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Masters' Thesis in Engineering

Analysis of Policy Barriers to Universal Electricity Access Using AHP

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Technology Management, Economics, and Policy Program
College of Engineering

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Analysis of Policy Barriers to Universal Electricity Access Using AHP

지도교수 허은녕

이 논문을 공학석사 학위 논문으로 제출함

2019 년 2 월

서울대학교 대학원

협동과정 기술경영경제정책 전공

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무투리의 공학석사 학위논문을 인준함

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Abstract

Universal access to modern energy, more so electricity, has become a key priority for governments and policymakers in countries with low electricity access rates especially in the sub-Saharan Africa, where around 80% of the 1.1 billion people without electricity are domiciled. Access to electricity is closely linked to a significant majority of the 169 targets of the 2030 Agenda for Sustainable Development and the world targets to attain them by achieving universal access to modern energy by 2030. However, at the current pace, the policies and strategies put in place have proved inadequate and unless urgent measures are taken, it is projected that over 700 million people in Sub-Saharan Africa will be without electricity in 2040.

In Kenya, the Last Mile Connectivity Project (LMCP) was established in 2014 with the goal of attaining universal electricity access by 2020. While the project has seen connected households increase by fourfold, slow growth in demand and consumption has continuously plagued the policy implementation. Statistics show that millions of people still remain without access to electricity, including the "under grid" while those connected consume small units and suffer unstable, unreliable supply. The low demand of connections and consumption locked out inflow of private sector investments, and as the government and donor organizations run out of subsidies, plans for further extension of electricity to the last mile are now in jeopardy.

This study endeavored to identify impediments to the universal access goals and the critical decision factors to not only ensure the extension of electricity services to the last mile, but also to ensure that through consumption of the electricity services, the beneficiaries climb up the energy access ladder in a manner that justifies a financially sustainable extension of electricity services to the last mile. The study appraised the universal access policies as previously employed against the UNCTAD's paradigm of transformational electricity access.

The study applied the Analytic Hierarchy Process (AHP) as a multi-criteria decision making analysis (MCDMA) to evaluate between four (4) main criteria and fourteen (14) factors identified from an extensive literature review and subjected to expert review. Our results led to the conclusion that six major factors revolving around affordability, sectoral governance, and quality of electricity services as critical to the attainment of universal access goals in Kenya. Low productive uses and little industry as well as lack of linkages between universal access goals and other social-economic policies was deemed to be uniquely important, and closely linked to the transformational access paradigm.

The study results gives important implications for the redesign of the LMCP and future similar universal electrification policies.

Keywords: (Transformational access, Universal access, Multi-criteria

Decision Analysis, Analytic Hierarchy Process, Kenya.)

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LIST OF ACRONYMS

ADB	Asian Development Bank
AfDB	African Development Bank
AHP	Analytic Hierarchy Process
ERC	Energy Regulatory Commission
GDC	Geothermal Development Company
GWh	Gigawatt Hour
KENGEN	Kenya Electricity Generating Company
KPLC	Kenya Power & Lighting Company
KNEB	Kenya Nuclear Electricity Board
Kshs	Kenya Shillings
LMCP	Last Mile Connectivity Project
MCDA	Multi-criteria Decision Analysis
MW	Megawatt
PPA	Power Purchase Agreement
REA	Rural Electrification Authority
SDG	Sustainable Development Goals
UNCTAD	United Nations Conference on Trade and Development

Chapter 1. Introduction

1.1 Research Background

Access to electricity and other forms of modern energy has in the past been underlined as one of the essential inputs of socio-economic development Davidson and Sokona (2002); Mielnik and Goldemberg (2002). IEA (2017b), added that the rate of global economic growth over the past century have been closely linked to the rate of growth in energy use, lifting billions of people worldwide out of poverty. Mitra and Buluswar (2015), as well contend that electricity is potentially the most crucial for development owing to its ability to provide services most important for human needs. IEA (2017b), notes that no country has gone from poverty to prosperity without making electricity affordable and available in bulk. World-Bank (2017), concurred that in absence of electricity, the pathway out of poverty is narrow and long.

Today however, IEA (2017b) asserts that, over a billion people worldwide lack access to electricity as universal access remains elusive and over 700 million people are expected to remain without electricity in 2040, 80% of whom will be living in Sub-Saharan Africa. Nevertheless, universal access to electricity has been made a policy priority in many countries which are yet to attain universal access. The United Nations' Sustainable Development Goals has likewise made universal access to affordable, reliable, sustainable modern energy services by 2030 (IEA, 2017a) a top priority. An appraisal of the other SDG targets by Vera (2016) shows that energy is interlinked to 125 (75 percent) out of the 169 targets which means that the entire SDG will be won or lost around the entire agenda of access to modern energy, more so, electricity.

1.2 Research Motivation & Problem Definition

In Kenya, universal electricity access initiatives became a government priority in 2013/2014 with a target of attaining 100% access by 2020. The Last Mile Connectivity Project (LMCP) was launched by the government in 2014 to scale up connectivity by providing subsidy for extending the grid to enable Kenyans get electricity supply at affordable cost. The project aimed at increasing electricity access mainly to rural and sub-urban areas, accelerate economic growth at the micro-economic level and improve quality of lives. ME&P and AfDB, (2017) pointed that the direct beneficiaries of the project was targeted to the population to be connected to the distribution system. It was expected that the project would foster an increase in economic activity (industrial services, agricultural, commercial) and social well-being (households and social institutions). The LMCP policy included establishment of new generation, transmission and distribution facilities, where the government targeted to add at least 5000MW to the grid by 2017, raise peak demand and consumption by 296% and 306% respectively and connect one million customers of electricity per year. However, unable to raise demand, it was forced to halt the plan for additional generation, which was at the focal point of the universal access plans.

According to the statistics of KPLC, by June 2017, the consumer connections had increased from 2,330,962 in 2012/2013 to 6,182,282, a significant 165% change. However, energy consumption per capita at the same time grew dismally from 192.9Kw/h to 221.5Kw/h representing only a 15% change. Similarly, against the 5000MW new generation in 40 months to 2017 target, only 681MW was realized. Against the huge increase of connections, the electricity retailing company, KPLC, reported only a 26% increase in energy sales, from 6581GWh in 2012/2013, to 8272 in 2016/2017. This shows a very low consumption levels new customers connected under the programme and the pre-existing customers as well. In fact, the ERC in July 2018, Otuki (2018) reported that the monthly electricity bill of half of KPLC's customers were Kshs 305 (approximately $3.5) or Kshs 10. ($0.1) per day.)[1] This represents a monthly consumption of less than 15kWh. Statistics also show that despite the efforts to expand electricity to the rural and sub-urban areas, a large share of electricity demand is still centrally located

[1] Half of Kenya Power clients Use Shs 10 daily: The Business Daily. Monday, July 2, 2018. Extracted from https://www.businessdailyafrica.com/economy/Half-of-Kenya-Power-clients-use-Sh10-daily/3946234-4643380-tmq6js/index.html

around the capital city, where 47% of electricity sales were reported in 2016/2017, representing a meagre improvement from 53% in 2012/2013. Due to these problems of low demand and consumption, new generations have been halted and the entire project is in limbo. Paradoxically, millions of target populations still remain even without a physical access to electricity and in dire need of electricity, millions more who are within reach to grid/micro-grids are unable to pay for connections and those connected consume too little to justify new generations or extended connections. Lee et al. (2016), while those connected still suffer unstable, unreliable supply, sometimes not worth paying for. In theory, in absence of new demand, additional generation creates idle capacity which translates to additional per unit costs for those already connected. This creates a vicious cycle that further pushes tariff costs beyond their affordability ceiling, and at the same time raising the connection fees for those who would wish to be connected, further exacerbating the electricity inaccessibility problem.

The goal of this research is to solution to these challenges. In so doing, this study conducts a quantitative evaluation of the barriers that hinder the success of universal electricity access initiatives. We endeavor to find solutions from a policy perspective and study the barriers and the policy components that are essential to the success of financially sustainable universal electrification initiatives. The economic structure transformational access paradigm as proposed by UNCTAD (2017) and, the household oriented universal electricity access paradigms as proposed by Bhatia and Angelou (2015); C.Bhattacharyya and Ohiare (2012); F.Gómez and Silveira (2015); IEA (2017a); Ministry-of-Energy (2017); Mitra and Buluswar (2015); Pueyo (2015) forms a critical part of the study as will depicted in the literature review and selection of methods.

1.3 Research Questions

This study aims to answer the following questions:

1) What are the key policy issues and multi-stakeholder challenges/barriers towards the attainment of financially sustainable universal electricity access in Kenya?
2) Which policy framework, between universal access paradigm (a household focused, step-wise approach that is premised on increasing physical access to electricity in terms of enhanced proximity and additional connections a) and the transformational energy access (based on the energy transformational nexus, that is, from electricity access to productive uses and economic structural transformation which results in a sustainable demand for and expansion of electricity to the last mile) best addresses the above challenges?

3) What are some of the policy recommendations or the optimal path towards the attainment of universal electricity access?

1.4 Research Objective

The primary objective of this research is to analyze the policy challenges and find solutions to the expansion of financially sustainable universal electricity access initiatives in Kenya. Muturi (2017b), argued that the experience of the LMCP demonstrated that making electricity available in the system, or a physical connection to a household, doesn't automatically lead to consumption. Similar postulations have been alluded to Ahlborg and Hammar (2014); Barnes, Golumbeanu, and Diaw (2016); Bhatia and Angelou (2015); Mitra and Buluswar (2015); Odarno, Agarwal, Devi, and Tahakashi (2017) who also noted that, connections without reasonable consumption, are unsustainable and cannot stimulate economic growth. Instead, the country runs at a loss occasioned by having excess capacity in the system, which in turn pushes up per unit costs for the existing electricity consumers. Previous studies have dwelt on the strategies and steps towards the universal access goals, but there's a lacuna of quantitative analysis of the barriers and/or challenges that hinder the successful implementation of such policies and strategies. This study seeks to bridge these knowledge gaps by conducting a quantitative analysis and priority weighting of the barriers to financially sustainable universal access goals. In so doing, this study will identify the critical policy components to unlock the access to, demand for and consumption of electricity services and provide policy recommendations for the re-design and implementation of the Last Mile Connectivity Project and such other future policies in Kenya.

1.5 Literature Survey

The problem of electricity access in the developing economies has been a widely studied topic in the recent years. A large proportion of these studies have been devoted to strategies of acquiring access, circumventing the affordability challenges as in Mitra and Buluswar (2015) and the technical issues such as the potential of smart grids and other distributed micro-grids fed on renewable energies to close the electricity access gaps as in the works of Ahlborg and Hammar (2014); Barnes et al. (2016); Bhatia and Angelou (2015); C.Bhattacharyya and Ohiare (2012); Dagnachew et al. (2017); Lee et al. (2016); Ruijven, Schers, and Vuuren (2012). The works of Bhatia and Angelou (2015); IEA (2017a); (World-Bank, 2017) describes different strategies for gaining access, with the UNCTAD (2017) approach differing with the latter's approaches towards the same. Odarno et al. (2017), extended these approaches in their essay and stressed on the importance of creating linkages between access and other development goals and at the same time creating sound governance structures for the electricity sectors.

Their sentiments are echoed in the work of Perez-Arriaga (2017) who emphasized the crucial roles of governance, institutions and regulations. The works of Mitra and Buluswar (2015), Dagnachew et al. (2017) , and F.Gómez and Silveira (2015) addressed the issues of affordability, and the technical issues of micro-grids as a solution to the access challenges. These studies adopted qualitative approaches, and as such are all descriptive based on practical experiences of the researchers and their review of pre-existing literature. This research intends to go a step further and quantitatively analyze the access challenge and rank the relative importance of the challenges. The nature of the research goal points to a decision problem that warrants for the application of methodologies that allow for priority weighting, ranking of criteria and factors in decision analysis. This consequently points to multi-criteria decision analysis (MCDA) methods and the Analytic Hierarchy process (AHP) proposed by (Saaty, 1980) and as applied in energy policy related studies in the works of Wang, Jing, Zhang, and Zhao (2009), Kaya and Kahraman (2010), Heo, Kim, and Boo (2010) and Laxman (2016) is preferred. This is described further in the next section.

1.6 Methodology

To attain the aforementioned objectives, this study commenced by conducting detailed literature review of the policy barriers and challenges of expansion universal electricity access. This is followed by a multi-stakeholder survey that involved the energy planning team from the Ministry of Energy & Petroleum in Kenya, representatives of the electricity business community, electricity consumers (specifically the targets of the last mile connectivity initiatives), the civil society and donor organizations.

The Analytic Hierarchy Process (AHP) is then applied to quantitatively analyze the barriers and rank them according to their weights from a pairwise comparison survey. The AHP is a useful and a popular decision making tool that uses subjective perception from the respondents (Laxman, 2016; Nigim, Munier, & Green, 2004; Wind & Saaty, 1980). By using AHP, this study establishes various barriers as criteria and factors with their relative importance in the quest for the expansion of financially sustainable universal electrification initiatives in Kenya.

1.7 Research Outline

This research is organized into six chapters as depicted in Figure 1. Chapter one gives a brief description of the study area, the problem definitions and motivations for this study. The research questions and objectives of the study are also covered in this chapter. A brief synopsis of the literature review and methodology is also introduced here. Chapter two provides a background of this study, and gives a detailed description of the power sector in Kenya. Chapter three provides an extensive literature review on the research topic and the choice of methodologies. The literature review covers previous studies on universal electricity access. The importance of Multi-Criteria Decision Analysis (MCDA) as used in in policy decisions, the selection of AHP for this study and its application in this study and other energy related studies is covered in this chapter. Chapter four explains the research methodology and process. A description of the AHP methodology, the hierarchy structure and the selection of criteria and factors used in this study are covered in this chapter. In Chapter five, the quantitative results of the study are provided and an enriched analytical section that seeks to explain the results and findings of this study is depicted here. In chapter six, the overall research conclusions and recommendations are provided. Limitations of scope and recommendations for future studies are covered in this chapter.

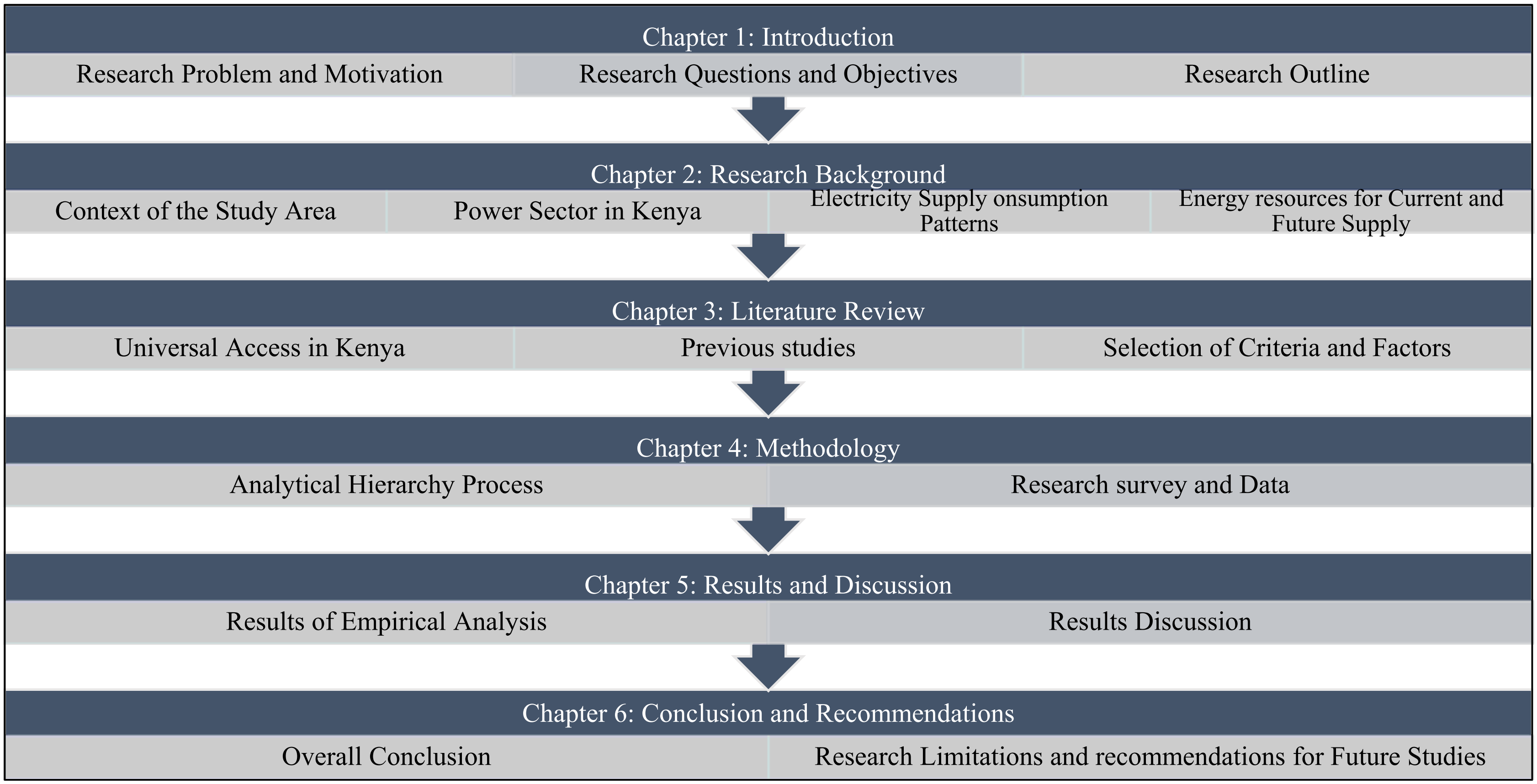

Figure 1: The Research Framework & Process

Chapter 2. Research Background

2.1 Context of the Area of Study

Kenya, officially known as the Republic of Kenya, is geographically located on the equator and overlies the East African Rift, covering a diverse and expansive terrain that extends from Lake Turkana in the North, bordering Uganda and sharing Lake Victoria in west, and extends further to the Indian Ocean in the south-east. Its territory is roughly 581,309Km^2 (224,445 sq. mi) and has a population of 45.3 Million as of 2015 (KNBS). Kenya, the 9th largest economy in Africa and the 4th in Sub-Saharan Africa is alive with economic activity and in dire need of stable and affordable supplies of energy on a progressive scale.

Kenya, according to the ERC (2017) and Muturi (2018b) has an installed capacity of 2,300MW (37% hydro, 27% geothermal, 30% thermal, 2.5% Gas Turbine, 1% cogeneration and 0.55 solar PV).The electricity production is barely compatible with the demands of the growing population and the expanding economy. In the year 2016/2017, the national primary energy consumption was heavily dominated by biomass (charcoal and wood fuel) accounting for 69%, followed by petroleum products at 22%, and electricity at 9% (ERC, 2017). Additionally, the electric power consumption per capita is significantly low at 166.7Kwh compared to other African economies like Algeria with 1356.2KWh and

South Africa with 4198.4 Kwh (World Bank Development Indicators, 2014 figures).

The electricity sector is also characterized by high frequency of outages, low access rates and load shedding and power rationing (especially in adverse hydrology) and high system losses. Low penetration rates and high costs of electricity is associated with heavy dependence on wood fuel and other biomass in the total energy consumption with wood fuel dominating the basic energy needs of the rural communities, urban poor, and the informal sector[2].

2.2 The structure of the Power Sector

Kenya commenced the liberalization of the power sector in 1996 with the unbundling of the state owned monopoly after the enactment of the Electric Power Act, 1997 (Muturi, 2017c). An Electricity Regulatory Board was formed in 1997, which was replaced by the Energy Regulatory Commission (ERC) a decade later, when the Energy Act of 2006 was assented. The two legislations separated the roles of generation of electricity from transmission and distribution. They also liberalized the procurement, distribution and pricing of power and allowed the participation of private sector in a field that was previously a state controlled monopoly. The changes were aimed at improving the service

[2] The German-Dutch-Norwegian Partnership - Energizing development (EnDev) - Upscaling Proposal 2012 (secure document)

delivery, quality and to meet the national demand in a cost effective manner, and at the same time provide an innovative environment and stimulate capital inflows and investments in energy infrastructure Onyango (2013). The players in the sector is represented in Figure 2. The functions of the organizations are summarized in Power Generation and Transmission Master Plan, 2016[3] and ERC (2017) as:

1. Ministry of Energy & Petroleum (MOEP): Responsible for making and articulating energy policies to create an enabling environment for efficient operation and growth of the sector. It sets the strategic direction and for the growth of the sector and provides a long term vision for all sector players.
2. Energy Regulatory Commission (ERC): Responsible for regulation of the energy sector. Its functions include setting tariffs and oversight, coordinating the development of Indicative Energy Plans, monitoring and enforcement of sector regulations.
3. The Energy Tribunal: Was established by the Energy Act of 2006 as an independent legal entity responsible for arbitrating disputes within the sector, particularly appeals brought against decisions of the Energy Regulatory Commission.

[3] Power Generation and Transmission Master Plan, Kenya Long Term Plan 2015 - 2035 – Vol. I

4. Planning Team: Responsible for developing the major power sector plans under the supervision of the ERC and within the policies and the guidelines of the MOEP.
5. Kenya power & Lighting Company (KPLC): Responsible for the existing transmission and distribution systems, and is the off taker in the power market buying power from all generators on the basis of negotiated power purchase agreements (PPAs) for onward transmission, distribution to final consumers. It is owned by Government of Kenya and the National Social Security Fund (NSSF) at 50.1% and 49.9% by private shareholders.
6. Geothermal development Company (GDC): was incorporated in 2008 as a fully government owned special purpose vehicle (SPV) to accelerate the development of geothermal resources. GDC is mandated to develop steam fields and sell geothermal steam for electricity generation to KenGen and other private investors for electricity generation.

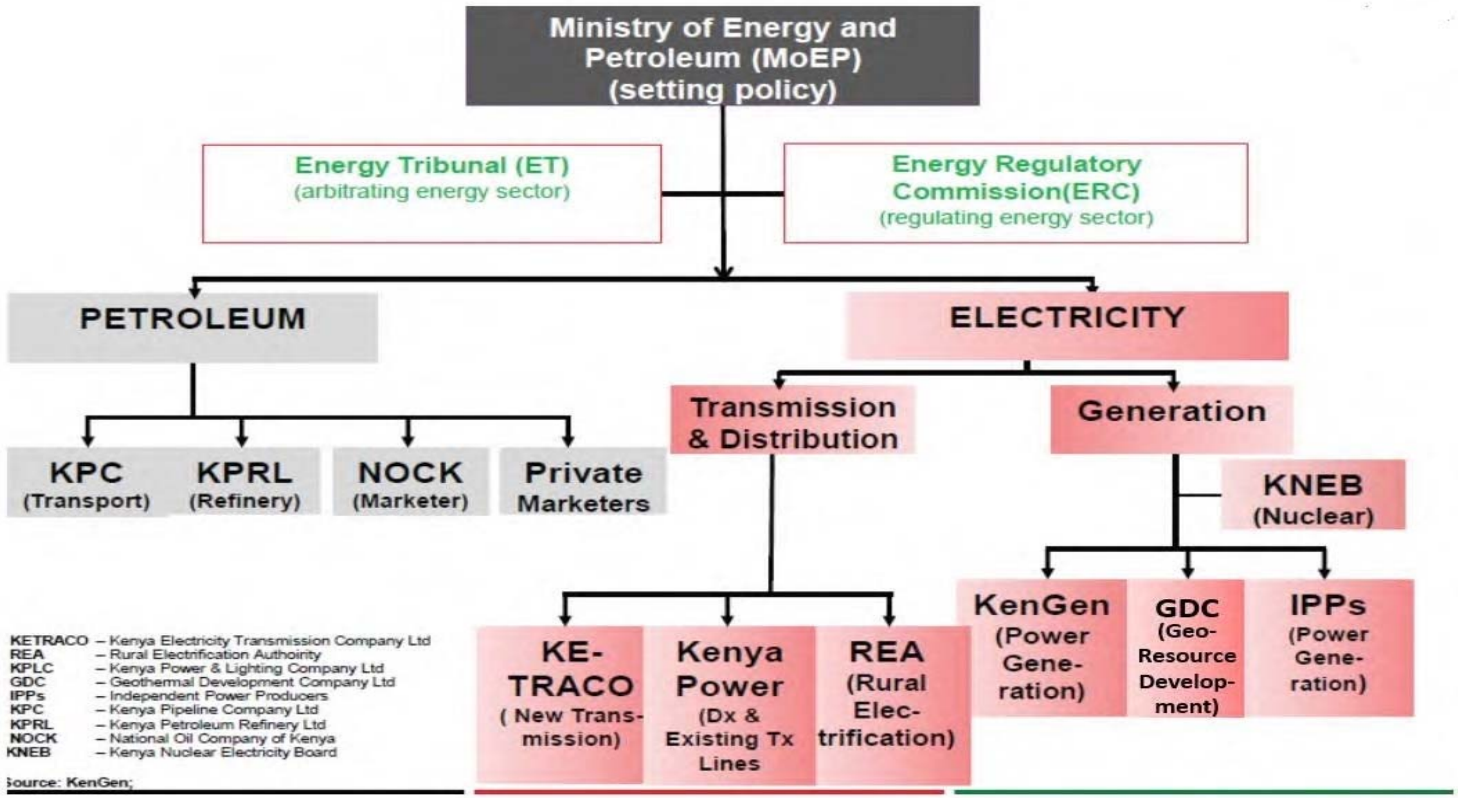

Figure 2: The Structure of the Power Structure

7. Rural Electrification Authority (REA): Was established in 2007 with the mandate of implementing the Rural Electrification programme (REP).
8. Kenya Nuclear Electricity Board (KNEB): Is charged with the mandate of conducting preliminary studies and to undertake preparatory activities towards the development and implementation of the Nuclear Power Programme in order to enhance the generation of electricity from nuclear power in the future.
9. Kenya Electricity Generating Company (KenGen); Is a listed company in the Nairobi stock exchange, owned 70% by the GoK and 30% by private shareholders. KenGen currently has an installed capacity of 1631MW, and is the main player in electricity generation business.
10. Kenya Electricity Transmission Company (KETRACO). This was established in 2008 as a fully state owned corporation. Itd *raison d'etre* is to plan, design, construct, own, operate and maintain new high voltage (132KV and above) electricity transmission infrastructure in national transmission grid and regional interconnections.
11. Independent Power Producers (IPPs): Are private investors in the power sector in generation either on a large scale or for the development pf renewable energy under the Feed-in-Tariff policy

2.3 Key Energy Policies & Strategies

Kenya has in the last two decades been facing challenges in meeting its growing energy demands mainly due to the unreliable and expensive means of energy generation and import. Muturi, Lee, Zaw, and Alfina (2017), asserted that the fuels industry, commerce, transport and agriculture are the bulwarks of the economy, and, therefore, the provision of safe and reliable energy is a critical component of the socio-economic development now and in the coming years. Moreover, the country's development blueprint, the Kenya Vision 2030, identifies energy as a key enabler towards the attainment of the country's aspirations of accelerated economic growth, increased productivity in all sectors, equitable distribution of national income, poverty alleviation through improved access to basic needs, enhanced agricultural production, industrialization, and accelerated employment creation as expounded by Muturi (2017a).

The overall goal of the energy sector is to ensure sustainable, adequate, affordable, competitive, secure and reliable supply of energy to meet national and county needs at least cost, while protecting and conserving the environment[4], but there are a number of challenges towards this goal including; (Long Term Plan 2015-2035)

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[4] Source: Ministry of Energy & Petroleum, (Draft national Energy and Petroleum Policy)

1. The need to improve competitiveness, reliability and quality of energy supply (in particular power generation and network are barely able to meet the growing demand leading to increasing suppressed demand and economic losses)
2. Lack of major investments in the sector by the private sector versus high initial capital needs for new investments in the sector
3. Long lead and implementation time for new infrastructure projects Lack of competitiveness of the country and negative impact in available household income and domestic wealth due to high energy costs and dependency on energy imports.
4. Insufficient access to and quality of electricity supply due to low connectivity rates and weak transmission and distribution network (leading to high losses and costs including theft of equipment and electricity).

In order to address these issues and generally improve the energy sector the Kenyan government has introduced a number of policies over the past years to govern the energy sector by different policies, institutions and legal framework. The main strategic objectives of the energy sector are to:

1. Increase supply and security of supply by diversification of energy sources, and particularly the development of domestic energy sources and upscaling of power generation capacity,

2. Increase affordable and reliable access and connectivity to electricity (and other energy sources)
3. Provide and enabling environment and framework for private investments and the provision of energy services by provision of necessary standards and regulations, proper planning, research and training, incentives and international training.
4. Limit environmental and social impacts by increased use of renewable energy sources and promotion of energy efficiency.

The key energy policy and strategy documents put in place relevant to the goals are described next.

2.3.1 Kenya Vision 2030

The Kenya Vision 2030 is the country's long-term development blueprint aimed at making Kenya a globally competitive and prosperous country with a high quality of life by 2030. It aims to transform the country into a newly industrializing, middle-income country providing a high quality of life to all its citizen in a clean and secure environment. The Vision 2030 acknowledge energy as an enabler and prioritizes the growth of energy generation and increased efficiency in energy consumption. This is to be achieved through continued institutional reforms in the sector, including a strong regulatory framework, encouraging private sector participation in power generation, and securing new sources of energy through extending the exploitation of local geothermal resources, coal renewable energy sources, and regional interconnections.

2.3.2 Sessional Paper No. 4 of 2004

The Sessional Paper No. 4 of 2004 is a policy document that stipulates the liberalization reforms implemented in the energy sector in the mid-1990s. Its vision is to promote equitable access to quality energy services at least cost while protecting the environment. The paper lays down the policy framework upon which cost effective, affordable and adequate quality energy services will be made available to the domestic economy on a sustainable basis over the period 2004-2023.

2.3.3 Energy Act No.12 of 2006

The Act was enacted following the proposals of the Sessional Paper to succeed the Electric Power Act No. 11 of 1997 and the Petroleum Act, Cap 116 of 1994 and facilitate the creation of a single platform for regulation and enhancement of all energy resources in the country. The Act provides for the establishment of the Energy Regulatory Commission (ERC), Rural Electrification Authority (REA), Kenya Electric Transmission Company (KETRACO), and the Geothermal Development Company (GDC). In addition, the Act established the Energy Tribunal whose purpose is to hear appeals from decisions of the

ERC. The institutional setup situates the two bodies, namely the ERC and the Tribunal as overall regulatory bodies independent of state influence. Both institutions coordinate and advise the Ministry of Energy on policy and strategy.

2.3.4 Draft Energy Policy and Bill 2017

The draft energy policy considers actual challenges and opportunities for the energy sector such as the discovery of domestic oil, gas and coal and high energy costs and capital needs. Its objective is "to ensure affordable, competitive, sustainable and reliable supply of energy to meet national and county development needs at least cost, while protecting and conserving the environment." The purpose of the draft Energy Bill 2017 is the consolidation of laws with regard to energy. It consists of various regulations for renewable energy promotion and energy exploration. It further defines powers and functions of existing and various new entities for regulation and advisory of the energy sector. It also clarifies the respective functions for national and county governments in matters regarding exploitation of energy resources and sharing of revenues.

2.3.5 Least Cost Power Development Plans (LCPDPs)

The Least Cost Power Development Plans (LCPDP) are the Ministry of Energy and Petroleum (MOEP's) power implementation plan for delivering the power sector targets outlined in Vision 2030.The main contents of the plans are demand forecast scenarios for electricity consumption, assessment of energy resources and generation and transmission expansion plans for the respective study periods.

2.3.6 Rural Electrification Masterplan

This is the master plan for the extending the electricity coverage to the last mile through the rural electrification strategy. The Masterplan falls under the jurisdiction of REA and is updated on an annual basis to reflect the attained milestones and the most urgent needs of rural population regarding electricity connectivity. The government of Kenya provides the main funding sources for REA projects (80%) and is supported by various development partners (20%).

2.3.7 Feed-in Tariff (FIT) Policy

The Feed-in Tariffs (FIT) policy was introduced in 2008 to provide investment security to renewable electricity generators, reduce administrative and transaction costs and encourage private investors in establishment of Independent Power Production (IPPs) in the realm of renewable energy exploitation. The FIT were reviewed in 2010 and 2012 and they currently apply to grid-connected plants and are valid for a 20-year period from the beginning of the Power Purchasing Agreement

(PPA), with approval of the PPAs granted by the ERC.

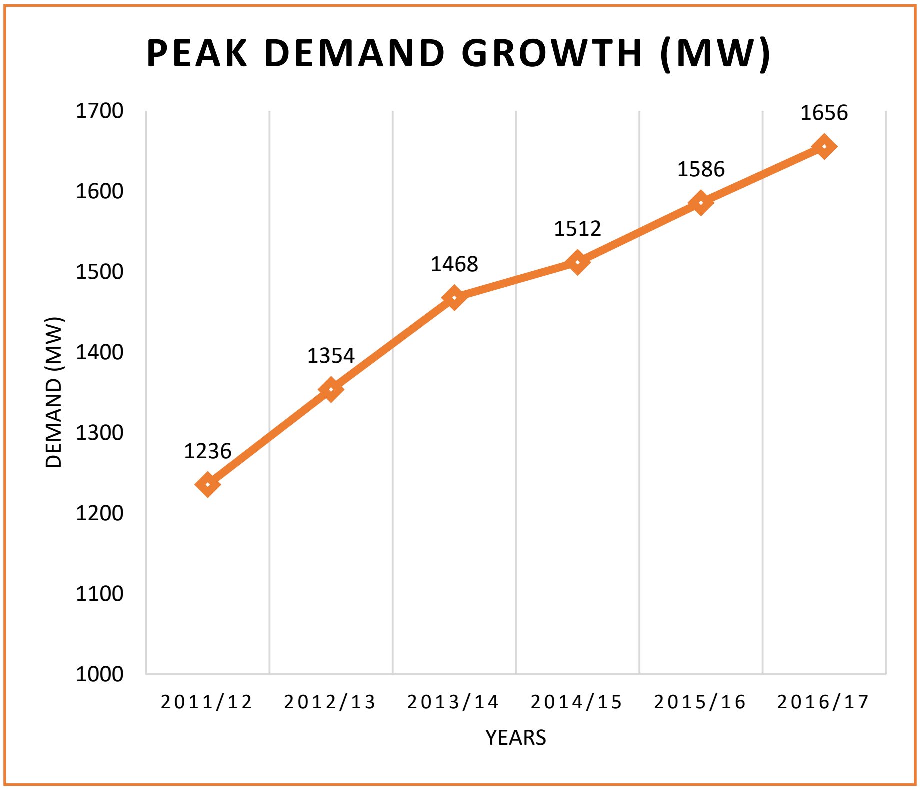
2.4 Electricity Demand, Supply and Consumption Patterns

2.4.1 Demand

The demand for electricity has shown an upward trend in the last 5 years. In 102/13 demand was 6,581GWh and increased to 8,272 GWh in 2016/17 (ERC, 2017). This represents an average annual percentage increase of 5% with the highest growth recorded in 2013/14 (10%). In 2009/2010, electricity was supplied to less than 15% of the total population, predominantly comprised of the middle and upper income groups[5]. Since then, a growing population which increases the demand for most general services using electricity; increased electricity intensity occasioned by penetration of telecommunication and information end use technologies; continued growth in manufacturing, agricultural and other sectors of the economy; and the country's initiatives to connect new customers has led to the increase in demand for electricity services.

[5] LCPDP 2011-2030

Figure 3.1 5-Year Peak Demand Growth



Overall, there has been a positive growth among all consumer categories. The nation has seen an upward trend in demand for electricity over the past decade. In the past five years, the peak demand increased from 1,236MW in 2011/12 to 1,656MW in 2017. This represents an average annual increase of 6% as depicted in Figure 3.

The rise in peak demand is can also be associated with the increased number of consumers connected over the same period. The country has experienced a significant increase in the number of customers connected by an average annual growth of 25.1%.This is as a result of the accelerated electrifications in all consumer categories.

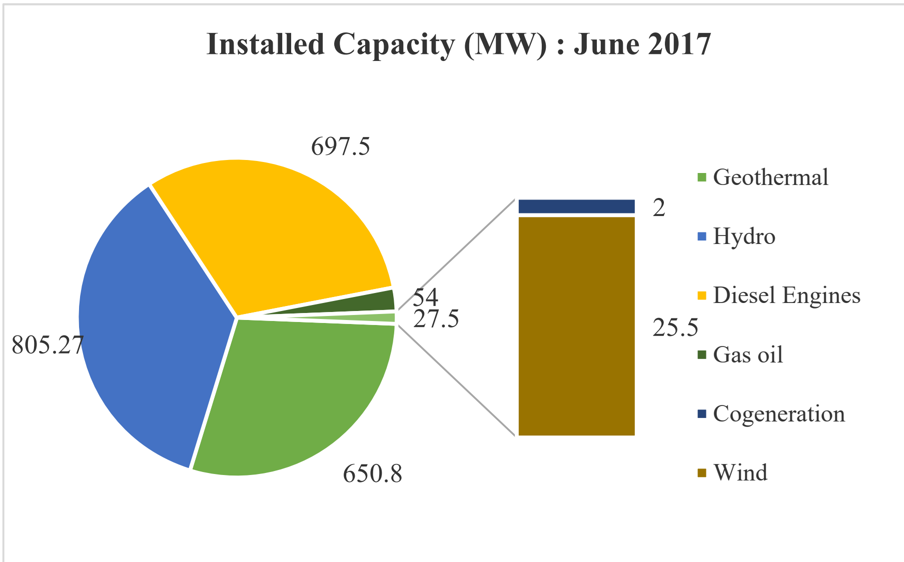
2.4.2 Generation and Supply

Over the years, the installed electricity generation capacity has considerably grown rising from 1310MW in 2008 up to 2333MW by June 2017. This represents an average growth rate of 7.8% annually. The peak demand also grew from 1044MW in the same year to 1656MW in 2017[6]. As at 30th June 2017, Kenya had an installed electricity generating capacity of 2333MW comprising of hydro (824MW), thermal (803MW), geothermal (625MW), wind (26MW), biomass/cogeneration (28MW) and solar (0.55MW). In 2016/17 fiscal year, the Kenya Electricity Generating Company (KenGen), which is the largest power generator in the country accounted for 69.2% of the industry's effective generation capacity. The Independent Power Producers (IPPs) accounted for 29.0% including Emergency Power Producers during the same period. Besides the interconnected national electricity grid, there are 16 isolated grids in Kenya. These serve the remote and sparsely populated areas far away from the grid. The isolated grids in comparison to the interconnected grid only generate and supply less than 1 %(0.8%) of the electricity under the Rural Electrification Programme (REP). This interconnected grid generation mix is comprised of 36% of hydro, 34% fossil fuels, 28% geothermal, cogeneration 1.0% and 1% from wind and solar. Due to the poor hydrology during the period, hydro generation declined marginally.

[6] Kenya Power Annual Report 2017/17 Financial Year

There was therefore increased generation from fossil fuel. Kenya's current effective installed (grid connected) electricity capacity is 2,259 MW as depicted in Figure 4[7]:

Figure 3: Installed Capacity (MW): June 2017



For the period 2017-2037, the LCPDP envisages that the share of geothermal and hydro generations will decrease from 29.1% to 26.7% and 36% to 17.9% respectively, while coal and natural will rise 0% to 19.5% and 0% to 7.6%. In the same period, Wind and solar will increasingly play a major role in the generation mix during, rising from 1.1% to 8.5% and 0% to 8.6% respectively.

[7] Data extracted from the Updated version of the Least Cost Power Development Plan: 2017-2037

2.4.3 Consumption

The total consumption of electricity grew continuously by an average of 6% in the past five years to 2016, rising from 4% during the preceding 10 years. Compared to the average Sub-Saharan countries, the growth rates are twice as high for the period 2002 to 2012 and below average for the period before (1992 to 2002)[8].

Most of the electricity generated is consumed domestically; exports and/or exchanges with the neighboring countries is negligible[9]. In the 2016/17 financial year, only 20Gwh and 2Gwh representing 0.2% and 0.02% of the total electricity sold was exported to Uganda and Tanesco. In terms of consumer categories, the consumption growth have been even throughout the years with the exception of the street lighting. For most years, domestic consumption increased above average while the consumption from the large commercial and industrial consumers increased slightly below. Analysis of the consumption patterns reveal that a few large customers account for a huge segment of the total consumption as shown in Figure 5.

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[8] Power Generation and Transmission Masterplan, Kenya Long Term Plan, 2015-2035

[9] Power Generation and Transmission Masterplan, Kenya Long Term Plan, 2015-2035 (less than 1% of the total generation is consumed beyond the country's territorial borders)

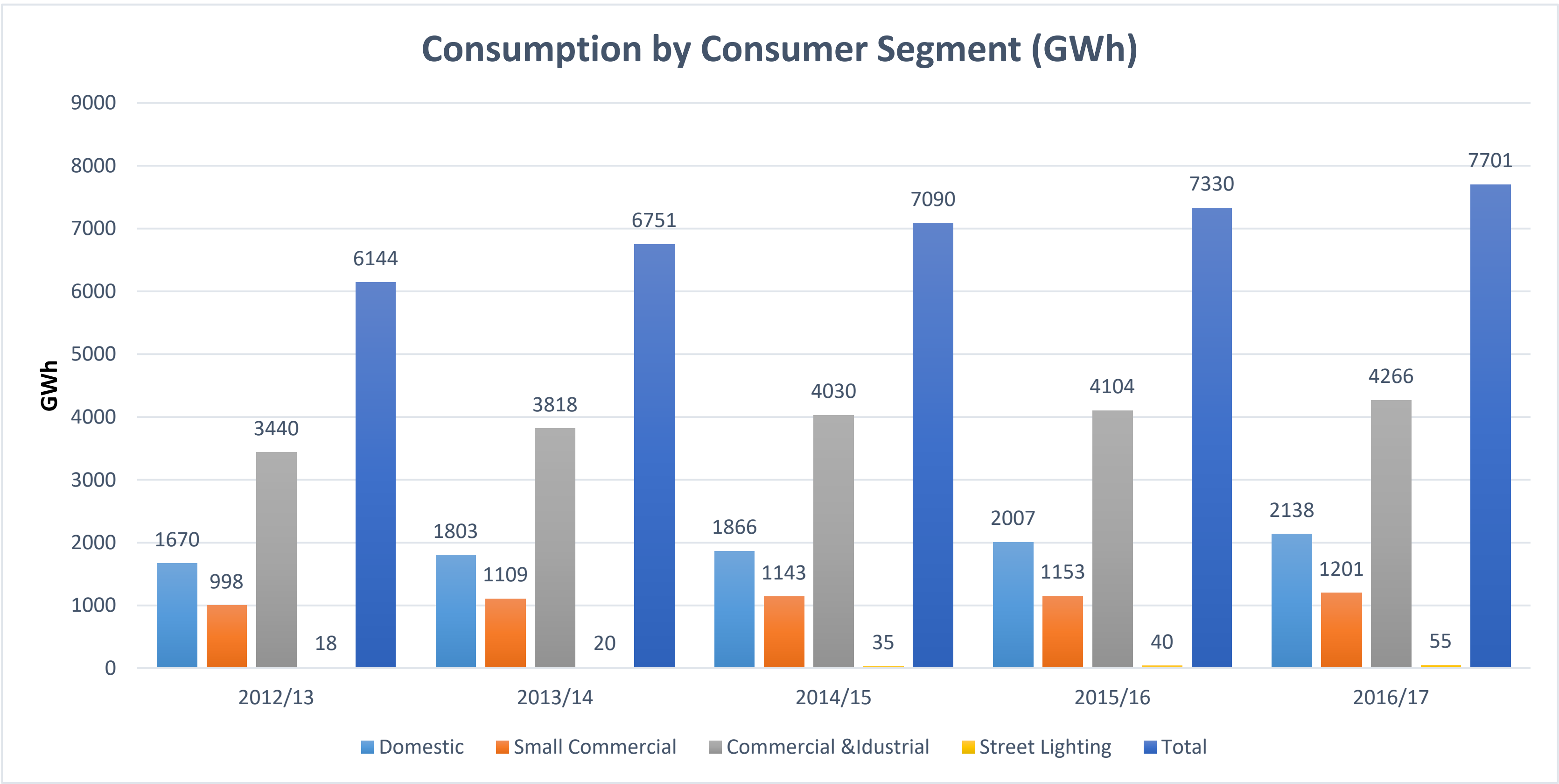

Figure 4: Electricity Consumption by Consumer Segment

In 2014/15, some 3,400 consumers were registered under the large commercial and industrial tariff and they accounted for more than 50% of the total consumption. This share has been on a gradual decline from a high of 61% in 2004. Half of this (about 25% of the total electricity) was consumed by 550 entities only (25 customers consumed 15% of which 14 consumed 10%, the largest 3 consumers took 5%). The contribution of domestic consumers to total consumption is only about 30% although they account for 90% of the connections. The consumption of electricity in the past 5 five years is summarized in Figure 5.

2.4.4 Regional Electrification and Consumption

The electrification of the country has been unbalanced for many years[10]. A quarter of the national population (i.e. of Nairobi power system area) accounts for 50% of the access to the power supply and consuming half of the electricity as shown in a five year trend in Figure 6. The Coast area accounts for an above average connectivity level and consumption in comparison to its population share. This partly mirrors the economic structure of the country: Coast and Nairobi regions show a higher share of large commercial and industrial consumption due to a concentration of these consumers in Nairobi and Mombasa. In Western and Mt. Kenya regions, the share of small commercial consumption is higher. The share of domestic consumption is slightly smaller for Coast and Western area. The Government introduced the last mile connectivity project partly to alleviate this challenge, but while connectivity has improved, the consumption patterns hasn't.

[10] Power Generation and Transmission Masterplan, Kenya Long Term Plan, 2015-2035

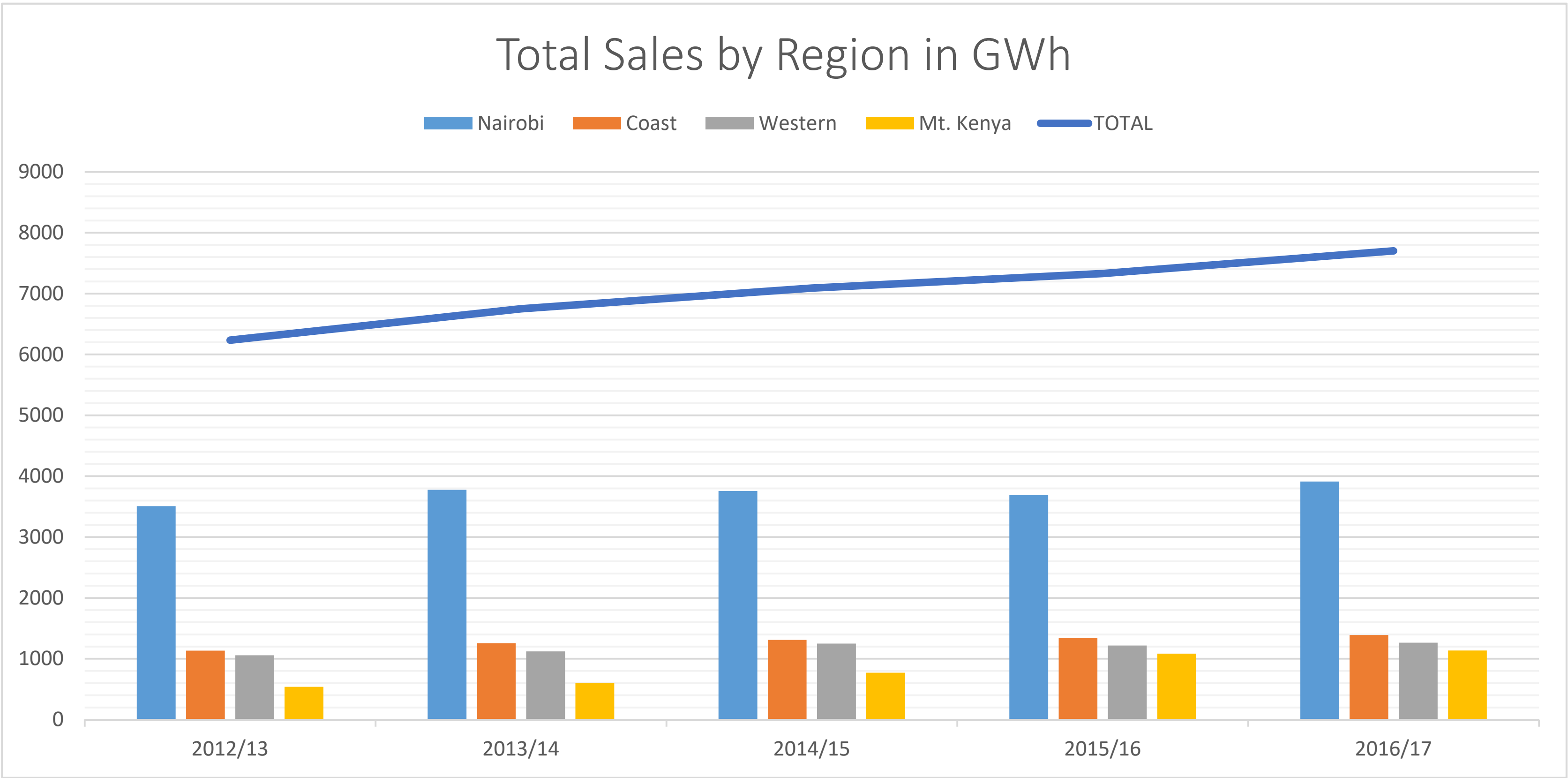

Figure 5: 5-Year Regional Consumption patterns

The connectivity level on county level is also very uneven. For rural population, the situation has been even more severe throughout the country, with connectivity levels only a fraction of the overall county level. If the electrification figures are overlaid with the population density, the areas close to Lake Victoria stand out: millions who live comparatively close together (which should facilitate electrification) are still below national average in terms of electrification.

In these areas, the high share of rural (and thus often technically and economical difficult to connect) population has been a challenge in the past and is expected to continue.

The National Electrification Strategy attributes the difficulties of expanding the grid to these areas to high costs of supplying rural and peri-urban households; lack of appropriate incentive; weak implementing capacity and the costs of the internal wiring of consumers' premises. Additionally, a high population growth rate (of about 2.4% p.a.) is a big challenge for electrification. It requires some 300,000 new connections per year only to keep the connectivity level constant. The shrinking average household size will further severe this situation. Because of this the electrification ratio has increased at a slower rate than the number of connections.

2.4.5 Suppressed Demand

According to Kenya Electricity Generation and Transmission Masterplan 2015-2035[11], suppressed demand, also referred to as non-served demand refers to demand for electricity which cannot be met by means of the national electricity supply due to various technical and economic limitations. The most common form of suppressed demand is the one that occasions load shedding due to insufficient power supply or transmission capacity (especially during peak hours) The recent Least Cost Power Development Plan (LCPDP 2017-2037) assumes a suppressed demand of about 3.58% in the Kenya power system. ERC (2017) attributed the suppressed demand projections to; system load outages at the time the peak demand occurred; loads switched off by industrial customers at peak to avoid running their plants under poor voltages; customers disconnected from the system for various reasons and new customers awaiting to be connected having paid fully.

Suppressed demand is also exemplified by curtailed demand caused by poor security and quality of power supply, especially in periods of peak demand. This usually necessitates self-supply of electricity and utilization of energy substitutes. In terms of quality and stability of power supply, analysis of past performances show that the Western part of the country experiences the most instances of grid instability, experiencing

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[11] Power Generation and Transmission Masterplan, Kenya Long Term Plan 2015-2035

more than ten incidents on average per month and has the greatest effect on consumption[12]. In the other regions, the self-supply and consumption of substitutes is as well widespread. At the distribution level, poor quality and lack of security of supply is much more frequent. This is caused mainly by an old/ailing distribution network and overloading of the same.

Insufficient ability to pay for connections and eventual consumption of electricity is also a common phenomenon in Kenya. Even though electricity is available in many areas, the rates of connections are not universal. This is mainly attributed to insufficient incomes to pay for connections and units of electricity they consume. Domestic tariffs have nearly doubled if particular months are compared. This is mainly caused by the highly fluctuating Fuel Cost Charge (FCC) and to, a lesser extent, the Foreign Exchange Rate Fluctuation Adjustment (FEFRA) which change every month. Additionally, the grid doesn't cover all the populated areas, leading to more potential consumers being locked out of supply system.

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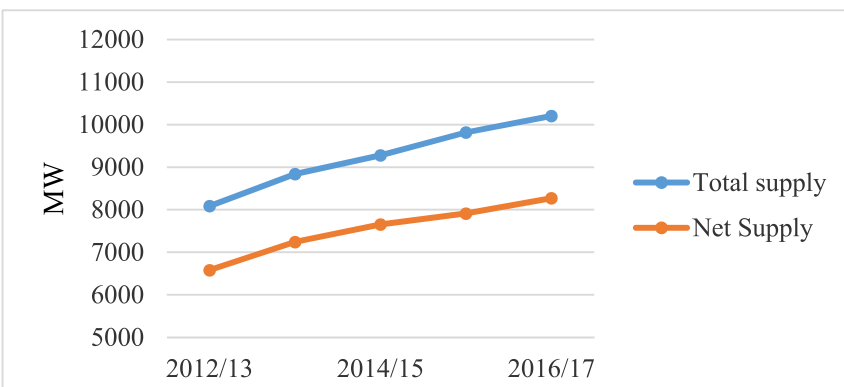
[12] Power Generation and Transmission Masterplan, Kenya Long Term Plan 2015-2035

2.4.6 **Technical & Commercial Losses**

Electricity utilities experience both technical and commercial losses along the value chain from the generation front to the retail end. Technical losses are inherent in the process of transmitting and distributing electrical energy because power networks consume and lose a proportion of the energy transported. Commercial losses occur due to electricity pilferages, faulty meters and inaccuracies in meter reading (KPLC, 2017). In the period between 2012/13 and 2016/17, the total generated capacity rose from 8,087 GWh to 10,205GWh, while the net supply increased from 6,581GWh to 8,272 GWh. The total loses have consistently increased over the same period from 1,507 GWh in 2013 to 1,933 in 2017, which represents a 28% increase. It can be deduced that with increased connectivity technical loses will rise as a result of low voltage connections that have typical higher losses.

Figure 6: Margin of Losses: Total Supply against Net Supply



As at June 2017 the system loses stood at 1,933 GWh which is about 18.9%

of the total energy purchased[13].

2.5 The Universal Electricity Access Strategy: The Last Mile Connectivity Project

In 2013, in recognition of very low access rates in comparison with similar African countries with only 35 % on average and 12% in rural areas having access to electricity, the GoK introduced the Last Mile Connectivity Program (LMCP) with an aim of achieving a universal access to electricity by 2020. The Project target was to get 5 million new customers in 5 years, at a time when Kenya Power, the sole distributor had only 3 million customers. Through this project, the Government aspired to[14]; increase the number of connections around distribution transformers and extend the Medium Voltage and Low Voltage distribution grid where needed in Kenyan rural areas; increase access to reliable electricity for households and businesses; improve economic development in Kenyan rural areas and reduce disparities between rural and urban areas (KPLC, 2017; Ministry-of-Energy, 2017).

The Project was designed in three phases. The first Phase of the project targeted at benefitting approximately 314,200 non-commercial customers (Domestic/households) and expand electricity access to an

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[13] Kenya Power Annual Accounts, 2016/17 Financial Year

[14] The European Union; International Cooperation for Development : https://ec.europa.eu/europeaid/blending/rural-electrification-kenya-last-mile-connectivity_en

additional 1.5 million Kenyans[15]. This was financed by the Government of Kenya in conjunction with the African Development Bank (AfDB) at the cost of KShs.13.5 Billion, ($13.4 Million approx.).This phase was primarily designed to extend the low voltage distribution network to reach households located within 600 meters of a transformer. The second and third phases of the project would see the installation of new transformers and further extension of low voltage network to reach an additional 500,000 customers thereby adding 2.5 million Kenyans to the power grid. The government intended to scale up supply and strategically diversifying the generation mix and generate new 5000MW+ in 40 months to 2017 as shown in Table 1.

[15] Kenya Power : http://www.kplc.co.ke/content/item/1120/last-mile-connectivity

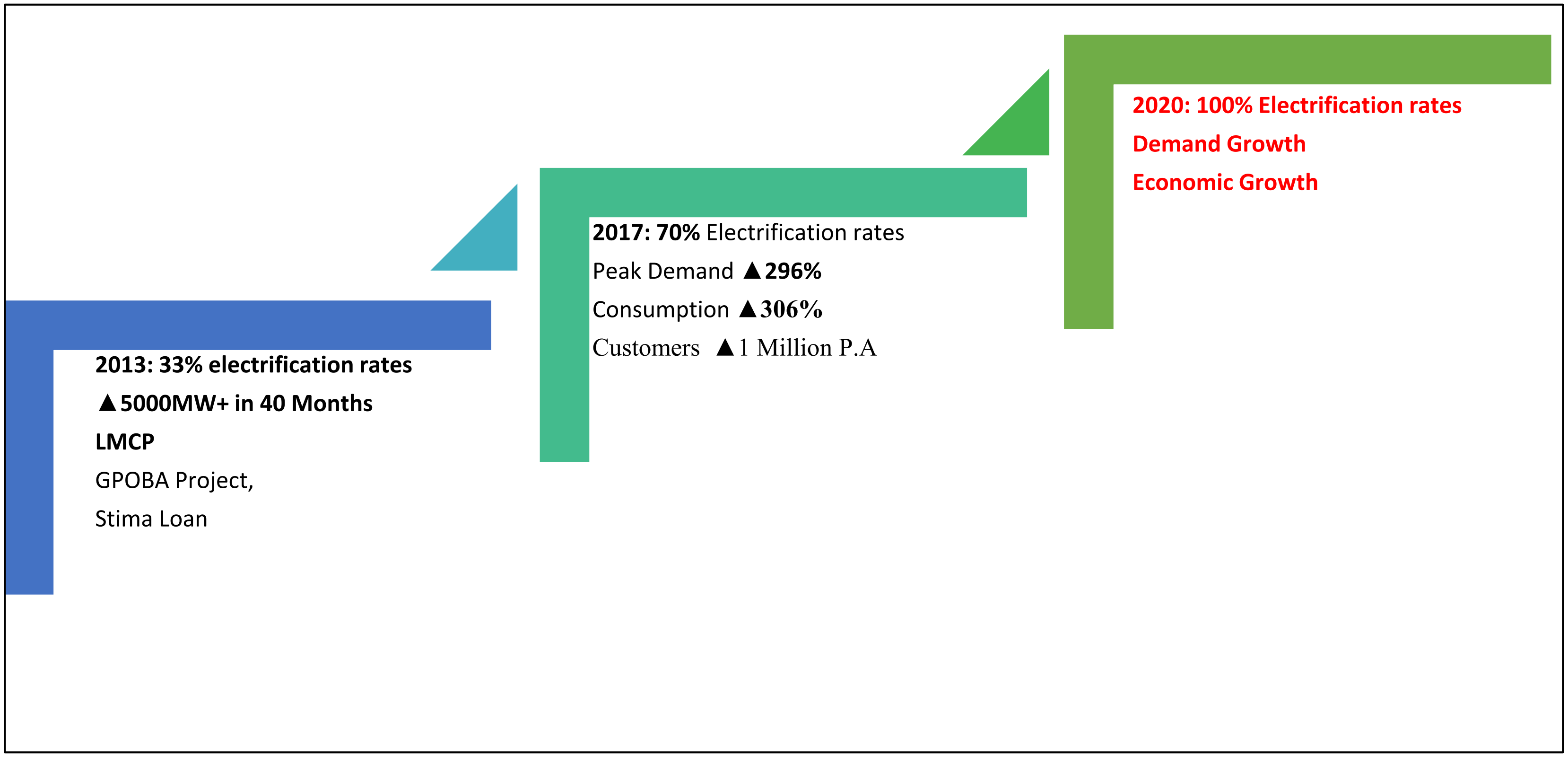

Figure 7: The Last Mile Connectivity Project in Figures

Acknowledging the reality of many Kenyans living in informal settlements with limited or no access to electricity, KPLC in partnership with the government and development partners, also launched the Global Partnership Output Based Aid (GPOBA) electrification project to provide safe, legal and affordable electricity to these settlements as well as reduce prevalent commercial losses attributed to electricity theft. To address the affordability of electricity connections, KPLC introduced *Stima*[16] *Loan*, a revolving fund for lending to potential customers who'd require financing for new electricity connections.

Additionally, the government through Rural Electrification Authority (REA), was charged with the responsibility of extending the connections to all public facilities, especially the public primary schools, dispensaries and health centers. It was expected that, the extension of electricity services to these facilities would bring electricity even closer to the people and raise the demand of new connections.

[16] "Stima" is a Swahili word meaning electricity

Table 1: The 40 Month 5000+MW Strategy

40 MONTH GOVERNMENT 5000+MW STRATEGY								
TIME/MONTH	**6**	**12**	**18**	**24**	**30**	**36**	**40**	**TOTAL**
HYDRO/ (COGEN.)	24	-	18	-	-	-	-	42
THERMAL/(COAL)	87	163	-	-	960	-	960	2170
GEOTHERMAL	90	176	190	50	205	150	785	1646
WIND	-	-	20	60	300	250	-	630
NATURAL GAS	-	-	-	700	350	-	-	1050
TOTAL	**201**	**339**	**228**	**810**	**1815**	**400**	**1745**	**5538**
Cumulative Additions	**201**	**540**	**768**	**1578**	**3393**	**3793**	**5538**	

The National Primary Schools Electrification Programme [17] was launched in this regard with a target of connecting all 22,175 public primary schools by June 2017, compared to the 8,203 schools had access to electricity in 2013.

It was expected that full implementation of the Last Mile Connectivity Project will facilitate Government objective of connecting 70% of Kenyan households by 2017 thereby achievement of universal access by 2020 (KPLC, 2017). The Project has however been met by a myriad of challenges, most of them financial related and low demand for and consumption of electricity by the newly connected customers**.** Aware of these challenges, the President on the launch of the second phase announced some fundamental changes of approach at how electricity connections were done. Whereas Kenyans used to make applications with long procedures in the past, the President announced the new tact where Kenya Power and the Rural Electrification Authority would solicit for consumers by knocking on doors asking Kenyans to allow them to connect their households to electricity. These agencies would also ensure that all households near electricity transformers were connected to power whether the owners have made applications or not. '*Everything we do is aimed at making Kenyans become busy with work, more productive and*

[17] Kenya Power: Launch of the LMCP: http://kplc.co.ke/img/full/2nPEsH9Dge4K_Launch%20of%20the%20Last%20mile%20connectivity%20Project.pdf

wealthier[18]', he said.

To ease the financial burden, the costs of connections was reduced from Kshs. 35,000 ($350 approx.) to Kshs 15,000 ($150 approx.), (57% reduction). Those who still couldn't pay the KSh15, 000 at one go would still get connected and have the option of making payment by installments through their monthly bills.

2.6 Energy Resources for Current and Future Demand

2.6.1 Fossil Energy Sources

2.6.1.1 Crude oil

According to the Kenya Power Planning unit the latest Least Cost Power Development Plan (2017-2037), commercially exploitable crude oil was discovered in Lokichar Basin, Turkana County in 2012 and in mid-2018 Tullow oil, the lead exploratory company started the Early Pilot Scheme which entails transport of crude oil to Mombasa by road mainly for export[19]. The potential for natural gas deposits are underway but still in the appraisal stage. The electricity sector currently relies considerably on imported crude oil and petroleum products for almost 40% of the

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[18] Accessed from http://www.president.go.ke/

[19] Extracted from Tullow oil website: https://www.tullowoil.com/operations/east-africa/kenya and reports in local newspapers such as Daily Nation, Monday, June 4 2018: https://www.nation.co.ke/news/Kenya-s-journey-as-an-oil-exporter-starts/1056-4593378-j9fim8z/index.html and the Star: https://www.the-star.co.ke/news/2018/06/04/kenyas-oil-export-plans-peak-as-first-barrels-leave-turkana_c1766041

installed power generating capacity[20]. Today, all petroleum products used in Kenya are imported including crude oil as well as refinery products.

2.6.1.2 Heavy Fuel Oil (HFO)

A large share of HFO used in Kenya is burned in diesel power plants, such as in the Kipevu Power Station in Mombasa. Besides power generation, the remaining share is used for industrial production. At present all HFO is imported through Mombasa port and transported by road to the power plant sites. HFO is not recommended as suitable fuel option for any expansion candidate given its negative environmental impacts.

2.6.1.3 Natural Gas

In 2017, ERC (2017) and Ministry-of-Energy (2017) reported that Africa Oil Corporation, a Canadian oil and gas exploration and production company, had discovered natural gas onshore in north-eastern Kenya. In cooperation with the GoK, the company is currently evaluating an appraisal plan to follow up the gas discovery is. In addition, the Africa Oil Corporation[21] is considering drilling an appraisal well on the crest of the large Bogal structure to confirm the large potential gas discovery which has closure over an area of up to 200 square kilometers. The gross best estimate of prospective resources for Bogal are 1.8 trillion cubic feet

[20] Kenya Power & Lighting Annual Report: 2014/15
[21] http://news.africaoilcorp.com/releases/entry/122489

of gas based on a third-party independent resource assessment.

Due to the early stage of exploration, it is assumed that domestic natural gas will not be a potential energy source for power generation.

2.6.1.4 Coal

Local coal reserves have been found in the Mui Basin which runs across the Kitui county 200 km east of Nairobi. Coal of substantial depth of up to 27 meters was discovered and 400 million tons of coal reserves were confirmed. The GoK has awarded the contract for mining of coal, and it is expected to be an important fuel option for expansion planning.

2.6.2 Renewable Energy Sources

Owing to her strategic geographical positioning (between the tropics and traversing the Great Rift Valley), Kenya has abundant potential for renewable energy sources. Sufficient solar, hydro, wind, biomass and geothermal resources has led the government to prioritize the expansion of renewable resource-based electricity generation in the country. Following a least cost approach, the government has invested heavily in the development of geothermal and wind energy plants as well as solar-powered mini-grids for rural electrification.

2.6.2.1 Geothermal Sources

The prospects of geothermal energy are located within and associated with the development of the Rift valley in Kenya (Muturi & Boo, 2017).

Currently, geothermal capacity provide nearly 50% of total power generation. Exploration studies of geothermal energy in Kenya has revealed rich prospects in the central sector of the Kenyan Rift and over 22 areas have been identified with a prospective capacity of 10000MWe The Geothermal Development Company (GDC), a state utility whose raison *d'etre* is to accelerate the development of geothermal resources in Kenya is in the process of exploratory wells in the rest of the sites. Muturi (2018a), named Menengai, Baringo Silali and Suswa as projects in near term development with estimated capacity of 5000MWe (3000, 1600 and 750MW respectively)[22].It is expected that geothermal power will an essential role in the future power system.

2.6.2.2 Hydropower

According to the latest least cost power development plan (ERC, 2017) Kenya has an estimated hydropower potential of between 3000 and 6000 MW[23]. Currently, the installed capacity is comprised of over 750MW of hydropower owned by the main power generation utility, KenGen. The existing hydropower plants contribute about 30% of national annual electricity generation. At least half of the overall potential originates from smaller rivers that are key for small-hydro resource generated electricity. With the introduction of the feed in tariff policy in 2008, it is

22 The Geothermal Development Company: available at http://gdc.co.ke/projects_intro.php
23 The LCPDP 2017-2030

expected that small-scale candidate sites are likely to come up as well, mainly supply of host villages, small businesses and large agricultural farms.

Ministry-of-Energy (2017) power plans and the ERC (2017) estimates that the undeveloped hydroelectric power potential of economic significance is about 1449 MWe, 1249 MW of which is for projects of 30MW or bigger. The average energy production from these potential projects is estimated to be at least 5,605GWh per annum. Exploitation of hydro resources have in the past been hampered by challenges of resettlement of population, and big projects such as the Magwagwa hydro project on river River Sondu that is in a densely populated area failed.

2.6.2.3 Wind

KenGen's 25.5MW wind farm in Ngong is the most recent investment in wind energy in Kenya. The farm is comprised of thirty (30) 850kW turbines. However, local production and marketing of small wind generators has started and few pilot projects are under consideration. However, ERC (2017) provides that only very few small and isolated wind generators are in operation so far. A remote Solar and Wind Energy Resource Assessment (SWERA) mapping exercise for Kenya was completed and published in 2008. This provides general information on the areas with the highest wind potential. A wind energy data analysis and development programme conducted in 2013 by WinDForce Management Services Pvt. Ltd indicates a total technical potential of 4,600 MW.

2.6.2.4 Solar Energy Sources

Due to her strategic geographic location near the equator and with an average of 4-6 kWh/m2/day levels of insolation, Kenya has great potential for the use of solar energy throughout the year (ERC, 2017). It is estimated that there are about 200,000 photovoltaic solar home systems countrywide, most of which are rated between 10We and 20We estimated at a cost of Kshs. 1,000/We. These generate 9GWh of electricity annually, primarily for lighting and powering television sets and other home based appliances. This however represents only about 1.2% of households in Kenya.

ERC (2017); KPLC (2017) contend that, with the enhanced state support, the rate of market penetration will improve considerably. The over four million households in rural Kenya spells a great potential for photovoltaic solar home systems. It is expected that the diversification of rural electrification strategies to incorporate solar based home solutions will see an exponential; growth in the number of installed solar home systems. This energy can and shall be harnessed to provide energy for water heating, and electricity generation for rural mechanized agriculture, households use, small industries and telecommunications facilities in off-grid isolated locations.

2.6.2.5 Biomass and other Bio-Energy Sources

According to ERC (2017), biomass energy refers to renewable energy coming from sources such as wood and wood residues, agricultural crops and residues, animal and human wastes. The conversion technology depends on the biomass itself and is influenced by demand side requirements. Biogas is a mixture of methane and carbon dioxide with small amounts of other gases and needs a further cleaning step before it is usable. Biogas is similar to landfill gas, which is produced by the anaerobic decomposition of organic material in landfill sites.

Municipal Solid Wastes (MSW) constitutes a potential source of material and energy as well. Because of its heterogeneous components, it is necessary to pretreat this wastes (or collect it separated by source) before it can be used. The objective is to recycle as much as possible and use the remaining material with a high calorific value in an incinerator or gasification process to provide heat, electricity or syngas. The wet material can be used in a fermentation process to produce biogas.

A study conducted by GTZ in 2010 shows a biogas energy potential mainly for heat production and a rather small potential for power production. However, some biogas power projects have been submitted to the FiT scheme.

2.6.3 Other energy Sources

Besides fossil fuels and renewable energy sources as a basis for power generation, nuclear energy and regional inter-connections to facilitate energy imports is considered as strategic for the country.

2.6.3.1 Nuclear Fuel

Conventional nuclear power production technology entails neutrons bombarding heavy elements such as uranium ("nuclear fuel") to disintegrate ("nuclear fission") which results in huge amounts of heat helping to produce steam and power through steam turbine operation (Muturi, 2018c). Uranium ore is the raw material used in the production of nuclear power. Currently, only low levels of uranium oxide have been discovered in Kenya. However, exploration of uranium is still on-going[24]. Worldwide uranium reserves are estimated at 5 million tons[25]. At current consumption levels, these reserves would last more than 100 years[26].

2.6.3.2 Regional Interconnections

Currently the Kenyan national grid is interconnected with Uganda via a 132kV transmission line. The interconnection aims at providing mutual

[24] Power generation and transmission masterplan 2016
[25] World Nuclear Association
[26] OECD Nuclear Energy Agency, International Atomic Energy Agency: Uranium 2011: Resources, Production and Demand

support for system stability. The country has also established cross boarder distribution systems with Tanzania and Ethiopia mainly to provide supply to the isolated boarder areas.

The East African Power Pool (EAPP), an intergovernmental organization established in 2005 aims to provide an efficient framework for pooling electricity resources and to promote power exchanges in Eastern Africa. So far, ten countries have joined EAPP that is Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Libya, Rwanda, Sudan, Tanzania and Uganda. As part of the "Regional Power System Master Plan and Grid Code Study" published in 2011, major interconnection projects have been identified as well as planning criteria to support inter-regional power exchange and a phased interconnection plan for the EAPP countries has been developed. Additionally, a regional master plan study for the EAPP region has been carried out. The interconnections endeavors to provide mutual benefits such as discounted electricity market and additional security of supply. Three interconnection projects between Kenya and Ethiopia, Uganda and Tanzania are already in the implementation stage.

Chapter 3. Literature Review

3.1 Existing Studies on Universal Electricity Access

Universal access to electricity has gained impetus as the world approaches the year 2030, the global target for the attainment of the SDGs, and particularly the Goal 7; to ensure universal access to affordable, reliable, and sustainable modern energy services. The Climate Change Agenda, especially the commitments to reduce carbon emissions and protect the environment arrived at the Conference of Parties (COP 21) under the auspices of the United Nation's Framework on Climate change (UNFCC). IEA (2017a, 2017b) noted that these aspirations saw many developing countries list universal access to electricity in their Intended Nationally Determined Contributions (INDCs). UNCTAD (2017), adds that the rapid technological advancements in renewable energies and the associated cost reductions have as well opened up unprecedented opportunities for electrification especially in rural areas through decentralized generation and mini-grids . The IEA (2017b) reckons that an estimated 200 million people who are likely to gain access by 2040 potentially do so through on-grid renewables, and 255 million more through decentralized renewables.

Studies on this subject have focused on different range of themes. The definition for universal access has for a long time focused on households, a binary issue of connected or not, but has recently evolved to focus on other attributes. Bhatia and Angelou (2015) proposed a multi-tier framework for electricity access, from tier zero at the lowest to tier five being the highest with different tiers distinguished by progressive attributes (including peak capacity, duration, reliability, duration, quality, affordability, legality, health and safety) and typical applications of household electricity services as shown in Figure 9. Odarno et al. (2017), concurred with this model and adds indicative technologies, with solar lanterns and rechargeable batteries at the tier 1 and access to the grid at the level, tier 5.

IEA (2017a), provided a progressive model for attaining universal access that starts from Pico solar through decentralized mini-grids and culminates to central grid connection. In other literature, other aspects such as regulatory approaches and the electrification business models as in Perez-Arriaga (2017), governance of the electricity sector in Scott and Seth (2013), technical issues Ahlborg and Hammar (2014); Barnes et al. (2016); C.Bhattacharyya and Ohiare (2012); F.Gómez and Silveira (2015), as well as the affordability and financial dimensions Abdul-salam and Phimister (2016); Abdullah and Jeanty (2011); ADB (2016); Barnes et al. (2016); Bhatia and Angelou (2015); Davidson and Sokona (2002); Mitra and Buluswar (2015); Nworie (2017); Pueyo (2015); Scott and Seth (2013); Smith (2004). The study of Odarno et al. (2017)

recommended a bottom-up approach to demand estimation, creating of synergies between the goals of electricity access and economic growth, and sound governance framework of the electricity sector is critical to the goal of universal access.

UNCTAD (2017) disputed these approaches on the premise of their focus on household needs for minimum energy needs, basically for lighting, cooking and the disregard of electricity supply for productive purposes. They argue that the costs of electricity generation and distribution require a minimum level of demand to make investments viable, and productive uses of electricity is the key to raising demand directly and indirectly by raising household incomes.

The transformational energy access framework is anchored on an energy-transformation nexus depicted in Figure 10. It asserts that electricity access has the potential of transforming the economic structure of the recipients, only if used in the productive sectors of the economy. It holds that, through productive uses, the transformation of the economy creates more jobs, new products and services while at the same time creating the demand required to make electricity investments viable. The economic transformation means improved incomes for households, which in turn leads to enhanced lives leading to consumption of electricity, creating more demand to warrant private investment.

While faulting the universal access paradigms, it is argued that following the progressive approach, leads to problems of raising demand for electricity and locking the economies into suboptimal development paths. For instance, it would not be economically attractive for consumers who already have solar home systems, to connect to a mini-grid, especially where there is a connection charge involved, and this. Instead, providing electricity to the needs of producers on a scale and quality necessary to create an economic structural transformation, is the key towards financially sustainable extension of electrification to the last mile.

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Typical applications for household electricity services	None	Radio, task lighting	Tier 1 + General lighting, TV, light office applications	Tier 2+ Air cooling, food processing, task-oriented food preparation	Tier 3+ Refrigeration, water heating, pumps, expanded food preparation	Tier 4+Air conditioning, space heating
Indicative Technologies		Solar lantern Rechargeable batteries Stand-alone Home System Mini-grids Grid	Rechargeable batteries Stand-alone Home System Mini-grids Grid	Home System Mini-grids Grid	Home System Mini-grids Grid	Home System Mini-grids Grid
Attribute 1: Peak Capacity	Power	V. lower power min 5W	Low power min 70W	Medium Power Min 200W	High power Min 800W	V. high power min 2 kW
	Daily capacity	Min 20 Wh	Min 270Wh	Min 1.0kWh	Min 3.4kWh	Min 8.2 kWh
Attribute 2: Duration	Hours per day	Min 4 Hours		Min 8 Hours	Min 16 Hours	Min 23 Hours
	Hours per evening	Min 2 hours		Min 2 Hours	Min 4 Hours	Min 4 Hours
Attribute 3: Reliability				Max 3 Disruptions per day	Max 7 disruptions per week	Max 3 disruptions per week of total duration <2hrs
Attribute 4: Quality				Voltage problems do not prevent use of desired appliances		
Attribute 5: Affordability				Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
Attribute 6: Legality				Bill is paid to the utility/prepaid seller or authorized representative		
Attribute 7: Health and Safety				Absence of past accidents, low perception of risk in the future		

Figure 8: The Multi-Tier Universal Access Paradigm Bhatia and Angelou (2015) and Odarno et al. (2017) Pg. 6

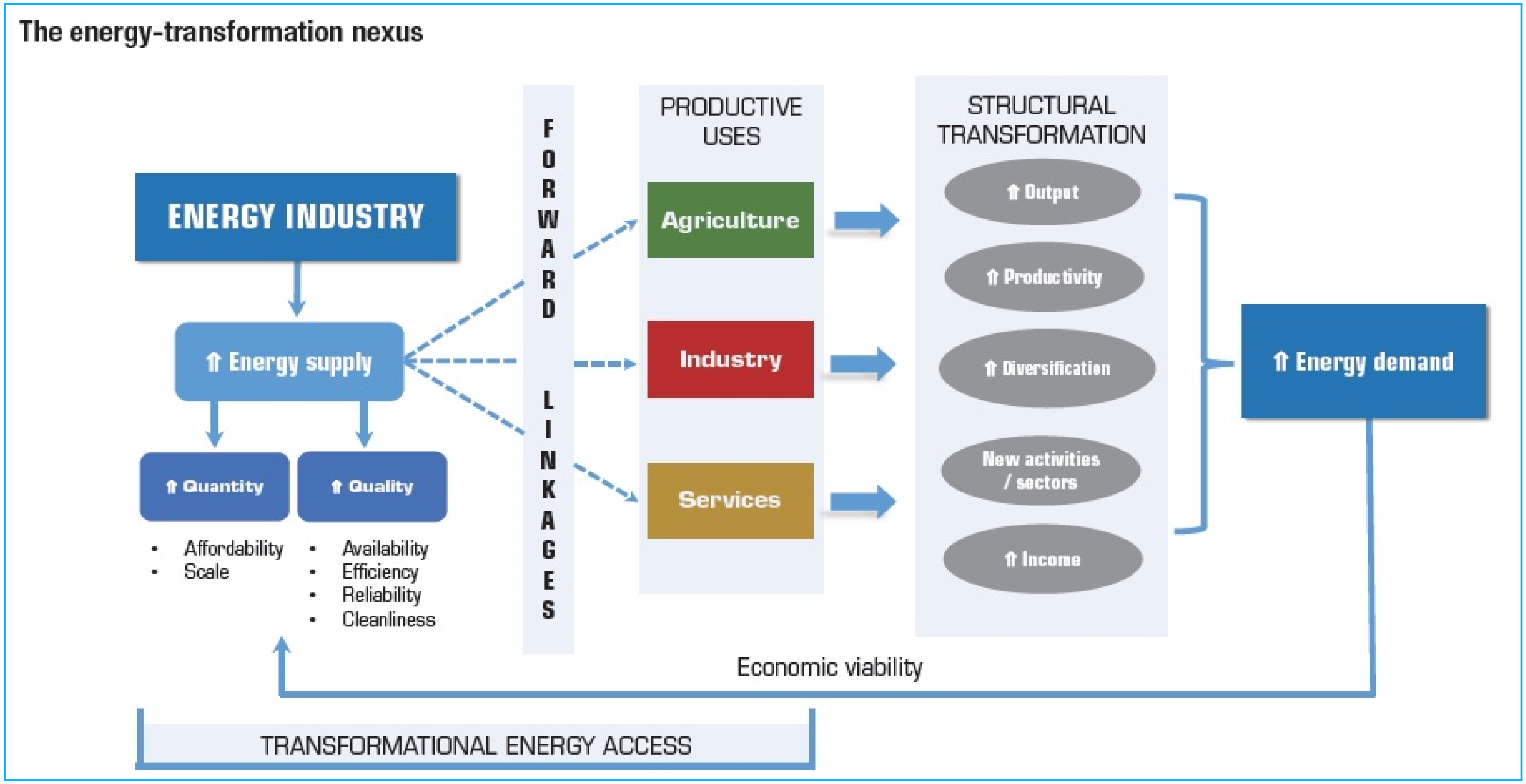

Figure 9: The Energy-Transformational Nexus (UNCTAD, 2017) Pg. 78

Governance of the energy sector has dominated many studies and has been cited as a critical component to the goals of universal access. UNCTAD (2017), defined governance structures as the set of institutions, policies and regulations that frame ownership structures and operations, and the rights and responsibilities of actors in the electricity sector. They are important determinants of sectoral performance, the quality of services and the extent of the private capital flows into the sector.

Perez-Arriaga (2017) underpinned the importance of governance by focusing on the importance of a sound regulatory approach in particular and argued that, whereas the technology and sufficient funding necessary to attain the universal by 2030 exist, a regulatory component and the associated business model package that is suits the specific characteristics of electrification in the developing countries, and that can be merited by a quantitative feasibility of costs and benefits is lacking. Muturi and Boo (2017), stressed that the regulations should be context-specific, and create credible institutions that have the requisite independence to implement and enforce regulations. The regulations must in a transparent manner assign responsibilities to provide reliable, efficient and affordable services, and establish the avenues for identification and solution of disputes.

ADB (2016), and Price Water House Coopers[27] (PWC) in a study of Indonesia similarly identified regulatory uncertainty as a major barrier to the extension of electrification in that country. World-Bank (2017), also contends that in countries striving to achieve universal access, both grid and off-grid solutions must be supported by an enabling environment with the right policies, institutions, regulations and incentives.

Scott and Seth (2013), extended a similar line of thought and underlined the crucial role of governance in their study on the political economy of electricity distribution in developing countries. They found evidence of how weak governance structures and institutions are manipulated by politicians to the detriment of universal access goals. In rural areas for instance, where grid extension may be limited for technical difficulties and financial ineffectiveness, some political incentives exists too. The combination of low population and with high upfront investment costs rural areas don't reciprocate the political returns in form of votes, or political support. They found politically motivated electricity theft in India and Nepal where corrupt staff were bribed to allow electricity theft in form of meter tampering, unmetered consumption, and unsanctioned connections to the grid. The political actors were as well willing to allow the practice to continue as long as they received their kick-backs. Similar

[27] Powering the Nation; Indonesia Power Industry Survey accessed from https://www.pwc.com/id/en/energy-utilities-mining/assets/power/power-survey-2017.pdf (publication details unavailable)

issues were alluded to in the works of Abdul-salam and Phimister (2016), Jack and Lipscomb (2017) and Mahalingam et al. (2006); Sovacool (2012). Nepal and Jamasb (2011), on their case argued that political instabilities and information asymmetries in Nepal created avenues for unfair rent seeking and corruption, where government officials licensed and approved unfeasible projects, committed the country into loss making power-purchase agreements (PPAs) with the private sector and as well used state utilities for electoral and political purposes.

Electricity supply continues to be used as a political tool in many countries. Scott and Seth (2013), also notes that in India, the level of subsidies tends to increase significantly in the election year. In Nepal, they add, the power tariffs are not economically determined, but are rather based on the vested interests of the politicians. Sovacool (2012), concurred that many politicians secure support by delivering highly subsidized electricity to the citizens. Similarly, Golden and Min (2012) asserts that power thefts are often overlooked by the government over the concerns of losing political support. Rehman et al. (2012), suggests that major consequence of such weak governance and politically motivated policies is losses of funds in state owned electric utilities, which impair their ability to extend and improve service delivery.

Mahalingam et al. (2006), endeavored to study the strategies employed in various countries to provide sustainable access for all and reported various challenges. In India for instance, he reports that due to mismatch in priorities, there were incidences of people informally hooking-on, modifying and hacking the systems. Solar lanterns and their panels were being hacked to charge mobile phones, and a biomass micro-grids was being illegally used to power on televisions, fans and water pumps. This, he attributed to lack of flexibility to accommodate people's needs in the supply systems.

Practical-Action (2010), categorized the barriers to expanding universal electricity access as financial and economic; capacity and technical; and policy and institutional. The first revolves on the high costs associated with the investments in generation and extension of transmission and distribution facilities as well as the household affordability of power tariffs, access to finance for investments, and the effectiveness of the options for recovery of sunk costs. The second category entails all that in the technical and managerial competencies in designing, installation and operation of electrical systems, and the efficiency in which technologies are deployed to generate sufficient returns to investments. The third category addresses the adequacy of the planning and policy framework, the governance structures and the right institutions with the necessary capacity and autonomy to implement policies.

Mitra and Buluswar (2015), extended the financial and economic dimension of access to focus on the affordability challenges to the universal access to electricity. They argued that electricity can only change lives when people afford electricity-powered services to meet their basic needs, which is basically more than a light bulb and a fan. However, in the current market conditions and in absence of subsidies, a majority of consumers are trapped in the affordability chasm. They argued that technology breakthroughs will significantly reduce the up-front costs for solar photovoltaics and mini-grids, bulk storage and affordable easy to use grid management solutions for decentralized renewable energy mini-grids and eventually bridge the affordability gap. World-Bank (2017), noted that affordability remains a critical barrier and called for lowering of the upfront costs by providing targeted financing and subsidies, harnessing new business models and creating sound policies and institutions. The affordability challenge ought to be addressed by ensuring that household electrification strategies take into account other development goals and opportunities to use electricity access for productive purposes to stimulate economic growth.

Dagnachew et al. (2017), delved into the technical aspects in their study on the role of decentralized systems in providing universal access in Sub-Saharan Africa. By using the costs of electricity supply technologies (leverised costs of electricity (LCOE), the distance to the power line, population density, household electricity consumption, and resource availability, they modelled a quantitative approach to explore a baseline scenario and a universal access scenario. Their study concludes that there is still a significant gap between the projected electricity access rate in their base line level of 2010, and such, the goal of 2030 universal access is unachievable. They further argue that the technology mix for providing full access to access would depend on the demand/or the desired levels of electricity consumption.

F.Gómez and Silveira (2015), focused on the role the off-grid solutions in their study and argued that small-scale off-grid generation based on local resources are the keys to the goals of last mile electricity access. Their sentiments are echoed by C.Bhattacharyya and Ohiare (2012) who also recommended the adoption of off-grid solutions based on local resources and early recognition of rural electrification and rural development networks in a bottom-up approach to electrification. Ahlborg and Hammar (2014), as well concluded that in Tanzania and Mozambique where rural electrification rates are as low as 5%, despite the efforts to extend the national grid, most remote areas will not be reached in the foreseeable future devoid of significant inclusion of off-grid supplies in the electrification plans.

This survey of literature shows that despite the efforts geared towards the attainment of universal electricity by 2030, there are still plenty of challenges to be tackled. These range from policy and institutional governance of the electricity sector, economics and financing dilemmas, the technical infrastructure that include grid and off-grid technologies, and the associated environmental and socio-political considerations. While a number of these challenges have been studied in the past, the literature doesn't provide a consensus on the issues. A new approach to the universal access, the transformational access has been proposed with the promise of addressing the challenges of the predecessor, the household oriented universal access, mainly the sustainability issue by raising the demand for electricity and enhancing financial sustainability. However, there has been no research that have evaluated the policy challenges to universal access on a quantitative scale.

This research contributes to the literature and fills this knowledge gap by analyzing the challenges to electrification while using AHP as a multi Criteria Decision Making Analysis (MCDA) to rank the choice alternatives and deduce policy contributions.

3.2 Multi Criteria Decision Analysis as a Method

The determination of policies that affect a country's entire energy and other policies is a complex process and unlike other everyday problems that may be handled intuitively, such decisions are often complex and involve many conflicting objectives. In such situations, Aljamel, Abdi, and Shewtan (2017) explains that it is desirous to apply a formal and an objective procedure that take into account a wide range of parameters to make the decision-making more clearer, fair to all, and prudently allocate the scarce resources. Ishizaka and Nemery (2013), conveyed that the Multi-criteria Decision Analysis (MCDA) methods offer such formal procedures of solving decision situations

Locatelli and Mancini (2012), explained that MCDA is a scientific discipline that includes mathematics, informatics, management, psychology, social sciences and economics, and has the versatility to be applied in many strategic decision making dilemmas. These techniques deal with the problem of choosing the best solution among a finite set of competing alternatives. The decision problems keep on evolving as new developments in science and technology, political and environmental landscapes as well as the businesses and industry emerge. Roy (1981), decision categories fourfold into:

1) The Choice Problems; this involves selecting the best option out of many alternatives,
2) The Sorting Problem; this involves grouping problems based on their characteristics or similar behavior
3) The ranking problem; this involves using some scale or a pairwise comparison to allocate scores or evaluate the alternatives on a range of from the best to the worst.

4) The description problem; this involves providing a qualitative description of all alternatives and their consequences. This is normally conducted in the preliminary stages of decision making to provide a deep understanding of the alternatives to the decision makers.

e'Costa, Corte, and Vansnick (2005), added to the above the *'elimination problem'*, which is an advancement of the sorting problem. Keeney (1998), also suggested *Design Problems* in which he proposed that there are some specific actions that are supposed to be taken in order to achieve the desired purpose. Regardless of the type of the decision problem, there are a number of MCDA methods that can be used in a number of different problems. Table 2 presents a summary of the MCDA methods, their strengths and weakness as highlighted by Locatelli and Mancini (2012).

Table 2: Strengths & Weaknesses of Select Multi-Criteria Decision Analysis Methods Locatelli and Mancini (2012).

	Comparison of various MCDA Methods	
	Strengths	Weaknesses
AHP	~ Well established method ~ Very flexible to fit in many problem sets ~ Effective in integration of qualitative and quantitative assessment ~ Pairwise comparisons approach allows a simple and effective elicitation of attribute's weights ~ Simplifies complex problems by breaking it into simpler hierarchical components ~ Doesn't require specific utility functions for each of the attributes; performance functions for each of the	~ Translating a complex problem into a hierarchy is difficult and quite subjective ~ Each judgement must be expressed on Saaty's nine-point scale, based on crisp numerical values ~ In presence of many attributes, too many judgements from experts are requited ~ There is a risk of rank reversal

	Comparison of various MCDA Methods	
	Strengths	Weaknesses
	attributes; performance of the alternatives on attributes are elicited from the experts. ~ Measures the consistency of the experts' judgements and the sensitivity of the results.	
Fuzzy AHP	• It better represents the uncertainty of judgements than the AHP by using overlapping fuzzy variables to represent expert opinions • Decision makers cognitive process is made simpler by use of linguistic variables to express judgements	• Comparison and ranking of fuzzy sets in the final evaluation are complex and unreliable • Hierarchical structures with more than three levels are difficult to completely and comprehensively examine. • Measurement of consistency is more complicated than the traditional AHP

	Comparison of various MCDA Methods	
	Strengths	Weaknesses
ELECTRE	• Well established method • Based on particular outranking relations, less restrictive than dominance relations • The outcome is a ranking, and easier to understand than AHP indices	• More use with many alternatives and few attributes • Normally identifies a restricted group of preferable solutions, instead of the best one. • It considers only the number of attributes for which alternative A outranks B.
PROMETHEE	• Thresholds for preference and indifference indexes permit considering non-linear preferences • Thresholds permit defining different degrees of preference between two alternatives on each attribute	• More useful with many alternatives and few attributes • Thresholds are subjective and decision-maker-dependent

	Comparison of various MCDA Methods	
	Strengths	Weaknesses
TOPSIS	• It's intuitive and easy to understand • It provides for decision matrix normalization • Considers the real existing gap between values of different alternatives, and does not only count the number of outranked attributes	• More useful with many alternatives and few attributes • To consider positive and negative ideal solutions could be meaningless for some applications

The nature and scope of this study leads one to a ranking problem decision analysis. From our goal to analyze the main challenges of universal electricity access, the AHP is a close fit to the nature of the problem. Additionally, the nature of input variable being a pairwise comparisons on a ratio scale as shown in Table 3influenced this decision. The nature of input and output variable makes it possible to employ a varying range of technical complexity in the survey questions on varying degrees of respondent's competencies.

Table 3: Varying Input/output for MCDA Ranking Choice Methods (Ishizaka & Nemery, 2013)

Inputs	MCDA Method	output
Utility function	MAUT	Complete ranking with scores
Pairwise comparison on a ratio scale and interdependencies	ANP	
Pairwise comparison on an interval scale	MACBETH	
Pairwise comparison on a ratio scale	AHP	
Indifference, preference and veto thresholds	ELECTRE	Partial and complete ranking (pairwise outranking degrees)
Indifference and preference thresholds	PROMETHEE	Partial and complete ranking (pairwise preference degrees and scores)
Ideal option and constraints	Goal Programming	Feasible solution with deviation score
Ideal and anti-ideal option	TOPSIS	Complete ranking with closeness score
No subjective inputs requires	DEA	Partial ranking with effectiveness score

The AHP is preferred because of its relative effectiveness in integration of qualitative and quantitative evaluation of attributes, and its pairwise comparison approach allows a simple and effective way of elicitation of attributes' weights.

AHP was first introduced as a valid approach to solve economic, technological, socio-political and other complex problems by Saaty (1980) who proposed four steps to the ranking decision making problem:

1. Determine the goal of the decision making process (problem structuring)
2. Establish a hierarchy structure describing the criteria, factors and alternatives
3. Make a set of pairwise comparisons
4. Evaluate the calculations obtained from the pairwise comparison matrices to weigh the propriety for each level until the local and global priorities are achieved.

Significant to AHP is that the problem is modelled into a hierarchy, where the goal or the central decision to be made sits at the apex of the hierarchy. The subsequent levels are reserved for the criteria and the decision alternatives in that order. The priorities/weights are central to the AHP objective as they are used to describe the respondent's preference of an attribute with respect to a particular variable. In AHP, Ishizaka and Nemery (2013) conveyed that there are three types of priorities:

1. Criteria priorities related to the importance of each criteria relevant to the overall goal;
2. Local alternative priorities which are criterion specific and;
3. Global alternative priorities, which rank alternatives with respect to all criteria.

The criteria and local alternatives priorities use pairwise comparison of a criterion against another and pairwise comparison of an alternative against another alternative with respect to a certain criterion. The criteria central to the goal development is selected from literature review and expert recommendation.

3.2.1 AHP Application in Previous Energy Studies

Since the introduction of AHP by Thomas L. Saaty in the 1980s, the method has been used in a variety of disciplines to make different decisions and have been improved over time. Keeney, Renn, and Winterfeld (1987), used it to evaluate the applicable criteria in the determination of the future energy systems in West Germany. Hamalainen and Karjalainen (1992), used it to evaluate the criteria with the greatest impact in Finland's energy policy. Locatelli and Mancini (2012), used it as framework for selecting the right nuclear power plant to invest in.

In ranking problems, a number of somehow similar and/or related criteria have used in a previous studies to guide energy-related policy. Kabir and Shihan (2003), used AHP to rank the renewable energy sources and technology options for Bangladesh from among solar energy, wind and biogas. They used cost per unit of power produced, social impact, technical, location and environmental impacts as the ranking criteria and found solar to be the best choice of renewable energy.

Nigim et al. (2004), augmented their AHP study by performing additional expert surveys to evaluate the need to establish pre-feasibility ranking of local renewable resources and their potential to minimize dependence on imported energy sources. The criteria used for this study included ecological impacts, social and economic benefits, educational benefits, resource availability, technical feasibility and financial viability.

Kaya and Kahraman (2010), used technological indicators, economic, social, and environmental indicators to analyze a policy for renewable energy planning in Istanbul and ranked wind energy as the most cost effective source of renewable energy. A keen observation of these studies shows a pattern of recurring themes, or similar criteria being used in energy policy analysis in AHP studies. In fact, Wang et al. (2009) contends that technical, economic, environmental and social criteria are recurring themes in AHP studies. Different criteria however can be used depending on the nature and the desired goals of the particular study.

Heo et al. (2010), applied technical, market, environmental and policy as criteria in their study of the factors affecting renewable energy dissemination programs in Korea. They included the market factor to evaluate the readiness and competitiveness of Korean domestic market, its existing technology and readiness to adopt the renewable energy technologies. The study found more relevance in the economic feasibility and the technology maturity of individual renewable energies as the most important determinants of the success of the renewable energy dissemination programs.

There is a deficiency of literature on AHP that have focused on barriers of universal electrification and the evaluation of the critical components that constitute a sound a policy for attaining sustainable universal electricity access. This research intends to address this gap, and will identify the barriers to universal electrification from literature, and use AHP to analyze how they can be addressed by selecting the right electrification policy. The criteria used for this study and the AHP methodology applied in this study is described next.

Chapter 4. Research Methodology

4.1 The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) has become a popular methodology amongst researchers and policy makers in various fields. Sangwook (2016), attributed this largely to its relative ease of application, and adaptability across various research disciplines. Saaty (1980), explained that the AHP can provide a framework and methodology for the determination of a number of key corporate decisions in a firm. According to Saaty (2008), the framework is in itself "a theory of measurement through pairwise comparisons and relies on judgements of experts to derive priority scales. Wind and Saaty (1980), conveyed that, the novel aspect of and the major distinction of AHP is that it structures any complex, multi-person, multi-criterion, and multi-period problem hierarchically. In AHP, a particular method is used for scaling the weights of the elements in each level of the hierarchy with respect to an element (or a criterion) of the next higher level, a matrix of pairwise comparisons of the activities can be constructed where the entries indicate the strength with which one element dominates another with respect to a given criterion. This scaling formulation, Saaty (1980), explained is translated into a largest eigenvalue problem which results in a normalized and unique vector of weights for each level of the hierarchy which in turn results in a single vector of weights for the entire hierarchy . The vector scores are the measures of the relative importance of each factor to the goal and the basis of formulation of strategies..

Saaty (1980); (Saaty, 1986, 2008; Wind & Saaty, 1980) explained that, to make a decision in an organized way to generate the priorities needed in AHP, the decision problem is decomposed into the following steps:

1) Define the knowledge and determine the kind of knowledge required,
2) Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (usually a set of alternatives)
3) Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it
4) Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Repeat this for every element. Then for each element in the level below add its weighted values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

In this research, the fundamental goal and basis of the problem was to identify and rank the barriers that contribute to failed electrification policies, which are basically the same policy factors that should contribute to the goal of sustainable extension of electrification initiatives. The problem was then decomposed into a simple 2-level hierarchy, with a goal, 4 main criteria, and 14 sub-criteria as shown in Figure 11.

4.2 AHP Criteria Selection

The criteria for this evaluation was elicited from the literature review as presented herein. Additionally, the researcher made use of internal correspondences, working policies and plans of the power planning entities in the Republic of Kenya. The Financial Reports of KPLC, Energy Regulatory commission (ERC), Rural Electrification Authority (REA) and Kenya Electricity Generating Company (KenGen) were also used to formulate the criteria for this study. The criteria was discussed with experts in the energy sector in Kenya, and specifically the energy planning team at the ERC. The multi-disciplinary team comprising of engineers, economists, lawyers, urban and regional development managers who are bestowed the responsibility of developing the major power sector plans under the supervision of the ERC and within the policies and the guidelines of the MOEP was in agreement that the selected criteria adequately represented the challenges of electrification in Kenya.

Table 4: Summary of Literature Applied in Criteria and Factors Selection

Barriers to and the Framework for Selecting a Sustainable universal electrification Policy		
Criteria	Sub-criteria	References
1. Policy & Institutional	1. Inadequate Policies/Plans 2. Weakness in governance structures & Institutions 3. Bureaucratic red tapes, politics and leakages (corruption)	(Lee et al., 2016; Odarno et al., 2017; Perez-Arriaga, 2017; Practical-Action, 2010; Pueyo, 2015; Rehman et al., 2012; Ruijven et al., 2012; Scott & Seth, 2013; Sovacool, 2012; Szabo, Bodis, Huld, & Moner-Girona, 2013; UNCTAD, 2017; Vera, 2016; World-Bank, 2017)Wood, et.al, 2014; (S mith, 2004)

Barriers to and the Framework for Selecting a Sustainable universal electrification Policy		
Criteria	Sub-criteria	References
Economic & Financial	1. Challenges in Demand Forecasting & Planning 2. Funding & Financing Gaps 3. Poverty & Low Household Affordability 4. Low productive use and little industry	(ADB, 2016; Bhatia & Angelou, 2015; C.Bhattacharyya & Ohiare, 2012; Dagnachew et al., 2017; IEA, 2017a, 2017b; Kaya & Kahraman, 2010; Kenneth Lee, 2016; Mitra & Buluswar, 2015; Nepal & Jamasb, 2011; Practical-Action, 2010; Pueyo, 2015; Smith, 2004; UNCTAD, 2017; Vera, 2016) (Barnes et al., 2016) (Abdullah & Jeanty, 2011)
3. Technical	1. Low generation capacity 2. Low levels of Reliability & quality of supply 3. High technical losses and low efficiency	[UNCTAD, 2017; K. Lee et al. (2014); Dagnachew, A. G et al., 2017; Labordena et al,. 2017; Bhattachayya, C. and Subhes, O. (2012); Ouedraogo, 2017; Hogarth and Granoff, 2015; Deshmukh et al., 2013; Africa Progress Panel, 2017;

Barriers to and the Framework for Selecting a Sustainable universal electrification Policy		
Criteria	Sub-criteria	References
		Maria, F. G. and S. Silveria 2015).
4. Environmental & Socio-Political	1. Limitations of exploitable Energy resources 2. Challenges of land use and acquisition, compensation & resettlement of population 3. Limitation of rural infrastructure 4. Problems of local participation, theft and vandalism	(Gies, 2016 (IRENA, 2016a).; K. Lee et. al (2014) UNCTAD, 2017] [IRENA, 2017] Ahlborg, H. and H. Linus (2014); Bhattachayya, C. and Subhes, O. (2012)

The four criteria selected from literature and expert contributions encompass the essential elements of an electrification policy. It is also expected that the challenges to sustainable electrification in Kenya, which is the central theme of this study, revolves around the same criteria. The following section provides a description of the criteria and the factors.

4.2.1 Policy and institutional

This criterion addresses the adequacy of the planning and policy framework, the governance structures and the institutions put in place to implement policies. It is desirous that the right policies are put in place and they adequately address the problems at hand, while they are at the same time dynamic enough to accommodate the expected growth in power demand. The governance structures should as well put in place transparent and fair regulatory regimes devoid of bureaucratic inefficiencies and avenues for political patronage to curb corruption and encourage flow of investments in the electricity sector.

4.2.2 Economic and Financial

The economic and financial criterion addresses the high costs associated with the investments in generation and extension of transmission and distribution facilities as well as the household affordability of power tariffs, access to finance for investments, and the effectiveness of the options for recovery of sunk costs. In household focused universal access paradigms, issues of low productive use and little industry hurt growth of demand for electricity and limit generation. Lack of linkages of access to electricity with other development goals and high demands for compensation for land acquisition are also significant barriers in this category.

Additionally, the (World-Bank, 2018) notes that in countries without universal access, affordability concerns affect 57% of those who already have access. Given that a proportion of levies bestowed upon the connected consumers is used to expand access, this has the potential of crippling further extensions of the electricity services.

4.2.3 Technical

This criterion entails all that in the technical and managerial competencies in designing, installation and operation of electrical systems, and the efficiency in which technologies are deployed to generate sufficient returns to investments. The challenge factors in this domain include limited generation capacities, low efficiency and high technical losses mainly occasioned by long transmission distances and ailing distribution facilities, low reliability (including infrastructure) and quality of supply. Limitation in the generation and installed capacity inhibits the scalability further limiting the reliability of the electricity to support the expansion of economic activities.

4.2.4 Environmental and Socio-Political

Challenges like geographical terrains make it technically challenging and financially costly to exploit energy resources and extend transmission and distribution facilities to some areas. Such factors also influence the levels of investments in other infrastructure like road networks and consequently affect the population distribution and the nature of economic activities. These factors contribute greatly to the affordability and demand of electricity and have an influence on the electrification policies. Likewise, the demographic characteristics of the population such as the number of people in a household, their economic activities, household incomes, and their education background influence the extent of their participation especially in the rural electrification initiatives. Creation of employment at local levels is always expected with penetration of electricity where literacy levels are high. Otherwise, lack of local participation is often associated with high incidences of theft and vandalism of infrastructure.

The fundamental principle behind AHP is measurement through pairwise comparisons and depends heavily on the judgements of the respondents to derive the priority measurements. When the goal of the study is decided and the criteria is selected, and the alternatives identified, the next step is usually to design the problem into a hierarchy. In the hierarchy, the top level represents the main issue that becomes the subject of the decision making process. The next level represents the important criteria that are used to explain the main goal. The subsequent levels represent the sub-criteria or factors and alternatives (Ishizaka & Nemery, 2013). The hierarchical structure illustrates the relationship between the various factors and the criteria underlying the decision making process (Shapira & Goldenberg, 2005). The hierarchical structure used in this study is as presented in Figure 11.

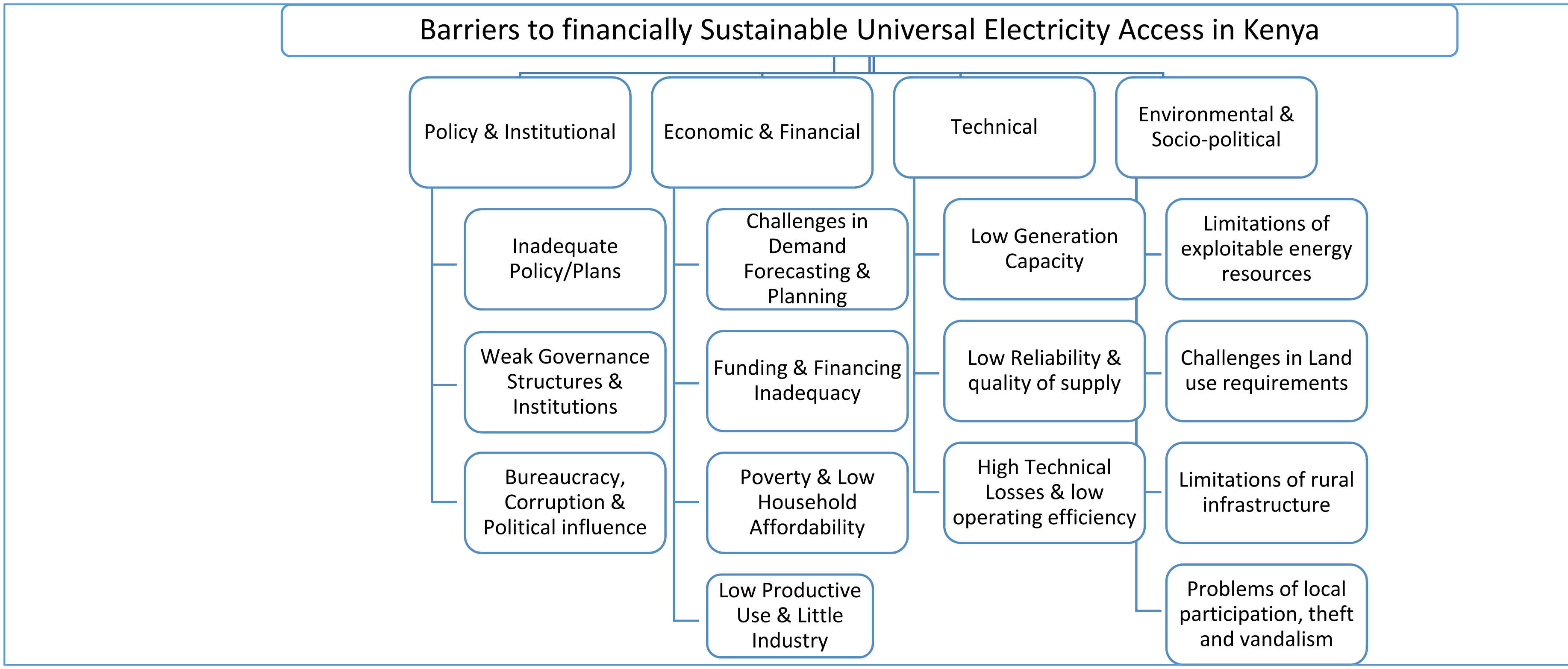

Figure 10: The AHP Hierarchy Structure

4.3 Quantitative Analysis and Pairwise Comparisons

The next step as explained in Saaty (2008); (Wind & Saaty, 1980) is to define a measurement methodology to establish the priorities among the elements within each stratum of the hierarchy. This is achieved by requiring the decision makers to evaluate the sets of elements by conducting pairwise comparisons with respect to each of the elements in a higher level. This Wind and Saaty (1980), expounded is achieved by breaking down the hierarchy structure into a series of pair comparison matrices.

Table 5: A Pairwise Comparison Matrix (Saaty, 1980)

Criterion	C_1	C_2	C_3	………	C_n
Weights	W_1	W_2	W_3	……….	W_n
Alternative					
A1	a_{11}	a_{12}	a_{13}	……….	a_{1n}
A2	a_{21}	a_{22}	a_{23}	…………	a_{2n}
A3	a_{31}	a_{32}	a_{33}		a_{3n}
……					
A_m	A_{m1}	A_{m2}	A_{m3}		A_{mn}

The decision makers are then required to evaluate the off-diagonal relationships in one half of the matrix, whereas the reciprocals are placed in the transposed positions of the matrix as in Table 6;

Table 6: Pairwise Comparisons and Reciprocity (Wind & Saaty, 1980)

Criteria	A	B	C	D
A	1			
B		1		
C			1	
D				1

Where;

(blue)	Judgements B vs A, C vs A, D vs A, C vs B, D vs B and D vs C
(orange)	Reciprocal Values of B vs A, C vs A, D vs A, C vs B, D vs B and D vs C judgements

To provide a numerical judgement, the AHP requires that the qualitative expert judgements be translated into numerical figures. (Saaty, 1986, 2008; Saaty & Vargas, 2011) provides a 9-point scale for making these conversions and the same was utilized in (Sangwook, 2016) explained that they are transposed as highlighted in Table 7.

Table 7: Numerical Scale for Verbal Judgement of Predilection

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two criteria are equally important
3	Weak/moderate importance	Experience and judgement slightly favor one criteria over the other
5	Essential or strong importance	Experience and judgement slightly favor one criteria over the other
7	Demonstrated importance	An criteria is strongly favored and its dominance is demonstrated
9	Absolute importance	There's evidence favoring one criteria over another in the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed
Reciprocals (Non-zero)	If activity *i* has a nonzero judgement assigned to it when compared to criterion *j*, then *j* has the reciprocal value when compared to criterion *i*.	

Using this scale the decision makers assess the relative importance of one criteria over another within the hierarchy. The judgements are then posted into the matrix, with the reciprocals completing the transposed half of the matrix, as shown in Table 6.

To calculate the priorities, we assume that if we have *n* objects that is A_1………A_n whose vector of corresponding weights $w = (w_1$ …………$w_n)$ is known, then the matrix of pairwise comparison is given as shown herein;

$$A = \begin{pmatrix} A1 \\ . \\ . \\ . \\ . \\ . \\ An \end{pmatrix} \begin{pmatrix} A1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots An \\ \frac{w1}{w1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \frac{w1}{wn} \\ . \\ . \\ . \\ . \\ \frac{Wn}{w1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots. wn/wn \end{pmatrix}$$

The scale of weights is recovered by multiplying *A* on the right with by *W,* to obtain the *nw,* and then solve the eigenvalue problem of *Aw=nw* which has a nontrivial solution given that n is the largest eigenvalue of *A.* It follows that matrix A has unit rank and therefore all of its eigenvalues are zero, except one. After eliciting the judgements of the experts and entering them and their reciprocals in the transpose positions, we sum the totals of all matrix columns and use it to create the normalized-comparison matrix whose all columns sum are equal to 1 by using the equation;

$$\alpha_{jk} = \frac{\alpha_{jk}}{\sum_{l=1}^{m} \alpha_{jk}}$$

From the normalized matrix, (Saaty, 1980) expounds that we can derive the normalized eigenvector for each row of the matrix, which in essence represents the relative weights of each criterion with respect to the goal, and the final relative weights of each of the criterion with respect to the following criteria. This is achieved by applying the formula:

$$W_j = \frac{\sum_{l=1}^{m} \alpha_{jl}}{m}$$

After obtaining the individual priorities, it is important to combine the decisions of the various decision makers involved in the analysis to arrive at the group decision. Saaty (1980), explains that there are more than one methods that can be used in AHP to aggregate the individual priorities into a group decision. Saaty and Vargas (2005), explained that two aggregation methods, the geometric mean method (GMM) and the weighted arithmetic mean (WAM) can be used to aggregate the group priorities. In the GMM approach, average individual opinions are used in a comparison matrix to compute group priorities. In the WAM method, the priorities of individual judgements are combined to determine the group decisions.

In their study, Ishizaka and Nemery (2013) preferred the GMM approach and opined that the approach maintains the consistency of the reciprocal system in aggregating the group decisions. In this study, the GMM approach is also preferred. In conducting pairwise comparisons, it is important to note that the judges are not immune to subjectivity, and that their decisions are mainly based on this subjectivity, their intuition, and therefore an element of bias is expected in their decisions. It is however recommended that the judgements relied upon in decision making portray a reasonable degree of consistency, especially in the transitivity relationships relied upon in the reciprocity of pairwise comparisons. This requires that, for instance, if criteria A is adjudged as more important than B, and that B is more important or contributes more to the decision than C, then it automatically means that A also contributes much more to the decision than both A and C.

Perfect consistency requires that the decisions requires that the maximum eigenvector, (λmax) is equal to the number of criteria (*n)*. However, this consistency is difficult to achieve, and Saaty (1980) asserted that a consistency ratio of less than 10% can be tolerated. The consistency ratio (CR) is obtained in a two-step process as;

a) Calculate the Consistency Index:

$$\text{Consistency Index (C.I)}\ \ C.I. = \frac{\lambda max - n}{n-1}$$

b) Consistency Ratio C.R.

$$\text{Consistency Ratio,}\ \ C.R. = \frac{C.I}{R.C.I}$$

Where; Random Consistency Index (RCI), as advised in (Saaty, 1980).

Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RCI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.45

4.4 Research Data and Quantitative Analysis

4.4.1 Research Data

As aforementioned, this study applied the AHP methodology following the framework set up by Saaty (1980); (Wind & Saaty, 1980) and thus pairwise comparisons and expert judgements formed the research. The AHP method was preferred as the best alternative amongst the MCDA procedures due to its close fit with the study objectives and the relative ease of its application.

Data was this research was acquired through interviews and online questionnaires. The respondents for this research were selected mainly from the decision makers in the energy sector in the Republic of Kenya, and other reputable organizations who have been involved in the LMCP or other rural electrification plans. The respondents were drawn mainly from the power planning team in Kenya, which is comprised of senior employees of the Ministry of Energy, Energy Regulatory Commission, Kenya Power & Lighting, Kenya Electricity Generating Company, Rural Electrification Authority, and the Kenya Nuclear Electricity Board. Other participants hailed from The National Treasury, the academia, represented by the Technical University of Kenya (TUK) and the National Commission for Science, Technology and Innovation. Due to their level of involvement in matters of poverty alleviation and energy access, the research also involved non-governmental organizations and donors including the Digital Opportunity Trust (DOT-Kenya), and the Inter-Agency Working Group East and Central Africa (IWGEA). The recipient targets of the universal access policies also contributed in the research as well as select business acumen and community lawyers.

Apart from the representatives of the target communities, all respondents had a postgraduate qualification in major disciplines and were reputable engineers, economists, lawyers, accountants and heads of government procurement, geologists, lawyers, environmental scientists, and community development and social work.

The research questionnaires were drafted in June and July 2018 and administered in August 2018. Few responses were received on September and October, 2018, but majority of the research data was collected from the field in the month of August. During the interviews, the respondents were taken through the questionnaire which had seven sections to ensure they understood the objectives of the study and the nature of their responses and were then left to make their judgements. An assistant was recruited to assist the respondents from the target community that had been connected to electricity for the first time, and they couldn't access the digital formats of the survey on their own.

In total, 18 responses that satisfied the consistency criteria of less than 10% proposed by (Saaty, 1980, 2008) were received and processed.

4.4.2 Quantitative Analysis

The following calculations are applied to elicit the priority weights and the ranking of each criteria.

4.4.2.1 Criteria Comparison Matrices

The AHP calculation for the priority weights of criteria and factors follows five steps as shown in this section.

1. Collect the expert judgements from the questionnaires and convert them into a matrix form, entering them and their reciprocals in the transpose positions. 18 matrices resulted from the judgements, as summarized in Table 8.

Table 8: Judges Pairwise Comparison Matrices of Main Criteria

Pairwise comparison matrices (judgmentsof n (18) respondents									
1					………..				
	Policy & Institutional	Economic & Financial	Technical	Envt & Socio Political		Policy & Institutional	Economic & Financial	Technical	Envt & socio political
Policy & Institutional	1.00	0.14	1.00	0.33		1.00	0.14	1.00	1.00
Economic & Financial	7.00	1.00	7.00	7.00		7.00	1.00	7.00	7.00
Technical	1.00	0.14	1.00	0.50		1.00	0.14	1.00	0.33
Envt & socio political	3.00	0.14	2.00	1.00		1.00	0.14	3.00	1.00
SUM	**12.00**	**1.43**	**11.00**	**8.83**		**10.00**	**1.43**	**12.00**	**9.33**

2. **Aggregation of the Comparison Matrices to a single Matrix**

The entries of the aggregation matrix are a product of each of the corresponding individual entries to the reciprocal power of the total number of entries such that;

$\sum_{En}A = \sum (A_1 * A_2 * A_3 .... * A_{18})^{1/18}$
Where; $_{En}A$ = aggregated entry,
$A_{1, 2, 3......18}$ = corresponding 18 comparison matrices.

This yields the pairwise comparison matrix of the parent level with respect to the goal as in the AHP hierarchy.

Table 9: Pairwise comparison of the criteria with respect to the goal

	Policy & Institutional	Economic & Financial	Technical	Envt & socio political
Policy & Institutional	1.00	0.35	1.10	1.33
Economic & Financial	2.88	1.00	2.60	2.49
Technical	0.91	0.44	1.00	0.92
Envt & socio political	0.75	0.40	1.14	1.00
SUM	5.54	2.19	5.83	5.74

3. **Normalization:**

Normalize the aggregate matrix to elicit the individual weights; we sum the totals of all matrix columns and use it to create the normalized-comparison matrix whose all columns sum are equal to 1 by using the equation;

$$\alpha_{jk} = \frac{\alpha_{jk}}{\sum_{l=1}^{m} \alpha_{jk}}$$

4. The final relative weights of each of the criterion with respect to the following criteria. This is achieved by applying the formula:

$$W_j = \frac{\sum_{l=1}^{m} \alpha_{jl}}{m}$$

Table 9: Normalized Matrix for the Main Criteria

	Policy & Institutional	Economic & Financial	Technical	Envt.. & socio political	Weights/ Priority Vector (W)
Policy & Institutional	0.180408621	0.15859382	0.187903589	0.231589319	0.189623837
Economic & Financial	0.519276972	0.45648660 2	0.445735707	0.433251052	0.463687583
Technical	0.164634707	0.201407555	0.171474357	0.160988521	0.174626285
Envt. & socio political	0.1356797	0.183512024	0.194886347	0.174171108	0.172062295
Sum	1	1	1	1	1

5. **Consistency Index**

To test if the priority weights in Table 11 were consistent, calculate the average value for the λmax by multiplying each row of the comparison matrix with the priority vector/weights and then divide the results of each column product with the corresponding priority vectors as in Table 11.

Table 10: Calculation of the Average priority Vector (λmax)

a)	(1.00*0.189623837)+(0.35*0.463687583)+(1.10*0.1746285)+(1.33* 0.172062295) = (0.77/0.189623837) = 4.07
b)	(2.88*0.189623837)+(1.00*0.463687583)+(2.60*0.1746285)+(2.49* 0.172062295) = (1.89/0.463687583) =4.08
c)	(0.91*0.189623837)+(0.44*0.463687583)+(1.00*0.1746285)+(0.92* 0.172062295) = (0.71/0.174626285) = 4.07
d)	(0.75*0.189623837)+(0.40*0.463687583)+(1.14*0.1746285)+(1.00* 0.172062295) = (0.70/0.172062295) = 4.07
	$\lambda max = \text{Average } (4.07, 4.08, 4.07, 4.07) = 4.07$

Using the λmax in Table 2;

a) Consistency Index (C.I)
$C.I. = (\lambda max - n)/\ (n - 1)$ = (4.07-4)/ (4-1) = 0.02360015
b) Consistency Ratio C.R. Consistency Ratio,
$C.R. = (C.I)/\ (R.C.I)$ = 0.02360015/0.9 = 0.026223472
$RCI = \text{Saatys Random Consistency Index}$
Since CR is less than 0.1, the results satisfies the consistence test of Saaty (1980)

Table 13 provides the final priority weights for the main criteria and the corresponding consistency requirements as stipulated in Saaty (1980, 2006).

Table 11: Final Priority Weighting & Consistency of Main Criteria

Criteria	**Priority Weight**	**Weights %**		**Consistency Index (CI)**	
Policy & Institutional	0.189623837	18.962384		Average (λMax)	4.07
Economic & Financial	0.463687583	46.368758		CI=(λmax-n)/(n-1)	0.023601125
Technical	0.174626285	17.462629		CR=CI/RI	0.026223472
Envt & socio political	0.172062295	17.20623		**CR<0.1**	**YES**

4.4.2.2 Calculation of Weights of Factors (siblings) of the Main Criteria

Calculate the priority weights at the sibling level of the AHP tree.

1. Conversion of expert judgments into a matrix form

a) The factors at sibling level of the hierarchy are analyzed individually with respect to their corresponding criteria; a snapshot of the Policy & Institutional criteria comparison matrices is shown in Table 14.

Table 12: Pairwise comparison Matrices for Policy & Institutional Factors

Pairwise Comparison Matrices for n (18) judgements								
			1	…………				18
	Inadequacy of policy/plans	Weak Gov structures	Bureaucracy, politics & corruption			Inadequacy of policy/plans	Weak Gov structures	Bureaucracy, politics & corruption
Inadequacy of policy/Plans	1.00	8.00	8.00		Inadequacy of policy/plans	1.00	3.00	7.00
Weak Gov. structures	0.13	1.00	2.00		Weak Gov structures	0.33	1.00	3.00
Bureaucracy, Politics & corruption	0.13	0.50	1.00		Bureaucracy, politics & corruption	0.14	0.33	1.00
Sum	17	3.13	1.63		Sum	11	4.33	1.48

b) The calculation and equation stipulated are used for aggregation, normalization, elicitation of weights and consistency index. Following this calculation, Table 15 and Table 16 presents the aggregation of the comparison matrix of three factors with respect to the policy and institutional criteria.

Table 13: Pairwise Comparison with respect to Policy & Institutional Criteria

	Inadequacy of policy/plans	Weak Govt. structures	Bureaucracy, politics & corruption
Inadequacy of policy/plans	1.00	0.29	0.33
Weak Govt. structures	3.49	1.00	0.71
Bureaucracy, politics & corruption	2.99	1.41	1.00
SUM	7.48	2.69	2.04

Table 14: Normalized matrix for Policy & Institutional Factors

	Inadequacy of policy/plans	Weak Govt. structures	Bureaucracy, politics & corruption	Priority Vector / Weights (W)
Inadequacy of policy/plans	0.133650079	0.106419451	0.163340602	0.134470044
Weak Govt. structures	0.46609869	0.371133089	0.347491882	0.394907887
Bureaucracy, politics & corruption	0.400251232	0.52244746	0.489167516	0.470622069
SUM	1	1	1	1

Calculation of the Consistency Index: following equations as in (4) above:

Table 15: Calculation of the Priority Vector (λmax)

a) (1.00*0.134470044)+(0.29*0.394907887)+(0.33*47) = (0.40/0.134470044) = 3.01
b) (3.49*0.134470044)+(1.00*0.394907887)+(0.71*470622069) = (1.20/0.39)= 3.03
c) (2.99*0.134470044)+(1.41*0.394907887)+(1.00*47) = (1.43/0.47) = 3.04
$\boldsymbol{\lambda max = Average\ (3.01, 3.03, 3.04) = 3.03}$

Using the λmax in Table 17;

a) Consistency Index (C.I)

$C.I. = (\lambda max - n)/(n - 1)$ = (3.03-3)/ (3-1) = 0.013625521
b) Consistency Ratio C.R. Consistency Ratio,
$C.R. = (C.I)/(R.C.I)$ = 0.013625521/0.58 = 0.023492277
RCI = Saatys Random Consistency Index
Since CR is less than 0.1, the results satisfies the consistence test of Saaty (1980)

Table 16: Final Priority Weighting & Consistency of Policy & Institutional Factors

Factors	**Priority Weight**	**Weights %**		**Consistency Index (CI)**	
Inadequacy of Policy/Plans	0.134470044	13.45		Average (λMax)	3.03
Weak Govt. structures	0.394907887	39.49		CI=(λmax-n)/(n-1)	0.0136
Bureaucracy, politics & corruption	0.470622069	47.0		CR=CI/RI	0.02349
				CR<0.1	**YES**

A similar approach was applied for the rest of the factors. The results are presented and analyzed in the next chapter.

4.4.2.3 Calculation 3: Global Priorities

The results of the global ranking are the product of weights of the criteria (at parent level) and the corresponding weight of each factor (at sibling level) as explained in Heo et al. (2010).

Chapter 5. Results and Discussion

5.1 Results of Empirical Analysis

5.1.1 Weights and Ranking of the Criteria

This section presents the aggregated results of the pairwise comparisons of the main criteria applied in the study. The aggregated results show indifferent weighting of the technical, environmental and socio-political criteria in the universal electricity access. More priority weights was accorded to the policy and institutional criteria, and the most weights was accorded to the economic and financial criteria. The results of specific priority weights are presented in Table 8 and graphically illustrated in Figure 12.

Table 17: Priority Weights of the Four Criteria

Criterion	Priority Weight	Rank
Economic & Financial	0.46369	1
Policy & Institutional	0.18962	2
Technical	0.17463	3
Environmental & Socio-Political	0.17206	4

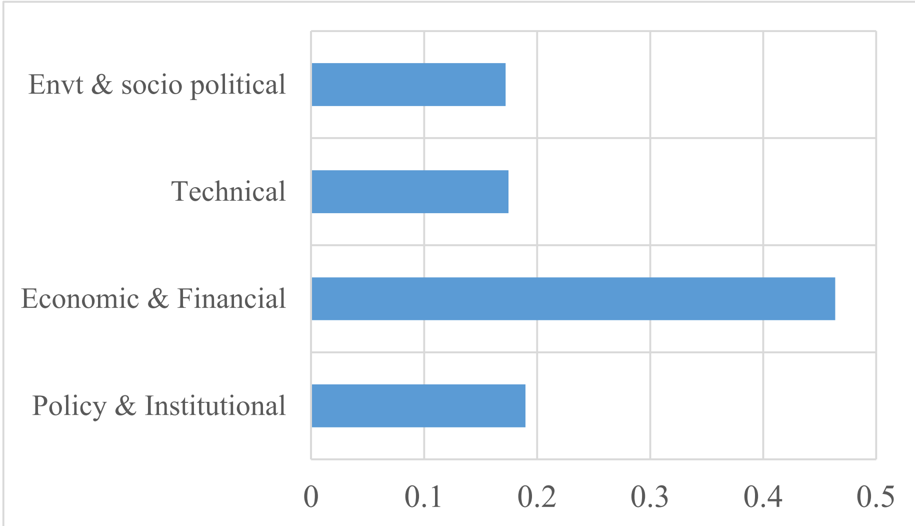

Figure 11: Priority weights of the Main Criteria

5.1.2 Estimated Weights of the Sub-Criteria (Factors)

Each criteria (at the parent level) had three or four sub-criteria, also referred to as factors in (Saaty, 2008; Saaty & Vargas, 2005, 2011) in the sibling level. This section presents the results of the calculation of the pairwise judgements with each of the criteria (at parent level).

In the Policy and Institutional criteria, there were three sub-criteria in which the judges presented their pairwise comparisons and judgements. The respondents adjudged that the adequacy of the universal electrification policy and plans is the least important in the trio of factors, only attributing to it a 13% of the total weight. Additionally, the aggregation of comparisons showed that weakness of governance structures in the energy sector as important issue and ranked it second with a priority weighting of 39.4%. Probably due to the weaknesses of the governance institutions, the weighting of the results ranked the factor of corruption and bureaucratic red tapes as the most important factor with a 47% of the priority weights in this trio of factors under this criteria. The specific ranking and respective weights of the factors in the sibling level of the hierarchy under Policy and Institutional criteria is as shown in Table 9 and illustrated in Figure 15.

Table 18: Priority Weights & Ranking of Policy and Institutional Factors

Factors	Priority weight	Rank
Bureaucratic red tapes & corruption	0.47062	1
Weak Governance Structures	0.39490	2
Inadequacy of Policy/Plans	0.13447	3

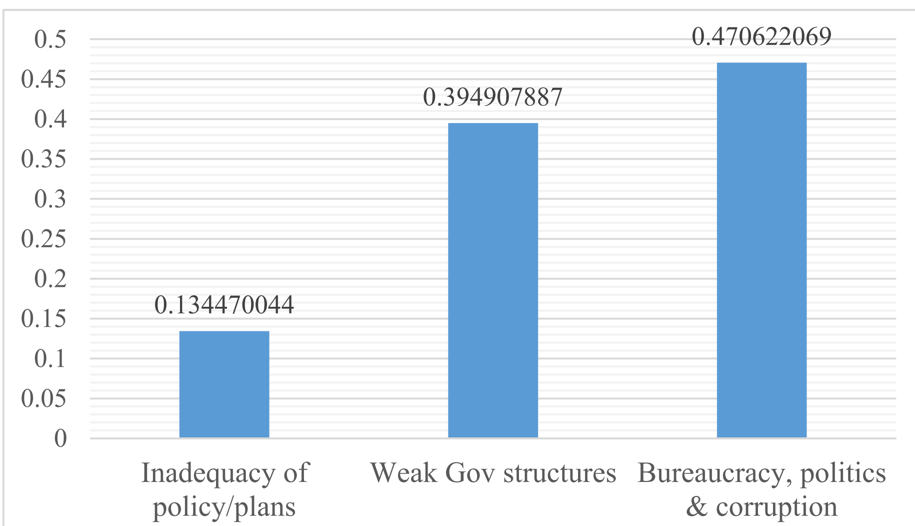

Figure 12: Priority Weights & Ranking of Policy and Institutional Factors

In the economic and financial criterion, which was adjudged with the most important with 46% of the total weight of the main criteria were four factors in the sibling level of this criteria. Amongst the four, poverty and low household affordability factor was accorded 38% of the priority weights, ranking as the most important factor in this criteria. Significant priority weights of 26.9% and 25.5% respectively was accorded the funding and financing inefficiencies and low productive uses and little industry respectively. Challenges in demand forecasting, which was expected to be a significant factor only elicited a meagre 9% of the weights in the quartet of factors. The respective weights are shown in the preceding Table 10 and illustrated in Figure 14.

Table 19: Priority Weights & Ranking of Economic and Financial Factors

Factors	Priority weight	Rank
Poverty & low household affordability	0.38567	1
Funding & Financing Gaps	0.26905	2
Low Productive uses & little industry	0.25549	3
Challenges in demand forecasting & planning	0.08977	4

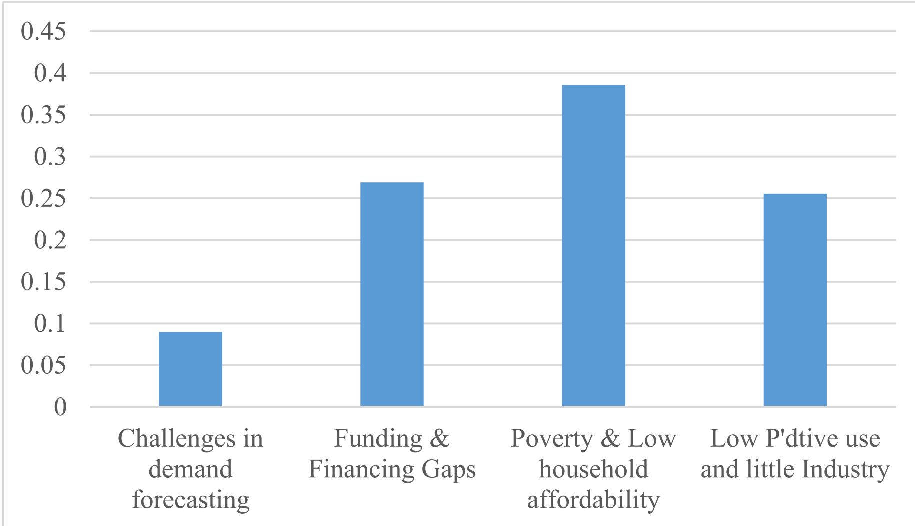

Figure 13: Priority Weights & Ranking of Economic and Financial Factors

In the technical criterion, there were three factors to be evaluated in the sibling level. The respondents adjudged that low reliability and quality supply was the most important factor in the trio with a relative priority weighting of 49.3%. Low operating efficiency and high technical losses on part of the generators and distributors as used in the study was accorded a significant weighting of 33% with low levels of generating capacity factor only eliciting 17.9% of the weights, the least in the technical criterion. These findings are summarized in Table 11 and Figure 15.

Table 20: Priority Weights & Ranking of Technical Factors

Factors	Priority weights	Rank
Low reliability and quality of supply	0.49332	1
Low operating efficiency and high technical losses	0.32755	2
Low generation capacity	0.17913	3

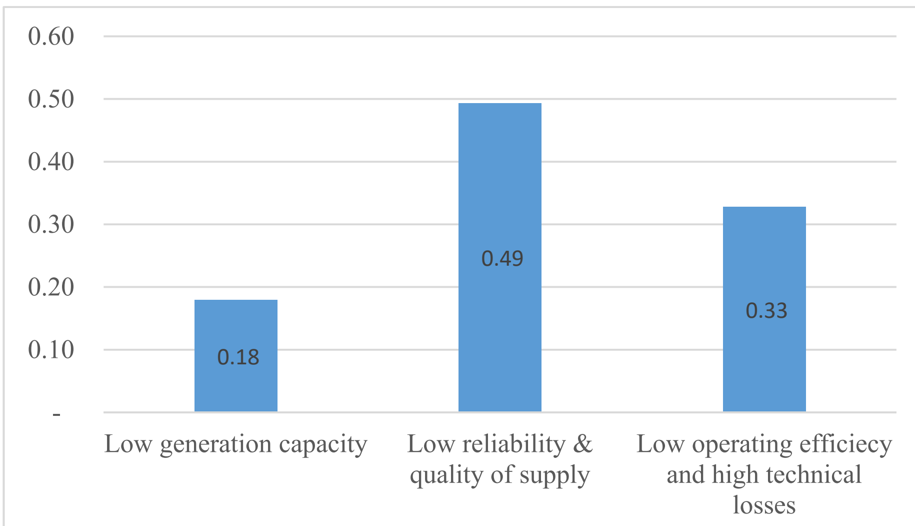

Figure 14: Priority Weights & Ranking of Technical Factors

In the environmental and socio-political criterion, challenges of land acquisition and resettlement of population, limitations of rural infrastructure, limitations of local participation and the ensuing vandalism and/or theft and lack of economically exploitable energy resources are factors that comprised the sibling level of this criterion.

Our results show that lack of energy resources only commanded a 9.8% of the priority weights.

The challenges associated with acquisition of land (as way-leaves for transmission and distribution, and as well putting up the necessary infrastructure that includes generation stations and switch yards) and the ensuing demands for compensations and resettlement of population as used in this study elicited the highest relative priority weighting of 32.2%. This was closely followed by the limitations of rural infrastructure factor, (referring especially roads and other physical amenities) ranked second with a relative priority weight of 29% of the total weights in this criteria, similar to the challenges of theft and vandalism of equipment factor. The results of relative weights and ranking are presented in Table 12 and Figure 16.

Table 21: Priority Weights & Ranking of Environmental and Socio-Political Factors

Factor	Priority Weight	Rank
Challenges in land uses & acquisition	0.32261	1
Limitations of rural infrastructure	0.29243	2
Lack of local participation, vandalism & theft	0.28646	3
Lack of energy resources	0.09847	4

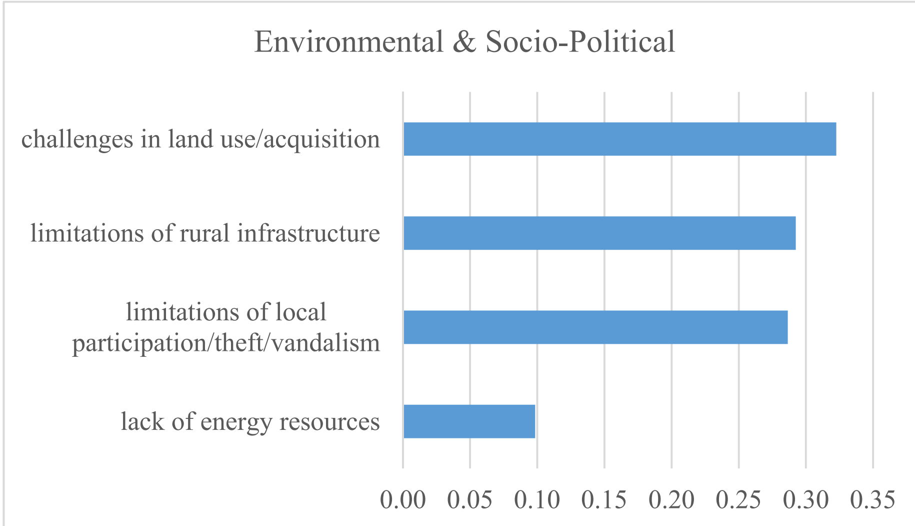

Figure 15: Priority Weights & Ranking of Environmental and Socio-Political Factors

5.1.3 Results of Global Priorities

The results of the global priority ranking of the factors in the sibling level used in the study gives useful information as it presents the relative priority weighting and ranking of all the factors used at the sibling level of the AHP hierarchy. From this, we can deduce relationships and make relevant conclusions. In this study, fourteen such factors were used and their priority weighting and ranking was conducted. In their study, (Heo et al., 2010) explained that the results of the global ranking are the product of weights of the criteria (at parent level) and the corresponding weight of each factor (at sibling level). Following their work, the results of our global priorities are as presented in Table 13 and Figure 17.

Table 22: Ranking of the Global Priorities

Factor	Priority weight (%)	Rank
Inadequacy of Policy/Plans	2.55	13
Weak governance Structures & Institutions	7.49	6
Bureaucratic red tapes & corruption	8.92	4
Challenges in demand forecasting	4.16	11
Funding and financing gaps	12.48	2
Poverty & low household affordability	17.88	1
Low productive uses & little industry	11.85	3
Low generation capacity	3.13	12
Low reliability & quality of supply	8.61	5
Low operating efficiency & high technical losses	5.72	7
Lack of energy resources	1.69	14
Limitations of rural infrastructure	5.03	9
Challenges in land use/acquisition	5.55	8
Limitations of local participation, theft/vandalism	4.93	10

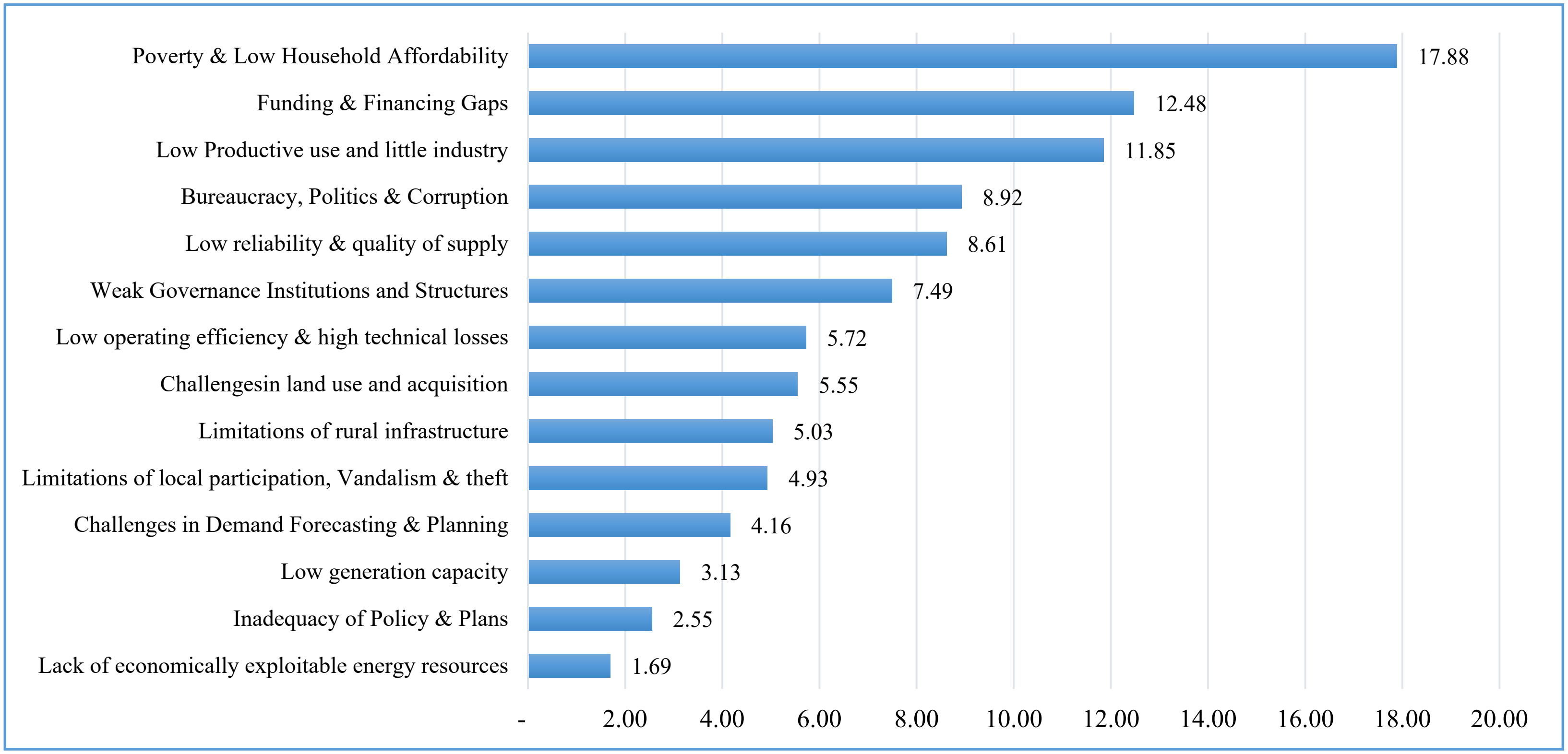

Figure 16: Results of Ranking of Global Priorities

From the aggregation of the judgements on the global scale poverty and low household affordability had the highest priority weight in comparison to the other thirteen factors with a share of 17.9% of the priority weights. This was followed by funding and financing gaps and low productive uses and little industry factors in the ranking of importance with 12.5% and 11.9% of the priority weights respectively. Bureaucratic red tapes and corruption, low quality of supply and the weaknesses of governance structures and institutions ranked among the top five factors in that order with a combined priority weighting of 25.02%.

The next five factors in the order of priority ranking garnered a priority weighting between 6% and 4%, and are this classified as factors of medium importance. Amongst those, low operating efficiency and high technical losses ranked as the most important of the medium factors with a 5.72% of the total weights. Challenges of land acquisition and limitations of rural infrastructure closes the list of factors with priority weight of above 5% with 5.55% and 5.03% respectively. The medium factors together command a priority weighting of 25.39%.

Low generation capacity, inadequacy policies/plans and lack of economically exploitable energy resources were ranked the lowest, and are deemed as the least important of the factors in that order. Together, they contributed only 7.37% of the relative priority weighing with respective weights of 3.13%, 2.55% and 1.69% respectively.

5.2 Results Discussion

5.2.1 Discussion of Local Priorities

The aggregated results in this study showed that economic and financial criterion is the most significant impediment to universal electricity access goals in Kenya. Poverty and low household affordability also emerged as the most significant factor within this criteria. These results concur with the findings of Bhatia and Angelou (2015); (IEA, 2017a; Kenneth Lee, 2016; Lee et al., 2016). The works of Odarno et al. (2017); (Practical-Action, 2010; Pueyo, 2015) also pointed out issues of affordability as one of the greatest barriers locking rural and peri-urban populations in energy poverty. In their study, Mitra and Buluswar (2015) analyzed the affordability gap in universal access goals and concluded that the price of electricity tariffs and push electricity services beyond the affordability ceiling of most of the populations targeted in universal access policies. Similarly, Kenneth Lee (2016) in their study of appliances ownership and aspirations for grid connection in Kenya reported a very ownership of high-end electricity powered appliances hurt both demand for and consumption of electricity. This, they claimed is occasioned by the high prices of the appliances, and a general lack of subsidies, and where credit facilities were extended, the poor could not still afford the credit costs, terms and conditions.

In their 2018 report of tracking the progress of the SDG 7, the (World-Bank, 2018) notes that in countries struggling with universal access, affordability challenges affect 57% of those who already have access; as opposed to 30% of the total population in countries that have attained universal access. In Kenya, the affordability challenge can be linked to the relatively high prices for new connections and subsequent consumption tariffs and to a lesser extent the affordability and ownership of electrical appliances. In fact, while recognizing the affordability challenge, the GoK through a Presidential directive subsidized the connection fees by more than 50% from Kshs. 35,000 (approx.. $350) to Kshs. 15,000 ($150) and extended credit facilities for the same, payable together with the consumption bills for a period of three years. This was however not extended to power consumption tariffs, which according to (Lee et al., 2016) and the Kenya Institute for Public Policy Research and Analysis (KIPPRA) are amongst the highest in Africa. A similar opinion is confirmed by a survey by Statistica in 2016 that ranked Kenya amongst the countries with the highest power costs in Africa as shown in Figure 18. The research of Odarno et al. (2017) noted that consumption of electricity is correlated with income. Low-income households tend to consume a minimum amount of electricity (for lighting), and are prepared for this, but beyond this minimum, their demand is highly priceelastic. Therefore, connection charges and tariffs can be a barrier to access for low-income households even when an electricity is physically available as portrayed by our findings in Kenya.

In comparison to other countries with some of the best practices in electricity provision in Europe and in USA, there are a number of issues which may be linked to the challenge of relatively high electricity tariffs in Kenya. In United Kingdom (UK) for instance, the electricity retail market is liberalized to enhance competition and efficiency. The electricity retailers compete in the wholesale electricity market and strive to lower as much as possible the electricity wholesale costs. The networks costs which is related to transmission is regulated by the country's office of gas and electricity markets (ofgem) mainly to protect the consumers from exploitation. The retailers also offer different and competing tariffs structures to their customers, such as time of use tariffs (peak, off-peak and others)[28]. This gives the consumers some leeway to control their energy consumption budgets. A similar trend is exhibited in Italy and Sweden. In the USA, the wholesale electricity markets is largely liberalized in many States, and inter-state electricity transactions are regulated by the Federal Energy Regulatory Commission (FERC). The states' public utility/service commissions regulate network charges

[28] Ofgem: www.ofgem.gov.uk

and electricity tariff of the distribution and retail sectors. The electricity tariffs generally consist of a regulated portion (for network services) and a non-regulated portion (for generation and retail supply).

Electricity supply companies structure their tariffs to cater for different types of customers or consumptions; general charges based on kWh consumed, time-of-use (TOU), and seasonal rates such that charge per kWh is higher in summer (peak time) than in winter. Special tariff schemes for the lower income group such as the "CARE" scheme of PG&E. As part of the tariff setting process, regulated power companies are required to report detailed costs and charges to the regulators in support of their tariff applications[29].

In Kenya on the contrary, electricity retail market is a monopoly of KPLC, a state controlled entity. The eventual tariffs are mainly dependent on the existing power purchase agreements (PPAs), entered into by the retailer and the generators, which is regulated by the ERC. According ERC, the retail tariff is structure follows KPLC's Underlying Long Run Marginal Cost (LRMC) structure such that the utility is able to meet its revenue requirements. The consumer tariff mainly comprises of a fixed charge (levied to cover customer related costs of metering, meter reading, inspection, maintenance billing and customer accounting), demand

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[29] Source: Electricity Tariffs in the U.S.A., U.K. and Australia https://www.enb.gov.hk/sites/default/files/en/node73/Reference03.pdf

charge (costs for distribution and transmission networks), energy charge (the per kilowatt hour costs set on the long run marginal costs tariff rates adjusted to the real financial revenue requirement of KPLC and vary per kWh). Additionally, the KPLC pushes extra risks to the consumers in levies packaged as four-pass through costs that are considered uncertain and outside the control of the utility. These include a fuel cost charge (as a result of fluctuations in world prices and in quantities of oil consumed in electricity generations), foreign exchange rate fluctuations adjustments (price variations and exchange rates of the Kenya shilling against foreign currencies), water resource management authority levy (charged by water regulatory authority for water used by the hydro plants), inflation adjustment (reflect the impact of inflation on electricity supply), and value added tax (charged on supply at 16%). In total, the pass-through costs account for over 30% of the consumer consumption bill, excluding the fixed charges. This, according to our analysis makes the electricity cost among the most expensive comparatively in the whole of African region, averaging at $0.20. (20 US cents/kWh)[30].

Against the backdrop of these issues, it is possible that a liberalization of the retail markets to induce competition, and a controlled regulation to protect the consumers rather than the revenue targets of the utilities, and tariff revolution would largely have an impact on this important factor

[30] https://stima.regulusweb.com/

towards universal access goal.

The second ranked of the criteria is the Policy & Institutional criterion. This was as expected among the highest ranked criteria as had been highlighted in previous UNCTAD (2017) report that proposed a different policy paradigm. Additionally, the works of Abdul-salam and Phimister (2016); Barnes et al. (2016) were also critical of the minimalist views and step-wise access paradigms as proposed by IEA (2017a) and Bhatia and Angelou (2015); (IEA, 2017a) and the variations of the same as proposed by Odarno et al. (2017); Ruijven et al. (2012). In their approach, Mitra and Buluswar (2015) and UNCTAD (2017) maintained that for universal access to be meaningful and sustainable, it has to go beyond the minimalist view of having a physical connection, or as a binary issue of connected or not. Additionally, the policy itself must be exogenous to consider the impact on other sectors of the economy. The works Leach (1992), conveyed the premises of energy ladder and energy stacking hypothesis; where consumers transition from consumption of basic fuels such as wood fuel, dung and other biomass to transitional fuels like kerosene and LPG and finally to electricity as their economic welfare and level of income improves. Lay, Ondraczek, and Stoever (2013), validated these premises in Kenya where they found evidence of a cross-sectional energy ladder, the income threshold for modern fuel use to move beyond traditional and transitional fuels to be very high with income and education being key determinants. In Kenya, the contributions of policy and institutional issues can be extended to structures and institutions of governance in the electricity sector as discussed in the next section. These challenges demean the sectors independence, its ability to withstand political and bureaucracy, fight leakages and attract private sector capital.

The technical, environmental and socio-political criteria were adjudged to contribute the same to the universal electricity inaccessibility challenge. Technical issues were deemed to be important in the study of Dagnachew et al. (2017) who argued that decentralized systems were the answer to universal electricity access in sub-Saharan Africa. The same hypothesis was extended by Ahlborg and Hammar (2014); F.Gómez and Silveira (2015) in Tanzania, Mozambique and Brazil. The findings of this research concurs with the conclusions of Perez-Arriaga (2017) who argued that the technology and the technical solutions to the universal electricity access already exist, with the only exception of technical reliability and quality of supply as discussed in the list of global priorities.

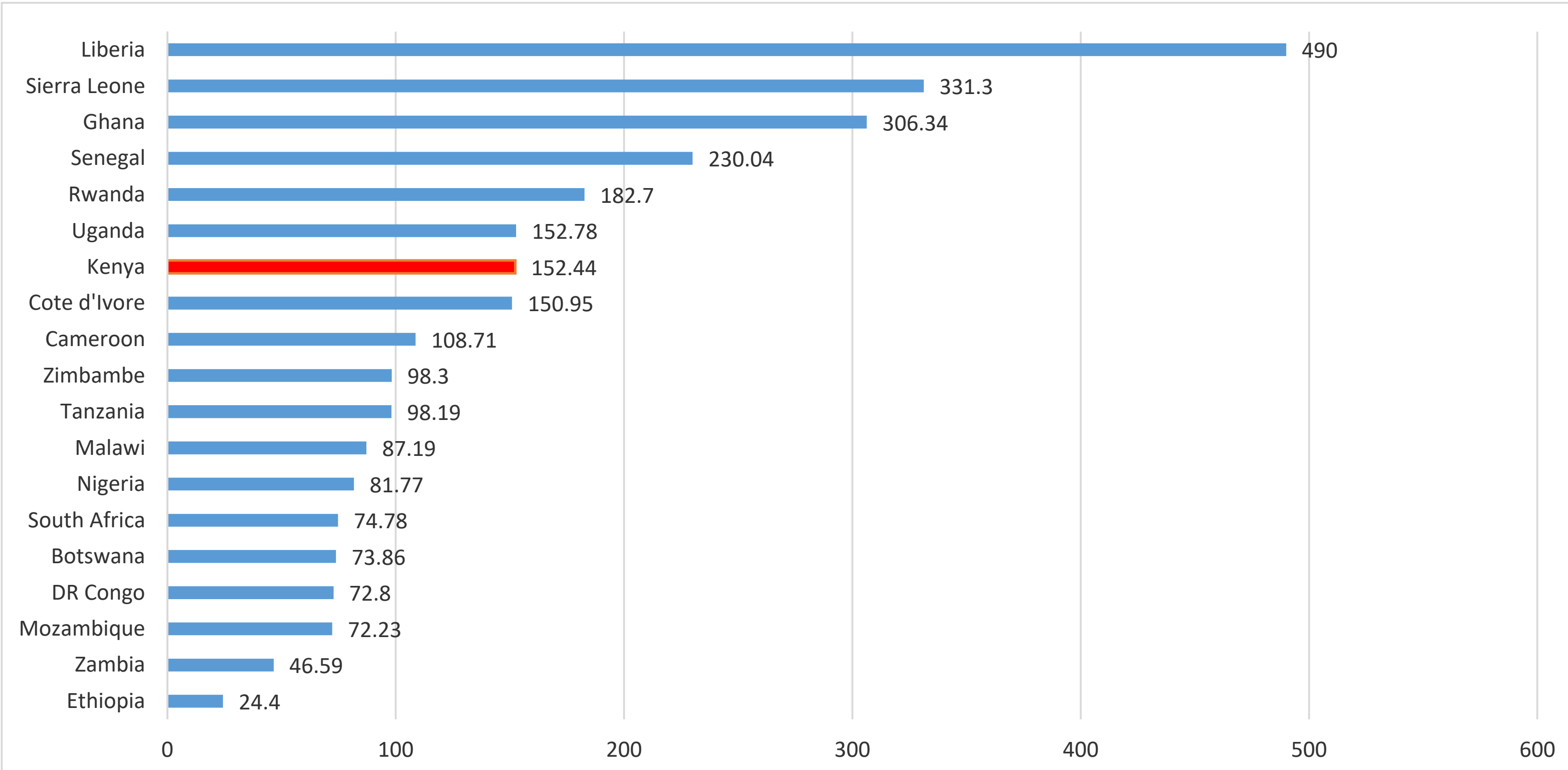

Figure 17: Comparative Electricity Prices ($/MWh): Statistica, 2016

5.2.2 Discussion of Global Priorities

The analysis of the study results extend to the global factors, and this section analyzes the comparative priory weights of the fourteen factors that were in the sibling level of our AHP hierarchy.

As shown in the Table13 and the corresponding Figure18, three factors of the economic and financial criterion, that is, poverty and low household affordability, funding and financing gaps, low productive uses and little industry occupied the top three spots and a combined 42.21% of the total global weights. Bureaucratic red tapes and corruption, low reliability and quality of supply, and weakness in governance structures and institutions followed commanding significant weights.

The top three issues of the economic and financial criterion emphasize the burden of affordability of electricity in Kenya, especially amongst the poor rural population at the bottom of the pyramid. As aforementioned, electricity retail business is a monopoly of a state controlled agency, KPLC. The Company buys power from all generators on the basis of negotiated Power Purchase Agreements (PPAs) for onward transmission, distribution, and supply to consumers ERC (2017).

The studies of Mitra and Buluswar (2015); Pueyo (2015); Sovacool (2012) argued for the inclusion of subsidies, and pro-poor lifeline tariffs for the poor, and in fact Kenya adopted this in the reviews of July 2018, where a lifeline tariff price of Kshs. 12.00 was introduced and the fixed charges were scrapped. However, analysis of the new tariff structure shows that it actually made the poor worse off. In the new regime, the first ten units of energy consumed by a domestic consumer will now cost Kshs 12.00 each, up from the Kshs 2.50 previously charged. For the next forty units, the consumer will be charged Kshs 15.80 per unit, up from the Kshs. 2.50 previously charged, meaning they will pay Kshs 632.00 instead of Kshs. 100 previously charged, which is a 600% increase.

Our global priority weighting also shows a relevance of the governance of the electricity sector, as well as the bureaucratic red tapes and corruption. This is consistent with the findings of Miguel, Wolfram, and Lee (2017) who concluded that leakages (in form of corruption and deviation of funds) and bureaucratic red tapes are among the biggest challenges to the Kenya's last mile electrification goals. In their study, they found that number of installed poles was less than the budgeted poles by 21.3%. Moreover, due to unnecessary bureaucracy, it took a staggering 212 days on average to complete one electrification project. This, somehow reduced the demand for electrification as well as consumption.

Issues of bad governance of the electricity sector were highlighted as important in the works of Perez-Arriaga (2017) and emphasized by

UNCTAD (2017). Corruption related issues were found to derail universal electrification projects in the works of Golden and Min (2012); Scott and Seth (2013) in India, Bangladesh and Nepal Smith (2004), and in Ghana Abdul-salam and Phimister (2016). In Kenya, in the course of this research, we encountered a number of issues related to governance and corruption which may be attributed to the high relative priority weights in this factor. In one case, the Lake Turkana Wind Power Company, in the course of delivering 310MWe of wind power, was entangled in Environment & Land Case 163 of 2014 (Formerly Nairobi ELC 1330 of 2014) for irregular acquisition of 150,000 acres of land in Laisamis constituency. The project also faced other governance related issues led to the delay of construction of a 428KM transmission line, causing the consumers hefty fines on the part of the off-taker who had already a signed PPA as reported by Omole (2018).

At the same time, in a different case, the KPLC was sued for inflating consumer bills amongst other malpractices. In the pro bono case, the plaintiffs' lawyer claimed to have received over 600 emails with complaints which related to overbilling, reduction in units purchased, bill adjustments, unexplained fluctuating tariffs, standard charges exceeding the value of actual electricity among others. In yet another case, the company was embroiled in abuse of office and corruption-related scandals, which saw its chief executives and senior managers arrested and prosecuted for graft according to newspaper journalists Menya (2018)[31] and Kiplagat (2018)[32]. Kariuki (2015); Muchira (2018) reported similar scandals also rocked geothermal development strategies and its managers were sent on compulsory leave on graft related issues Low productive uses and little industry and low reliability and quality of supply factors ranked as important impediments of universal access goals in this study. The works, Ahlborg and Hammar (2014); Kenneth Lee (2016); Mitra and Buluswar (2015); Odarno et al. (2017); UNCTAD (2017) concluded that when electricity is not used for productive uses, it neither creates economic benefits nor meaningful demand. The UNCTAD (2017) opines that universal access to modern energy could have a transformative effect on the economies; but realizing this potential is strongly dependent on the expansion of productive uses of electricity, to increase productivity in existing activities and diversify output into new sectors and products. Additionally, the expansion of productive uses provides a solution to one of the greatest challenges of the electricity sector, providing the demand needed to make investments viable. Harnessing this synergistic relationship requires going beyond the social and environmental lenses that have tended to dominate discussions of energy access, and focus more on transformational access. This requires

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[31] The Daily Nation

[32] The Business Daily: https://www.businessdailyafrica.com/news/64-set-to-testify-in-Kenya-Power-corruption-case/539546-4700586-1214uaa/index.html

development of an electricity system that, meets the needs of expanding productive sectors. Energy requirements for productive uses typically go far and beyond the minimalist view of universal access as the physical connections of households to sources of electricity. It means meeting the producer's energy needs-in terms of adequate peak power, reliability, quality of supply and affordability.

In Kenya, long term generation and transmission masterplan of 2015-2035[33] claimed that there exists in the recent past a strong correlation between domestic consumers, small industries and street lighting as shown in Figure 19. This shows the impact of, and correlation of electricity access with productive uses of electricity.

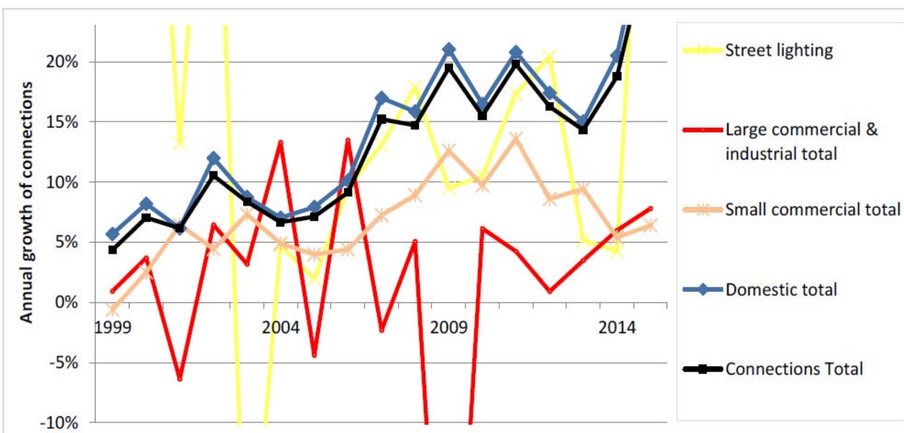

Figure 18: Correlation between Domestic, Small Industries and Street Lighting[34]

[33] Kenya PGTMP Final LTP Vol-I-Main Report October 2016

[34] Adopted from The Long term Power generation, transmission Masterplan 2015-2035

In this research, we defined reliability simply as the absence of unpredictable outages. More technically, this is measured by a combination of frequency of outages using the System Average Interruption Frequency Index (SAIFI) and duration outages using then Systems Average Interruption Duration Index (SAIDI). In Kenya, the rates of unscheduled outages are high, and typically last for more than two hours. The low demand for consumption may be attributed to the poor quality of services, which customers deem as unworthy paying for. The (IEA, 2017a) contends that energy efficiency should be an integral part of universal access goals. In our analysis of current generation, transmission and distribution in Kenya, both technical and commercial losses are as high as 18% to 20% of gross supply. These costs are pushed on to the consumers, which further push the tariff costs.

The global factors of challenges in land acquisition, limitations of land use and vandalism ranked also commanded significant weights on the global average. This points out to the importance of harnessing land and environmental policies and the expected liaisons with the universal access policies. Efficient communication of policy goals and objectives and involvement of people was cited as among key frustrations of universal access in Kenya. The policy did not involve for instance alternative energy businesses, especially firewood and charcoal which is rampant in the populations energy stack. The IEA (2017a) advised that involvement of people, especially women, whose domestic roles are directly impacted on by access to modern energies. Similarly, the UNCTAD (2017) advised that conversion of businesses in the traditional energies to electricity business, which involves electricity appliances and services should be an integral part of universal access policies. These issues were however not included in the LMCP which partly explains the relevant weights in these factors. Following these analysis, this study classified the top six factors as the most important as shown in Table 15.

Table 23: Most Important Factors

Rank	Factor	% Weight
1	Poverty & Low Household affordability	17.88
2	Funding & Financing Gaps	12.48
3	Low Productive Use & Little Industry	11.85
4	Bureaucratic red tapes, politics & corruption	8.92
5	Low reliability & quality of supply	8.61
6	Weak Governance Structures & Institutions	7.49

The last three issues on the global scale which garnered 3% and below are classified as the least important factors. We therefore concur that Kenya has adequate generation resources, the bulk of them being over

10000MW of geothermal (as explained in chapter 2) and has adequate plans. However, whereas the country has a low generating (installed capacity), the problem can only be sorted by addressing other challenges highlighted herein. These factors are deemed as the least important as summarized in Table 16.

Table 24: Least Important Factors

Rank	Factor	% weight
1	Lack of energy resources	1.69
2	Inadequacy of Policy/Plans	2.55
3	Low generating Capacity	3.13

5.2.3 Comparative Analysis

As previously indicated, this research involved experts from the energy sector's planning team as well as other experts from other institutions including The National Treasury, and a horde of non-governmental/donor organizations. To further synthesize the results of the study, we grouped the respondents in two; the energy sector experts, and the non-energy sector experts to analyze any differences in their combine priority weighting. The comparative results are discussed next.

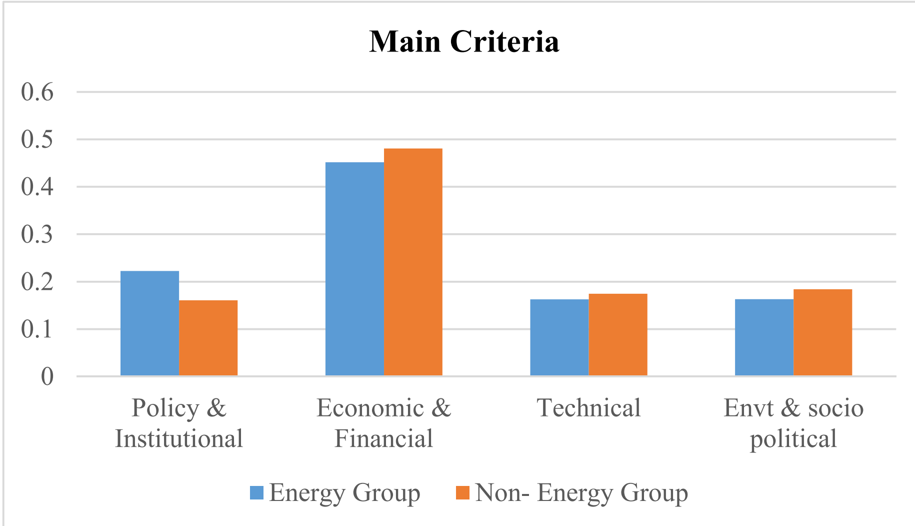

Figure 19: Comparison of Main Criteria Weighting

As shown in Figure 20, it can be inferred that there were no significant differences as to the priorities of the research criteria. Both groups concurred that economic and financial criteria is the most significant. Small variations can also be noted in the policy and institutional criteria. The energy group considered it as more significant than their non-energy counterparts.

In the local priorities in each criteria, a similar trend is exhibited.

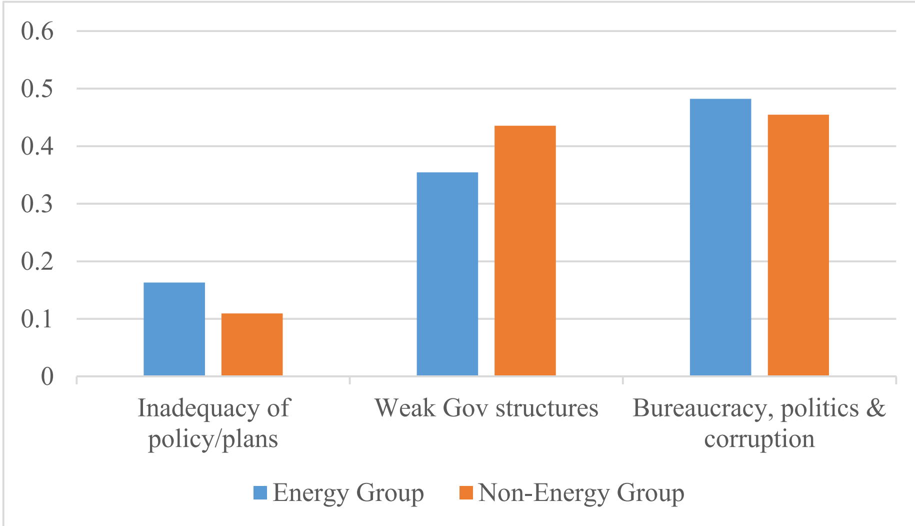

Figure 20: Comparison of Priorities in the Policy & Institutional Criteria

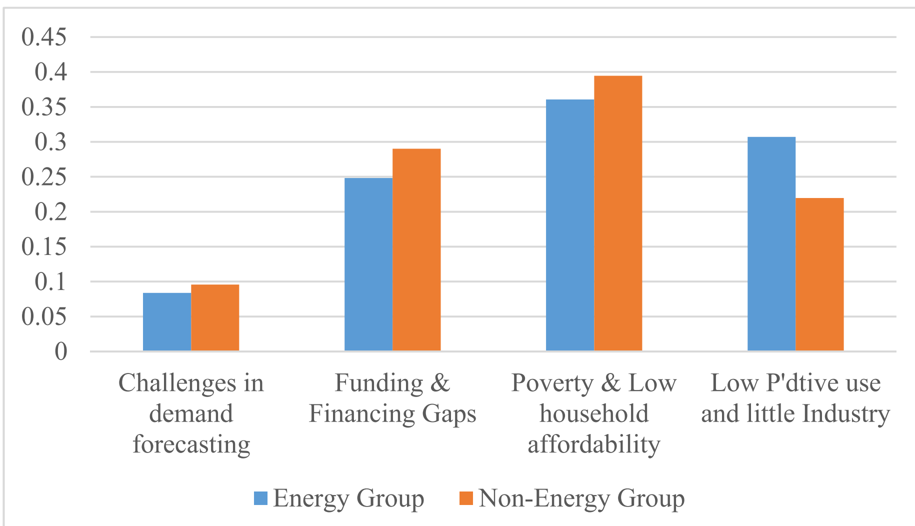

Figure 21: Comparison of Priorities in Economic & Financial Criteria

In the technical criterion, there are notable differences in the weighting of two factors, the low generation capacity and low operating efficiency and high technical losses. The energy group attributes more weight to the low operating efficiency and technical losses as opposed to their non-energy counterparts who opined that there's a low generation capacity.

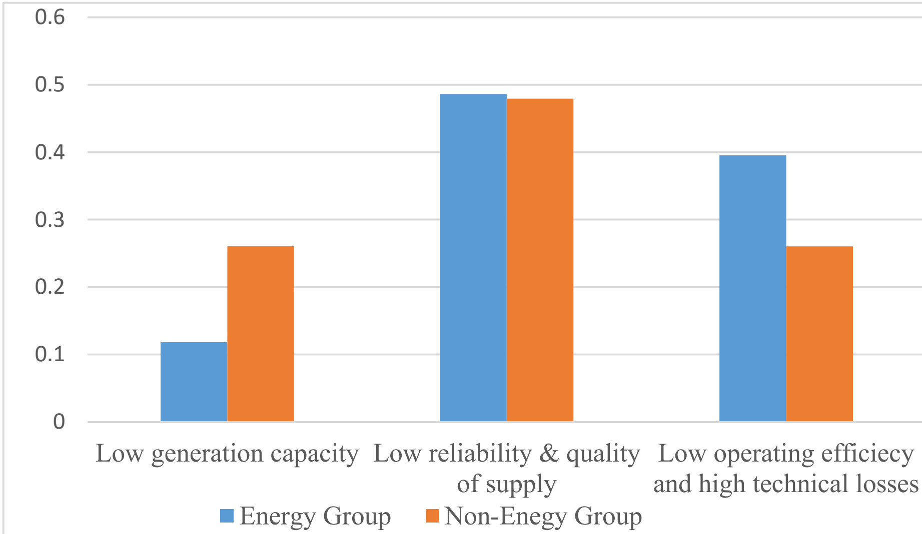

Figure 22: Comparison of Priority weights in Technical Criteria

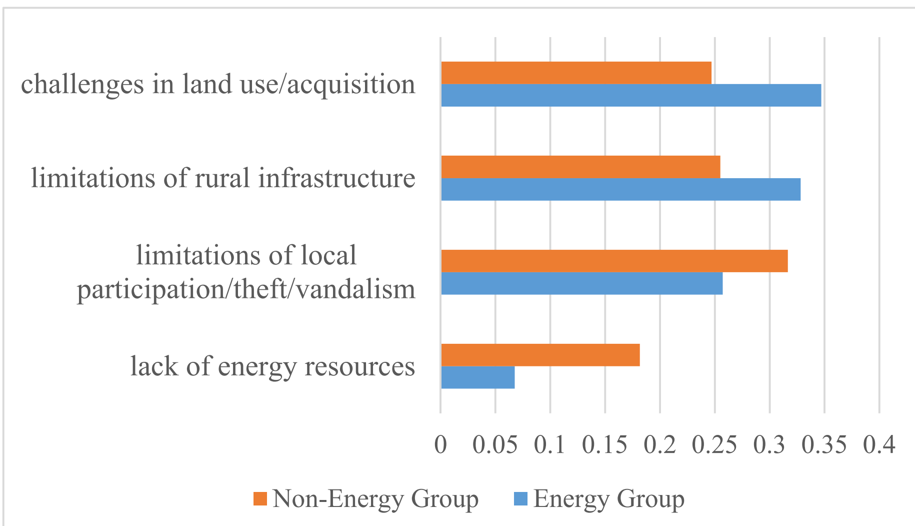

Figure 23: Comparisons in the Environmental & Socio-Political criteria

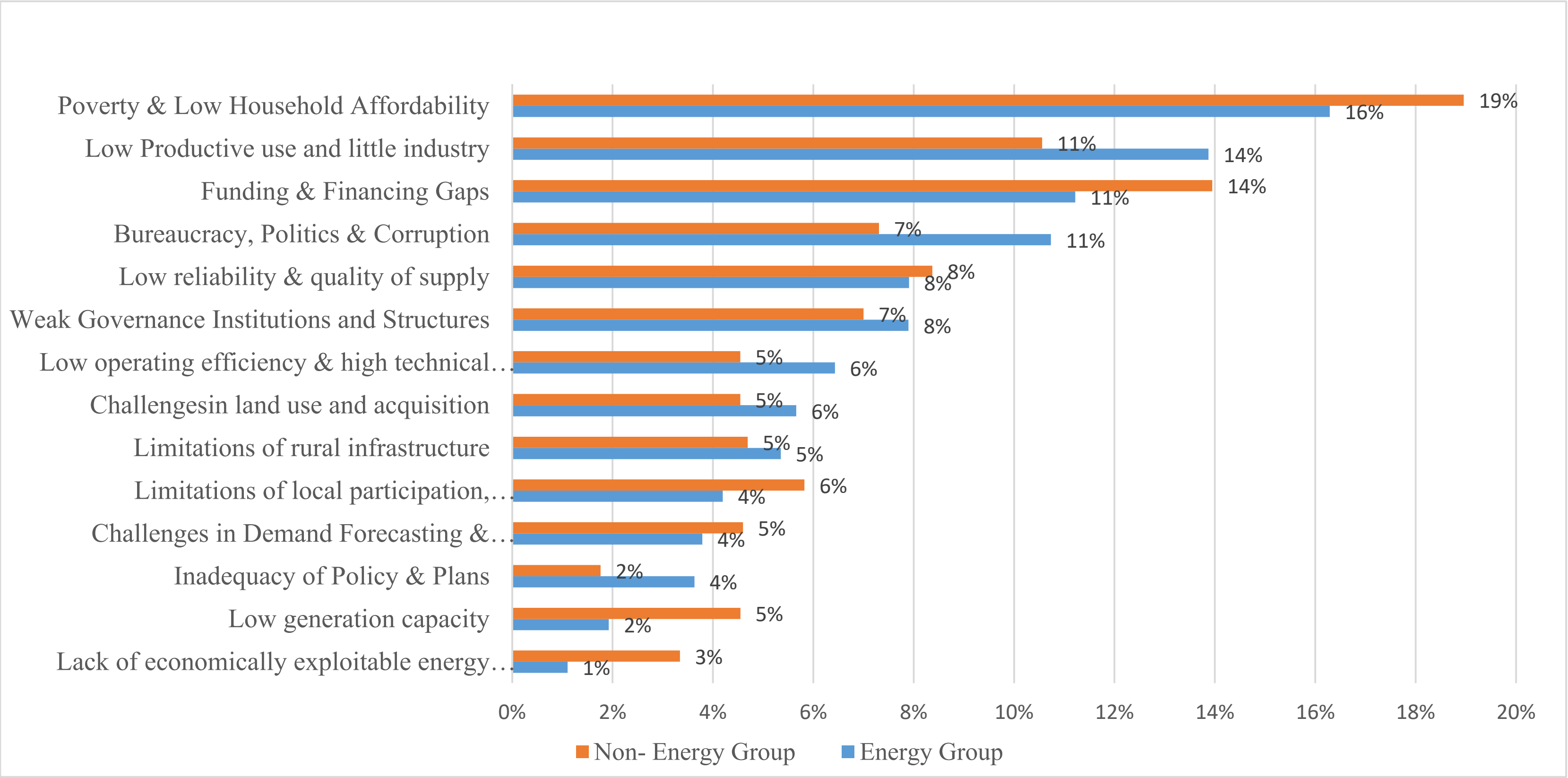

Figure 24: Comparisons for Global Priorities

In comparison of priorities at the global segment, it is noted that there are some differences in the top six and bottom three factors. While both groups concur on what are the top six issues, their degree of weighting significantly varies on each factor. In the bottom three issues, there are again differences in the two groups, and they as well differ as to what are the least important factors. The energy group opine that lack of economically exploitable energy resources is the least important, while their counterparts on the other hand opine that inadequacy of policies and plans is the least critical factor. The graphical representation of comparison is depicted in Figure 25.

5.2.4 Summary of Results Discussion

Our quantitative results indicate unique importance of the top six issues that account for more than two-thirds (67%) of the policy challenges in universal electricity access aspirations. These results traced these issues to economic and financial and the governance related criteria in the realm of universal electricity access goals. Additionally, the quality and reliability of electricity supply, which ranked as the fifth (5^{th}) most important criteria, and the operating efficiencies and technical losses, ranked seventh (7^{th}), together accounted for 17% of the weights as assessed by the more technically knowledgeable energy group. This shows that these are real issues and should be adequately addressed in the (re)design of universal electricity access policies.

The universal access to electricity is in most cases funded by the government and using public funds, and thus, whereas not a public good per se, it still has some aspects of public goods and prone to negative externalities and the tragedy of the commons. Whereas our research focused on a quantitative analysis of policy barriers, it is possible that the public goods characteristics of electricity supply may be a contributing factor to other aspects of failures such as high cases on non-payment of electricity bills, meter-tampering, illegal connections, hook-in and other forms of electricity theft. Additionally, the political angle and the influence of politics in electricity generation and supply is known to be high in developing countries, and it is not different in Kenya. This research did not quantitatively analyze these aspects, but in this research it is acknowledged that these are real issues that should be addressed in another study with a different scope and objectives.

Consumption of electrical energy substitutes, especially charcoal and kerosene for lighting and cooking is rampant in Kenya. The prices of these substitute, and the policies that regulate this sector are in most cases deemed to be more favorable than those of the electricity sector. Electricity, especially for heating and cooking is thus more expensive than charcoal, and the monthly bills (including the fixed components) are quoted informally as significant obstacles in extension of electricity services.

Chapter 6. Conclusion and Implications

6.1 Overall conclusion

This study endeavored to identify the main policy challenges and impediments towards the universal electricity access in Kenya. Extensive literature review and expert discussions led to identification of four criteria and fourteen factors. These were subjected to a quantitative analytical review which incorporated judgements of energy planning experts and other knowledgeable participants drawn from some reputable organizations in the country in AHP pairwise comparisons.

Despite the significant efforts put in place to ensure universal access by 2020, the aspirations seem more of a mirage mainly due to low demand of connections and consumption of electricity amongst the target sections of the population. This study aimed at analyzing these challenges from a policy perspective to ascertain the critical areas where the gridlock of electricity extension, demand and consumption can be disentangled. From the analysis carried out, four major conclusions can be derived from this study;

1. Six (6) factors out of 14 accounts for 67% of the total global weights. This study therefore concludes that the universal electricity inaccessibility challenge in Kenya is a result of the

cumulative contributions of these factors, as well as the intertwined relationships between them. These relationships form forward and backward feedback loops that in an electricity inaccessibility vicious cycle as shown in Figure 27 and explained hereafter.

2. Universal access to electricity requires more than a physical connection of households to electricity supply. Our study shows that electricity access goals should be anchored on other issues than physical access should underline the as follows:

a. Economic characteristics of the target population, more so affordability. 46% of the inaccessibility challenges were attributed to economic and financial related criteria, while poverty and the ensuing affordability challenges ranked as the highest global factor account for almost 20% of the priority weights.

b. Governance of the electricity sector is critical, and in a feedback relationships affects all other factors. Weaknesses in governance is attributed to run away leakages and undue bureaucracies, which accounted for 87% of the policy and institutional criteria weights. Combination of these challenges push up electricity project costs, further exacerbating the affordability problems

c. Access should be linked to productive uses. 26% of priority weights of economic criteria are linked to lack of productive uses, and a lack of prioritization of electrification to cause an economic transformation. After the affordability challenges, low productive uses and little industry is ranked second in global priorities, with a 12% priority weighting, which is significant. This can be linked back to affordability, and contributes to lack of new demand for electricity and stagnation of electrification initiatives.

d. Physical connection/access ought to consider other aspects of electricity, especially the quality and reliability. Our results showed that 82% of the challenges are associated with poor quality and reliability of supply as well as operating inefficiencies. This loops back to the problems of low productive uses and also to affordability challenges.

Comparative analysis of other countries revealed that Kenya has among the highest expensive electricity costs. Affordability issues highlighted in these results have also been alluded to by Miguel et al. (2017), World-Bank (2018) and Mitra and Buluswar (2015). The homesteads we visited in the data collection visits had only one meter, one light bulb and one connection even where there were more than one buildings in the homestead. The owners alluded to financial challenges in acquiring additional meters and wiring costs, which were not part of the government subsidy scheme. To unlock this gridlock, it is important for the policy planners to address the issues of affordability of electricity connections, consumption tariffs and electric appliances that allow for consumption of electricity services.

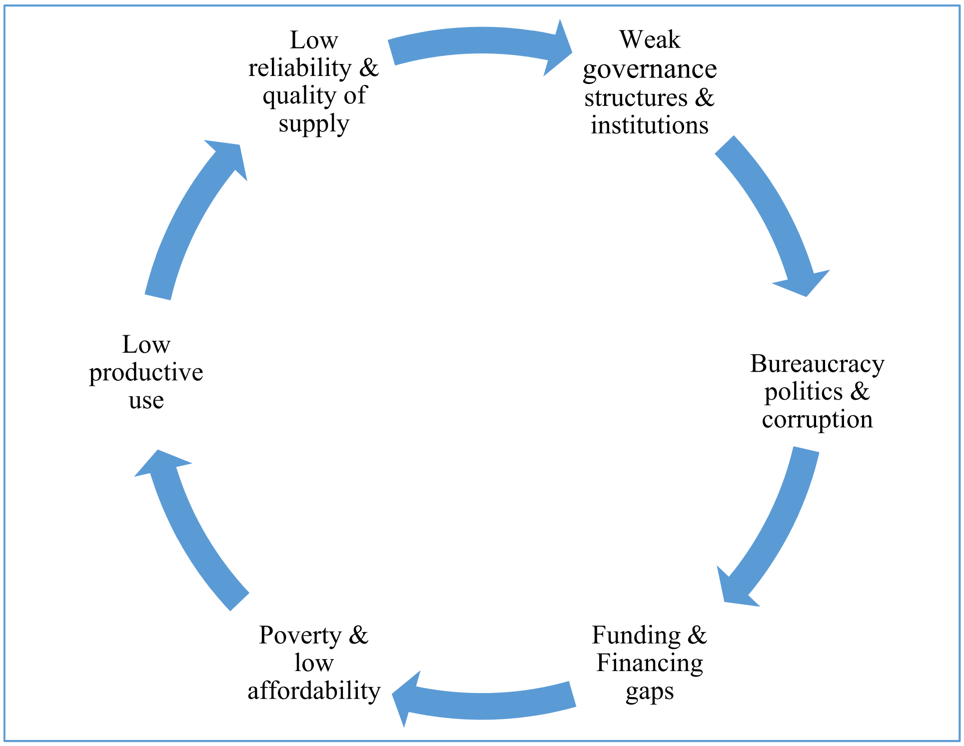

Figure 25: Interdependencies of Top 6 factors in an electricity inaccessibility vicious circle

The energy-transformational nexus as proposed in the transformational access paradigm highlights the importance of a feedback relationship between energy demand and consumption policy frameworks for structural transformation. The transformation nexus provides the virtuous feedback loops for financially self-sustaining electricity access initiatives. Productive uses creates the basis for strong and sustained demand for electricity services, a prerequisite for the economic viability of investments in electricity generation, transmission and distribution. In this context, productive uses is not merely additional to domestic use, but often complementary, as it helps smooth the time profile of electricity consumption; while the peak time of domestic uses is in the evening (for lighting, cooking, infotainment), productive uses occurs primarily during the day. Accordingly, the expansion of productive uses of energy may also be conducive to supporting the penetration of dispatchable/intermittent renewables.

The expansion of productive uses of electricity especially in the rural areas has the potential to trigger a slow and disruptive process of creative destruction where traditional activities are shaken up by the gradual introduction of electrical and electronic equipment into production processes. This completes the virtuous cycle, shown in Figure 28, which creates new jobs, raises income levels and additional sustainable demand for electricity.

We can therefore draw the conclusion that, transitioning from a minimalist household focused universal access paradigm based on a minimalist binary definition of connected or not, to a transformational energy access paradigm will most likely unlock the universal electricity access in Kenya.

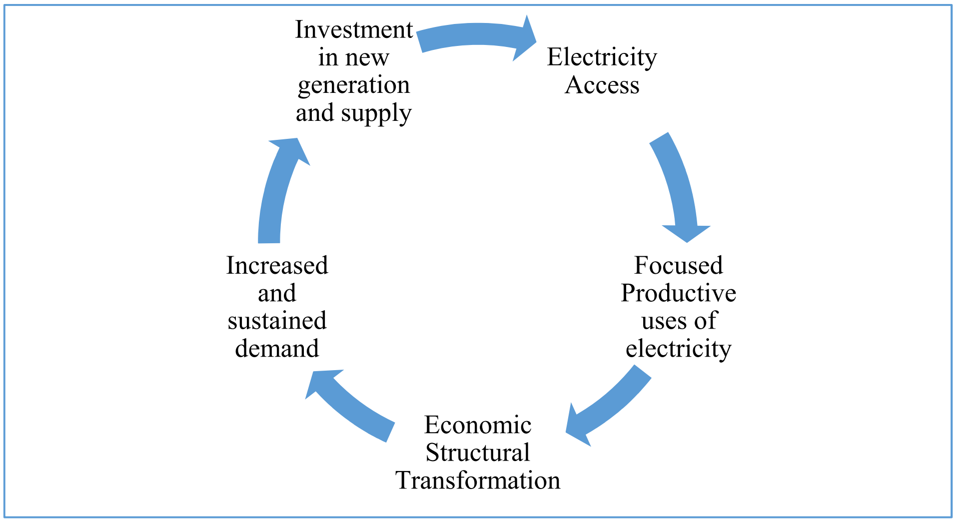

Figure 26: Virtuous circle in a Transformational Access Approach

Overall, this study concludes that universal electricity access policies should be designed to cate for other aspects of access than physical connection. Sufficient, reliable and affordable energy for all types of productive uses should be at the apex of electricity access policy in Kenya. Equally, strong governance institutions and structures are required to ensure the electricity services are adequately affordable, efficient, accessible, scalable, economically viable and reliable to enhance productive uses.

6.2 Policy and Academic Implications

These results can be used both for reevaluation and/or redesign of the existing universal access policy, and also for designing of future universal electrification policies. The relative priority weights obtained in this research can help the policy makers to establish a framework that reflects the challenges of policy implementation. The study results indicate that universal policy for electrification need to consider more than a physical connection or access to electricity facilities. It is implied herewith that universal electrification policies should be metamorphosed from a household focus to include other sectors like small businesses and industries or community centers, from electricity access to its affordability and appliances for its use, from a physical access to other attributes like reliability, efficiency and quality of supply. Our results also imply that design of universal electrification should start with strengthening of the institutions and structures of governance. They should be adequately financed, equipped and staffed with the relevant authority and independence to carry out their functions.

6.3 Research Contributions

The findings of our study concurs with those of (Bhatia & Angelou, 2015; Mitra & Buluswar, 2015; UNCTAD, 2017; World-Bank, 2018) in terms of the relative importance of different components of last mile electrification policies, especially the affordability and governance issues. However, whereas the previous works adopted a qualitative and descriptive approaches, this study adopted a quantitative approach in a multi-criteria decision analysis. The study provides new avenues to assess the relative importance and applicability of the various components of the universal access policies. The criteria and factors used in this study is relevant in the energy sector and has been previously adopted in other quantitative studies such as Aljamel et al. (2017); Heo et al. (2010); Keeney et al. (1987); Laxman (2016), and thus our findings can be applied to other countries striving to attain universal electrification.

This research advances literature and theory in energy policy matters by providing a policy assessment tool for universal electrification policies. To the best of our knowledge, there has been no research that have evaluated the policy challenges to universal access on a quantitative scale. Additionally, this study provided new theory that the top 6 factors are a critical deterrent in a vicious circle of electricity inaccessibility. This provides a thematic foundation for additional quantitative analysis.

6.4 Study Limitation and Future Studies

The focus and objective of this study was to identify the critical policy barriers towards the realization of universal access goals in Kenya. Whereas the study identified and ranked the barriers into a weighting of relative importance, it didn't objectively quantify the extent of funding and/or financing required or the extent of governance restructuring required in the redesign of the universal access policy into the transformational paradigm.

To make an informed use of these results, it is hereby recommended a follow up study be conducted to determine the social-economic impact of universal electrification in the country to determine the design of the transformational access policy.

This study should provide a mapping of distribution of electricity usage in the country, especially in the rural areas targeted by the policy, assess the consumers' willingness and the ability for electricity, their price sensitivity and switching costs to alternative fuels in order to determine effective pricing of affordable fees and tariffs. It is also recommended that the institutional and sectoral governance of the electricity sectors be studied deeper with an objective of delivering the much needed reforms.

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국문 초록

AHP를 이용한 보편적 전력 접근성 대한 정책적 장애요인 분석

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보편적 전력 접근성은 정부 그리고 정책 입안자들에게 높은 정책우선 순위가 주어진다. 특히 아래 사하라사막 이남 아프리카에서는 전력 접근성이 낮아, 11 억 인구 중에 80%가 전력이 없는 곳에서 거주하고 있다. 전력 접근성은 지속가능한 발전을 위한 2030년 목표 달성을 위한 169 의제들과 밀접하게 연관되어 있다. 이 목표에 따르면 모든 나라들이 보편적 전력 접근성을 2030년 안에 달성하는 것이다. 그러나, 현행 정책과 전략의 실현에 도 불구, 2040년에는 사하라사막 이남 아프리카 인구 중에 700백만 명이 전기공급을 받지 못하는 상황이 벌어진다. 2014년 케냐에서는 Last Mile Connectivity Project (LMCP)가 수립되어, 2020년에 보편적인 전력 접근성을 달성하도록 하였다. 그동안 프로젝트를 통해서 전력 접근성이 4배로 증가하였지마는, 수요와 소비의 증가 속도 저하 때문에 정책 이행의 문제가 지속적으로 대두되고 있다. 통계를 보면 여전히 백만 이상의 인구가 전력공급을 받지 못하고 있다. 비록 전력

접근성을 갖춘 사람들이라도 소량의 전력 밖에 공급받지못하고 전력 품질과 공급신뢰도가 굉장히 낮다. 전력계통 연계 설비 부족과 느린 속도의 전력소비가 민간부문의 투자유치를 저해하였다. 또한 정부 및 기부 단체의 보조금의 부족으로 미래 LMCP 프로젝트의 계획과 전망이 불투명해지고 있다.

본 연구는 보편적인 전력 접근성 목표를 저해하는 요인들과 부추기는 결정 요인들을 찾아냄으로서 LMCP 프로젝트가 계획대로 추진되는 것뿐만 아니라, 전력서비스의 향상과 소비증가를 통해 재정적으로도 지속가능한 방법으로 LMCP 프로젝트가 수행되도록 한다. 본 연구는 분석적계층구조프로세스(Analytic Hierarchy Process: AHP)의 다기준의사결정분석(Multi-Criteria Decision Analysis: MCDMA)을 동원하여, 4 가지 주요 기준들과 14가지 요인들을 광범위한 연구 리뷰와 전문가 리뷰 통해서 이루어졌다. 본 연구결과를 통해 결론적으로 6 가지 주요 요인으로서 경제성/가격접근성, 부문별 거버넌스, 전기 서비스 품질 등이 케냐에 보편적인 접근성 목표의 결정적인 요인들로 나타났다. 이와 함께 낮은 생산성, 산업규모의 소규모, 그리고 보편적 접근성 목표와 기타 사회-경제 정책과의 연관성 미흡 등이 중요한 요인으로 대두되었다.

본 연구 결과는 Last Mile Connectivity Project (LMCP)의 재설계/구축에 중요한 정책적 시사점을 제공하고 미래의 유사한 보편적 전

력 접근성 확대 정책에도 도움을 줄 것으로 기대한다.

키워드: (케냐, 보편적 전력 접근성, Last Mile Connectivity Project, 다기준의사결정분석, 분석적계층구조프로세스)