Such circumstances helped to explain the low satisfaction levels expressed among households which were interviewed, and why the assessment scores for the institutional and technical dimension were among the lowest values in this case study. It can also be deduced that these are the circumstances which have led to consumers expressing strong interest in connecting to the national grid operated by Kenya Power. Most consumers believe national grid services would be more affordable than the mini-grid, and therefore may consider such an opportunity if the possibility is presented. Hence, while economic contributions of the GIZ mini-grid project are notable, resulting in a somewhat meaningful contribution to the sustainable development of the town of Talek, various technical and institutional concerns addressed in interviews with managers and consumers bring to question the long-term sustainability of the GIZ Talek mini-grid project itself. As for the social dimension, a final score 0.54 indicates the project has not had any significant impact on the social aspects of the community, but rather has maintained its current standard of living (just as a score of 0.5 in scoring an indicator was meant to illustrate; a neutral, insignificant impact, as discussed in Chapter 4). The low environmental dimension score is attributed to the failure of the mini-grid systems to reduce reliance on kerosene and cooking fuels for a majority of households that were surveyed, and the fact that the mini-grid relies on diesel for power generation.

Regardless of the many observations that have been made from a small sample of households interviewed, it must be noted that the sample size may remain insufficient for drawing definitive conclusions regarding the sustainability of the project, and the contribution of the project to the socio-economic development of the Talek community. In order to confirm the aforementioned findings, a larger sample size may be necessary to better support conclusions drawn from this assessment. However, a detailed description of the various circumstances surrounding each dimension of the sustainability framework, as provided by managers, operators and households (especially the technical and institutional dimensions) helped to provide a clear picture of the electrification experience with the installation of this hybrid mini-grid. GIZ echoed some sentiments regarding the selection of the location for their hybrid mini-grid project, explaining that choices of locations for installing their hybrid mini-grid was affected by the difficulty experienced in understanding the regulatory environment for mini-grid electricity service provision. Managers vowed to take lessons learned from this project in order to continue to install more mini-grids in strategic locations around rural Kenya

5.2.3 Powerhive

Powerhive's solar mini-grid installed in Kisii was the best performer in the sustainability assessment. However, such a finding should also perhaps come as no surprise. The organization itself focuses on promoting socio-economic development in all rural areas where their solar mini-grids are installed, hence the organization ensures its sustainability objectives are met with every installation. As mentioned, the solar mini-grid was installed by Powerhive in Kisii, a tropical, heavily forested and hilly village which receives rain year round. Agriculture (banana and tea-farming was the primary source of income for most inhabitants surveyed in this area. The company employs technologies such as the smart meters to monitor equipment performance, energy consumption data, and receiving load balancing commands. The company also uses software to analyze potential sites for mini-grid installation, focusing on financial, technical and geographic data which helps reduce project development costs. It was made clear by managers of Powerhive, nevertheless, that costs for installing mini-grids remain high, and recovering the costs for their installation can take up to 20 years. The energy demand of its consumers is met without any problems, enabling the mini-grid systems to operate seamlessly without technical difficulties. Powerhive has installed a total of 16 mini-grids, in Kisii, with 4 currently under construction, strategically located, as per company policy, no closer than 600 meters from KPLC grid power lines. Challenges specified by managers regarding the services provided in Kisii include vandalism and theft of key components of the mini-grid (photovoltaic panels), high installation costs, and power outages which can occur due to heavy rain and strong winds which sometimes cause trees to fall down and cut power lines.

The solar mini-grid installation visited for the field survey was completed in 2013, with a capacity of 20 kW. Managers and operators had confirmed that there were some technical challenges that had to be overcome in the beginning. However, such issues were resolved, leading to blackouts becoming an inapplicable concern in assessing the technical dimension of the

Powerhive project. Additionally, a majority of respondents reported periodic payments for the mini-grid services being affordable, and reported income savings generated from switching to electrification for energy consumption. The increase in savings also was made possible due to a decrease in purchases of Kerosene for lighting purposes, and households reported that such reliance on cooking fuels were also expected to decrease. These aforementioned findings, which are consistent for a majority of households that were interviewed in this survey, helped to explain why the assessment scores for Powerhive were highest in the technical, and environmental dimensions. The company's score in the economic dimension as a result has also been one of the higher scores among the projects evaluated in this assessment. This solar mini-grid's performance in the social dimension was also inevitably good, given the health benefits derived from a reduced dependence on Kerosene purchases, and many children in the area being able to increase their study hours with light being available for a longer period of time in the evening. Interviewed households unsurprisingly expressed great satisfaction levels with the services provided by the mini-grid, which helped Powerhive obtain the highest assessment score in the institutional dimension. It also is therefore unsurprising that most households in this part of rural Kenya expressed no interest in connecting to the national grid due to their energy demands being satisfied by this solar mini-grid.

5.2.4 Gennex

Gennex sells solar home systems of varying sizes to households, businesses and institutions all around Kenya, situated on or off the national grid. So it was evidently important for interviews to be held with households that were located off the national grid, in order to undertake an appropriate off-grid rural electrification assessment for Gennex. The organization also focuses on promoting socio-economic development, ensuring the welfare of rural communities is also improved via electrification activities.

Gennex was also among the better performers in this sustainability assessment. Scoring highest in the institutional dimension is attributed to the fact that the company maintains excellent relationships with all its clients (this was evident during the field survey and reported by all households), which helps to maintain customer loyalty and build a good reputation for this organization. This circumstance plays an important role in improving the longevity of the organization, especially given the Kenyan solar PV market with solar home systems in the past have faced issues of reliability. Gennex technicians and experts are readily available to assist clients in handling any problems that may arise, enabling delays in repairing technical issues that may arise to be minimal. The solar home systems produced by Gennex are also capable of operating for extended hours, ensuring that energy demand is met as effectively and efficiently as possible, especially in the evening when energy is consumed more substantially by all members of a household. This finding has enabled the assessment score for the technical dimension to be the second highest in its assessment. However, this score could have been higher if consumers in this sample had not expressed interest in connecting to the national grid, indicating a possible failure in the ability of Gennex solar home systems to completely meet energy demand in a specified household. It must be noted, however, that Gennex undertakes all of the pre-installation and post-installation procedures necessary to determine the energy demand in the household, and ensure the longevity of the solar home system. Thus, SHS consumer negligence in the Gennex case can also be considered a culprit for reduced product performance, reduced technical dimension scores, and consequent desires to connect to the national grid. Consumers should therefore be trained to use the solar home systems appropriately, a measure that Gennex now takes with all consumers that look to purchase a solar home system.

Many of the Gennex consumers also have children that go to school, so it was easier for Gennex to derive greater social impacts in this survey, resulting in the highest assessment score in this dimension. Additionally, social activities related to telecommunications (watching TV, listening to the radio, increased frequency of reunions or gatherings for watching TV and other leisure activities) have helped to raise the social dimension score for Gennex. However, while households have been able to replace Kerosene lamps, a dependence on cooking fuels has not been relieved in the sample size of interviewed homes, resulting in a reduced environmental dimension score, entailing lower degrees of sustainable development promotion.

Gennex has also had an impact on income generating activities on the basis of employment opportunity discovery. Households reported mobile phone charging services as a means for generating additional income. This finding is also not a surprise, given the way their solar home systems are designed with two USB ports which enable mobile phone charging activities. It must nevertheless be noted, that while Gennex has had its economic impacts in rural households, a majority of the clients interviewed were higher income earners compared to households in other electrification projects. The company implements a flexible payment plan for clients to pay for their solar home systems through a series of installments, paid over a period of several months. These installments ranged from 15,000 to 30,000 Kenyan shillings per month ($150-$300) according to respondents, while some households that were able to purchase this system with a one-time payment paid over 50,000 Kenyan shillings ($500) for the system. Thus, given the higher income status of clients in consumers served by Gennex, the economic dimension score for Gennex was somewhat low compared to those of other projects, indicating a sustained standard of living rather than having significant economic impact.

Discussions with the Gennex manager revealed some information regarding challenges that the organization had to overcome. The manager spoke of dealing with high tax payments, complex laws, and requirements for obtaining various licenses which would legally enable Gennex to provide its services in Kenya. The process undertaken to obtain all of the required licenses were thought to be tedious, time-consuming, costly, and difficult to achieve, along with observations of a lack of transparency in the process of obtaining some of these licenses. Despite the hurdles perceived by the managers in undertaking its endeavor in rural Kenya, has been able to perform well in promoting and maintaining sustainable development in its rural communities.

5.2.5 SunKing

SunKing is a private sector company that has found major success in the solar PV market in Kenya, selling over 1,000,000 solar home systems to households across various rural parts of the country. Their products vary in size and capacity depending on the needs of the consumer (ranging from 6 to 40 watts), and payment plans are made flexible to facilitate the purchase of their solar home systems. The company uses the pay-as-you-go method for customers that buy their products, meaning consumers are typically paying for their products through a series of installments (made on a weekly basis on average) until the total cost of the product is completely paid. The wages of the SunKing clientele ranges from $2 to $10 a day. The 6 watt pico-system is the highest selling system for SunKing, and indications during the managerial interview suggest the company's operations in Kenya have been supported by multiple investors which have been able to financially support the company's operations. However, information regarding financial performance was not divulged by the manager, in strict observation of company policy regarding sensitive information. SunKing operates in several countries but has established its largest markets in India and Kenya. The company obtains its financial resources through equity and debt financing, from institutions with strong interest in development, impact investment, development finance. Private funders have also supported the work of the company. SunKing has dealt with some operational challenges as a business in Kenya, including the experience of importing their products through customs with limited transparency (it was unclear which items were exempt from duty tax) such as when clients inadvertently provide incorrect ID which delays payment for their services, product malfunction due to improper product use, or component related issues. The company did not experience too many obstacles in establishing its business in Kenya.

In the sustainability assessment, the outskirts of the towns of Narok, Kisii, and Kisumu were visited for interviews, while the interview with the manager was held in Nairobi. A total of 27 households were interviewed, and as the results suggest, SunKing was also one of the better performers in the sustainability assessment. SunKing's economic dimension scored highest amongst all projects. Consumers using SunKing products reported increases in disposable income, given a reduced reliance on kerosene lamps and fuel for lighting. Payment plans for SunKing are also tailored to the income levels of consumers, enabling consumers to simply pay what they can afford, making affordability and accessibility to SunKing's services highly practical.

However, while SunKing's products have enabled households save money by replacing kerosene for lighting with pico solar systems, they have failed to reduce the dependence of households on traditional sources of energy such as firewood and charcoal for cooking. In certain areas, especially in Kisii and in Kisumu, firewood is available in abundance as a natural resource and never needs to be purchased, thus households have continued to rely on this resource for cooking. This in turn results in the continued depletion of finite natural resources in the immediate environment of SunKing products, which caused the environmental dimension score to be low in SunKing's assessment.

As in the case of Gennex, SunKing has been able to obtain a high institutional dimension score due to its salesforce, stationed in their respective offices in Narok, Kisii and Kisumu, working to maintain relationships with its clients. These SunKing employees also undertake marketing campaigns in which off-grid sites are visited for the distribution of SunKing flyers and contact information in order to attract more clients to the modern energy solution provided by SunKing. The result of such efforts is that a vast majority of consumers reported having excellent relationships with representatives. This notable finding is a good indicator for customer retention, which enables SunKing to maintain a strong customer base and market presence in rural Kenya. In addressing the technical aspects of the product, consumers did not have any complaints regarding the reliability of the services provided. Given low energy demand in the households, a typical pico-solar system would consist of 2-3 light bulbs, coupled with a small radio, and a USB port for mobile phone charging. Solar home systems sold by Sunking with greater capacity include a TV ranging from 19 to 32 inches depending on the willingness to pay of the consumer. However, households have expressed interest in connecting to the grid in the future, illustrating that SunKing products may be a temporary solution for households as they wait for a more powerful source of energy supply. The products have nevertheless served their purpose, with households having expressed complete satisfaction with the services that have been provided.

5.2.6 KPLC – Mfangano Mini-grid

The hybrid solar-diesel mini-grid constructed by KPLC on Mfangano Island in Western Kenya was commissioned in 2010. The mini-grid has installed power generation capacity of 800 kW from diesel and 10 kW from solar PV, and has established over 1200 connections since its commission. The number of businesses connected to the mini-grid is estimated to be around 300, which is certain to help in the development of the economy of Mfangano Island. Unlike in the case of GIZ, this mini-grid's power generation capacity was increased in accordance with increases in energy demand of the community, minimizing technical challenges of operating the mini-grid. It has nevertheless been noted that a small, lower-income portion of the island has still not been connected to the mini-grid.

The Mfangano mini-grid was also a better performer in the assessment, compared to grid extension and the GIZ mini-grid, obtaining a higher score in almost all the project dimensions that were assessed. Regarding the economic dimension, the score was obtained as a result of the previously mentioned token system (which enables consumers to pay for a specific amount of electricity that is affordable for the households), in addition to increases in savings and business operation hours. The mini-grid also does not experience many technical difficulties in providing electricity to its connected consumers. However, maintaining the mini-grid was recognized by the managers as being costly, due to its remote location being more difficult to reach. Obtaining supplies to reinforce the infrastructure for the mini-grid is shipped from the mainland, which increases costs for the mini-grid's maintenance and operation. Hence, there are certain instances in which a technical issue reported by a household (eg. transformer failure) is swiftly addressed, but logistical challenges delay its resolution. Households nevertheless recognized the benefits of the installed mini-grid and mostly expressed their satisfaction for the services provided (which in turn contributed to the high institutional score).

The Mfangano mini-grid, as in the case with the other projects assessed in this case study, has enabled households to reduce their dependence on kerosene for lighting. But the availability of firewood as a natural resource has maintained the dependence of households on this traditional form of biomass energy. Obtaining firewood, as in the case of Kisumu and Kisii, is as easy as stepping into the surrounding forest and collecting wood. Households also reported the intention to continue to purchase a consistent quantity of charcoal for cooking. The environmental dimension score for the Mfangano mini-grid, therefore, as in the case of SunKing, was also the lowest in its assessment. The Mfanagano mini-grid managers however have reported that they are lobbying for an increase in solar PV generation capacity, which would help reduce the mini-grid's operation costs and help the mini-grid contribute to sustainable development.

The impact that the mini-grid has had on the community of Mfangano is not negligible. Consumers spoke very highly of the benefits and the changes that the mini-grid has brought to the standard of living of various rural households, and thus expect that improvements in operations will only help to sustain the economic development that has been experienced in the community. Hence, it must be clarified that while the assessment scores suggest the project having a rather neutral impact, realities discussed on the field reveal that the standard of living in Mfangano was improved with the installation of the mini-grid. Mfangano is recognized as a work in-progress which will continue to promote sustainable development and improve the standard of living of people on the island.

5.3 Case Study Result Discussion

In congruence with the main objectives of this research, the sustainability assessment framework developed for this case study establishes three important findings. The framework determines; (1) what rural electrification projects have been able to do for the local community, (2) the degree to which rural electrification projects have been able to promote sustainable development, and (3) the sustainability of the rural electrification projects, given sustainable development in rural communities can only be made possible if the rural electrification activities are sustained. The assessment scores therefore not only reveal the degree to which the six electrification projects have impacted the rural communities they serve, they also assessed their sustainability, and the degree to which they have promoted sustainable development in their respective communities. The result of this case study reveals that, rural electrification activities primarily undertaken by the private sector, especially through the installation of solar home systems and mini-grids were the better performers in the sustainability assessment in comparison to the public sector actors. In this research, quantitative estimations were produced in conjunction with qualitative data to best reflect the modern energy access experiences of the rural households in Kenya. The recording of qualitative data gave a greater meaning to the assessment scores, hence contextualizing and facilitating their interpretation including in terms of significance.

The private sector is highly valued as an actor in the promotion of sustainable development. In the energy sector, these stakeholders provide modern energy services with high levels of expertise and if costs are recoverable, they are able to provide multiple solutions in promoting sustainable development in rural communities. The impact that the private sector can have on rural development is made evident in several reports, beyond the findings of this research. The July-December 2016 report titled "Global Off-Grid Solar Market Report – Semi-Annual Sales and Impact Data", for instance, reveals a 141% increase in available light per household, a 164% increase in available hours of light per household, an average of $200 (USD) in savings on energy-related spending, and 1.9 million livelihoods benefiting from the use of off-grid solar products (Global Off-Grid Lighting Association 2016). The report also estimates that 26.9 million tons of greenhouse gas emissions have been cumulatively offset. This report in particular is significant in how it strongly supports this case study, given in Sub-Saharan Africa, the report finds that Kenya was the country with the highest amount of sales of these off-grid solar products (32%), followed by Ethiopia (24%). The 2018 Off-Grid Solar Market Trends Report, prepared by Dalberg Advisors and Lighting Global also confirms many of these findings, discussing how consumers use off-grid solar products for income-generating activities, experience positive impacts on health and study time for children (Lighting Global 2018). The complementary findings of the aforementioned reports help clarify the role that the private sector can play in promoting rural development. They also help illustrate how the private sector companies in this sustainability assessment case study were able to obtain higher final dimension scores. It is with such findings that key actors in the Kenyan energy sector can consider facilitating private sector operations in rural Kenya, or consider private sector actors as partners in rural electrification progression, in order to further promote sustainable development.

As previously mentioned, one common theme emerging in all discussions on the field was the use of M-PESA. The M-PESA concept is a "pay-as-you-go" business model, which enables consumers to use some of the most basic mobile phones to make payments on a daily, weekly, or monthly basis. However, most consumers reported paying sporadically, necessitating an estimation of monthly expenses for the modern energy services provided. Inevitably, depending on various economic or personal circumstances, some households reported opting to not pay the necessary fee for the energy services, which cuts power to the household until the fee is paid and negatively affects the revenues of the company or institution providing the service.

Another common theme noted during interviews with managers is the discussion of regulations for the energy sector, which proved to be a challenge particularly for GIZ and Gennex. In both interviews, representatives discussed the challenges of navigating excessive, complex regulations for establishing their operations, and the payment of high import taxes (high import taxes were a noted hurdle for SunKing as well). The Gennex manager in particular discussed challenges of obtaining various licenses, a time-consuming procedure that was notably limited in transparency. Such challenges inevitably reduced the speed with which businesses are able to begin operations, which ultimately penalizes the rural households with limited energy access (or none). A review of the regulatory requirements for starting a renewable energy project in Kenya helps clarify the challenges project managers had faced. The document titled "Inventory of Regulatory Requirements to Start and Operate A Renewable Energy Project in Kenya" (Kenyan Renewable Energy Agency 2011) details the various procedures that need to be undertaken for renewable energy projects to obtain permission to operate, and finds that requirements and procedures are redundant, and procedures are time consuming (potentially last from 1 day to 24 months depending on the type of renewable energy project being employed) for obtaining the necessary license. The number of licenses to be obtained depends on the renewable energy project being implemented. It has also been found that multiple authorities are involved, and the details of specific requirements for a particular renewable energy project type (solar, wind, geothermal, hydro etc.) have not been clarified, which can create confusion, and cause some managers to take additional steps (some of which were never needed) in establishing a renewable energy project. This document has helped provide substance to the observations that had been made by managers during interviews, discussing the initial stages (2012-2015) of establishing their business or implementing a renewable energy project.

However, as mentioned in Chapter 2, it is to be recognized that Kenya is a country in the midst of energy transition. The energy sector in Kenya has continued to transform through the implementation of new regulations and the establishment of new institutions in order to streamline the energy sector and help facilitate activities in this sector of the Kenyan economy. The regulations which existed under the 2006 Energy Act have been amended under the 2019 Energy Act. Hence, the regulatory challenges that had existed for companies like Gennex may have been addressed, and this was made clear during interviews conducted with the newly established Energy and Petroleum Regulatory Authority (EPRA) (see Chapter 6). Such adjustments, nevertheless, should be clarified for all future prospective actors in the private sector which look to invest in rural electrification activities in Kenya.

Government policy for solar energy dissemination is also a recent development, with several initiatives beginning to contribute to an increase in the share of solar PV in Kenya's national energy mix, including the installation of solar PV in public facilities across rural Kenya through the Rural Electrification and Renewable Energy Corporation, the Kenyan Off-Grid Solar Access Project developed by the Ministry of Energy to increase energy access in underserved areas in Kenya with solar mini-grids and stand-alone solar home systems, and the integration of solar PV in existing diesel mini-grids across the country (Ministry of Energy 2018). Hence, the country has recognized the value of PV dissemination in developing its economy.

As for households interviewed in this case study, there is a specific finding which stood out in most of the projects assessed. The environmental dimension is the dimension that typically obtained the lowest scores in the assessment of each project; such was the case for SunKing, the Mfangano Island hybrid mini-grid, and Gennex. The environmental dimension scores for grid extension by KPLC and GIZ were also relatively low. These findings are due to the consistent theme of households turning to alternative solutions for lighting to avoid the harmful effects of using kerosene. Modern energy access has enabled a vast majority of households to begin using electricity as the primary source of lighting. However, the rural electrification projects have failed to influence the use traditional sources of biomass (firewood and charcoal) for cooking. Thus while the communities have experienced various socio-economic benefits which improved standards of living from the rural electrification projects that have been assessed in this case study, the projects did not necessarily effectively promote the sustainable development of these communities. More effort is therefore required to reduce community reliance on finite natural resources for cooking.

Additionally, during the field survey, notable visual and response patterns while undertaking site visits led to a general set of expectations regarding the sort of data that would be obtained from additional household interviews. Such visual patterns would include the living circumstances of households, especially those in the business town of Talek as previously mentioned, and the tea farmers in the heavily forested, hilly village located in the county of Kisii. SunKing is also a company that provides services to a specific demographic (typically low income households, earning $2 to $10 per day) in a way that enabled consumers to provide notably consistent responses. Information collected while visiting households (regarding electrification impacts) were thus becoming increasingly repetitive in nature, making the qualitative nature of this research important for yielding analysis regarding modern energy access provision experiences that would be unique for each electrification project that was assessed. Thus, while it is recognized that supplemental interviews would have led to the establishment of assessment scores which can draw more clear and definitive conclusions, it was also important to establish the rationale (rationale being the qualitative research approach, in the form of discussions regarding modern energy access experiences and field observations) to validate assessment scores produced with the sustainability framework used in this study. Hence, it was of paramount importance for this case study to employ a qualitative research design in order to obtain and analyze data regarding the impacts of off-grid electrification projects.

Finally, Kenya Power, the utility company that connects rural households that desire and are able to afford connecting to the national grid, was the notably poorest performer in the assessment. Firstly, grid extension primarily occurs where households are able to afford the service. This slows down the speed with which Kenya Power is realistically able to economically extend the national grid, unless KPLC obtains substantial financing to further extend the national grid into unconnected communities that are unable to afford national grid connection and monthly payment fees. The national grid also appears to be operating less effectively in rural areas than in urban areas, and infrastructural designs in certain rural areas have been problematic for proper electricity service provision. These challenges have led to poor assessment scores in this case study. The poorer performance of grid extension in terms of promoting socio-economic development, however, is not an unusual observation. Lee, Miguel and Wolfram (2016) discuss in their research how electrifying households in rural communities with grid infrastructure does not improve social welfare, on the premise of connection costs being significantly higher than energy demand, which effectively prices out low-income households. Nevertheless, despite the many challenges that the organization needs to overcome, Kenya Power remains an ambitious organization that aims to definitively connect all households to the national grid by the year of 2030 (a deadline that has been reset to 2022, entailing accelerated efforts), not only through grid extension but through the installation of mini-grids and stand-alone solar home systems in accordance with energy demand in a targeted location, and in accordance with KNES 2018.

5.4 Concluding remarks

This case study was completed using a sustainability assessment framework to produce the results discussed in this chapter. Not only was the research question of this dissertation answered with this section, but one of its principal objectives were also attained: the formulation of a framework that enables an assessment of grid and off-grid electrification in rural Kenya, in order to develop a deepened understanding of the modern energy access experiences in the Kenyan case. Given the results of this case study, the following chapter will discuss policy recommendations for achieving electricity access in accordance with sustainable development. The next chapter will discuss policy recommendations, based on the results of the case study, internship experiences of the author working in UNDP (and participating in multiple workshops regarding private sector engagement and rural electrification), and interviews that were conducted with key actors in the Kenyan energy sector.

Chapter 6 – Policy Recommendations

The results of the field research presented in Chapter 5 conducted in Kenya, using the sustainability assessment framework to evaluate rural electrification projects in September and October of 2017 and 2019, yielded several findings. Firstly, off-grid rural electrification projects completed by the private sector companies were the overall better performers in the assessment. Secondly, the mini-grid in Mfangano was the best performer in the assessment among public sector actors. Thirdly, the Powerhive solar mini-grid was the best performer among all projects. In addition to these findings, many observations, ideas, comments and thoughts were shared throughout the author's experience undertaking this research, conducting interviews with key stakeholders in the Kenyan energy sector, and working in organizations with key actors in promoting sustainable development in Africa. Nevertheless, the primary finding of this research was the ability of the private sector to provide modern energy services at a level on par (at least) with the public sector actors (KPLC, GIZ, local government). However, the case study, also being qualitative in nature, learned of the many experiences of households and rural electrification managers during project implementation, operation, and maintenance (discussed in Chapter 5).

Therefore, this chapter will discuss several policy recommendations regarding the energy sector for the promotion of sustainable development, based on three main premises. The first premise is the results of the Kenyan case study. Secondly, the recommendations will be discussed based on the detailed experiences of the author in working with experts in African development. Finally, recommendations will also be discussed based on interviews that were conducted with key stakeholders in the Kenyan energy sector.

6.1 Academic Research Perspective – Case study results

6.1.1 Recommendation – Energy sector regulations

Based on the results of the case study, several policies can be considered which support the private sector in the renewable energy market. Firstly, Kenyan policy makers should consider easing regulations related to the private off-grid solar energy market. Discussions with the GIZ hybrid mini-grid and Gennex managers revealed some of the challenges with having to navigate excessive regulations for establishing an enterprise in the energy sector. These challenges were echoed in the document discussed in Chapter 5 titled "Inventory of Regulatory Requirements to Start and Operate a Renewable Energy Project in Kenya". It was found in this document that the involvement of multiple authorities, the inconsistent duration for obtaining the appropriate licenses (ranging from 1 day to 24 months), redundant procedures and minimal clarity regarding requirements for a specific renewable energy type (solar wind, geothermal, hydro etc.) would complicate the development of private sector involvement in the energy service provision. Policy makers therefore need to ensure streamlined regulatory procedures to enable the private off-grid solar energy market to thrive, and contribute to sustainable development in rural Kenya. Kenya has proved to be a country which leads in the renewable energy transition, and interviews conducted with key actors in its energy sector have revealed that substantial progress has been made in enhancing the regulatory framework. The country continues to revise its regulations in order to determine how to better organize the energy sector, and has most recently done so with its 2019 Energy Act, which has created new roles for several institutions in the Kenyan energy sector. The relevant new regulations therefore need to be transparently disseminated to potential players in the private renewable energy market, to avoid the confusion that has been created in the past. As also mentioned in Chapter 2, there are also several commendable government initiatives that are being undertaken to contribute to the dissemination of solar power in off-grid areas. Hence, while one policy recommendation is to facilitate the regulatory environment for the private sector, the government of Kenya has proactively taken various steps to continue to promote rural electrification through grid extension and the installation of mini-grids, in accordance with its Kenya Vision 2030 objective of 100% electrification.

Such an effort, however, in various ways competes with the off-grid operations of private sector actors. Therefore, a clear objective must be determined with regards to undertaking rural electrification. In this research, one of the two objectives identified was the formulation of policy recommendations for achieving 100% energy access in Kenya compatible with sustainable development. This research thus maintains that rural electrification activities must promote sustainable development in rural Kenya. However, the findings of the case study reveal that private sector actors have promoted sustainable development in Kenya as well as public sector actors (and in many cases have performed better in the sustainability assessment). Hence, it should be ensured that government involvement in rural electrification promotes sustainable development.

6.1.2 Recommendation - Partnership

Given therefore the ambition shown by Kenya in achieving universal access to electricity, a partnership with private sector actors can be considered, in order to effectively promote sustainable development; firstly through the mobilization of additional funds making rural electrification projects financially feasible for both government and private sector, and secondly a promote heightened professionalization of the energy sector (innovation, expertise, knowledge transfer). The Public-Private partnership (PPP) is a fundamental instrument for increasing private sector involvement in rural electrification. One such example of partnership which has been established is the one between the Government of Kenya and Toyota Tsusho Corporation. Both parties signed an MOU in 2012 to help Kenya achieve its Vision 2030. Toyota Tsusho Corporation completed the construction of the Olkaria plant in the Great Rift Valley in Kenya, which produces and feeds electricity to the national grid of Kenya from geothermal energy. The construction of the Olkaria power plant was made a safer investment as a result of the partnership. Additional strategic PPPs can therefore be considered in order to promote sustainable development in rural Kenya. Since PPPs models and definitions can vary from one linguistic and cultural environment to another; and there is no official legal definition for a PPP, possibilities can be explored based on the needs of a specific rural electrification project. For instance, as discussed in Chapter 5, the Mfangano mini-grid incurs high costs for operation and maintenance due to its geographic location. A partnership can be established regarding transportation, in order to reduce the costs incurred in providing supplies for the mini-grid on Mfangano Island. Moreover, PPPs can be formed for the development of future mini-grids, which the government of Kenya has established as a key mechanism for achieving 100% electrification.

The concept of PPPs can be a cost effective solution for rural electrification in Kenya, which in turn would enable the government of Kenya to invest in other key drivers of its economy, including human resources (given the noted limited local capacity of operating/installing rural electrification technologies). Additionally, the liberated capital that could be used in rural electrification can be re-invested in improving procedural transparency for businesses, and to have energy sector regulations and standards fully enforced.

Enabling private sector actors to contribute to off-grid rural electrification in Kenya allows the high capital costs of renewable energy investments to be reinvested in other sectors of the Kenyan economy to promote sustainable development. Not only would such investments improve these other sectors of the Kenyan economy, they would also have an indirect effect on the Kenyan energy sector. For instance, redirecting investments in the construction sector would increase accessibility to remote locations with increasing energy demand, facilitating various players in the private renewable energy market to reach such areas. Having travelled through the country, it was noted while travelling to various communities across rural Kenya (particularly in the county of

Narok, Kisii, and Siaya), that certain roads which lead to a town are still in need of development (they remain off-road tracks best maneuvered with 4x4 Safari Landcruisers). In Narok in particular, towns such as Talek, which are near game reserves are therefore also difficult to reach, complicating the ability to provide modern energy access in these areas. If such investments, are focused in construction (renovating roads, in this instance), not only may the tourism sector greatly benefit from increased accessibility to game reserves (which in turn increases revenue for government), the private sector will more readily be able to meet increased demand in modern energy consumption. Hence, such investments in other sectors of the economy (tourism and construction sectors) can in the long-run facilitate the development of the energy sector and indirectly contribute to Kenya achieving 100% electrification.

6.1.3 Recommendation – Clean cooking advocacy

Another finding from the case study was the poorer performance in the environmental dimension of most rural electrification projects assessed. While households reported replacing kerosene with lamps for lighting, consumers have consistently reported the ease of access of firewood, and the need to buy charcoal for cooking. Thus, the rural electrification projects were not able to effectively address the continued consumption of finite natural resources. Therefore, there has been more socio-economic development experienced in rural communities in this case study, rather than sustainable development. In line with the objective of this research, a policy action that can be taken for rural electrification which promotes sustainable development is raising awareness regarding food preparation using renewable energy sources such as biomass, biogas and solar. This initial action can then lead to increased demand for such services, and increased opportunity for private sector intervention. Moreover, such products that are subsequently imported can be exempted from duty taxes due to the role they play in natural resource preservation and sustainable development.

6.1.4 Recommendation – Grid-tied solar PV

One final policy that can be considered regards strengthening grid operations in rural areas, via grid-tied solar PV. Rural households that own solar home systems can connect to the national grid and feed electricity into the grid. A net metering program can then be implemented to determine appropriate feed-in-tariffs, thus contributing to a minimization of power outages experienced more frequently in rural households connected to the grid. Undertaking a survey of consumers to determine those that own a complementary renewable energy device can help to then determine the number of consumers that qualify for having a net-metering system established on their premises in order to feed excess renewable energy produced into the grid. Such a survey can also be completed by establishing a PPP, to facilitate the identification of households that own a solar home system with the appropriate capacity to feed the national grid. A similar partnership could also be established with mini-grids installed by private companies. Since there is no definitive objective for net metering in Kenya (EUEI-PDF Kenya 2013 Project, 2014) (beyond its consideration as an option for national electrification), the above approach can be considered to establish this net metering system, entailing partnership with private sector entities.

6.2 Practitioners' Perspective

6.2.1 Working in UNDP

In conducting this research, the author has had the opportunity to work with organizations such as the United Nations Development Programme, and the Ministry of Foreign Affairs in Japan. This work has enabled encounters with high-level officials with a great interest in the sustainable development of the African continent. It has also created opportunity for involvement and participation in multiple meetings, workshops, seminars and conferences which focus on development in Africa. As such, the author was able to obtain perspectives from various stakeholders in the field, which help support the policy recommendations that have been made in the field.

The author worked for 6 months as an intern with the United Nations Development Programme, as a TICAD Intern. The Tokyo International Conference on African Development (TICAD) is a triennial conference that is held in Japan or in an African country. TICAD is an open and high-level policy discussion held between various stakeholders, co-organized by the Government of Japan, the World Bank, the African Union Commission, United Nations Office of the Special Adviser on Africa, and the United Nations Development Programme since 1993. The most recent edition, TICAD 7, was held in in Yokohama in August 2019. Thus, the TICAD intern's responsibility at the UNDP representation office in Tokyo was to undertake various roles and assignments related to TICAD and African development.

The TICAD Intern was tasked with conducting desk research regarding socio-economic circumstances in developing regions, entrepreneurship in Africa, and preparing reports on various TICAD or UNDP related events. The work also consisted of assisting in the organization of several

UNDP events, and networking with key contacts of the UNDP Tokyo office, along with upper-level officials that are implicated in the TICAD process. Working as a TICAD intern has therefore been a diversified experience. The job entailed working in various environments, with people of different backgrounds. The TICAD intern was also exposed to the perspectives of various high-level officials on the matter of African development, and keys to its development. Information gained during discussions in various events, the networking opportunities, and day to day responsibilities have helped to expand the knowledge base necessary in the development of policy recommendations for this PhD thesis.

The desk research work consisted of obtaining information on various aspects of economic development. The consistency with which this assignment is performed varied, depending on needs of the office; events or meetings that are taking place; and private discussions that are expected to be held with officials outside the organization. Much knowledge was been obtained regarding TICAD, the UNDP and its various projects, international conferences on African development, entrepreneurship activities in Africa, and several other development initiatives. It is with desk research that the author was able to obtain knowledge from various perspectives. The information that was collected was then assembled in order to produce a multitude of reports, PowerPoint presentations, or summaries depending on the occasion, audience, and purpose.

While working in this internship, research regarding TICAD and UNDP was conducted to create an informative flyer regarding TICAD, since TICAD 7 was approaching. Hence UNDP had been working to raise awareness of the event and its importance, in order to attract more stakeholders to this relatively rare occasion. Additionally, since the Japanese private sector is recognized as key stakeholders in the promotion of African development, existing relationships with UNDP Tokyo also led to requests to learn more about conferences similar to TICAD, and what results such conferences have been able to produce to this point. Thus, research was conducted on similar conferences being held in Korea, China, India, France, Turkey, and the United States.

Similar conferences to TICAD in these countries include the US-Africa Leaders Summit, in which $33 billion were announced in investments, $110 million committed to help African militaries for 3 to 5 years, and a $65 million program was announced to help strengthen security institutions against extremist groups. The AU-EU Summit (African Union and European Union) identified common priorities in 4 areas, including (1) investment in human capital through education, science, technology and skill development; (2) strengthening resilience, peace and governance; (3) migration and mobility; and (4) the mobilization of investments for African structural and sustainable transformation. It was also found that China pledged a $60 billion package for aid investment and loans to Africa at the 2018 Forum on China-Africa Cooperation (FOCAC), the India Africa Forum Summit resulted in the pledge of $10 billion for development projects over 5 years, and that India had committed $7.4 billion in concessional credit for nearly 140 projects in 40 African countries since 2008. In Korea, a memorandum of understanding was signed between the African Union and Korea at the 2016 Korea-Africa Forum (KAF), in which Korea is expected to provide, through the African Union Peace Fund, level-2 medical facilities worth $2 million to Mali; and at the 2018 Korea-Africa Economic Cooperation (KOAFEC), over 4000 participants were in attendance from African countries, world organizations and the private sector as agreements were made to deliver $5 billion in bilateral financial assistance to Africa over two years, and $600 million towards the African energy sector. Finally, outcomes of the Turkey-Africa Economic and Business Forum in 2017 included the agreement for knowledge and technology transfer to solve issues of R&D, aquaculture, animal husbandry, and rural development. It was fascinating to see the interest that has grown in investing in Africa and the multiple partnerships that were formed with African countries to promote development. Africa is recognized as a country with tremendous potential across the globe, and the partnerships and commitments unveiled showed the seriousness of stakeholders in promoting the African cause.

With regards to UNDP projects, work had been done compiling several UNDP projects focused on promoting peace and stability in African countries, especially those that are French speaking. Upon completion of a revision of several project documents, summaries were prepared and made available for reference in future discussions regarding UNDP activities in Africa that will be held with various stakeholders in African development and interested learners. Additional research was also conducted regarding gender inequality challenges in Africa, and development efforts being undertaken by the UN body in Papua New Guinea, employing an approach summarized by the 4 Ps (People, Prosperity, Planet, and Peace). This research was conducted to prepare a presentation that was to be given to various audiences.

Desk research conducted as a TICAD intern has thus helped learn of the various approaches employed beyond academia and research to promote sustainable development in Africa, the objective of this PhD dissertation. This aspect of the internship established itself as an introduction to the different activities and methods in which development is being promoted not only in Africa but across the globe in the developing world. The new helped broadened research perspectives regarding how sustainable development in Africa and in Kenya can be achieved.

6.2.2 TICAD Ministerial Meeting and AFRI-CONVERSE

Events organized by the UNDP Representation Office in Tokyo also played a large role in the work experiences gained during this TICAD internship. Not only was there heavy involvement in preparations for the event, the intern was to also play a supporting role during the course of these events, participate in networking activities, and produce reports regarding the event which took place. This interpersonal aspect of the internship has provided opportunities to interact with high-level officials, and who in turn share additional knowledge related to this doctoral academic research.

On October 6th and October 7th of 2018, the TICAD Ministerial Meeting was held in Tokyo, in preparation for the major TICAD event which was take place in Yokohama in August 2019. The UNDP, in collaboration with the Ministry of Foreign Affairs (MoFA) and the Japan External Trade Organization (JETRO) were organizing a side event, titled "Private Sector Engagement: Showcasing Business Opportunities in Africa", which was set to take place on October 5th. The event, which expected to attract high-level officials and over 400 participants, at the minimum required the assistance of the entire UNDP TICAD team in preparing for the event. Members of the TICAD team in New York were present in the Tokyo office for over a week to help with various aspects of this preparation. Several meetings were held, roles were assigned, and each member of the TICAD team proceeded to undertake the responsibilities assigned. During preparations, our team conducted a venue visit, before the author went with two colleagues to take a courtesy call at the Embassy of Eritrea, with the Ambassador, H.E. Estifanos Afeowrki, who was expected to speak at the side event. During our exchange at the Eritrean embassy, the Ambassador discussed the tremendous development potential of Eritrea, especially given its strategic location in the horn of Africa.

In other preparations for the event, the author was assigned the role of working with the African participants that were going to be speaking at the event, and accompanying them to meetings with MoFA, JETRO, and JICA. At the meetings with the aforementioned Japanese organizations, discussions were held regarding key African sectors that should be considered for investment, current Japanese involvement in African countries, and prospects for partnerships. Energy has consistently been cited as a key sector for investment. The participants were also assisted in preparing for the side event, in which they were expected to showcase the investment climate in their respective countries, in order to attract private investment. Throughout these preparations, it became clear that the private sector is recognized as a stakeholder which plays a role of paramount importance in the development of an economy. This observation was made evident by the scale of the event being prepared by the UNDP and its partners, the high-level officials in attendance at the event, and the hundreds of participants that had registered for the event.

Figure 6.1 – 2018 Ministerial Meeting Side Event

Photo credit: Author

Many responsibilities were also given to the TICAD intern in the aftermath of the Ministerial Meeting, including assisting in the formulation of a questionnaire for participants that had attended the event to obtain feedback on the event, and writing reports summarizing the discussions that were held during the event in French. Hence, the author is well-versed in the proceedings of the workshop which looked to engage private sector in investing in Africa. The participants discussed the attractive investment climate, the possibility of forming partnerships, and the steps that can be taken to invest in their respective countries. Japanese companies that have already invested in Africa also shared their experience with the audience.

As a TICAD intern, the author was heavily involved in all aspects of AFRI-CONVERSE, a monthly event organized by the UNDP Tokyo office TICAD team. AFRI-CONVERSE is a networking and informal discussion platform for stakeholders in African development, organized to galvanize discussion on African development leading to TICAD 7. The event is hence a preparatory platform for stakeholders involved in TICAD 7 preparations, TICAD 7 itself, and ultimately development in Africa. The event took place on the final Friday of each month, in which experts from various disciplines and sectors were invited to discuss specific issues pertinent in efforts to promote sustainable African development.

The author was involved in all aspects of AFRI-CONVERSE from its 4th edition, which was held in September 2018. The work relating to this monthly event consisted of preparing registration forms and post-event questionnaires for participants, meetings with potential speakers at the event, on-site registration of participants, note-taking during the event for the drafting of event reports, and drafting the reports on the AFRI-CONVERSE event. The event attracts high-profile participants from various sectors including government, international organizations, UN organizations, the private sector, media, academia, and civil society. Hence, on a smaller scale compared to the 2018 TICAD Ministerial Meeting (but with some more frequency), the author was been able to interact with people from various professional, academic, cultural, and linguistic backgrounds and has been able to learn from speakers regarding the various matters that need to be addressed to successfully promote development in Africa.

As with the Ministerial Meeting, involvement in AFRI-CONVERSE has been an opportunity for knowledge expansion in addition to being in an environment with leaders, thus enabling a practice of leadership. Many perspectives were shared at these events, which have also helped broaden understanding of the various implications regarding African development efforts. In the 4th edition of AFRI-CONVERSE, speakers from civil society were invited to discuss proposals for TICAD 7. Six proposals for TICAD were made, based on the civil society meeting that was held in Cameroon in August 2018. Proposals included having a TICAD that has a multi-stakeholder structure for African development, promotes peace, respects human rights, represents Africa's cultural identity, and showing a concrete direction to a concerted collaborative, transparent, and constructive partnerships beneficial for all parties. Speakers and participants throughout the event particularly recognized the importance of food security and peace, given 820 million people are still living with hunger. A fundamental premise in discussions at this event was established, in which any form of development can be achieved if the people are fed. It was emphasized that a lack of food security can be a source of conflict, which highlighted the importance of addressing basic human needs that may be lacking before attaining development that is sustainable. This premise of the need to meet basic human needs was also addressed in the introduction of this dissertation, in order to better emphasize the need to develop appropriate strategies to overcome the societal challenges, of poverty and inequality, which are the main factors complicating the ability of rural households to meet these basic human needs discussed in this session of AFRI-CONVERSE.

AFRI-CONVERSE 5 focused discussions on prospects and challenges related to the industrialization of Africa through science, technology, and innovation (STI). Over 90 participants were in attendance as speakers and participants engaged in conversations regarding the role of STI in African development. Noted observations throughout the event included the importance of making an adjustment to the education systems in Africa, since matters such as STI and other academic subjects are taught in non-native languages. The consequence of this circumstance is the probability of education being a greater challenge for locals, especially the use of STI, which then complicates the ability of the African workforce to fully industrialize. Another participant then noted the importance of energy access as a prerequisite to industrialization, challenging the floor by asking how STI can be materialized when a majority of people in Africa lack access to electricity. This participant then added the importance of having more organized human settlements with basic infrastructure for electricity in order to make industrialization more readily achievable. In response, off-grid solar PV was agreed upon amongst audience members as a solution for providing electricity to communities that grid services are unable to reach.

Figure 6.2 – AFRI-CONVERSE at UNDP Tokyo

Photo credit: Author

At AFRI-CONVERSE 6, held in November, discussions focused on the prospects of Japanese SMEs (small and medium-sized enterprises) and entrepreneurs in Africa. Two speakers were invited to attend this event, namely Dr. Katsumi Hirano, Executive Vice President of JETRO, and Mr. Ken Shibusawa, CEO of Shibusawa and Company. Dr. Hirano provided extensive insight on how JETRO operates and promotes Japanese SME business and investment in Africa. So far, over 50 SMEs have started business through its support. He also stated that it is critical for Japanese businesses to look for opportunities to invest outside of Japan with its domestic market shrinking. In his observations and analysis of the African market, the Executive Vice President noted that the conventional market in Africa is already occupied by corporations from other countries, and that Japanese SMEs could potentially explore opportunities in the tech industry, focusing especially on the development of health care equipment which Japanese corporations are capable of producing with advanced and sophisticated technology. He further pointed out that high-standard stationary items produced by Japanese corporations can open up a new market opportunity in Africa. Regarding the strategy for promoting Japanese business engagement in Africa, Dr. Hirano mentioned the need to collaborate with stakeholders in the private sector from other countries, especially France and China. He mentioned the MOU between JETRO and its counterpart entity in France signed to expand both countries' business operations in Africa, especially since Japanese businesses have a smaller network and less experience in West African countries and could leverage those of French corporations. He commended the trend of some Japanese corporations (few in number) engaging in mergers and acquisitions to expand their business in Africa as a sound strategy. Mr. Shibusawa, on the other hand, discussed his initiative, the Japan-Africa Entrepreneurship Consortium, which through seed funding has helped several young energetic Japanese entrepreneurs take on the challenge of investing in Africa. It was noted that the funding is provided for support rather than a substantial financial investment. Mr. Masahiko Kiya, TICAD Ambassador from MoFA, was also present, and briefly discussed a plan to have a business-to-business discussion platform at TICAD 7, and an entrepreneurial business pitch contest, with winning entrepreneurs obtaining the financing to implement their business plans in Africa. Notable in this session of AFRI-CONVERSE was the approval for the establishment of partnerships being a good strategy for private sector to enter African markets.

AFRI-CONVERSE 7 focused on human resource development in Africa. Invited speakers were Tadashi Yokoyama, Head of the Asia External Representation Office at the African Development Bank,. Kaori Fujita, Director at Hinode Sangyo Corporation, Nico De Wet, an ABE initiative participant, Shogo Kudo, Assistant Professor at the University of Tokyo, and Kanako Matsuyama, of UNU-IAS (United Nations University Institute for the Advanced Study of

Sustainability). Nico De Wet discussed Kakehashi Africa, a voluntary network formed in Japan. Kakehashi Africa aims to strengthen ties among graduates of the ABE initiative, and enable graduates to take advantage of knowledge gained through the ABE initiative in the Kakehashi network after returning to their home countries. The term “Kakehashi” actually means “bridge” in Japanese, and is used to convey the idea of building a bridge between Japan and Africa; identifying the location and skillset of graduates from African countries, and using an online platform and various networking events to create connections and partnerships. The organization looks to establish itself as one which provides knowledge and matching services to Japanese companies and organizations. Members of the network include ABE graduates, and Japanese corporations interested in hiring ABE graduates. Graduates have the potential of being key contacts for enabling Japanese private sector companies to consider investing in Africa, making Kakehashi Africa a facilitator of this possibility. The ABE initiative, which was originally established at TICAD V, has enabled human resources from Africa to study and gain work experience in Japan which in turn will help to facilitate investment and human resource development in Africa. Kakehashi Africa has enabled the concept of private investment in Africa to become a greater possibility, a consequence of the initiation of the ABE initiative.

After AFRI-CONVERSE events, the TICAD intern was to handle many of the post-event responsibilities, starting with logistical arrangements immediately after the event to begin networking activities. In addition to logistics, the intern was in charge of gathering the questionnaires to produce data and prepare reports discussing the results, in order to find ways in which the AFRI-CONVERSE series can be improved. The intern was also in charge of drafting reports regarding the event itself, summarizing comments given by the speakers, moderator, and participants. Through involvement in and activities relating to AFRI-CONVERSE, the author has been able to forge new relationships, expand knowledge in the area of African development, and obtain perspectives that can play a role in the development and finalization of the doctoral dissertation. Given sustainable development fundamentally is recognized as a multi-dimensional approach, the various additional factors that influence development need to be recognized in order to develop a comprehensive understanding of the challenge of attaining sustainable development in Africa. The challenge could not be overcome following a one-size-fits-all approach, but a combination of multiple approaches and dimensions in order to produce desired results (as was the case with the Kenyan case study), and discussions throughout this AFRI-CONVERSE series have made this observation clear.

6.2.3 Workshop on Promoting Private Investment in Renewable Energy in Africa

Encouraged by the work experience gained as an intern at the office of the United Nations Development Programme in Tokyo, the decision was made to use TICAD 7 as a platform for organizing a workshop which focuses on discussions closely related to the research conducted for the dissertation. The workshop, titled "A Workshop on Promoting Private Investment in Renewable Energy in Africa" was to be held on August 27th, 2019, with the intention of gathering stakeholders in the renewable energy sector from various backgrounds to discuss energy policy for private sector engagement. Following the spirit of TICAD, stakeholders from government, international organizations, private sector, academia and civil society were invited to share their knowledge of the energy sector. Talking points for the workshop included opportunities and barriers to private investment in the energy sector, the role of the private sector in rural electrification, and policy proposals to accelerate universal access with renewable energy.

Discussions to be held at the event presented the opportunity to obtain from experts in the field multiple perspectives on policy for promoting renewable energy investment. It was also recognized that the discussions held at this event can be influential in the completion of the author's PhD dissertation. These objectives of learning from experts in the field and their evaluation of the investment environment for renewable energy led to the organization of this workshop. The event was undoubtedly to be an extension and expansion of the research that had been completed by the author.

After obtaining the approval from the Ministry of Foreign Affairs to organize this workshop as an official TICAD 7 side event, various speakers and participants were invited for the event through network connections obtained during the author's time as an intern at the UNDP. As mentioned, the event was open for everyone, from members of government to those of UN institutions, academia, private sector, and civil society. The invited speakers were Mr. Naoki Torii, Industrial Development Expert at the United Nations Industrial Development Organization (UNIDO), Dr. Jean-Claude Maswana, Professor of Economics at Ritsumeikan University, and Mr. Makoto Goda, CEO of Nippon Biodiesel Fuel. The author of this dissertation was also a featured speaker, using the platform to discuss the PhD research conducted in Kenya. Dr. Dimiter Savov Ialnazov was appointed as a moderator for this event. The involvement of stakeholders in the renewable energy sector from various backgrounds was valuable in enabling the diversification of perspectives regarding private investment, thus facilitating fruitful discussion throughout the event.

As the principal organizer of the event, the author contacted and personally met with each invited speaker to extend the invitation and discuss plans for the event. The speakers welcomed and accepted the invitation.

The workshop was to be initiated by the moderator, who introduced key concepts regarding renewable energy, sustainable development, and rural electrification. Following the introduction, short initial presentations were to be given by each speaker, touching upon various concepts relevant in the discussion of facilitating private sector investment in renewable energy. A panel discussion was to then take place, in which speakers and audience members engaged with each other addressing the topic of the workshop. Audience members and speakers were welcome to make comments or ask questions during this phase of the event. The event was then concluded with each speaker making closing remarks and making policy proposals for facilitating private sector investment in renewable energy in Africa, based on their perspectives and the panel discussions that were held.

Dr. Ialnazov initiated proceedings with an overview of renewable energy; discussing progress in attaining the 7th sustainable development goal, the importance of renewable energy, and off-grid rural electrification. Mr. Naoki Torii's presentation then followed, in which he discussed the current renewable energy market; revealing statistics on investments in various renewables globally, costs of renewable energy production (which are increasingly becoming competitive with fossil fuels), the tremendous potential of renewable energy production in Africa, and degrees of country readiness in Africa for private sector investment. Torii was able to illustrate that most countries in Africa are still in need of meeting many of the prerequisite conditions required for any form of private investment to occur, including supportive legislation, an issue that was also addressed in the Kenyan case study.

Dr. Maswana discussed in his talk the opportunities and challenges in investing in renewable energy in Africa. In his talk, he stressed the importance of continued industrialization to create employment for an exponentially growing African population. He also indicated that the power sector coincidentally plays an instrumental role in this industrialization. A question that must be posed, according to the Dr. Maswana, is the question of how African countries can improve the industrial climate to make it suitable for promoting investment in renewable energy. In concordance with observations made earlier by Mr. Naoki Torii (and complementing them), Dr. Maswana cited the need to improve institutional and regulatory settings, and improve financing conditions in the country. It was noted that most national electrification companies in Africa remain state-owned, which makes these enterprises competitors of the private sector, rather than facilitating private investment. Regarding the need to improve financing conditions, Dr, Maswana expressed the importance of public-private partnership schemes as an effective opportunity for realizing the renewable energy production potential in Africa.

Dr. Maswana's talk was followed by Mr. Makoto Goda who introduced and discussed business operations and experiences in Mozambique. Nippon Biodiesel fuel is a company that operates in several countries including Mozambique, where they produce biomass energy from Jatropha seed oil extracts. The author of this paper gave the final presentation (Figure 6.3), in which the renewable energy transition in Kenya was discussed, along with the research results conducted prior to the second visit in Kenya in 2019, which reveal the private sector as principal actors in rural electrification with solar PV for the sustained development of rural communities (Boliko and Ialnazov, 2019).

Figure 6.3 – TICAD 7 Workshop presentation

Photo credit: Author

The presentations were then followed by a panel discussion in which audience members engaged speakers on various aspects of renewable energy investment in Africa. Discussions during this phase of the event were focused on the challenges to promoting private investment, including institutional collaboration for investing in renewable energy, the need to develop local capacity for effective and profitable energy service provision, country readiness for private sector investment, and remarks regarding how the author's research results were obtained. Participants actively engaged with the speakers regarding the aforementioned challenges during this part of the event.

The event concluded with a citing of solutions to the aforementioned challenges, through policy recommendations being given by each speaker to facilitating private investment in renewable energy in Africa. Naoki Torii focused on the need to establish a facilitating environment in countries that have shown limited readiness for private investment, and an establishment of stability which ensures the security of various forms of private investment. Dr. Maswana addressed the importance having a sense of ownership, explaining that production of renewable energy in Africa should first and foremost be a local initiative ("Africans first"), and that foreign investment can then join this local initiative in a productive, innovative partnership.

As for Goda, encouraging the private sector in Japan to invest in Africa was an important step in enabling an increase in investments in renewable energy in Africa. He emphasized the need for Japanese companies to study, seek and tackle new challenges and opportunities abroad to expand business operations and enhance their business resilience. The author also took this opportunity to re-emphasize the importance of public-private partnerships, in order to effectively promote investment in renewable energy in Africa, giving the example of the MOU signed by Toyota Tsusho Corporation with the Government of Kenya to build a geothermal power plant in Kenya. It was argued that the effectiveness of such partnerships will be due to the combination of the expertise of the parties involved. Such partnerships would then facilitate technology transfer and sustained renewable energy investment in Africa. The moderator of the event then proceeded with concluding remarks before ending the session.

Overall, the event produced fruitful discussions which have been beneficial for all participants, with post-event social gatherings enabling participants to exchange contact information for future collaboration focused on the energy sector in Africa. The event, promoted as one of many side-events which were held during TICAD 7, attracted over 50 participants well versed in the renewable energy sector. It was also able to attain its objectives; (1) addressing important issues that need to be taken into consideration for stakeholders looking to promote investment in renewable energy in Africa; and (2) illustrating the tremendous renewable energy production potential that exists in Africa, which can be realized if investments are to be made effectively. The author has been able to hear from others their perspectives regarding the energy sector in Africa, which in certain ways influences the final writing of this doctoral dissertation.

6.2.4 Nexus – Practitioners' perspective and academic research perspective

Each participant in the workshop brought unique perspectives in addressing the facilitation of private sector investment in renewable energy. The experiences gained from working with stakeholders in African development also clarified the direction and findings of this doctoral research. In terms of the discussion of policy, several important things were done for the author's research. Discussions at the workshop echoed many of the observations that had been made in the Kenyan case study, contributing to the validation of the author's initial findings from the first field survey. Connections could be made between the need to develop local capacity for the provision of energy services (an observation made at the workshop), and the need to obtain consumer trust due to sub-standard products being disseminated in rural areas in the past (an identified barrier to renewable energy transition). Stakeholders actively working to promote sustainable development in Africa recognize the important role that private sector plays in promoting sustainable development. This observation is evident from the various meetings that have been held regarding TICAD. In concordance with the efforts of these stakeholders, the Kenyan case study developed in this dissertation had also concluded that private sector actors played a significant role in promoting sustainable development. The research also proposed the policy recommendation of establishing partnerships with the private sector, a sentiment that was echoed by one of the speakers of the workshop, and during several discussions held at AFRI-CONVERSE, and at the 2018 TICAD Ministerial Meeting Workshop. These connections between the matters discussed during internship experiences, the workshop, and the contents of the research help solidify the grounds upon which the research had developed.

In addition to the validation of several findings and conclusions, certain discussions helped to illustrate the uniqueness of the research. Several speakers at the TICAD 7 workshop recognized the importance of having a benevolent environment for private investment to take place, and the importance of having strong institutions and regulatory framework (comments by Naoki Torii, and Dr. Maswana). It was also revealed in this same discussion that most countries in Africa lack many of the prerequisites for facilitating private sector investment. These observations, therefore, help position this research as one which examines a success story (the one of Kenya) in the renewable energy transition, which can be replicated in various forms in other countries in SSA. Various concepts, literature, and data have led to the research being focused in Kenya, and this focus on Kenya has revealed many enabling actors for the renewable energy transition to occur in the rapidly changing country. Among these enablers is the institutional environment that has been created in

Kenya for the energy sector. Therefore, the workshop helped illustrate this doctoral research as a study of an exemplary success story in renewable energy investment, in addition to echoing many of the findings that have been made in the research. There is therefore the validation that lessons can be learned from the case of Kenya in this research in order to not only find a way to replicate this success in other developing countries, but also to ultimately promote sustainable development in other parts of Africa. The workshop, along with the internship work experiences, hence, have enriched and solidified the policy discussions that can be held regarding this current research that was completed in Kenya.

6.2.5 Nexus – Practitioners' perspective – Academic research perspective – Policy Recommendations

Hence, policy recommendations can be made, based not only on the research conducted, but also through the TICAD internship experience and the workshop conducted for TICAD 7. Firstly, it has been established that private sector actors need to be encouraged, and play a bigger role in promoting sustainable development. This is because it has been recognized not only in this academic research, but also by stakeholders which actively work to promote sustainable development in Africa that, the private sector has shown great capacity for enabling sustainable development. These observations solidify the case for addressing how to facilitate private sector investments in renewable energy not only in Kenya but in SSA. They also further substantiate the policy recommendation made from the academic perspective in this dissertation of focusing on developing an enabling regulatory environment for the private sector. Secondly, as mentioned from the academic perspective, the establishment of partnerships is a highly valued strategy for facilitating private investment, and this concept has been echoed in various discussions beyond academia. Such partnerships should also therefore be pursued.

Peace and stability, a topic discussed in AFRI-CONVERSE and addressed in recently established partnerships; is an issue that has not been addressed in the case study which certainly requires further policy action. Continued participation in the various conferences which promote development in Africa, will help Kenya to establish the partnerships which contribute to resolving the challenge of peace and stability which to a certain degree persists in certain parts of the country. Such participation can also enable Kenya to find opportunities to establish strategy (via partnerships) for developing local capacity, a fundamental driver for the dissemination and maintenance of renewable energy technologies in rural Kenya.

6.3 Stakeholder interviews

While undertaking the case study in Kenya, multiple interviews were conducted with key stakeholders in the Kenyan energy sector. Discussions during interviews provided insight on the development of the energy sector in Kenya. Additionally, challenges faced in implementing the national electrification plan, adopting renewable energy and promoting rural electrification were also discussed, giving the author a deepened understanding of current circumstances in the Kenyan energy sector.

Interviews were conducted in September 2017 and September 2019, with discussions about the Kenyan energy sector being held with managers of the rural electrification projects assessed in the case study, and representatives from UN Habitat, Strathmore University, the Ministry of Energy, Energy and Petroleum Regulatory Authority (EPRA), Kenya Power, and the Rural Electrification and Renewable Energy Corporation (REREC). One principal observation was made by the author upon completion of the interviews: the Kenyan energy sector has the regulatory framework and the institutions in place to enable the country to attain its national electrification objectives. There is a clear ambition in attaining the objectives that have been set forth for the energy sector, and the interviews have revealed that various steps have already been taken to work towards their achievement.

Unlike in the recent past, it has been revealed during the interview held at EPRA that many regulations regarding operations in the energy sector have been streamlined to facilitate engagement in energy related services. Regulations were under revision, which meant there was a transition phase in which many regulations were being adjusted to facilitate operation in the energy sector. This discussion painted a clearer picture regarding the unclear regulations specified by some of the rural electrification project managers that were interviewed in discussions regarding their experiences operating in Kenya. It was also discovered during discussions at the Ministry of Energy that Kenya aims to extend the national grid to any household within 15 km of the grid, and expects to connect the more remote households to modern energy services with mini-grids. Over 100 mini-grids are expected to be constructed in order to complete this task according to the 2018 Kenyan National Electrification Strategy (Ministry of Energy 2018).

In discussions regarding private sector involvement with the Ministry of Energy, a power auction system was mentioned as an existing plan the government of Kenya looks to implement in order to make energy services in Kenya more affordable. References were also made to the Public

Private Partnerships Act 2013, establishing the Public Private Partnerships Unit which reviews and approves various proposed partnerships based on regulations for PPPs to be formed. Interviews with REREC revealed that many of the mini-grids that have been commissioned are hybrid mini-grids and additional mini-grids are expected to be hybridized with increased capacity of solar PV generation. However, while financing from government for the mini-grids have been a challenge due to limited resources, partnerships formed for the Kenya Off-Grid Solar Access Project (KOSAP) have enabled continued development of off-grid electrification activity. Private sector involvement has therefore been confirmed during interviews with REREC and the Ministry of Energy with regards to achieving the 100% national electrification objective, especially with regards to the construction of the mini-grids. The formulation of partnerships for the construction of several geothermal, solar, coal, power plants (some being independent power producers) are currently undergoing various phases of approval according to the PPP Unit (PPP Unit 2019). The referenced document also reveals that the coal power plant proposal is currently in abeyance (temporary suspension).

The challenges cited in these interviews in working towards 100% electrification are challenges that have been cited throughout this dissertation. Unclear regulatory environment, capacity building, and financing were cited repeatedly as the challenges which needed to be overcome in achieving the national electrification plan. REREC cited a unique observation regarding tribal conflicts complicating the possibility of connecting mini-grids to each other.

Results of discussions during these interviews have led the author to revisit and emphasize many of the policy recommendations that had been made. Based on discussions during these interviews, it is again recommended that the regulatory framework be fully established, finalized and distributed to relevant stakeholders in order to enable each stakeholder to best understand the roles to be assumed in the energy sector (eg. there is currently some overlap in KPLC and REREC mandates). Additional emphasis is also placed on continued pursuit of partnerships to proceed with the completion of the national electrification plan. While the Public Private Partnerships Act was established in 2013, very few off-grid electrification partnerships have been formed in Kenya, and those that have been formed with private sector actors seem to have been established under the radar. Partnerships should be actively pursued, especially given discussions of the role the private sector has played in off-grid electrification in this dissertation, and the frequency with which the term “partnership” has been used with regards to attaining the sustainable development goals (SDG#17) and promoting sustainable development in Africa.

While the currently pursued partnerships will have a significant impact on electricity generation capacity in Kenya, the development of local capacity is a challenge that must not be overlooked. Additional training programs, even through partnerships, can be established in order to enhance the capacity of local actors to undertake rural electrification projects effectively. To this point, discussions at UN Habitat and Strathmore University revealed that ENEL, an Italian multinational energy company is actively operating mini-grid development academies. The Kenya Power Institute of Energy Studies and Research (IESR) was also established in order to educate and train future actors in the Kenyan energy sector.

Given the findings from discussions held with the various stakeholders in the energy sector, the author concludes that the Kenyan energy sector is a success story in renewable energy transition and rural electrification given the active steps that key actors are taking to attain its national electrification goals. While certain progress remains to be made, the Kenyan energy sector has demonstrated tremendous potential for promoting sustainable development through national power generation, especially via renewable energy sources. Findings from the interviews also helped confirm many of the policy recommendations made as a result of the case study, and Kenya as a country has taken many of the steps in undertaking the proposed recommendations in order to solidify its energy sector, promote sustainable development, and ultimately enable the country to become a middle-income country upon completion of the Kenya Vision 2030.

6.4 Conclusion

This chapter focused on the formulation of policy recommendations, based on three premises: the results of the Kenyan case study, the author's experiences working with stakeholders promoting development in Africa, and discussions held during interviews with several key actors in the energy sector. It has also focused on illustrating how the author's internship experience was an integral part of the author's research, and supporting the recommendations. It was hence established in this chapter how several policy recommendations were echoed by practitioners in the field promoting African development. The recommendations were also echoed during discussions in interviews with key actors in the Kenyan energy sector.

The policy recommendations cited in this Chapter were the need to establish various partnerships which favor private sector investment in the renewable energy sector in Kenya, a streamlining of regulations to facilitate operations in the energy sector, increased advocacy for clean cooking, and sustained local capacity development. Discussions during interviews with key actors in the Kenyan energy sector have revealed that many of the recommendations made in this dissertation are in the process of being undertaken in order to facilitate private sector investment, further promote off-grid rural electrification, and ultimately promote sustainable development. Figure 6.4 illustrates a diagram of the interrelated recommendations made based on the three premises.

Figure 6.4 - Dissertation Policy Recommendations Summary

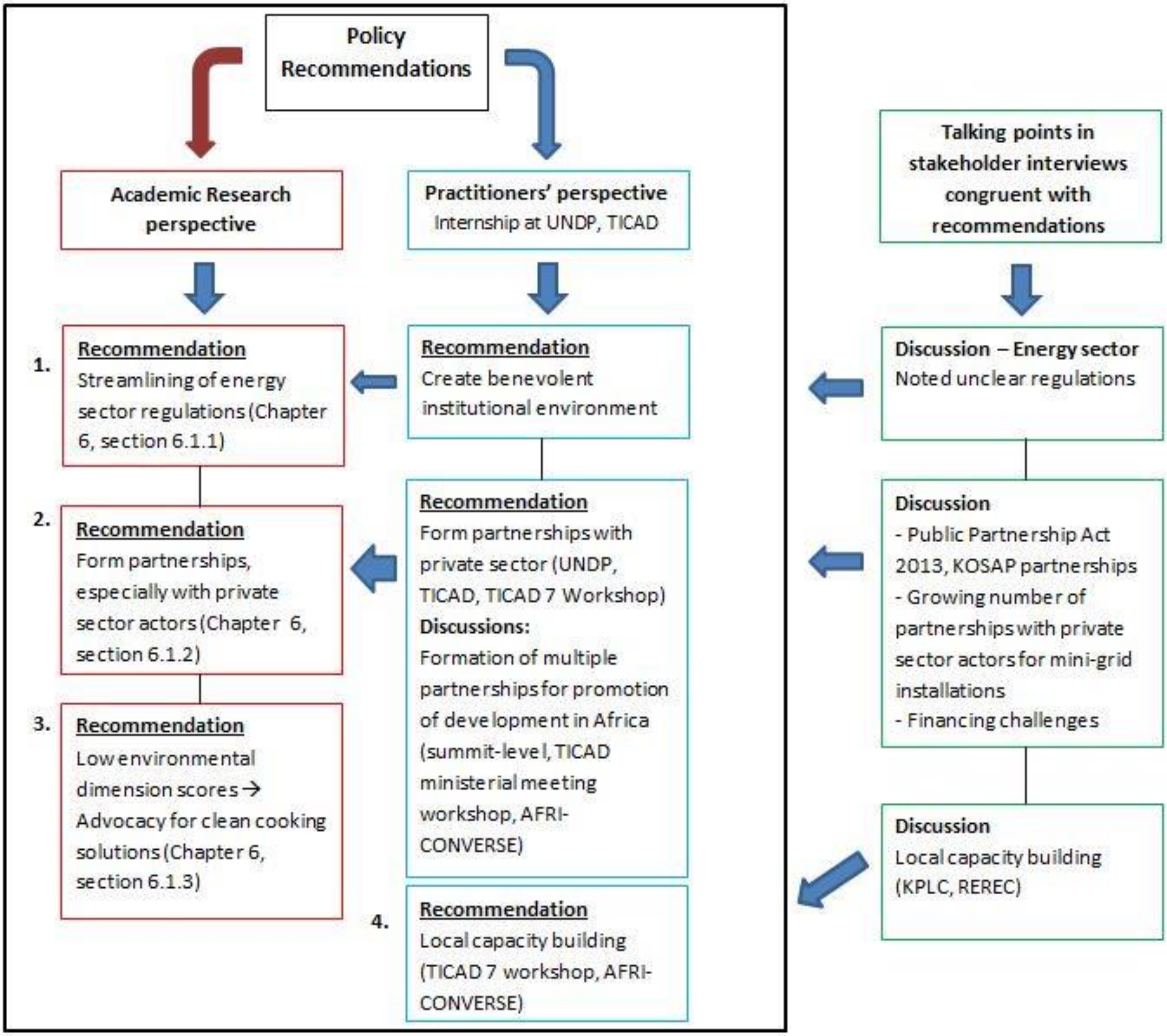


*Diagram constructed by author based on Chapter 6 policy discussions

The diagram in Figure 6.4 summarizes the policy discussion in this Chapter. It illustrates the main policy recommendations that have been made based on the results of the Kenyan case study, discussions held with experts working to promote African development, and discussions held with Kenyan energy sector stakeholders. In discussing policy recommendations based on the results of the research, recommendations made by experts in the field, and discussions in interviews held with key stakeholders in the Kenyan energy sector helped validate the recommendations made based on the academic research. Local capacity development, an aspect that was not addressed in the research, is also recognized based on discussions with experts as an important policy measure to be taken to strengthen the off-grid energy sector in Kenya. As illustrated by the diagram, the author looked to make policy recommendations based not only on the findings of the case study; but also based on an accumulation of experience working with experts, and discussions held with stakeholders in the Kenyan energy sector. The similarities of the issues addressed in the aforementioned policy recommendations helped to further validate the initial recommendations made by the author.

While some challenges need to be overcome in attaining these policy related objectives, Kenya has shown its tremendous potential for renewable energy generation and has demonstrated ambition in being able to attain its national electrification objectives effectively. The author therefore considers Kenya to be a success story in rural electrification and renewable energy transition, and is hopeful that the example set by Kenya can be studied by other countries in SSA in order to determine effective strategies for transforming their respective energy sectors and attain the sustainable development that not only contributes to improved societal well-being, but promotes human survivability. This research has looked to contribute to human survivability studies by following the rural electrification and renewable energy transition that has taken place in Kenya.

Conclusion

Paper Summary

This research looked to contribute to human survivability studies (HSS) through the lens of energy policy for the promotion of off-grid rural electrification in Kenya. HSS is a new academic research field which aims to develop solutions to societal challenges. Other characteristics of HSS are the adoption of a multidisciplinary research approach and the integration of academic research findings with practical insights obtained from integrating and working with key stakeholders. In this research, the societal challenges addressed in this research were poverty, inequality, and climate change, which primarily implicate the discipline, but also touched upon the fields of engineering, anthropology, business administration, and environmental science (an interdisciplinary academic field itself).

Given the challenges, a study on improving well-being of rural communities in developing countries was required, and this is known given these societal challenges exist primarily in these areas. Further examination of the literature and secondary data revealed that Sub-Saharan Africa is the only region in which poverty levels have remained the same, hence the research focused on Sub-Saharan Africa. Sustainable development was then recognized as the process required for resolving these societal challenges, and clean energy access was identified as the mechanism through which standard of living can be improved.

Additional literature revealed Kenya as the leading country in Africa in renewable energy investments. As a result, upon learning of the many enablers that have made Kenya a leading country in renewable energy investments, a case study of rural electrification in Kenya was conducted, in order to determine how rural electrification has impacted the standard of living of rural households, and how it has promoted sustainable development in these communities. The case study was conducted by using questionnaires to interview households and managers of rural electrification projects, using a sustainability assessment framework which assessed various dimensions of a rural electrification project in its ability to ultimately promote sustainable development. Interviews were also undertaken with key actors in the Kenyan energy sector to deepen knowledge of the electrification experiences and challenges in the country. The result of the case study, in conjunction with experiences working with stakeholders actively looking to promote development in Africa, contributed to the formulation of policy recommendations which promote rural electrification in accordance with sustainable development.

While the Introduction section introduced the key concepts elaborated upon in the dissertation, Chapter 1 detailed the solution to the societal challenges that exist in Sub-Saharan Africa, and the review of literature and secondary data in Chapter 1 revealed Kenya as a leader in renewable energy investments, hence the identification of the country as an ideal setting for the development of this research. Chapter 2 then further elaborated on why Kenya has proved to be a successful case in the renewable energy transition, before concluding with a question regarding how this success can be verified and evaluated. In Chapter 3, a literature review of various rural electrification evaluation methods was completed, revealing how the employment of a sustainability assessment framework could examine the renewable energy transition, or in more specific terms the performance of an electrification project from five dimensions (technical, economic, social, environmental, and institutional dimensions). The author used the framework to discuss the methodology employed in Chapter 4, before sharing the results of the case study in Chapter 5 and then subsequently formulating policy recommendations in the 6th Chapter of this dissertation.

This dissertation thus followed a logical, sequential structure in which various concepts and ideas were introduced in the first four sections of the paper which led led to the development of the case study that was conducted in Kenya. "Human survivability studies" was ultimately the principal academic perspective that drove this research, guiding the author in the development of this dissertation, with the aim to promote the betterment of societal welfare. The author looked to achieve this through the Kenyan case study, the formulation of policy recommendations based on the results of the case study (and other aforementioned premises), and the use of this research as an illustration of a success story which could be replicated in unique forms in other countries in Sub Saharan Africa.

Research Findings

This dissertation looked to attain 3 principal objectives. The first objective was to contribute to human survivability studies by undertaking research which ultimately aims to promote societal well-being. The second objective, closely related to the first, was the formulation of an appropriate framework to enable the assessment of rural electrification projects, with Kenya being chosen as an ideal setting for obtaining valuable information and data. The third objective was to develop policy recommendations that can be implemented for promoting electricity access which is compatible with sustainable development in rural communities in Kenya. This nexus of objectives were established in order to promote societal well-being.

The Kenyan case study revealed that the three private sector companies included in the sustainability assessment were the better performers compared to the three public sector actors that were evaluated. Additionally, the Mfangano mini-grid was the best performer amongst projects that were undertaken by public sector actors. These findings had the policy implication of finding ways to create a supportive business environment for the private sector to expand its contribution to sustainable development in rural Kenya; given the ability it has shown in the assessment to improve welfare of rural communities. Based on the research findings, a number of policy recommendations were discussed with key actors in the Kenyan energy sector, and in experiences working with stakeholders actively engaged in promoting sustainable development in Africa. The policy recommendations included the importance of formulating strategic partnerships (for mini-grid installation, grid-tied solar PV, infrastructure development, enhanced peace and security), streamlining and establishing regulations governing the energy sector to eliminate ambiguity, advocacy for clean cooking solutions, and continued local capacity development (human resource development and energy service training).

Research Contribution

As discussed in Chapter 3 of this dissertation, multiple studies regarding rural electrification have been conducted. This research however undertakes the study of rural electrification study using a unique approach: the employment of a contextualized sustainability assessment framework, in order to evaluate the degree to which rural electrification projects have promoted sustainable development in rural communities. This method for "comparing apples and pears", originally proposed by Ilskog (2008), has been undertaken to assess a single rural electrification project in a developing county, or to assess rural electrification projects in several countries. This research pioneers the (1) combination of quantitative and qualitative research methods, in conjunction with (2) the use of the sustainability assessment framework, to (3) assess multiple rural electrification projects in a specific country, (4) in order to formulate policy recommendations that effectively promote sustainable development in rural communities. It is this aspect of the dissertation that establishes the originality of the research, and contributes to the knowledge regarding rural electrification in Sub-Saharan Africa (more specifically in Kenya).

Research Limitations

While the case study was successfully conducted, several limitations hampered the ability of this research to be even more comprehensively completed. The research employed qualitative and quantitative methodologies, and the qualitative aspect of the research played a role of paramount importance in contextualizing and validating scores obtained through the quantitative dimension of the research method. The research findings produced from the quantitative method could have been more conclusive had the sample sizes gathered been larger for certain projects. Nevertheless, a deepened understanding of the Kenyan energy sector, the renewable energy transition which has taken place in Kenya, and the rural electrification experiences of the projects assessed undoubtedly clarified many of the findings of the Kenyan case study undertaken with the sustainability assessment framework.

Additionally, being able to meet key actors in the energy sector has been a challenge. Changes in circumstances while conducting the field survey in Kenya forced the author to make some adjustments to the final field survey plan. Thus, it is good for future research to consider a comprehensive plan which takes into consideration multiple variables that can be accounted for, enabling a researcher to adjust if circumstances on the ground negatively affect research progress. Time and logistical constraints also complicated the ability to complete the research, due to political unrest and financial restrictions. The author of this research looked to mitigate for these limitations with the development of a deepened qualitative understanding of the Kenyan energy sector and rural electrification experiences of the six projects that were assessed in this case study. Knowledge of on-ground experiences relayed to key decision makers in the energy sector would help in the employment of policy which is favorable for overcoming various challenges faced in rural communities that may not have been recognized.

A final limitation is the use of the sustainability assessment framework for undertaking this case study. Few studies have employed this approach in the literature to study rural electrification, which raises the question of the viability of the methodology. However, such studies are part of a newer set of academic literature (especially starting in 2008), which address the attainment of the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs), hence the author believes that in working to contribute to sustainable development and the attainment of the SDGs, this branch of literature employing this methodology can be expected to increase.

Potential future research directions

This research is one which focuses on the end consumer, focuses on well-being, and human survivability. Thus, there is a greater focus on the sustainable development of rural communities, through the alleviation of poverty, inequality, and enhanced resilience to the effects of climate change. There is therefore limited consideration for issues such as technical or economic feasibility, since these aspects of rural electrification were beyond the scope of this dissertation. In this research, the technical and economic dimensions of a rural electrification project were examined to determine the effectiveness with which modern energy services were provided (for the technical dimension), the profitability of a project and the economic impacts that the projects have had on rural households. Technical and economic feasibility are indirectly addressed in chapter 6, where the formation of strategic partnerships is discussed. Such partnerships encompass the technical and economic feasibility challenges (eg. engineering and financing) related to private investment and rural electrification, and are meant to be evaluated by the implicated parties in a partnership. Undertaking such research would not have contributed to knowledge in the academic field addressing rural electrification, given it has been conducted by various stakeholders, including and especially outside academia. It is nevertheless recognized that these aspects of rural electrification projects are of paramount importance, and almost naturally play a crucial role in being part of the "next step" to be taken with regards to research directions that can be chosen, following the results of this case study.

This research is also one in which a sustainability assessment framework was contextualized to study the case of Kenya, and the rural electrification experiences in Kenya. This contextualization is done to take into account the realities and variables existing on the site chosen for a field survey. Previous authors have contextualized their frameworks for their specific assessments, and future employment of this framework should also take into account unique aspects of a specific location chosen for conducting a sustainability assessment. The sustainability assessment framework is a tool that acts as a measuring stick to evaluate the performances of various rural electrification projects in promoting sustainable development. However, as in the case of previous studies, taking into account the variables and circumstances of the location in which such an assessment framework is to be employed is a valuable methodology to employ for the assessment. For instance, the case of Kenya is one in which geographic circumstances were favorable for facilitating and accelerating the energy transition. The case of Kenya is unique, making the assessment framework unique for Kenya. However, the exact framework used for Kenya in this dissertation cannot be applied in countries where geographic circumstances (circumstances which may even demonstrate an area being more prone to natural disasters) are not as favorable as in the case of Kenya. This difference in local circumstances is an example of what must be taken into account in formulating a suitable assessment framework to fairly evaluate rural electrification projects. Therefore, the concept of resilience, or even the “service reliability” indicator used in this dissertation, can be explored in greater detail to evaluate project sustainability, and help establish appropriate policy and regulations which improve the sustainability of electrification projects. An additional indicator which becomes of paramount importance is the availability and effectiveness of maintenance services, which in this dissertation was accounted for in the “service availability” indicator. Project profitability also becomes a valuable indicator to further examine how an organization, private sector company or NGO is able to financially support their project maintenance operations. Supplemental, unique findings from these indicators would produce results which facilitate energy policy discussion for the countries in which the framework is employed, given the framework used had taken into account various existing local circumstances in formulating a proper methodology for electrification project evaluation.

Therefore, another future research direction to be considered is the use of this framework to assess rural electrification in other countries. However, such an assessment is completed effectively when local circumstances are taken into account in the formulation of the framework which looks to assess the promotion of sustainable development. Such was the case in the development of this research, and should be the case for future studies looking to employ a sustainability assessment framework.

Kenya has proved to be a success story in the renewable energy transition. An examination of key factors which have enabled the renewable energy transition to take place in Kenya can be identified as blueprints, applied to the case of a separate country in which related circumstances are recognized. This use of the Kenyan blueprint then enables appropriate decision-making to replicate the renewable energy transition success that has been experienced in Kenya. In this Kenyan case, key enablers of energy transition primarily included government, geography, private market development, and partnerships. Such enablers can be examined in future energy transition assessment studies, in order to identify (based on a deepened understanding of local context) proper strategies unique to the specific location chosen for the study in order to facilitate energy transition. The author believes the employment of this research in other countries is possible as long as an understanding of the Kenyan case in renewable energy transition illustrated in this paper is used to effectively determine how this success can be replicated in other countries; with full knowledge of the importance of contextualization. Employing such a methodology in academia will certainly contribute to the promotion of sustainable development in other parts of the world. There is therefore this possibility of studying the Kenyan renewable energy transition as a success story, in order to determine how this same success can be achieved in other countries not only in Sub-Saharan Africa, but in other regions around the world.

Concluding Remarks

The information obtained from data collection activities for this case study has been accurately reflected in the sustainability assessment scores. While the number of respondents is relatively small, the author has obtained abundant information through his interview survey which enables him to undertake a comprehensive assessment of the rural electrification projects.

The sustainability assessment framework is the tool that has helped the author to reveal some of the shortcomings of rural electrification in terms of promoting sustainable development, including its limited impact on poverty alleviation and its inability to eliminate the dependence on traditional biomass. While energy access is meant to improve human, social, economic and environmental conditions, the author's analysis of the realities on the ground makes clear that additional steps need to be taken in conjunction with rural electrification in order to enhance the effectiveness of the projects in promoting sustainable development.

Examples of such steps have been given in the policy recommendations in Chapter 6 of this dissertation. It must be recognized that the sustainability assessment framework has given only a snapshot of the impacts of rural electrification in Kenya. In its current form it is not an instrument that can be used to assess the future progress of sustainable development in rural communities. Hence, we need to adapt the framework, to enable an assessment of the progress that has been made over time. The revised version of the framework should be able to demonstrate whether the impacts of the policy for promoting sustainable development will last in the future. The author is therefore hopeful that the results of this research will inspire future research in Kenya and in other developing countries to improve the measures of progress towards sustainable development.

Acknowledgements

Too many supporters in this academic journey which began in 2015 have helped to reach this point, the acknowledgement page of this dissertation. There have been many challenges, many opportunities, and new discoveries made, making the entire academic endeavor unforgettable. I would like to therefore take this space to recognize those that have been a part of this incredible journey.

The completion of this dissertation would be impossible without the support provided by the Graduate School of Advanced Integrated Studies in Human Survivability (GSAIS) at Kyoto University. The school has given me a platform to think creatively in order to examine how various societal challenges can be addressed, and for being able to provide this platform, I am forever grateful. I was able to grow as an academic, discover opportunities and new environments in a way only this school is able to facilitate, so I would like to express my deepest appreciation for the process that I have been able to undergo to complete this dissertation, in this specific graduate school.

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APPENDIX

Appendix A – Electricity access in Sub Saharan Africa 2017

Source: IEA, *World Energy Outlook-2018*

Electricity Access in Africa

	Rate of access						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2017	2017	2017	2017
Africa	**35%**	**39%**	**43%**	**52%**	**74%**	**36%**	**603**
Sub-Saharan Africa	**23%**	**28%**	**32%**	**43%**	**67%**	**28%**	**602**
Central Africa	**10%**	**15%**	**21%**	**26%**	**49%**	**6%**	**99**
Cameroon	20%	47%	49%	62%	96%	19%	9
Central African Republic	1%	2%	2%	3%	5%	1%	5
Chad	2%	3%	4%	8%	32%	1%	14
Congo	21%	23%	37%	60%	82%	18%	2
DR Congo	7%	7%	15%	15%	35%	0%	69
Equatorial Guinea	22%	25%	27%	80%	93%	48%	<1
Gabon	31%	46%	60%	91%	97%	38%	<1
East Africa	**10%**	**17%**	**21%**	**41%**	**63%**	**26%**	**173**
Burundi	4%	5%	5%	10%	35%	6%	10
Djibouti	46%	48%	50%	42%	54%	1%	<1
Eritrea	17%	23%	32%	44%	86%	17%	3
Ethiopia	5%	15%	23%	45%	71%	38%	58
Kenya	8%	14%	18%	73%	90%	68%	13
Rwanda	6%	8%	10%	43%	69%	37%	7
Somalia	5%	9%	14%	17%	35%	4%	12
South Sudan	0%	0%	0%	1%	4%	0%	12
Sudan	30%	31%	36%	45%	71%	31%	22
Uganda	4%	9%	9%	20%	23%	19%	34
West Africa	**33%**	**37%**	**42%**	**51%**	**77%**	**29%**	**182**
Nigeria	40%	47%	50%	60%	80%	40%	77
Benin	22%	23%	27%	30%	54%	9%	8
Cote d'Ivoire	50%	49%	59%	60%	88%	31%	10
Ghana	45%	51%	61%	84%	97%	69%	5

Senegal	30%	35%	54%	65%	90%	43%	6
Togo	9%	18%	28%	36%	64%	16%	5
Burkina Faso	13%	9%	15%	18%	58%	1%	16
Cape Verde	59%	65%	70%	96%	100%	89%	<1
Gambia	18%	27%	35%	45%	66%	13%	1
Guinea	16%	18%	20%	17%	46%	1%	11
Guinea-Bissau	10%	11%	12%	10%	14%	8%	2
Liberia	0%	1%	2%	10%	16%	3%	4
Mali	12%	14%	17%	38%	83%	6%	11
Mauritania	15%	17%	19%	30%	56%	1%	3
Niger	7%	8%	9%	12%	68%	1%	19
Sao Tome and Principe	53%	55%	57%	68%	87%	22%	<1
Sierra Leone	9%	11%	12%	20%	19%	20%	6
South Africa	**66%**	**81%**	**83%**	**84%**	**84%**	**84%**	**9**
Other Southern Africa	**14%**	**16%**	**22%**	**32%**	**63%**	**14%**	**140**
Angola	12%	17%	40%	43%	69%	6%	19
Botswana	22%	40%	45%	57%	69%	32%	<1
Comoros	30%	35%	40%	69%	89%	62%	<1
Lesotho	5%	12%	17%	34%	63%	24%	1
Madagascar	8%	16%	17%	23%	52%	7%	20
Malawi	5%	7%	9%	11%	49%	3%	17
Mauritius	100%	95%	99%	100%	100%	100%	<1
Mozambique	7%	7%	15%	28%	57%	12%	21
Namibia	34%	34%	44%	56%	78%	34%	1
Seychelles	50%	54%	58%	99%	99%	99%	<1
Swaziland	25%	30%	35%	75%	90%	71%	<1
Tanzania	11%	12%	15%	33%	65%	17%	39
Zambia	12%	19%	19%	33%	67%	6%	12
Zimbabwe	40%	36%	37%	34%	81%	11%	11

Appendix B – Use of traditional biomass in Sub-Saharan Africa 2017

Source: IEA, *World Energy Outlook-2018*

Access to Clean Cooking, Summary by Region

	People without access to clean cooking				Population without access (million)	Population relying on biomass (million)
	2000	2005	2010	2017	2017	2017
Africa	**76%**	**74%**	**73%**	**71%**	**895**	**825**
Sub-Saharan Africa	**90%**	**89%**	**87%**	**84%**	**893**	**824**
Central Africa	**94%**	**93%**	**92%**	**90%**	**120**	**118**
Cameroon	88%	83%	79%	74%	18	17
Central African Republic	>95%	>95%	>95%	>95%	5	4
Chad	94%	>95%	>95%	94%	14	14
Congo	94%	>95%	86%	75%	4	3
DR Congo	>95%	>95%	>95%	>95%	79	79
Equatorial Guinea	78%	78%	78%	76%	<1	<1
Gabon	37%	30%	20%	14%	<1	<1
East Africa	**>95%**	**95%**	**91%**	**89%**	**261**	**253**
Burundi	100%	>95%	>95%	>95%	10	10
Djibouti	>95%	>95%	94%	94%	<1	<1
Eritrea	94%	93%	92%	90%	5	4
Ethiopia	>95%	>95%	>95%	93%	98	97
Kenya	>95%	>95%	93%	85%	42	36
Rwanda	>95%	>95%	>95%	>95%	12	12
Somalia	100%	100%	>95%	94%	14	14
South Sudan	>95%	>95%	>95%	>95%	12	12
Sudan	88%	81%	65%	64%	26	26
Uganda	>95%	>95%	>95%	94%	40	40
West Africa	**>95%**	**95%**	**94%**	**89%**	**332**	**280**
Nigeria	>95%	>95%	>95%	93%	178	128
Benin	100%	>95%	94%	>95%	11	10
Cote d'Ivoire	94%	92%	80%	76%	18	18
Ghana	90%	87%	88%	71%	20	20
Senegal	72%	56%	69%	72%	11	11

Togo	>95%	>95%	>95%	90%	7	7
Burkina Faso	>95%	>95%	92%	87%	17	17
Cape Verde	33%	35%	26%	20%	<1	<1
Gambia	91%	91%	>95%	90%	2	2
Guinea	>95%	>95%	>95%	>95%	12	12
Guinea-Bissau	>95%	>95%	>95%	>95%	2	2
Liberia	>95%	>95%	>95%	>95%	5	5
Mali	>95%	>95%	92%	>95%	18	18
Mauritania	72%	63%	60%	49%	2	2
Niger	>95%	>95%	>95%	>95%	21	21
Sao Tome and Principe	77%	77%	90%	>95%	<1	<1
Sierra Leone	>95%	100%	>95%	>95%	7	7
South Africa	**45%**	**36%**	**21%**	**15%**	**9**	**6**
Other Southern Africa	**86%**	**85%**	**87%**	**83%**	**171**	**168**
Angola	55%	55%	58%	49%	15	14
Botswana	54%	48%	44%	42%	<1	<1
Comoros	91%	>95%	95%	92%	<1	<1
Lesotho	79%	79%	67%	62%	1	1
Madagascar	>95%	>95%	>95%	>95%	25	25
Malawi	>95%	>95%	>95%	>95%	18	18
Mauritius	7%	6%	3%	2%	<1	<1
Mozambique	>95%	90%	>95%	94%	28	28
Namibia	64%	59%	60%	54%	1	1
Seychelles	2%	2%	2%	2%	<1	<1
Swaziland	70%	61%	72%	46%	<1	<1
Tanzania	>95%	>95%	>95%	95%	54	53
Zambia	86%	84%	83%	83%	14	14
Zimbabwe	70%	66%	71%	70%	12	11

Appendix C – Manager Questionnaire

1. **Name** (name of organization/institution/project)

2. **Organization type**
    - Government
    - State owned enterprise
    - Domestic private enterprise
    - Foreign private enterprise
    - International NGO
    - Domestic NGO
    - Local community
    - Other (please specify):______________________________

3. **Address**

4. **Manufacturing location/address**

---

5. **Project name (if applicable)**

6. **Project Goals/Objectives – What is the project looking to achieve?**

---

7. **How many years has the organization been in business?**

---

8. **Service type**

- Grid connection/operation
- Mini-grid connection/operation
- Solar Home System (SHS) installation
- Other (please specify):_________________________

---

9. **When was the system installed? (for mini-grid)**

10. What is the capacity of the system? _________________

11. How much did the installation cost?

12. For mini-grid – Where is the system located?

13. For SHS – Where are the systems located?

14. Mini-grids – Who (which group/company/organization) is currently operating the system?

15. Energy Source (please select the choices which apply, and specify percentages)

- Diesel:_____%
- Solar:_____%
- Hydro:_____%
- Geothermal:_____%
- Wind:_____%
- Biomass:_____%
- Other (please specify): 40KWh peak solar 10 KW diesel

16. Who are the consumers that obtain your products/services?

- Households
- Businesses
- Organizations/Institutions
- Schools
- Health centers
- Other:___________________

17. How do/did consumers obtain your product/service?

- One-time purchase
- One-time purchase with discount
- Periodic payment – installments – pay-as-you-go
- Donation/gift/free

18. If you responded "periodic payment – installments" in the previous question how often are payments typically made?

- Daily
- Weekly
- Monthly
- Semi-Annually
- Annually
- Other (please specify):________________

19. **For installments – Please rate the frequency with which consumers default on a payment (fail to make payment)** (circle one)

Never Rarely Occasionally Often Very often

20. **Does the system ever experience technical difficulties which lead to a power outage (blackout)?**

21. **If so, what is the typical duration of a power outage before restoration of service?**

22. **When there are no power disruptions, is the system capable of 24/7 service?** (all respondents welcome; *this question applies especially for SHS providers*)

23. **Are operation and maintenance costs fully covered from the revenue received from consumers of your product/service?**

24. **If not, how are the costs covered?**

- Subsidy
- Loan (other organizations/institutions)
- Loan (from bank)
- Other (please specify):____

25. **Project business financial situation for the past 3 years (select one):**

- Profitable
- Breaking-even (no financial profit, no loss)
- Unprofitable

26. **Profitability percentage (please specify):**__________%

27. **What percentage of profits (if any) are reinvested in business operations?** (please specify, 0%-100%)

28. **How would you define the income class of your household consumers?** (select choices which apply)

- Low
- Middle-low
- Middle
- High middle
- High

29. For Solar Home Systems – What happens to the product at the end of its life cycle?

- Disposal
- Recycle
- Other (please describe):

30. What were some difficulties/challenges that were encountered throughout the process of providing your service to the consumer and how were they over come?

31. What are some current difficulties/challenges facing daily service operations and how are they being managed?

32. For mini-grids – What role does the local community play in managing the mini grid (if applicable)?

Appendix D – Consumer Questionnaire

<u>Electrification Survey</u>

Thank you for accepting to complete this questionnaire. I am a student currently studying in to obtain a PhD. My academic research focuses primarily in the field of economics, and my progress in this research has led me to the distribution of this questionnaire for information gathering and data collection purposes. You, the respondent, are thus indeed helping me to learn much more in my academic work, and are therefore also my teacher and helper. All information and data provided on this form will be used for academic research purposes only, so it will not be shared, distributed, or made public in any way. I would like to again express my sincere gratitude for your kind participation in the development of my work, and would like to contact you if there are any further questions.

Name: **Telephone number:**

<table>
<tr><td>1. Gender
○ Male
○ Female</td><td colspan="2">2. Location</td><td colspan="2">3. Age</td><td>4. No. of people in household</td></tr>
<tr><td colspan="4">5. Occupation (job for a living)</td><td colspan="2">6. Number of children in household (under 18 years of age)</td></tr>
<tr><td colspan="2" rowspan="2">7. Marital Status
○ Single
○ Married
○ Remarried
○ Divorced
○ Widower/Widow</td><td colspan="2" rowspan="2">8. Tribe</td><td colspan="2">9. Monthly income (KES)</td></tr>
<tr><td colspan="2">10. Monthly expenses (KES)</td></tr>
<tr><td colspan="6">11. When did electricity start being used in the household? (Year of purchase, month/year)</td></tr>
<tr><td colspan="6">12. Electricity source (select choices which apply)
○ National Grid (Kenya Power)
○ Mini-grid
○ Solar Home System (SHS)

13. Product Seller (or service provider) (for those that chose SHS in question 12; organization/company name)

14. Product capacity (for those that chose SHS in question 12)

________________ Watts (W)
15. System cost</td></tr>
</table>

- Single, One-time payment: ____________KES
- Periodic payment (daily): ____________KES
- Periodic payment (weekly): ____________KES
- Periodic payment (monthly): ____________KES
- Periodic payment (yearly): ____________KES
- Credit (loan from bank) ____________KES
- Free/gift

16. **What is the payment method that is used?** (select any choice that applies)
    - Cash
    - Mobile, Pay-as-you-go (example: M-PESA)
    - Credit (from bank)
    - Other (please describe):______________________

17. **If a loan from a bank was obtained to obtain the product/service, how much is the interest rate, if specified?**

18. **If payments are periodic (as specified in question 15), are payments made for a specified temporary period, or are they made as long as the product/service is in use?**
    - Periodic payments are made as long as product is in use
    - Payments will cease after a specific period (please specify period):

19. **If a periodic payment period is established, what is the *duration* of this payment period?**
    - ____________days
    - ____________weeks
    - ____________months
    - ____________years
    -

20. ***Motivation*** **- Why was this product/service purchased?**

21. **Product/Service Satisfaction (1 = completely unsatisfied, 7 = perfectly satisfied)**

22. **Please list below the electrical appliances used with this product/service (ex. # of light bulbs, TV, radio, etc.)**

23. **How has the product/service affected the frequency of internet access?** (circle one)

Significant decrease	Slight decrease	No frequency change	Slight increase	Significant increase

24. **How often do you communicate with service providers?** (circle one)

Daily   Weekly   Monthly   Rarely

25. **How is your relationship with the service providers?** (circle one)

Very Poor   Poor   Average   Good   Excellent

26. **Has the service/product experienced technical difficulties** (blackouts, out of order)**?**
    - Yes
    - No

27. **Typical technical difficulty duration** (estimate, minutes/hours/days/weeks/months)**:**

28. **For owners of solar home systems – about how much time does the system provide power until the battery of the system needs to be recharged?**

29. **Affordability – How affordable was the product/service when initially purchased?** (circle one)

Unaffordable	Hardly Affordable	Somewhat Affordable	Fairly Affordable	Very Affordable

30. **Was incomed saved to buy this product/service? If so, for how long?**

31. **For periodic payments – what is the degree of affordability for the service in your case?**

Unaffordable	Hardly Affordable	Somewhat Affordable	Fairly Affordable	Very Affordable

32. **For periodic payments – Has there ever been an instance in which a payment could not be made?** (Yes/No) (If yes, please describe the circumstance)

33. **Did the product/service have a positive impact on household income?**

Yes   Not noticeable   No   Negative impact

34. **If the answer to question 33 was "Yes", how?**
    - o Direct impact on current employment activities
    - o New employment opportunities discovered
    - o Increase in savings
    - o Other (please describe):

35. **If the answer to question 33 was "Negative impact", how?**
    - o Increased expenses for electricity service payment
    - o Other (please describe):

36. **How were new employment opportunities discovered?** (reply if applicable, describe)

37. **At present, what percentage of monthly expenses cover Kerosene purchase (if any)? Do you think this percentage is going to increase or decrease in the household in the future, or stay the same?**

38. **At present, what percentage of monthly expenses cover purchase of firewood, charcoal or coal (if any)? Do you think this percentage is going to increase or decrease in the household in the future, or stay the same?**

39. **Was the household more reliant on Kerosene, firewood and coal before electricity service/system purchase?**
    - o No
    - o Yes: Kerosene
    - o Yes: Firewood and coal
    - o Yes: Kerosene, firewood and coal

40. Education - Regarding the children (if applicable) - Select the choice that applies

- Total study hours decreased
- Total study hours increased
- Total study hours remained the same (difference is not noticeable)

41. If there was a change in total study hours, by how much?

42. What has been the impact of the purchase of the electricity system on overall health?

- Positive, significant
- Fair impact
- Insignificant, neutral impact
- Negative, significant

43. Please explain your reasons for your choice of answer for question 42 above.

44. **According to your experiences, if blackouts due to power outages or other service disruptions occurred, what was/were the activity/activities typically being undertaken when the blackout took place?**

45. **Please describe (if any) new leisure/social activities in the household or community that have been made possible as a result of the purchase of the electricity system or service.**

46. **Are you connected to the national grid and also own a Solar Home System (SHS)? Why own both?**

47. **Would you be interested in a connection to the national grid or a mini-grid in the future? Why? How much would it cost** (if you know)**?**

48. **Any additional comments, thoughts, ideas, and observations regarding electricity use experiences and impacts in the household or community are welcome and can be added in the space below (ex. quality of life).**

Appendix E – 2017-2019 schedule of stakeholder interviews and field visits

Date	Interview location	Interviewee (s)
September 29th, 2017	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmBH	3 Mangers
October 1st, 2017	Talek, Narok County, Kenya;	GIZ mini-grid households
October 2nd, 2017	Kisii County, Kenya	Powerhive mini-grid households
October 3rd, 2017	Kisii County, Kenya	Powerhive mini-grid households
October 4th, 2017	Kisii County, Kenya	Powerhive mini-grid households
October 5th, 2017	Siaya County, Kenya	KPLC grid connected households
October 6th, 2017	Siaya County, Kenya	KPLC grid connected households
October 7th, 2017	Eldoret, Kenya	KPLC grid connected households
October 8th, 2017	Eldoret, Kenya	KPLC grid connected households
October 9th, 2017	Nakuru, Kenya	KPLC grid connected households
October 10th, 2017	Nakuru, Kenya	KPLC grid connected households
October 13th, 2017	Nairobi, Kenya	Gennex Manager; Gennex SHS owners
September 23rd, 2019	UN Habitat; Strathmore University	Practitioners
September 24rd, 2019	JICA Nairobi Office; Ministry of Energy	Practitioner; stakeholder
September 25rd, 2019	Sunking	Sunking Manager
September 26rd, 2019	Kenya Power and Lighting Company	Stakeholder
September 27rd, 2019	Rural Electrification and Renewable Energy Corporation (REREC)	Stakeholder interview
September 30th, 2019	Narok County, Kenya	Sunking SHS owners
October 2nd, 2019	Kisii County, Kenya	Sunking SHS owners, Powerhive mnager
October 3rd, 2019	Kisii County, Kenya	Sunking SHS owners
October 4th, 2019	Homa Bay, Kenya	KPLC grid connected households
October 5th, 2019	Kisumu, Kenya	Sunking SHS owners
October 6th, 2019	Kisumu, Kenya	Sunking SHS owners
October 7th, 2019	Mfangano Island, Kenya	Mfangano mini-grid connected households
October 8th, 2019	Kisumu, Kenya	KPLC grid connected households
October 11th, 2019	Kenya Power and Lighting Company	Manager

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