UNIVERSITY OF NAIROBI

FACULTY OF ENGINEERING

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

A Comparative Tariff Assessment between Grid Electricity and Own Consumer Generation: A Case Study of Kenya

By

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Dedication

I would like to dedicate this work to my family, friends, teachers, and colleagues for the overwhelming support they have given to me over my academic and life journey. Thank you all for your support and believing in me.

Acknowledgement

First, I would like to acknowledge and give thanks to Professor Cyrus Wekesa for continued support and supervision given over in the period of this project. His continuous input and time over the entirety of this project had a significant role in successfully achieving the objectives. Thank you. Second, I would also like to acknowledge the supervising support given by Dr. Mutigi Kiruki in reviewing and giving feedbacks on the proposal and report. Thirdly, for all the participants – not named in this report - who gave their time and resources particularly during data collection period, this would not be achieved without your input and support. I am immensely grateful. My gratitude also goes to all the companies and EPRA management for prompt response and assistance with data collection that was core in attaining research aim and objectives.

Abstract

Consumers, particularly big companies and commercial enterprises, are increasingly moving away from the traditional national grid to own generated electricity. Arguably, with low sales, the utilities are forced to pass down the high systems maintenance, Power Purchase Agreement (PPA) obligation, and operating idling capacity to customer through higher tariffs. To counteract this, consumers opt for cheaper solutions in renewable sources. For self-generating consumers, the decision is imperative towards reliable, available, and sustainable electricity. Key component of this shift is that it is projected to challenge the established structures in the energy sector. However, from the literature, little research has been done hence limited understanding of the whole concept of consumers generating own electricity. The questions economic feasibility of own electricity generating systems, factors driving consumers to move away from grid, and needed policy in light of these changes are yet to be answered.

Therefore, this research aimed to conduct a comparative tariff assessment between grid and self-generated power. It took a case study of Kenyan energy sector. A mixed research approach was used. The secondary data was sourced from Energy and Petroleum Regulatory Authority (EPRA). Primary data was collected using a questionnaire from electricity consumers in commercial and industrial sector, and individuals working in Engineering Procurement and Construction (EPC). SPSS software was used to map Levelised Cost of Electricity (LCoE) the tariffs and thematic analytic tool was used in analysis questionnaire data.

The LCoE for own generated electricity – $418.12/MWh for solar & $372.36/MWh for diesel generators - is relatively higher compared to the energy cost from the utility provider ($200/MWh). This is attributed to low system utilisation factor and lack of economies of scale. Consumers have a hybrid system with majority indicating that 25-50% of the total electricity consumed is sourced from own generation. The findings indicate the decision to defect to own generation is driven by such factors as need for power reliability and quality, alternative cheaper source, environmental and energy sustainability, and poor customer services. From the findings, Feed-in-Tariffs (FIT) and net-metering policy have been enacted under Energy Act 2019 but their implementation remains slow. Proper planning, financing, and system integration measures is required to cater for growing uptake of Renewable Energy Sources (RES) by the consumers.

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List of Abbreviations and Acronyms

CAIDI	Customer Average Interruption Duration Index
CO_2	Carbon dioxide
CPI-U	Consumer Price Index
DG	Distributed Generation
DR	Demand Response
ESA	Energy System Analysis
ECS	Energy Consumption Structure
EPC	Engineering, Procurement and Construction
EPRA	Energy and Petroleum Regulatory Authority
FEC	Final Energy Consumption
FERFA	Foreign Exchange rate adjustment fluctuation adjustment
FIT	Feed-in-Tariff
GW	Gigawatts
IEA	International Energy Agency
INFA	Inflation Adjustment
IRENA	International Renewable Energy Agency
KPLC	Kenya Power and Lighting Company (Kenya Power Ltd)
kW	kilowatts
kWh	kilowatts hours
LACE	Levelised Avoided Cost of Electricity
LCOE	Levelised Cost of Electricity
LPG	Liquefied Petroleum Gas
NGO	Non-Governmental Organisation

O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
REP	Rural Electrification Programme
RES	Renewable Energy Source(s)
SSF	Security support facility
THD	Total Harmonic Distortion
UNEP	United Nations Environment Programme
USD ($)	United States Dollar (*1 USD = Ksh 110 at the time of writing*)
WARMA	Water Resource Management Authority Water levy

Chapter 1: Introduction

1.1 Background Studies

Energy sector is experiencing a significant ongoing transformation. This is driven largely by advancement in several distributed technologies such as flexible demand, distributed generation, energy storage, and advanced power electronics and control systems. These technologies are being deployed in the presence of several broad drivers of change in power systems: increased harnessing of renewable energy sources (RES), the increasing interconnectedness of electricity grids, and attempt to decarbonise the energy system (Rapier, 2020). This evolution is creating a new alternative for provision and consumption of electricity services.

Like industrial consumers, commercial entities are increasingly adopting a hybrid system where solar energy is used for heating, cooling, lighting, and even production during the day while relying on the grid power during off-peak and night hours. Although there is a push to diversify, the trend has accelerated over the past decade mainly due to maturity of renewable energy technologies (Obonyo, 2021). The key supporting factor to this new paradigm is the need by the consumers to have cheap and reliable energy (IEA, 2021).

A new trend currently is consumers opting to generate their own electric power. Industrial customers are shifting away from the grid to self-installed energy solutions. In 2019, Unilever Tea Kenya added a 619 kW solar plant to its existing hydroelectric and biomass electric power source in its Kericho tea factory (Unilever, 2019). Strathmore University has a 600 kW capacity solar PV plant to cater for its power needs (Strathmore University, 2021). Garden City Mall has an ongoing 858 kW solar PV project meant to generate and supply electric power within the facility (Garden City, 2019). Total Kenya recently announced plans to install solar PV in its 107 service stations for pumping, lighting, refrigeration, and air conditioning (Nyabira and Nduati, 2021). Mombasa International Airport is in planning stage to install a ground-mounted 500 kWp solar PV system projected to offset 1,300 tonnes of CO_2 annually (Solarcentury Africa, 2018). Similarly, the International Centre of Insect Physiology and Ecology (ICIPE) commissioned two solar-PV plants with combined capacity 1,156 kWp in its facilities in Nairobi and Kisumu (ICIPE, 2018). All these companies are heavy electricity consumers.

As shown in Figure 1.1, the world RE consumption has seen drastic increase since year 2001 (IRENA, 2021). The uptake of renewable has gradually increased over the years adding approximately 260 GW in 2020 (IRENA, 2021). More than 80% of new electricity source added in 2020 were from renewable sources. The bulk of this addition came from distributed systems and consumers doing own installation.

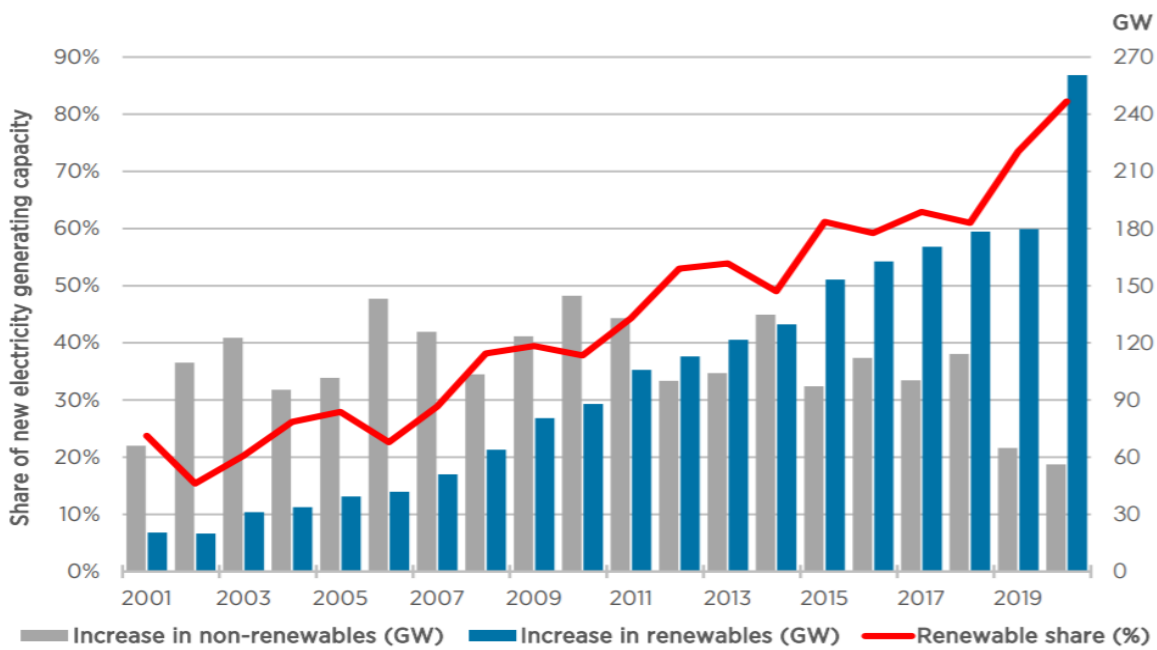

Figure 1. 1: New Annual Electricity Generating Capacity between 2001 and 2020 (IRENA, 2021)

Between 2009 and 2019, the levelised cost of energy (LCoE) for RES plummeted considerably. As shown in Figure 1.2, the global weighted-average LCoE of solar PV fell by 89% from \$378/MWh in 2009 to \$68/MWh in 2019. While that of onshore wind failing to \$41 from \$135/MWh (IRENA, 2020). Over the same period, electricity from coal and nuclear increased or seen a very small changes in prices per MWh. For nuclear energy, it LCoE increased from \$96/MWh in 2010 to \$155/MWh in 2019. While for the coal energy, it reduced by \$2 from \$111/MWh to \$109/MWh - (*1 USD = Ksh 110 at the time of writing*).

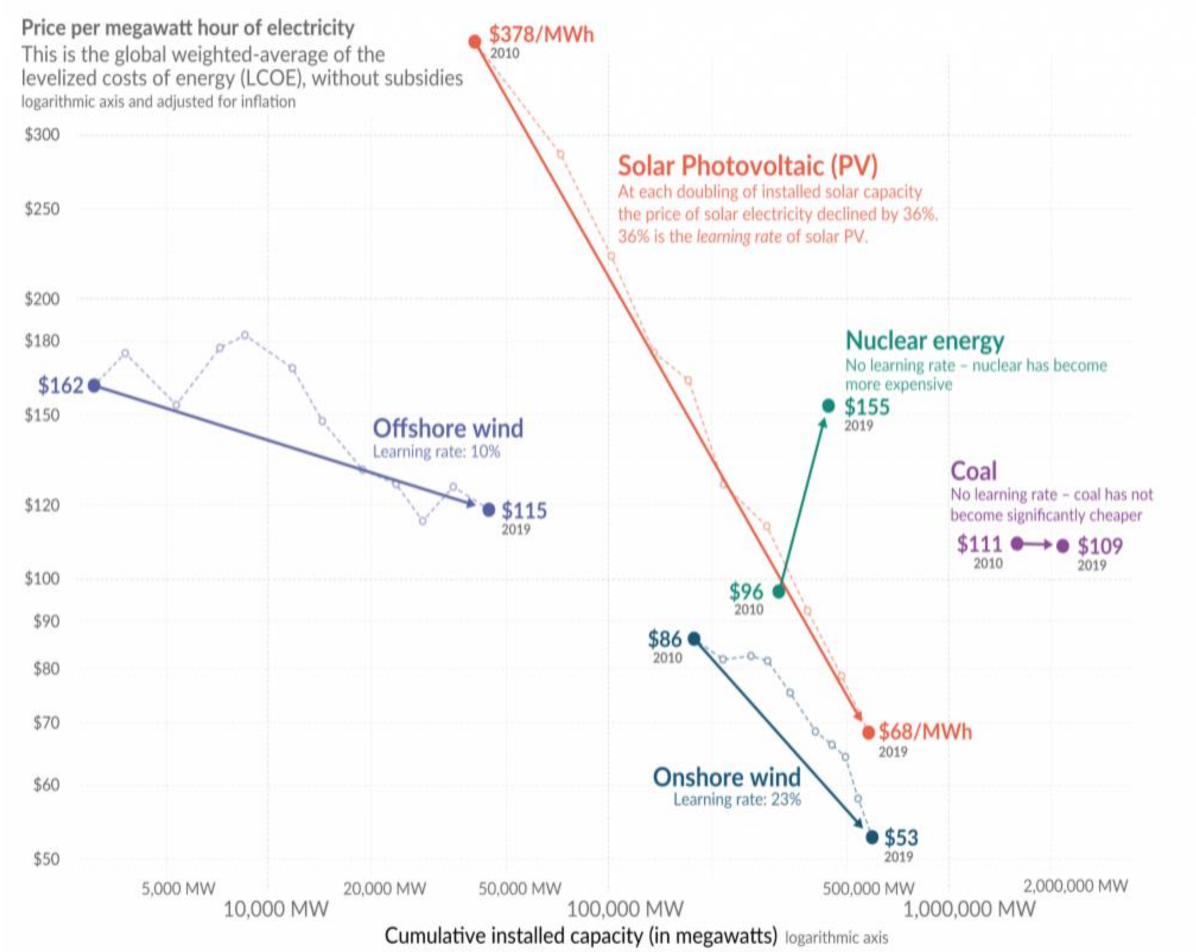

Figure 1. 2: Weighted-average (LCoE) with increased installed capacity (IRENA, 2020)

Comparatively, unlike renewables that saw a decline by 89% and 70% for solar PV and wind energy respectively, the electricity prices from coal declined by merely 2% attributed to little improvement in efficiencies of the plant technology and cost of coal fuel. Therefore, pointing to an indication of increased competitiveness of the RE compared to conventional sources.

1.2 Problem Statement

The major transition in electricity sector currently is that consumers are increasingly installing own electricity generating systems. This move involves incorporating either the existing network as a supporting infrastructure or moving away from the grid all together. This shifting paradigm in production and distribution of electricity is projected to challenge the established structures in the electricity market. For consumers using the traditional - expensive and inefficient - technologies, the RE technologies offer cheaper alternative. Whereas, the utility companies particularly those who have traditionally enjoyed monopoly in the market face new challenges.

On the other hand, all suggestions point to consumers enjoying cheaper, reliable, and convenient power. With improvement in RE technologies, generating electricity for own consumption is increasingly becoming feasible option for the consumers particularly with guaranteed reliability, convenience, and higher power quality. Financial estimates suggest consumers are to benefit from the shift, however, data supporting it is limited. Given the initial cost of installing a generating plant in addition to maintenance and operation cost as well as resources required for quality and reliable power being relatively high, the benefit from shifting to own generation is brought into question. Whereas, on the other hand, although the grid capitalises on economies of scale, it is perceived expensive energy source. Therefore, it begs the question; is the cost for producing own power lower than that from the grid?

Traditional tariff analysis and design are based on assumption of lack of alternatives to grid connection. However, with the breakthroughs in RES technologies and storage (batteries) resulting in renewables becoming more competitive, both domestic and commercial consumers can produce as well as control their energy consumption capacity and rate. However, the concept is relatively new and ongoing, and little is understood on the threshold at which it makes economic sense to defect as well as the implications it will have on consumers, utility, and country's energy sector. Therefore, there is need to have a better understanding of the influence it will have to the survival of conventional utility companies, consumers, and policy makers. From consumers' perspective, limited understanding due to little information available means their decision making relies on estimation and projections. As such, there is need to undertake an investigation to have a better understanding of this new paradigm of electric power production and consumption.

1.3 Research Objectives

1.3.1 Primary Objective

The primary objective of this study was to conduct a comparative tariff assessment between own consumer generated and grid electricity taking a case study of Kenya

1.3.2 Specific Objectives

The following are specific objectives to:

i. Perform levelised cost of energy (LCoE) for self-generated energy and compare with the prevailing cost of electrical energy from Kenya Power Ltd
ii. Determine the annual energy mix between self-generated energy and energy purchase from Kenya Power for a typical industrial/commercial consumer, given that most consumers do not defect from the grid entirely
iii. Establish and evaluate the factors causing defection by industrial and commercial electricity consumers from Kenya Power
iv. Propose policy measures to address the phenomenon of consumer defection from the Kenyan power grid

1.4 Research Questions

The key research question was: *how does electricity tariff for self-generated compare to that for the grid power in Kenya?*

The following are specific research questions:

a. How does the levelised cost of energy (LCoE) for self-generated power compare to that of the grid in Kenyan electricity market?
b. What is the annual energy mix, between self-generated and the grid power, for a typical industrial and commercial electricity consumer in Kenya?
c. What are the factors causing big electricity consumers to defect from the grid to self-generation?
d. What policy measures are needed to align the energy sector in Kenya to the emerging defection phenomena?

1.5 Justification

Currently, defection by consumers from the grid is considerably a major evolutionary step in the electricity sector. Consumers are doing significant self-generation aided mainly by failing prices of RE and storage devices. The argument currently held is that migration from the grid by the big consumers to captive power sources under self-generation would pose a significant financial challenges to the off taker. Therefore, this study aimed to conduct a comparative tariff assessment that would aid in understanding the emerging phenomena – defection/own generation- for the benefit of policy makers, the consumers intending to shift, and traditional companies, off-taker, in electricity sector.

Using the developed knowledge from this analysis, the consumers would make an informed decision based on threshold and LCoE trends for both self-generation and grid power in the country. Additionally, it intended to propose a policy change need to accommodate the emerging phenomena. Moreover, the off-takers, in this case Kenya Power, need to have a clear projection of what the future market direction for its survival. The purpose of this research was to assess comparatively the tariffs for the grid and self-generated power with focus on the following issues; threshold for defection, lost revenue for off-takers, tariff design, and energy cost savings for consumers.

1.6 Scope of the study

This study conducted a comparative tariffs assessment for grid and self-generated power aimed at determining a threshold at which big electricity consumers defect from the grid. It focused on heavy consumers in industrial and commercial sector in Kenya. Traditionally, electricity has been sourced from centralised and distributed systems but with advancement in RE technologies, demand for reliability, need for cheap energy, and push for diversification of energy sector, more consumers are shifting to own generated electricity. With this, this study premised the analysis on the consumers who have shifted by installing own electricity generating plants then compare the LCoE from that of power supplied by Kenya Power. This aided in determining the economic point at which consumer decide to rely on self-generated power rather than grid supply. In addition to outlining the economic drivers of grid defection, this study highlighted other factors driving grid defection. It then proposes policy measures need to align to emerging energy production and distribution in Kenya.

1.7 Organization of Proposal Report

The rest of the proposal report is organised as follows:

Chapter two is literature review that covers existing concepts, arguments, and findings regarding self-generation and grid defection. Key concepts reviewed include grid defection, self-generation, energy democracy, drivers of grid–defection, off-grid and distributed generations, and policies (net metering/ FITs). The chapter further reviews the related studies conducted by other scholars to peg the understanding of the phenomena on existing knowledge and what has been done before.

Chapter three covers methods and materials. It is framed to capture the methods which were used in data collection and subsequent analysis. The methods described are grounded on having a structured approach in which data and knowledge development was formulated. The chapter outlines the procedure and tools including sampling techniques, which were used in data collection process. It further describes analysis tools and processes that were employed to make sense of gathered data as well as validity and reliability that was observed.

Chapter four contains the expected results and findings. It outlines the data collected from the survey and secondary sources. The chapter cover the data interpretation and transformation to useful information. It then discusses the findings in relation to the previously done work on the research topic and objectives.

Chapter five is conclusion and recommendation. The chapter brings together the problem, aim and objectives of this study with the findings then make an informed inference on whether own-generated electricity in economically competitive in current Kenya electricity market. The recommendation is then made that is supported by the gather data and information following analysis and discussion.

Chapter 2: Literature Review

2.1 Introduction

This literature review covers analysis of the existing scholarly resources that include theorised concepts, findings from previous research, discussion and argument made by scholar on a specific field. It is ideally aimed at conceptualising by offering an overview of the current knowledge in the field of the research by enabling a researcher to identify theories, arguments, findings, and gaps in the stipulated area of the study. In this case, it is structured to critically analyse the existing concepts of self-defection and self-generation of electricity while looking for the tariffs comparison of the two at a wider worldview and in Kenya’s electricity industry.

2.2 Evolution of Electricity Generation and Consumption: Energy Democracy

In a study investigating RE in electricity generation in the transition economies, Pablo-Romero et al. (2020) found that most countries are moving away from conventional electricity sources such as coal and nuclear. Cucchiella et al. (2019) and Malinauskaite et al. (2019) pointed out that evolution of final energy consumption (FEC) - total energy consumed by end users - is driven by electrification of economies but also guided by push to reduce carbon dioxide (CO2) emission. At individual and country’s level, the need to meet international treaties and accords on climate change that include (Kyoto Protocol and the Paris Agreement) has necessitated switching to low carbon energy sources.

On the other hand, there is a transformation in the energy industry such as decentralisation of energy systems characterised by increased adoption and integration RE technologies. For residential consumers, such technologies as solar PVs, small scale combined cycle gas turbine (CCGTs), small wind turbines, natural-gas-fired fuel cells, and emergency backup generators are enablers (Goldthau, 2014; Di Silvestre et al., 2018; Bhatti, and Danilovic, 2018). For commercial and industrial electricity consumers, such systems as combined heat and power systems, solar PV panels, small wind and hydro-power, biomass combustion, and back-up generators have become widespread.

A number of reasons are driving the increasing adoption of distributed generation units. The findings by Gielen et al. (2019) showed that falling cost of renewables such as solar PVs and wind technologies becoming cost effective to most homeowners, commercial entities, and industries is a leading driving factor. In some countries such as the US, German, UK, and France, governments have instituted policies aimed at encouraging greater deployment of renewables due to associated energy security, resiliency, and emissions reductions benefits. According to Cantarero (2020), in the developing nations, the transition has been modelled by decarbonisation and sustainable development agendas. As a result, these countries have seen radical transformations in both production and consumption of electricity.

Developed nations with mature electricity markets and energy technologies base their transition largely on policies. In the United Kingdom, the reforms in the energy sector can be traced to 1990s with restructuring of the ESI, adoption of liberalisation models, creation of a wholesale electricity market, privatisation of electricity production, and concerns of climate change (Grubb, and Newbery, 2018; Keay et al., 2013). The result to this saw substantial support of energy from renewables and consumers encouraged to use clean energy sources. However, concern of falling electricity prices (below £16/MWh) in 2009 prompted recommendations for more significant reforms to consumers, industry, and policies (Grubb, and Newbery, 2018). In the United States (US), most states have implemented supportive policies in net metering allowing consumers to receive compensation for distributed generation.

According to Rotaru (2013), the need for competition in the electricity energy market was adversely impacted by carbon tax as well as incentives of generating low-carbon electricity. Although some researchers argue that maturity of the technology particularly renewables in terms of both reliability and efficiency was to blame for high cost of renewable energy production, the outcome for the shift was higher in the UK electricity compared to the other countries in Europe (Sioshansi, 2013; Finon, and Roques, 2013; Newbery, 2017). Moreover, as noted by Newbery (2013), in addition to disadvantaging the UK electricity production relative to its neighbours, the changes in the sector saw a significant fall in revenues and profit for utility companies and traditional energy generators (coal and nuclear) as well as electricity-intensive industries such as aluminium and steel.

In developing nations characterised by low GDP per capita, industrial output, high imports, low connection to the grid, low energy consumption index, lower energy intensity, and relying heavily on the biomass, the technological adoption in terms both energy production and infrastructural support stills lags developed nations. As highlighted by Malala and Adachi, (2020), the transition that include integration of renewable technologies remains slow. Countries in sub-Saharan Africa have seen significant adoption of energy efficiency policies, liberalisation of energy sector, rising energy demands, and decarbonisation process (Newell, and Phillips, 2016; Prabavathi, and Gnanadass, 2015). In Kenya, reforms such as unbundling the electricity sector leading to formulation energy production and consumption policies, investment in renewables, involvement of private entities, and emphasis of cheaper and efficiency have seen an increased demand reliability and cheaper energy (Imam et al., 2019; Boamah, 2020; Neofytou et al., 2020). More so, as pointed by Li et al. (2021) and Bos et al. (2018), rising population growth and GDP per capita in developing nation are other driving factors of energy consumption. Although, energy consumption per capita remains low, economic growth in this countries directly correlates with energy consumption.

2.3 Grid-Defection Concept

Peffley and Pearce (2020) described defection, in the electricity context, as a term used to highlight the electricity consumers moving away and being independent from the traditional electricity supplier, electricity grid. Grid defection outlines scenarios where the customers produce their own electricity under self-generation and use on site (Liu et al., 2019; Hittinger, and Siddiqui, 2017; Kantamneni et al. 2016; van der Mei, and Doomernik, 2017). Schill et al. (2017) described self-generation as the use of electricity generated on site by the consumer. Scholars have used the words ‘prosumers’, ‘self-generators’, ‘self-consumers’ and ‘self-consumption’ interchangeably to describe the own production and consumption of electric power.

Bronski et al. (2015) argues that grid defection has two paths (Figure 2.1). First, integrated grid driven by need for grid-optimisation supported by such systems as smart solar, transactive solar-plus-storage units, and integrated systems. Second path leads to grid defection supported by non-exporting solar PV and storage units. Conceptually, the electricity system is a roadmap defined by pricing structures, business models, and regulatory environments. These three prospects draw the path onto either integrated grid or grid defection.

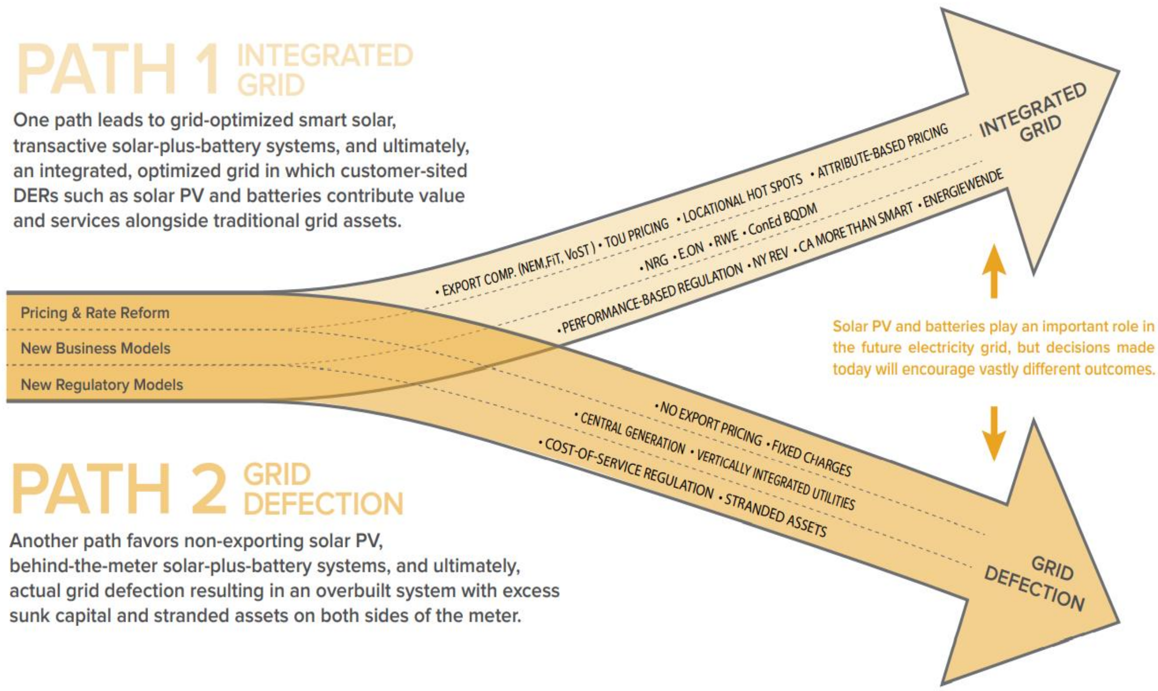

Figure 2. 1: Possible trajectories for electricity grid evolution (Bronski et al., 2015)

For a true grid defection, a consumer is independent from the grid entirely without importing or exporting electricity. A full defection is attractive to consumers when the economics favouring is attained (Bronski et al., 2015). An upward pricing spiral driven by curtained economies of scale means those remaining have to bear the disproportionate burden where the fixed cost of generating electricity is passed onto them. The increasing prices will exacerbate the phenomena causing more consumers to defect (Felder, and Athawale, 2014). However, for consumers to attain a self-sufficiency, the electricity resources need to be overbuilt and underutilised. The scenario would leave both the grid and consumers with excess electricity produced and resources invested.

On the other hand, integrated phenomena mean optimising the solar PV through transactive systems to supplement the grid. The consumers with installed self-generating systems are connected to the grid, exporting excess power and importing to supplement consumption needs (Bronski et al., 2015; Nwaigwe et al., 2019; Yáñez et al., 2018). The approach has a potential of lowering the cost of electricity across the board while also lying grounds for reliable, resilient, and low greenhouse emission grid. However, it requires intensive resource as well as regulation for the systems on both consumer and grid’s sides to work together.

2.4 Economics of Grid Defection

With RE becoming more economically feasible and favourable to consumers, there is a push for creation and sharing of values between the consumers and grid. At the third stage where the declining overall cost of installing solar PV outmatch the retail prices of electricity, the utility would be forced to coordinate with consumer. The integration stage supported by such structures as net metering and FIT incentivises cheap electricity and support grid infrastructure (Hittinger, and Siddiqui, 2017). Figure 2.2, illustrates the point at which grid parity is attained subject to electricity prices and quantity.

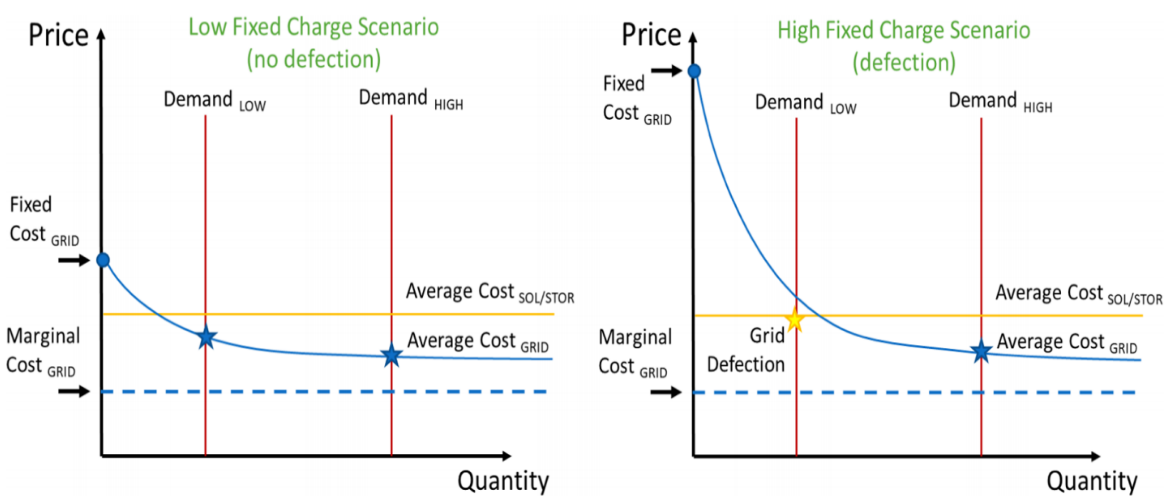

Figure 2. 2: Tariff rate design and corresponding point of grid defection (Gorman et al. 2020)

Conventionally, utility electricity tariff is structured such that it encompasses the fixed cost (metering and billing) and marginal cost (electricity consumed). Under the low fixed cost, the average cost of grid electricity (fixed + marginal cost) would be lower than average cost for solar PV systems (yellow line). However, under the high fixed cost structure, the cost of grid electricity paid by low demand consumers would be higher than average cost of solar power (Gorman et al. 2020). If the fixed cost of grid electricity crosses the low demand line below the point at which it meets average cost of solar PV, it makes economic sense to consume electricity from the grid. However, in the event the grid fixed cost crosses the low demand before solar PV average cost, it means a consumer would be forced to defect to cheaper electricity source. Therefore, the utility rate design plays a critical role towards point of grid parity where the cost of electricity from other source is cheaper than from the grid.

The parity point, threshold at which it makes economic sense to defect to cheaper source, is determined by taking into consideration the levelised cost of energy (LCoE). As described by Lai and McCulloch (2017), LCoE provides a comparative cost of different energy technologies with different capacity, life time, capital cost, risks, and returns. It outlines the economic assessment of the total cost to build and operate a power-generating plant taken against the total energy output over its lifetime. With this approach, competitiveness of different energy technologies over respective lifecycle can be compared. For instance, electricity from solar PV against coal plants.

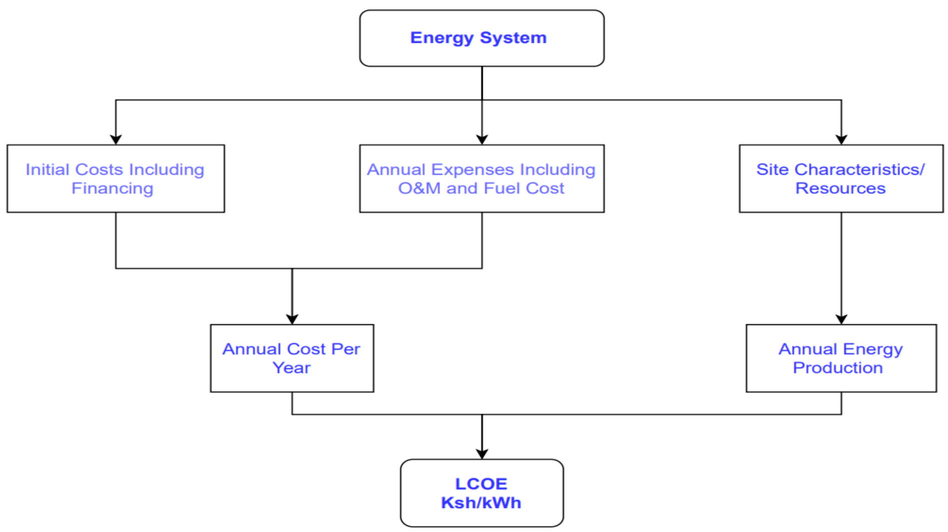

Figure 2. 3: LCoE Concept

$$LCoE = \frac{Lifecyle\ Cost}{Lifetime\ Electricity\ Production\ (kWh)} \tag{2.1}$$

$$= \frac{\left(\frac{\sum_{t=0}^{n}(I_t+O_t+M_t+F_t)}{(1+r)^t}\right)}{\left(\frac{\sum_{t=0}^{n}E_t}{(1+r)^t}\right)} \tag{2.2}$$

Where I_t is the Initial Capital Cost and may include installation cost. O_t is Operation Cost, M_t is Maintenance Cost, and F_t is Fuel Cost. E_t is the total sum of Energy produced over the lifecycle (t) of the plant/ system and a discount rate (r) accounting for depreciation in value of costs and energy (Lai et al., 2017). For wind and solar PV, fuel cost (F_t) is zero.

2.5 Role of Distributed Generation to Electricity Consumption

The rise of DGs pose a significant threat to traditional electricity production and distribution systems. Scholars have argued that the disruption caused by RE and by extension grid defection will have a potential death spiral of the established grid and utility systems (Felder and Athawale, 2014). As noted by Abdmouleh et al. (2017) and Prakash & Khatod (2016), this disruptive competition exacerbated by the growth of the solar PV has impacted not only the market structure but also the public policies on electricity production and distribution and business practices.

Vannini and Taggart (2014) noted that defection from the grid is mostly supported by customers seeking reliable energy source and increasing competitiveness of such technologies as solar PV, wind power, and battery storage in the electricity market. This practice goes beyond the small-scale consumers but also include big companies in manufacturing, logistics/transport, hospitality, and retail industries (Speidel and Bräunl, 2016; Peffley & Pearce, 2020; Child et al., 2016). The breakaway is largely driven by search of opportunities and ways of operating efficiently, reliably, cheaply, sustainably, and independently of the energy grid.

Mehigan et al. (2018) grouped the role of DGs on the electricity sector into six categories. First, social factors encompassing the habits, acceptance, demand response, and adaption, and neighbourhood effect (socio economic behaviour induced on an individual by neighbours) from consumers' end. Secondly, the DGs plays a critical role towards geographical, natural resources, and climate under safeguarding environment degradation, reducing pollution, abating greenhouse gases emission, and proper land use. Thirdly, the increasing penetration of DGs is projected to play a critical role in determining the direction of future electricity infrastructure under electricity grid systems, interconnectedness, transport systems, and communication infrastructure (Mehigan et al., 2018).

Fourth is the question of DGs in determining the direction of regulations and policy touching electricity sector. The changing dynamics in the energy sector is forcing countries to rethink energy aim and strategy of a country, targets, and assessment strategies. The fifth role of DGs is placed under the progress in components of heat, transport, and storage. This covers the storage vehicle-to-generation, CHP, electric vehicles, and electric heat pumps (Mehigan et al., 2018). Sixth category touches on challenges/technical requirements captured under DG technical performance, system operation limits, DG technology cost, and smart grid technologies.

Energy security encompassing the reliability, power quality, and efficiency is regarded as both drivers and benefits but under assumption that increased diversification of fuel mix matches the deferral from network investments. However, in a study examining the electricity futures focusing on emerging alternatives systems and architectures, Hojčková et al. (2018) and Kumar et al. (2017) argued that the concepts of ‘the super grid’, ‘the off-grid’ and ‘the smart grid’ would be the main building blocks of future electricity systems. In assessing the potential impact of connecting DG to the grid, Passey et al. (2011) highlighted that DG would offer positive impacts that include reducing network flows such losses and voltage drops.

On the other hand, high penetration of DGs means high voltage fluctuations, frequency regulation and harmonics, fault currents, unintentional islanding, and power factor fluctuations. According to Mehigan et al. (2018), DG role in either maintaining traditional centralised electricity grid or increase decentralisation depends largely on demand response (DR), distributed energy resources (DERs) (Figure 2.3). Manfren et al. (2011) and Paliwal et al. (2014) present a driver for increased deployment of DGs ranging from renewable energy targets, increased electricity demand, market liberations, government policies, and lower capital cost.

Investigating the impacts of net metering and market feedback loops, Darghouth et al. (2016) explored the influence they have on distributed PV deployment under retail-rate-design pricing in the US. The findings indicate that the feedback dynamics significantly affect the retail structures where the rates in a time-invariant format would result in higher aggregated national deployment levels rate, formulation of a rate structure with higher fixed customer charges, or lower solar PV compensation than retail rate eroding the aggregated solar PV adoption. In contrast, the findings also indicated that adopting time-varying rates would lead to accelerate near- and medium- term solar PV adoption rate but slowing the long-term adoption (Darghouth et al., 2016). Based on FIT policies, consumers are paid at full retail electricity prices for generating and distributing electric power to the grid.

However, in some cases, there are concerns of the effect of net-metering system deployment on the utility costs. Darghouth et al. (2016) argue that with more consumers opting to generate and receiving full compensation for distributed PV generation, there is a possibility of under recovery of fixed utility costs that might lead to an increase in the grid electricity costs. This, according to Borlick and Wood (2014), create a feedback loop system that high electricity prices push for deployment of consumer-sited generated electricity that in turn leads to increase in utility costs. It in turn translate to high electricity cost, causing more deployment of solar PV by consumers. This, as pointed out by Muaafa et al. (2017), might trigger a utility death spiral. However, Darghouth et al. (2016) contends that having a spate and opposing feedback loop in which increase in adoption of distributed solar PV systems might shift in timing of peak period that in turn results in reduced savings in bills. In this case scenario, the defection to solar PV would be dampened.

2.6 Feed-in-Tariff and Net-metering Policies in RE Transition

In attempt to promote RE transition, countries such as Albania, Armenia, Ukraine, and Kenya have implemented FIT policies. In addition to allowing the generators to produce and sell the generated electricity to off-taker, the FIT policy guarantees a fixed tariff per kWh for a stipulated period. In 2014, Kazakhstan introduced a fixed tariff and 15-year contract aimed at stabilising the electricity production and market, and renewable transition (Pablo-Romero et al. 2021; Trypolska, 2019). Although the country later replaced the model with a competitive auction, the structuring saw a significant rising in adoption of alternative electricity generation.

Another mechanism formulated to encourage investment in alternative renewable energy is net metering, where a regulated arrangement between a consumer who has installed own electricity production systems, and utility is reached to pay only for the energy consumed from the grid. In this approach, consumers who opt to supply the excess electricity into the grid only pay for difference in supplied and consumed energy (Cansino et al., 2010; Pablo-Romero et al., 2020). The net metering as adopted by transitioning economies such as Ukraine, Albania, Armenia, and Bosnia is largely structured to incentivise solar and wind installations of less than 500 kW electric energy (Del Río, and Kiefer, 2021).

In the case of Kenya, the bulk of electricity generation is sourced from national grid. The electricity market is structured to institute the main players: generators; retailers; and consumers. The grid extension remains the preferred approach to supply and connecting electricity in rural areas under rural electrification, industrial, and commercial entities (Prabavathi, and Gnanadass, 2015; Abdulganiyu et al., 2017). However, the extension to remote and sparsely populated areas can be either practically infeasible or unviable financially (Engola, 2019; Mori, and Le, 2017). While commercial and industry sector experience high cost and disruption frequency. The FIT policy was formulated and implemented in attempt to bridge the energy gap.

Although the formulated FIT policy has not been effective, key building blocks of the policy is to promote the uptake of RE, increase access to electric energy, reducing greenhouse gases emission, diversify electric power source, and meeting commitment on energy production and use (Ndiritu and Engola, 2020). The policy has been criticised for leading to increased electricity prices, failing to address initial high capital, and not being market-oriented. The findings by Ndiritu and Engola (2020) indicate heightened investment interest but a significant delay in implementation of the projects.

2.7 Related Research Works

Numerous studies have modelled the impact of the RES on energy prices (Tveten et al., 2013; Würzburg et al. 2013; Cludius et al., 2014). The result shows significant savings in cost for consumers who have defected but higher electricity prices for those remaining. However, as noted by Ribó-Pérez et al. (2019), the results can be significantly misleading where inaccurate description of the energy problems would lead to inappropriate measures including policy formulation. Globally, several studies exist exploring the perceived effect of RES adoption on the liberalised electricity market. Traditionally, renewables have been supported heavily with subsidies eliciting debate of their competitiveness compared to conventional sources.

Under the merit order effect, where energy sources are ranked in such a way that the source with lowest bid price is placed bottom to highest priced, the increased adoption of renewable electricity production should ultimately cause a fall in electricity prices in the short run (Würzburg et al., 2013). In merit order-based electricity markets, the RES have a huge advantage against conventional energy sources. In some markets, the energy sources with lowest environment pollution is lowest ranked. In reviewing the economic and environmental impacts of grid against off-grid electricity access options, Ortega-Arriaga et al. (2021) measured ways in which solar PV powering the off-grid systems are performing against the traditional fossil-fuel grid extension. The findings highlighted greenhouse gas emissions as a major concern. The Table 2.1 capture a summary of the related work.

Author(s)	Study Focus	Study Findings
Ortega-Arriaga et al. (2021)	It aimed on reviewing the economic and environmental aspects of grid vs off-grid electricity	RE off-grid generation is being competitive compared to traditional production
Gorman et al. (2020)	It focused on analyzing how electricity tariffs that shift cost recovery away from variable charges towards fixed charges influence a customer's decision to disconnect from utility service	The findings indicate that utilities and regulators seeking to limit rooftop solar adoption by lowering variable charges face a significant possibility that the corresponding increase in fixed charges could lead to inefficient grid defection
Würzburg et al. (2013)	It analysed merit-order effect of RE prices on the overall electricity cost taking a case study of Australia and Germany	Under the merit order effect, the increased adoption of renewable electricity production should ultimately cause a fall in electricity prices in the short-run
Peffley and Pearce (2020)	It analysed the economic and technical viability for hybrid solar PV systems, taking a case of SMEs in northern US	A grid-tied PV enables generation of lower cost electricity compared to most utility providers in the US

2.8 Research Gap

Despite apparent trends to off-grid generation by consumers, literature show little investigation done in relation to threshold at which it would make economic sense for consumers particularly in Kenya to defect from the grid. The cost of generating own electricity compared to that of the grid power plays a critical role in determining the point at which the consumer decide to defect. Although a number of studies have conducted LCoE for different RE technologies, variables such as capital cost, variable cost (operations and maintenance), taxation and incentives, discounting rate, and energy output vary considerable due to environmental conditions, geopolitics, consumers' socioeconomics, and others actors (social behaviour and beliefs, greenhouse consciousness, efficiency). Therefore, the threshold is not confined but varies from an organisation, region, to a country. Given the perceived trend as disruptor in the energy industry, one can argue on importance of investigating and having better insight of the whole concept of self-generation and grid defection.

2.9 Summary

The disruptive influence of technological innovation in energy generation and consumption has exposed utility providers in particular to regulatory constraints, varying economics, policy changes, and technological and customer preferences. In order for utility companies to survive in the fast-changing-environment, they need to facilitate power supply with efficient load distribution and minimal downtime including timely maintenance. The transition is largely driven by reliability, affordability, energy efficiency, and energy independence. With the changing energy dynamic, some countries are increasingly relying on consumers to operate their onsite energy generation to maintain electricity reliability and stability particularly during peak hours. The transformation in the energy sectors such as distributed and decentralised energy systems requires changes in power systems policies and regulations.

Chapter 3: Methods and Tools

3.1 Introduction

This section discusses the process and procedures through which the research questions were answered, and objectives attained. This chapter highlights the method and materials that were employed in ensuring the answers to the research questions were provided and the objectives addressed in a systematic and structured manner. Additionally, it outlines the approach that was used in analysing collected data as well as the ethical considerations followed during data collection and analysis process.

3.2 Research Method

As stated, this study aimed to conduct a comparative tariff assessment between the grid and self-generated power then determine the threshold at which consumers would opt to defect, with a focus on the Kenyan market. As described by Scheurich (2014), a research method encompasses a strategy, technique, and process utilised in addressing the aim and answering research question in a logical manner. Scholars have postulated several research methods that include qualitative, quantitative, and mixed method.

According to Bloomfield and Fisher (2019), quantitative research involves quantifying the research problems by expressing the findings numerically. Qualitative research aims to establish an insight into the problem by exploring and making sense of or interpreting a phenomenon based on the perception held by the research population (Silverman, 2020). Qualitative research is widely regarded as the explorative research, which is useful in gaining a deeper understanding of the motivations, opinions, as well as reasons attached to the research topic. In this context, there is need to capture numerically the tariffs from different self-generating consumers then compare with grid charges to obtain the difference while at the same time exploring the experts' opinions, perspective, and views on the concept of grid defection and own generation. Hence, this study adopted a mixed research method comprising of both qualitative and quantitative methods.

3.3 Data Collection Method

Igwenagu (2016) described data collection for research as a process of collecting, measuring, and analysing information on a targeted phenomenon within an established system to answer research questions. Theoretically, data collection process can either be primary or secondary. Primary data incorporate the data directly gathered by researcher through direct contact with the participants. Secondary data, on the other hand, is collected by someone not primary user. It includes censuses, published articles, institution data, and energy data for an organisation. This study used both secondary and primary data. The primary data was sourced directly from the electricity consumers using survey questionnaire method. The data captured the electricity generation, installed capacity, consumption rate, and reasons for opting to self-generate by surveyed companies in commercial and industrial sectors. The survey provided a mechanism of capturing the electricity tariffs of different companies then mapping against grid charges.

3.4 Data Collection Process

The data collection process was broken down into three phases. Phase I involved collecting energy production data from sampled companies. Using a survey questionnaire, the participants from different organisations with installed self-generation systems were asked to answer number of questions touching on plant installed capacity, reasons for installation, and challenges faced. This provided an insight into tariff for both grid and self-generated power. Importantly, it gave an overview of the incentives driving shift to own-generation. Phase II involved collecting data from vendors, that is companies and individuals in Engineering, Procurement, and Construction (EPC) in energy sector. The individuals working in the sector were perceived to have extensive experiences in procurement, consulting, and engineering works that would provide respective perspectives on capacities and cost in addition to highlighting trends, challenges experienced, incentives imposed, and core driving factors of grid defection. This is intended to eliminate any biases that might have been captured from the consumers and utility regarding tariffs, threshold, and other driving factors.

Phase III involved collection of secondary data from EPRA. The data provided tariffs and its structuring model of electricity supplied and consumed by heavy consumers. The tariffs from the grid was used in determining the threshold in which consumers might decide to defect from the grid. This provides an insight into electricity sourced from national grid. The data captured the driving factors into self-generation, guiding reason behind moving away from centralised/ distributed grid network, the impact incurred directly, and potential impact the shift will have on Kenya's energy sector. The data shows the tariff structuring and methodology behind the pricing between 2013 and 2022.

3.5 Tariff Assessment Tool

Levelised Cost of Electricity (LCoE) formula was used to calculate the least cost of generating own electricity. The cost derived from the lifecycle cost of individual organisation against the lifetime electricity produced discounted to present value highlights the threshold at which it makes an economic sense to defect.

$$LCoE = \frac{Lifecyle\ Cost}{Lifetime\ Electricity\ Production\ (kWh)} \quad (3.1)$$

$$= \frac{\left(\sum_{t=0}^{n}\left(\frac{(I_t+O_t+M_t+F_t)}{(1+r)^t}\right)\right)}{\left(\sum_{t=0}^{n}\left(\frac{E_t}{(1+r)^t}\right)\right)} \quad (3.2)$$

The tool is convenient summary measuring the overall competitiveness of different technologies. However, it should be noted that it does not consider all the cost associated with the project and actual financial decision (Hansen, 2019). Additionally, it ignores project risks as well as oversimplifying interest and discounted rates within the financial recovery factors. In a distributed system, the tool does not take into account the efficiency improvement putting the LCOE to relatively higher especially for small systems in an efficient load (Nissen, and Harfst, 2019). Some scholars have argued incorporating Levelised Avoided Cost of Electricity (LACE) or measuring both system cost and system value. However, in practice, these would entail collecting detailed information on hourly electricity production and consumption. Additionally, Energy System Analysis (ESA) offers complete analysis of the energy system including direct and indirect system dynamics such as heating and CO2 emission, which are difficulty to assess using LCOE (Hansen, 2019). The aim of this study was comparative tariff between grid and own generation focusing in particularly on the cost of electricity generation by different technologies. Therefore, despite the LCOE limitation, the approach is the most useful in tracking overall cost of a specific technology and then comparing with other systems in similar context.

3.6 Sampling Process

Taherdoost (2016) described sampling as a process of selecting a subset from a population of interest for the purpose of investigation/ observations and gaining inference about the population. Own-generation of electricity is relatively new prospect and largely regarded to be in its inception stages. Premising on the existence of several factors driving defection and the impact rippling beyond consumers' financial savings but also energy security and financial burden to traditional companies, this research intended to survey a number of companies doing own-electricity generation but still connected to the grid. As such, taking a narrowed approach in data collection process. A survey questionnaire was administered to two sets of participants: consumers from industrial and commercial sectors and vendors (EPC sector). The followed by secondary data collected from EPRA.

The sampling of the participants from consumers was set to be purposive driven. However, each participant was to meet outlined inclusion/ exclusion criteria. The criteria for the consumers was: be operating in Kenya, currently producing own electricity, previously/ still connected to national grid, and own-installed electricity exceed 20 kW. The sample size target was 25 companies sampled from commercial, manufacturing, horticultural, tea, and milk processing industries.

Similarly, participants from vendor sector were also sampled purposively. The population target for this phase was 50 individuals sourced some 20-25 companies in EPC sector. The inclusion/ exclusion criterion was that the companies must have undertaken a project in electricity production/ consumption sector in Kenya recently.

For phase III, the data was collected from EPRA. The data contained the tariffs and billing for different consumer classes between 2013 and 2022. The formula and calculations based in structuring the tariffs and pricings. The additional charges liable and levied to the consumers.

3.7 Data Analysis Tools

In data analysis, two approaches were used. For the quantitative data Statistical Package for the Social Science (SPSS) tool was used in analysing and transforming the collected data into useful information. This enabled drawing the trends, correlation, and projections of the electricity production by self-generating consumers mapping against the tariffs from the grid. The cost measured by LCoE from different organisations was then mapped against the Tariffs and Pricing from grid electricity. This acts as a threshold for defection by consumers in industrial and commercial sectors across Kenya.

For the qualitative data, was analysed using thematic analysis tool. Its usefulness lies on identification, analysing and reporting of patterns, themes, and connections available within raw data (Maguire, and Delahunt, 2017). This enables effective development of main patterns that highlight the benefits of own-generation adoption as well as any potential implications for its adoption in Kenya energy sector.

3.8 Summary

In addressing the research aim and objectives, this investigative study adopted a structured methodology based on specified procedures and techniques. A mixed research approach was followed premised on capturing the numerical and statistical aspect of tariff and energy mix for both grid and own generated electricity, and also delving to deeper to understand the causes, driving factors, and challenges for grid defection. Similarly, the insight into tariff measures available and formulation frameworks required following a qualitative approach. In research design, a case study of Kenyan energy sector was adopted. Both primary and secondary data were used in data collection. The primary data was sourced from consumers with hybrid electricity systems, and vendors. The secondary data was obtained from EPRA capturing tariff and billing structuring. In analyzing the data, two approaches were used. First, descriptive analysis was used in transforming the gathered quantitative data into useful information. Second, thematic analytic tool was used in analysis qualitative data.

Chapter 4: Findings and Discussion

4.1 Introduction

This findings and discussion chapter captures the results from the survey and secondary data from EPRA. The primary data from survey involved administering a questionnaire to participants working in self-generating electricity consumers and EPC in energy sector. The data aimed to capture the electricity generation capacities, utilisation factors, financial element for the system, and factors that led the consumers to opt for self-generation as well as reasons for having both grid and own-generated electricity. The data from the consumers provides the perspective from the own-generating companies while vendors try to eliminate biasness as well as getting perspective particularly on cost and driving factors from the independent observer. The secondary data collected from EPRA provide tariffs and billing structuring for different class of electricity consumers. Subsequently, the chapter discusses the findings linking to the previously done research and concepts.

4.2 Findings

This study into comparative tariff assessment between grid and own-generation of electricity used both primary and secondary data sources. The primary sources employed survey method to collect data on electricity installed capacity, generation dynamics, initial cost, and usage rate then compare to the electricity supplied by the grip power providers. The primary data collection was subdivided into two parts. First, it involved collecting data from commercial and industrial consumers with own generation. A semi-structured questionnaire was administered physically to 25 industrial companies and commercial centres across the country. However, nine of them responded and completed the survey questionnaire – a response rate of 36%. The questionnaire questions were structured such that it captured installed capacity (own generation), electricity usage from both own and grid, driving factors for installing own generation, and calculated energy cost. The second part of the data collection involved vendors. An online questionnaire survey was administered to 20 participants but with knowledge and understanding of the operations and installations of self-generating systems. Only 4 vendors filled and completed the questionnaire, a response rate of 16%. Lastly, the secondary data touching on the tariff trends particularly large commercial and industry consumers was collected from EPRA. In this section, the results from the three data sources is analysed by transforming into useful information.

4.2.1 Respondent Demographics

In both survey questionnaires, the participants were asked about their field of work and corresponding experiences. On the question of the field the respondents are currently working in, majoring indicate industrial maintenance and EPC (both 6 individuals), those working as energy auditors were 4, energy contractors were 3 and engineering consultants were 3 (Table 4.1). Only 3 participants saying they others professions. The demographics section of the questionnaire also included the years of experience the participants had in the larger energy and engineering field. Majority of the respondents stated having 5-10 years (38%), followed by those with 3-5 years-experience (30%), and those with over 10 year-experience were 3 (23%). From the response, the participants have extensive experiences and were drawn from several subsector of the wider energy field.

Table 4. 1: Participants demographics

Indicate	**Response**	**Respondents**	**% of the respondents**
Working Field	Engineering, Procurement, and Construction	6	46.15 %
	Independent Power Producers	0	0 %
	Industrial Maintenance	6	46.15 %
	Contractor	3	23.08 %
	Engineering Consulting	3	23.08 %
	Government regulator	0	0 %
	Energy Auditor	4	30.77 %
	Others	3	23.08 %
Years of Experience	0-3 Years	1	7.69 %
	3-5 Years	4	30.77 %
	5-10 Years	5	38.46 %
	10-20 Years	3	23.08 %
	More than 20 Years	0	0 %

4.3 Objective 1: Cost Comparison between Own-generated and Grid electricity

4.3.1 LCoE for Self-Generated Electricity

The questionnaire included a number of questions aimed at calculating the levelised cost of generating own electricity. Table 4.2 captures the energy source with respective installed capacities, initial capital, annual number of hours the system is in operation, and O&M for the firms surveyed. In attempt to maintain privacy and confidentiality, the companies are assigned letters A, B, C, etc.

Table 4. 2: System Variables for the Surveyed Firms *(1 USD = Ksh 110 at the time of writing)*

Consumer	**Energy Source**	**Installed Capacity**	**Initial Capital (Ksh in million)**	**Operating hours**	**Annual O&M (Ksh in million)**
A	Solar PVs	1.2 MW	270	2500	1.66
	Diesel Generators	7.5 MVA	90	300	2.1
B	Solar PVs	1.67 MW	300	2500	0.3
	Diesel Generator	400 kVA	5	400	0.7
C	Solar PVs	850 kW	60	3000	0.7
	Diesel Generators	2 MVA	20	250	1.5
	Natural Gas	10kW	20	1500	1.1
D	Solar PVs	20 kW	2.1	3000	0.1
	Diesel Generators	160 kVA	0.8	500	0.3
E	Solar PVs	230 kW	23	2500	0.8
F	Solar PV	2.5 MW	270	3000	0.56
	Diesel Generators	4.32 MVA	50	600	3.2
G	Solar PVs	150 kW	15	2500	0.5
	Diesel Generators	1 MVA	10	300	1.8
H	Solar PVs	560 kW	50	3000	0.8
	Diesel Generators	1.5 MVA	20	250	1.5
I	Solar PVs	410 kW	40	2500	0.5
	Diesel Generators	2.5 MVA	30	300	1.4
J	Solar PVs	290 kW	30	2500	0.4
	Diesel Generators	500 kVA	5	200	1.1
K	Solar PVs	670 kW	70	3000	0.9

The data collected show the sources for self-generated electricity include Solar PVs, Diesel generators, and Natural gas turbines. From the findings, most of the solar PV systems were in operations for between 2500 and 3000 hours annually and diesel generators were in use for approximately 200-500 hours in a year. The O&M cost for solar PV systems included spare parts and maintenance, clearing, administration, annual inspection, and security. Additionally, diesel generators incurred fuel cost as part of O&M.

The LCoE, as described by Aldersey-Williams and Rubert (2019), measures the comparative costs of electricity generation from different sources. The LCOE is obtained by taking lifecycle cost of the electricity system then dividing by energy produced over its lifetime (Equation 3.2).

The LCoE for these sources is calculated use the formula:

$$LCoE = \frac{Lifecyle\ Cost}{Lifetime\ Electricity\ Production\ (kWh)} \tag{4.1}$$

From the findings, O&M for diesel generators included the fuel cost and other cost incurred in operating and maintaining the system. The lifetime for solar PVs systems was based on the IRENA assumptions of 30 years (IRENA, 2016). On the other hand, theoretically, the lifetime expectancy for the diesel generator (7 kW – 10 MW rating) is taken as 50,000 hours (Benton, Yang, and Wang, 2017) and that of natural gas turbine rated at 25 – 500 kW is between 50,000 – 80,000 hours (Fadeyi, Arafat, and Abu-Zahra, 2013; US Department of Energy, 2014). For this study, the assumption made is the Genset and natural gas turbine both have a lifetime expectancy of approximately 20 years.

Table 4. 3: LCoE Economic Variables

Components		**Variables**
Discount rate		7.5%
Expected inflation rate		7%
Project lifespan	Solar PVs	30 years
	Genset	20 years
	Natural gas turbine	20 years
Land cost/acre		None

Using the collected data and the economic input, the calculated LCoE for the surveyed firms is given in the Table 4.4.

Table 4. 4: Calculated LCoE for the Surveyed Consumers

Consumer	**Energy source**	**Life cycle cost of the system (Ksh)**	**Life cycle electricity produced (Ksh)**	**LCoE (Ksh)**
A	Solar PVs	930,979,551	10,279,892.71	90.56
	Diesel Generators	433,631,018.70	9,534,232.50	45.48
B	Solar PVs	1,032,443,891	14,306,184.02	72.17
	Diesel Generator	26,837,098.88	677,989.87	39.58
C	Solar PVs	207,998,495.8	8,737,908.80	47.78
	Diesel Generators	101,227,653.70	2,118,718.33	23.80
	Natural Gas	99,344,348.48	70,623.84	70.33
D	Solar PVs	7,538,588	205,597.85	36.67
	Diesel Generators	5,179,089.26	338,994.93	15.28
E	Solar PVs	81,553,815.48	1,970,312.77	41.39
F	Solar PV	930,535,887.90	25699731.77	36.21
	Diesel Generators	250,479,589.50	10,983,435.84	22.81
G	Solar PVs	53,112,779	1,284,986.59	41.33
	Diesel Generators	55,557,502.94	1,271,231	43.70
H	Solar PVs	174,072,850	5,756,739.92	30.24
	Diesel Generators	101,227,653.70	1,589,038.75	63.70
I	Solar PVs	138,778,551.50	3,512,296.68	39.51
	Diesel Generators	147,839,457	3,178,077.50	46.52
J	Solar PVs	104,169,579.40	2,484,307.40	40.30
	Diesel Generators	28,720,404.06	423,743.67	67.78
K	Solar PVs	242,948,131	6,887,528.11	35.27

(*1 USD = Ksh 110 at the time of writing*)

From Table 4.4, the LCoE for various own-generating systems varied ranging from Ksh 15.28 to Ksh 90.56 per kWh. As shown in Figure 4.1, the difference in LCoE for different own-electricity generating system is not apparent. The average LCoE for solar PVs systems is Ksh 46.49/kWh and that of Diesel generators is Ksh 40.96/kWh (*1 USD = Ksh 110 at the time of writing*). For some consumers such as A, B, C, D and E, the solar PVs have higher LCoE compared to diesel generator. However, the difference for consumer A and B was significant.

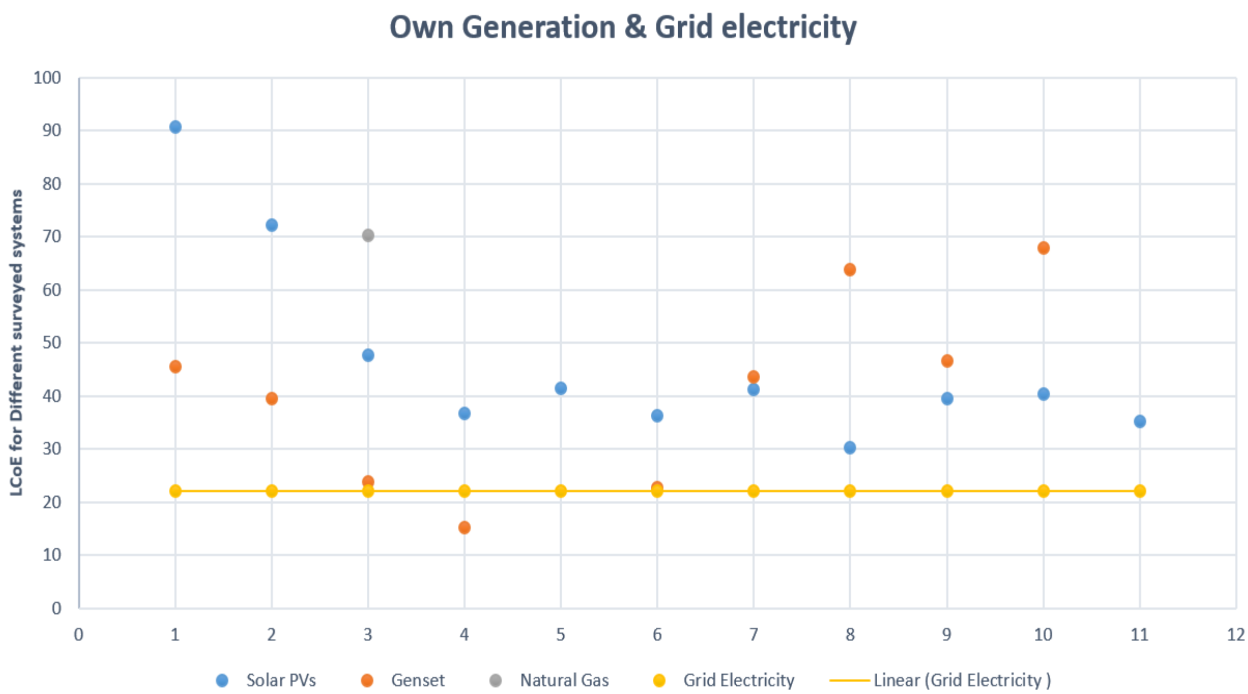

Figure 4. 1: Calculated LCoE for the surveyed consumers

4.3.2 Grid Tariffs and Pricing

The secondary data collected from EPRA captured the tariffs for various consumer group. It also included the methodology for structuring the pricing and billing for different consumer classes. According to the data from EPRA, the tariffs for both post-paid billing and pre-paid units purchase is categorised into several groups (Appendix 1). In this study, the companies under classes CI 1-4 (commercial and industrial companies) were surveyed (Table 4.14). The collected data (Table 4.14) is for the period between 2013 and 2022.

Table 4. 5: Grid Tariffs for Commercial and Industrial Consumers (2013-2022) - (*1 USD = Ksh 110 at the time of writing)*

Category	**Class Charges**	**Year 2013 – 2014 (Ksh)**	**Year 2014 – 2015 (Ksh)**	**Year 2015 – 2018 (Ksh)**	**Year 2018 – 2022 (Ksh)**	**Year 2022 (Ksh)**
Method CI1	Fixed Charge	2,000.00	2,000.00	2,500.00		
	Energy Charge /kWh	8.70	9.45	9.20	12.00	8.70
	Off-Peak Charges				6.00	4.35
	Demand Charge /kVA	800.00	800.00	800.00	800.00	800.00
Method CI2	Fixed Charge	4,500.00	4,500.00	5,500.00		
	Energy Charge /kWh	7.50	8.25	8.00	10.90	8.10
	Off-Peak Charges				5.45	4.05
	Demand Charge /kVA	520.00	520.00	270.00	520.00	520.00
Method CI3	Fixed Charge	5,500.00	5,500	5,500		
	Energy Charge /kWh	7.00	7.75	7.70	10.50	8.00
	Off-Peak Charges				5.25	4.00
	Demand Charge /kVA	270.00	270.00	270.00	270.00	270.00
Method CI4	Fixed Charge	6,500.00	6,500	6,500		
	Energy Charge /kWh	6.80	7.55	7.30	10.30	7.80
	Off-Peak Charges				5.15	3.90
	Demand Charge /kVA	220.00	220.00	220.00	220.00	220.00

Where

CI1: Commercial and industrial consumers for supply and metered at 415 volts three phase and power consumer exceeds 15,000 kWh per post-paid billing period

CI2: Applicable to commercial and industrial consumers provided and metered at 11 kV/post-paid billing period

CI3: Applicable to commercial and industrial consumers provided and metered at 33 kV post-paid billing period

CI4: Applicable to commercial and industrial consumers provided and metered at 66 kV post-paid billing period

From Table 4.5, EPRA outlines the stipulated tariffs and billing for different consumer groups that is applicable over a specified period. The classes CI 1-5 captures the commercial and industrial consumers with subcategory showing the provided and metered power from the utility provider. As shown in the table, the authority has restructured the tariffs and billing five times: Year 2013 – 2014; Year 2014 – 2015; Year 2015 – 2018; Year 2018 – 2022; and Year 2022. Under each category, the billing and tariffs are placed into: a fixed charge, energy charge, off-peak, and demand charge.

Between year 2013 and 2018, the tariffs and billing was based on fixed charges, demand charge and consumed charge. The fixed charged was levied to consumers on the virtue of being connected to the grid irrespective of whether or not they used any power over billing period – usually a month. The structuring was changed in 2018to be based on the electric energy consumed, off-peak charges, and demand charge. For CI1 consumers, the fixed charges were Ksh 2,000.00 between 2013 and 2015 then rising to Ksh 2,500.00 in 2015 -18 period (*1 USD = Ksh 110 at the time of writing*). In 2018 – 2022, the fixed charges were removed in favour of consumed electricity. CI4 were billed Ksh 6500 as a fixed charge between 2018. It was then restructured eliminating the fixed charges and increasing the charges for consumed energy from Ksh 7.30 to Ksh 10.30 and later Ksh 7.80 in 2020 (*1 USD = Ksh 110 at the time of writing*). The restructuring of the tariffs and billing in 2018 also saw introduction of off-peak charges that varied depending on the consumers' class. However, these consumers in commercial and industrial consumer bracket are charged for demand which has remained relatively the same since 2013. The trend of the charges has remained relative same over the decade (2013-22).

However, the consumers are subject to additional charges that include: Fuel charges, Foreign Exchange rate adjustment fluctuation adjustment (FERFA), Inflation Adjustment (INFA), Security support facility (SSF), Water levy (WARMA), and Taxes & levies (Appendix II). All consumers (billed as post-paid and purchased as prepaid) are liable to these additional charges calculated based on the formulated formula by EPRA (Appendix II). The fuel charges imposed is intended to cover the electricity generated by thermal generators that usually kept in as backup systems and used during peak period. FERFA charges comprises of the international currency inflation aimed to cushion foreign investors against local-international market and currency fluctuations. It also consists of consumer price index (CPI-U) as published by the US department of labour statistics.

Lastly, the FERFA charges covers specific inflation relating to KPLC's operation and maintenance costs to cover power transmission and distribution. The energy consumed is also liable to SSF charges that goes to meeting PPA agreement by KPLC with Lake Turkana Wind Power Limited (LTWP) for implementation 300MW wind project. The water levy is imposed on the billed and purchased electricity energy for water used by hydro power plants. Lastly, the government impose taxes, levies or duties to the consumer. These include: a 16% VAT to fixed charge, demand charge, foreign exchange fluctuation adjustment, fuel cost charge, and any other taxable energy consumed; a 5% rural electrification programme (REP) levy, and EPRA levy at 3 Kenya cents/kWh.

$$\frac{Cost}{kWh} = Demand\ Charges + Energy\ Consumed + [Other\ Additional\ Charges]$$

For a typical commercial and industrial consumer:

$$Other\ Additional\ Charges = FERMA + INFA + SSF + WARMA + Taxes\ \&\ Levies$$

Notably, this is not inclusive of penalties levied on poor power quality.

Cumulatively, although variable depending on the various conditions imposed, the additional charges add up to approximately 45% of the billed or purchased electric energy. The additional charges contributing nearly half the cost of billed or purchased energy makes the electricity from the grid to be relatively expensive. The pricing control that sets out the cost of consumed and demand energy does not reflect the actual cost of the electricity. From the finding, on average, consumers paid Kenya Power Ksh 22/kWh for the power purchased/ billed (*1 USD = Ksh 110 at the time of writing*).

Compared to the own-generated electricity, Kenya Power benefits from economies of scale and density. As pointed by Njeru, Gathiaka and Kimuyu (2021), with the economies of output being positive, means the average cost of electricity decreases with increase in the volume of electricity generated and sold to a fixed number of consumers. According to the findings by Njeru, Gathiaka and Kimuyu (2021), the elasticity of average cost in respect to the output decrease with an increase in output and customer density. This is unlike the own-generated electricity that confined to the consumer's consumption rate. From the findings, the participants pointed out that they do not have storage facilities. Additionally, when not in use, they do not supply to the grid. As such, own-generation of electricity lose the advantage held by economies of scale and at the same time idling of the system.

All these factors put into consideration, the cost of electricity drawn from the grid providers (Kenya Power) is subject to several variables. On the other hand, data from self-generating consumers show that in addition to initial investment, O&M, and installation of supporting infrastructure, the energy is not subject to additional charges. However, the LCoE of self-generating system indicate high cost relative to grid electricity.

4.4 Objective 2: Annual Energy Mix for Typical Industrial and Commercial Consumers

4.4.1 Electric Energy Sources

The questionnaire had a multiple choice question on energy sources used by the consumers. As shown in Table 4.6 all the participants indicated that the company used electricity from the grid (Kenya Power), 86.62% saying they had Solar PVs for electricity source, twelve (92.31%) pointing out that the company had diesel generators, while one participant responded that the company had natural gas/ LPG that is used to generate electric power. It should be noted that all the firms surveyed had more than one electricity source. A follow-up question on the ratio of the power consumed from the grid to own-generated show no company relied full on self-generated power to meet its electricity needs.

Table 4. 6: Energy Sources

Responses	**Respondents**	**% of the respondents**
Electricity from Kenya Power	13	100%

Solar PVs	11	84.62%
Biomass	0	0 %
Coal	0	0 %
Natural Gas and LPG	1	7.69 %
Briquettes and Charcoal	0	0 %
Diesel	12	92.31 %
Geothermal	0	0 %
Biogas	0	0 %
Others	0	0 %

Figure 4.2 shows the source for typical commercial and industrial consumers in Kenya.

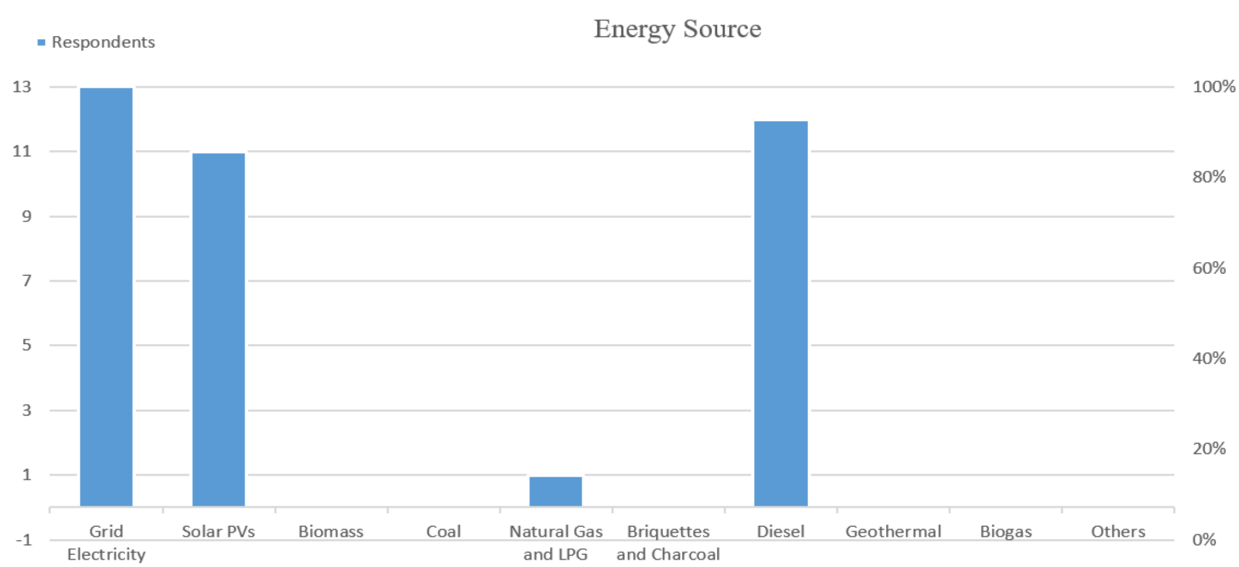

Figure 4. 2: Energy Source

As shown in Table 4.7, for most of the companies (53.85%), between 26-50% of the electricity consumed was sourced from own generation. Four companies indicated using between 51-75% of own generated power to meet their electricity needs while three (23.08%) of the surveyed firms saying self-generated power contributes between 1-25% of the total electricity consumed. Notably, no company stated to being fully relied on own generation or grid supplied electric power. The main reasons for these varied from power quality challenges to need for electricity reliability and availability.

Table 4. 7: Percentage of Own-generated to Total electricity Consumed

Response	**Respondents**	**% of the respondents**
0%	0	0 %
1-25%	3	23.08 %
26-50%	7	53.85 %
51-75%	3	23.08 %
76-99%	0	0 %
100%	0	0 %

As shown in Figure 4.3, majority (approximately 54%) of the consumers had 26-50% of the total consumed electricity sourced from own generation. None relied completely on the grid electricity or own generation. This formed a hybrid system for the consumers.

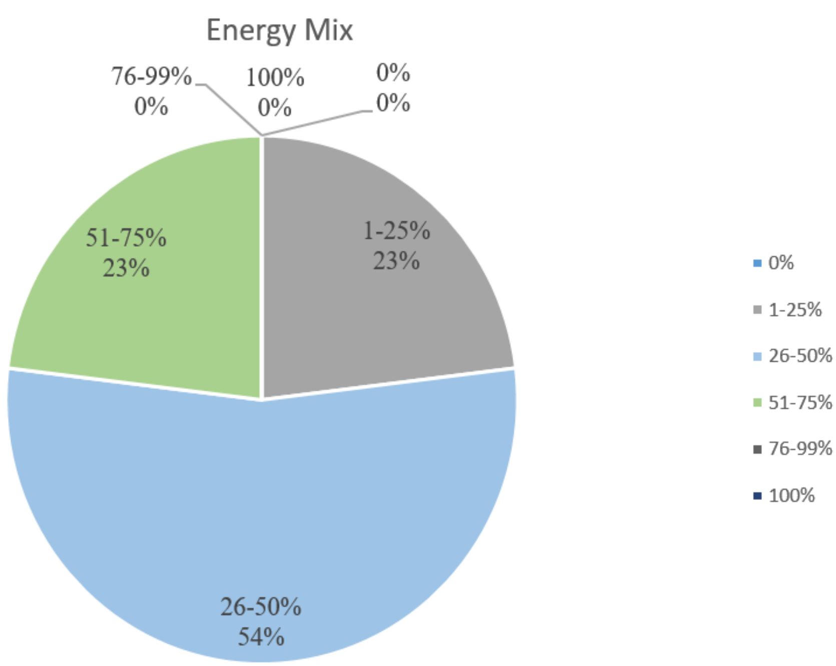

Figure 4. 3: Percentage of own-generate to total electricity consumed by the consumers

4.5 Objective 3: Factors Causing Commercial and Industrial Consumers to Defect

A follow-up question on reasons for the firm to have both self-generated and still connected to the grid saw the response varying from incentives from feed-in-tariffs to guaranteed electricity availability. The findings are captured in tables 4.8 and 4.9. Majority of the respondents (92.31%) stating that the need for electricity reliability and availability prompted the firms to seek other sources. Eleven (84.62%) of the respondents stated that the choice to generate own electricity was driven by need for cheaper electric power source and hence reducing the cost of production and operations. Other main driving factors were need for energy independence (61.54%), diversifying electric power sources (38%), and environmental conservation that pointed to need for clean energy sources (53%). More so, five (38%) of the participants also pointed to poor customers services and engagement from the power provider (Kenya Power) had an influence on decision to generate own electricity. From the responses, the need for reliable, consistent, and economics are three key driving factors that make electricity consumers to opt for alternative sources.

Table 4. 8: Factors Causing Consumers to Self-generate own electricity

Response	**Respondents**	**% of the respondents**
Electricity Reliability and Availability	12	92.31 %
Power Quality	4	30.77 %
Alternative Cheaper Energy Source	11	84.62%
Energy Sustainability	6	46.15 %
Diversifying Electricity Source	5	38.46 %
Electricity Independence	8	61.54 %
Clean and Environment-oriented sources	7	53.85 %
Poor Customer Service from Utility Provider	5	38.46 %
Others	0	0 %

From Table 4.8, the question on the factors causing the firms to self-generate electricity rather than rely on the grid supplied power saw respondents giving several different reasons.

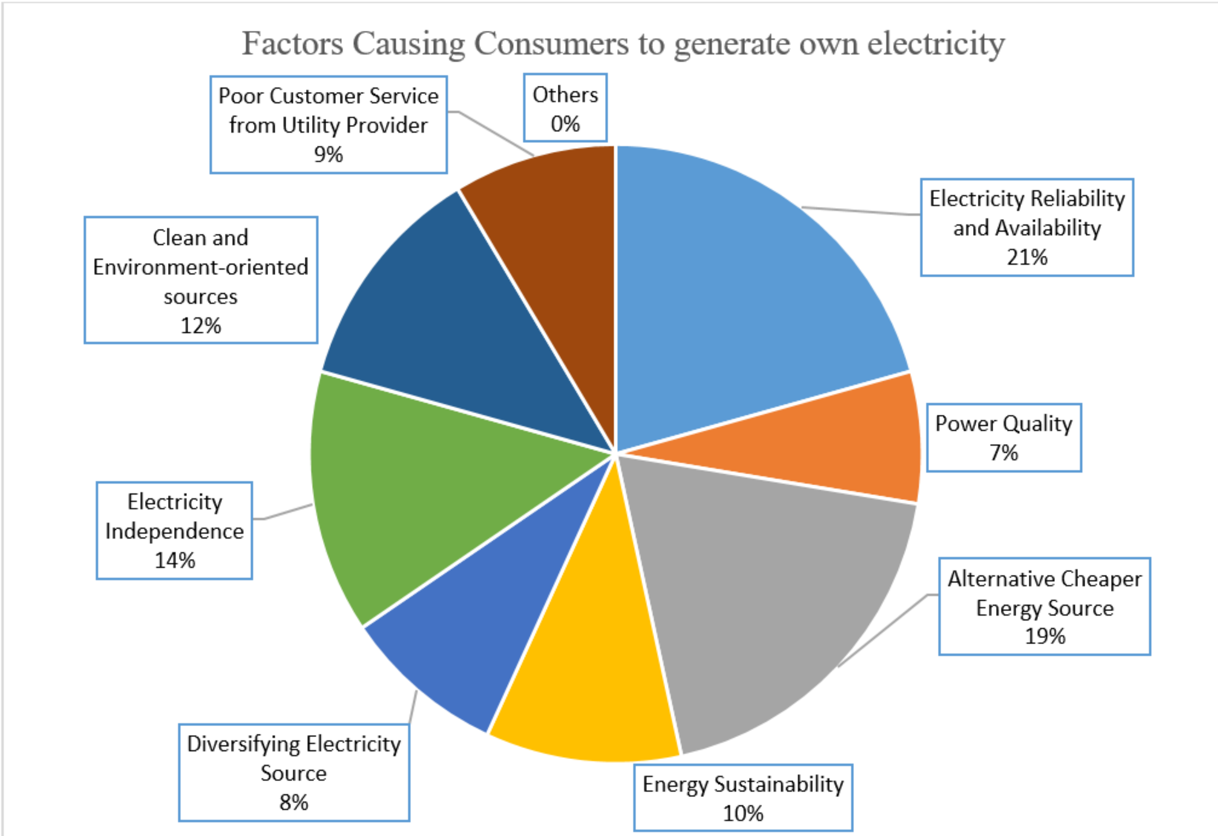

Figure 4. 4: Factors causing consumers to generate own electricity

As shown in the Table 4.9, majority of the respondents (84.6%) stated that the need to ensure electric power was available to sustain their respective operations was main factor for having both. As pointed by Lee and Callaway (2018), unreliability of electricity from power grid particularly in sub-Saharan Africa and Kenya included. The report by EPRA 2021 indicated that Kenya faces power interruption that takes up to 7 hours that is way higher that global average of 1.36 hours. In 2020, the average Customer Average Interruption Duration Index (CAIDI) was 4.63 hours and the average system frequency was 2.13 hours per month (EPRA, 2021). The report reflects similar findings by IEA showing Kenya electricity consumers both in Industrial and Household market facing an average of 25 days of power outages and interruption a year. Compared to the countries such as Tanzania, Uganda, and South Africa that faces interruption on average of 20 days, 19 days, and 5 days respectively per year (Amadala, 2022; Maende, and Alwanga, 2020). Therefore, arguably, this high interruption period measured annually and days plunged into outages and blackouts prompts firms and companies to explore other sources of electric power to maintain their operations.

However, as shown in Table 4.9, the firms opt for remaining connected to the grid in addition to having their own electricity self-generation systems because of cost of installing fully-independent electric power source. According to the findings, nine (69%) of the respondents saying high cost of going full off-grid, 61% pointing to cost of power storage units, and 46% indicating reducing infrastructural cost. In addition to enhancing and ensuring owner reliability with self-generation system acting as supplementary and power backup systems, 38% of participant also indicate that cheaper off-peak tariffs while 31% saying being incentivised by feed-in-tariffs.

Table 4. 9: Reasons for Hybrid Systems

Response	**Respondents**	**% of the Respondents**
Enhance power quality	7	53.85 %
High cost of installing full independent electricity source	9	69.23 %
Ensure power availability	11	84.62%
Take advantage of cheaper off-peak tariffs	5	38.46 %
Reduce cost for storage	8	61.54 %
Enhance electricity reliability	8	61.54 %
Feed-in-tariffs incentives	4	30.77 %
Reduce infrastructure cost	6	46.15 %
Others	0	0 %

Therefore, combinations of these myriad reasons have been key driving factors to commercial and industrial electricity consumers' decision to generate own electricity but still not disconnected from the grid. According to German et al. (2020), the decision to go off-grid under grid defection in largely depended on not only the need for power reliability but also the economics under the cost of installing and operating self-generating systems measured against the returns. Vannini and Taggart (2014) noted that defection from the grid is mostly supported by customers generating seeking reliable energy source and increasing competitiveness of such technologies as solar PV, wind power, and battery storage in the electricity market. This practice goes beyond the small-scale consumers but also include big companies in manufacturing, logistics/transport, hospitality, and retail industries (Speidel and Bräunl, 2016; Peffley & Pearce, 2020; Child et al., 2016). The breakaway is largely driven by search of opportunities and ways of operating efficiently, reliably, cheaply, sustainably, and independently of the energy grid.

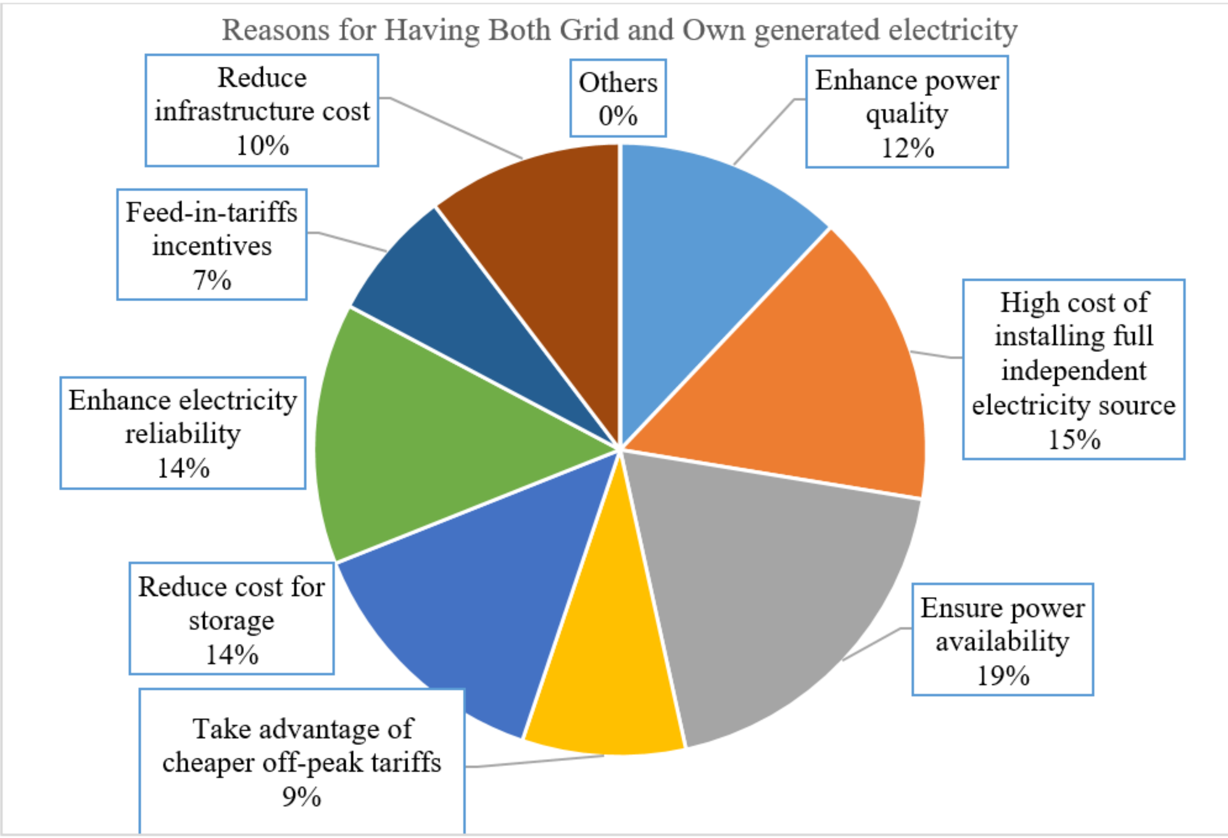

Figure 4. 5: Reasons consumers have both grid and own generated electricity

Analysis by Rocky Mountain Institute (2014) on the state-level grid-defection (New York, Texas, California, Hawaii, and Kentucky states in the US) found that in some areas such as in Hawaii State had achieved grid parity of solar hybrid systems. However, the solar PV adoption is limited to the southern states in the US with limited solar potential in the northern state seeing an increase in small-scale Combined Heat and Power (CHP) systems.

In addition to solar-plus-battery systems, residential electricity consumers in the northern states have installed CHP systems, which provide both thermal energy and electricity (Maleki et al., 2017; Winkler et al., 2016; Shah et al., 2015). The CHP systems is used to offset the thermal loads from conventional heating systems while at the same time meeting electricity load of household appliances. As pointed by Murugan and Horák (2016), the capability of recapturing waste heat that would otherwise go to waste in electricity production process makes the entire system and process economically cheaper than conventional sources. As such, the decision to install hybrid systems goes beyond the economics of electricity generation but also encompasses other beneficial factors such as auxiliary heating, offsetting carbon emission, and importantly reliability.

However, Kantamneni et al. (2016) states that despite the shifts, majority of the consumers remain connected to the grid. In some cases, most of the consumers rely on the grid because of such reasons as regulating imbalances between system demand and system generation, voltage and frequency control, and to some seeing an opportunity in exporting electricity to the grid. According to McLaren et al. (2015), utility companies in the US have proposed increasing fixed charges, minimum bills, and residential demand-based rates as a measure to cushion against the defection. Therefore, from the findings, the firms' consideration of initial capital (high cost of installing full independent self-generating systems), cutting cost of electricity storage units, reduce infrastructural cost, and taking advantage of cheaper off-peak tariffs indicate the role played by economics in making defection decision.

4.6 Objective 4: Policy Measures

For this study, policy framework is based on underlying driving such as system financing, barriers and challenges faced in installation and use of own generation. This is followed by highlighting current policies, uptake, and consumers' satisfaction levels. Recommendations on the policy changes is made based on the findings.

4.6.1 Financing of the own generation project

The participants were asked on the sources of the funds for the own-generation projects implemented by the firms. According to the findings (Table 4.10), 53% of the respondents said the financing was done internally and seen as an investment. However, majority indicate the financing was done from external sources (Banks and investors). In one case, the project was financed and owned by external investor who generated and then sells the electricity to the firm under agreed tariff.

External investment in the energy sector in Kenya is on the rise. According to Sergi et al. (2018), the unbundling and privatisation of power production in Kenya has attracted investment from banking sector, local and international investors, and private investors due favourable and supportive environments. The return on investment, according to Sanyal et al. (2016), in the electricity production sector is perceived favourable. The credit guarantees, technical assistance, and investment envisaged under the reforms and unbundling of energy in Kenya with potential of supplying generated power to the firms and surplus to the grid under FIT and power wheeling agreements has developed a coordinated approach for stakeholders and investors to increase investment in energy production and access. This is evident in the high local and external investors in the own-electricity generation by the surveyed firms.

Table 4. 10: Financing of Own Electricity Generation Systems

Response	**Respondents**	**% of the respondents**
Banks	4	30.77 %
Internal Investment and Financing	7	53.85 %
External investors	5	38.46 %
Grants	0	0 %
Electricity purchase agreements	0	0 %
International Donors	0	0 %
NGO funding	0	0 %
I don’t know	1	7.69 %
Others	0	0 %

From the findings (Table 4.11), the participants noted additional costs incurred include O&M (84%), power regulators and stabilisers (53%), metering and tariffs equipment (46%), licensing and insurance (30%), and cost of storage units (23%). Although, as noted by Steffen et al. (2020) and Enbar et al. (2016) the O&M cost for solar PV (inverter replacement and cleaning the panels) is relatively small compared to initial capital unlike GenSets and natural gas turbines that require fuels and replacement of moving parts.

Table 4. 11: Additional Cost incurred by Hybrid Systems

Response	**Respondents**	**% of the respondents**
Cost of storage units	3	23.08 %

Cost of metering and tariffs equipment	6	46.15 %
Energy management systems	0	0 %
Distribution systems and appliance	0	0 %
Power regulators and stabilisers	7	53.85 %
Operations and maintenance	11	84.62%
Fuel cost	5	38.46 %
Licensing and insurance	4	30.77 %
Other	0	0 %

Figure 4.6 illustrates the additional cost incurred by consumers with hybrid systems.

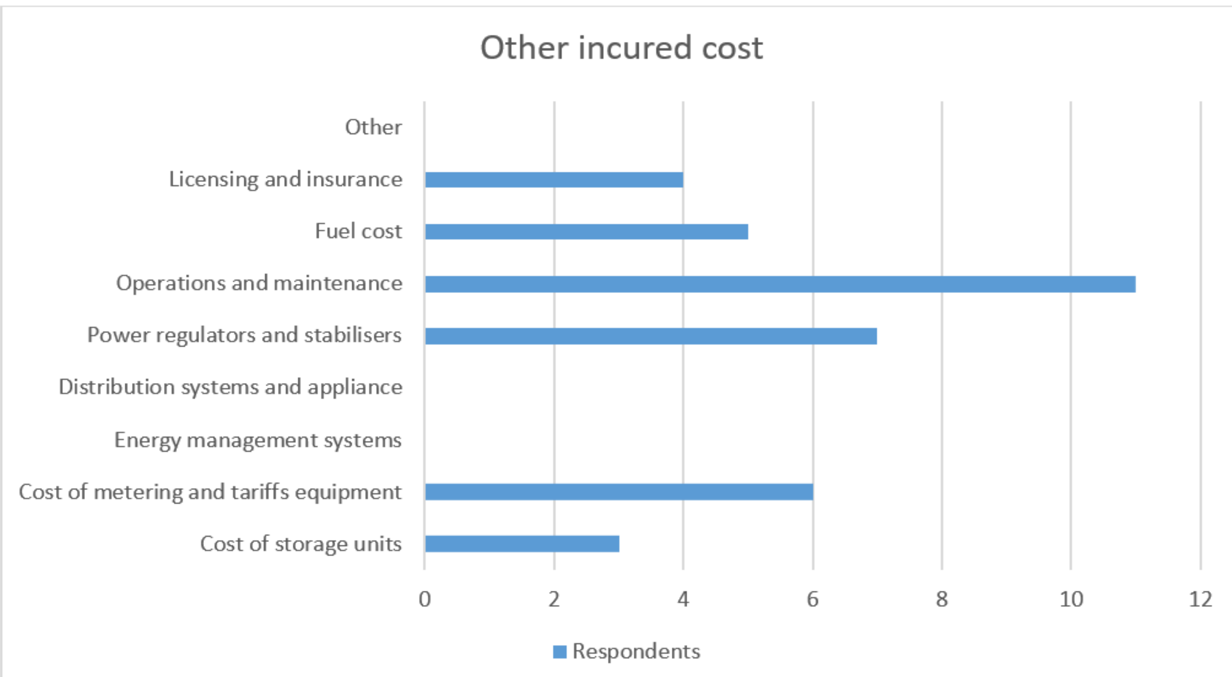

Figure 4. 6: Other incurred cost by consumer

The increasing uptake of solar PV globally have had an impacted on the supporting infrastructure including remote monitoring software and improvement on 'learning by doing' and 'learning by using' that have led to increasingly considering O&M providers (Steffen et al., 2020). This have had a significant impacted the overall economies-of-scale for solar PVs. However, as noted by the participants, electricity storage cost remains relative high opting most of the companies not to incorporate. Under The Energy (Solar PV Systems) Regulations 2019, firms are required to be licenced before installation and production of electricity from solar PVs (EPRA, 2019). As such, collectively, this additional charges drive the overall cost per kWh of the own-generated power to rise.

4.6.2 Barriers Switching to Own-generation

According to the participants, the barriers faced in own-generations ranged from monopoly from the utility provider (Kenya Power) to high initial cost of self-generation systems (Table 4.12). Majority of the participants (69.23%) stating that the initial cost made switching to own-generation and by extension going off-grid difficult. From the findings, other factors noted by the participants include: lack of financial funding (53%), electricity reliability (38%), and high cost of energy storage (30%) (Table 4.12). One participant argued that the space factor limited installation of more solar PVs by the firm. Building from the assertion made by Peffley and Pearce (2020), falling prices of the RE system have given rise to relies of both grid and own-generation but transition to complete off-grid generation has been faced by economic challenges. The point of parity for both solar PVs and diesel generators is seen in need for storage system and rising fuel prices respectively. Therefore, the hybrid system draws a balance between being connected to the grid and the economics going off-grid.

Table 4. 12: Barriers to Switching to Own-generation

Response	Respondents	Percentage
High cost energy storage systems	4	30.77 %
Variability of electricity generation	5	38.46 %
High initial capital cost	9	69.23 %
Lack of financial funding	7	53.85 %
Lack of trained and certified labour force	0	0 %
Government regulations and policies	0	0 %
Monopoly of utility companies (Kenya power)	2	15.38 %
Others	Space factor	

4.6.3 Technical challenges in having hybrid Systems

According to the participants, the challenges faced in having both the grid-connected and own-generated electricity include: load sensitivity and response time (53%), infrastructural integration (46%), system maintenance (38%), and power quality (30%) (Table 4.13).

Table 4. 13: Technical Challenges Faced by Hybrid Systems

Response	Respondents	Percentage
Infrastructure integration	6	46.15 %
Poor power quality	4	30.77 %
Inaccuracy in metering	2	15.38 %
High tariffs and pricing	5	38.46 %
Load sensitivity and response time	7	53.85 %
System maintenance and upgrading	5	38.46 %
Policies and incentives mismatch	1	7.69 %
Others	0	0 %

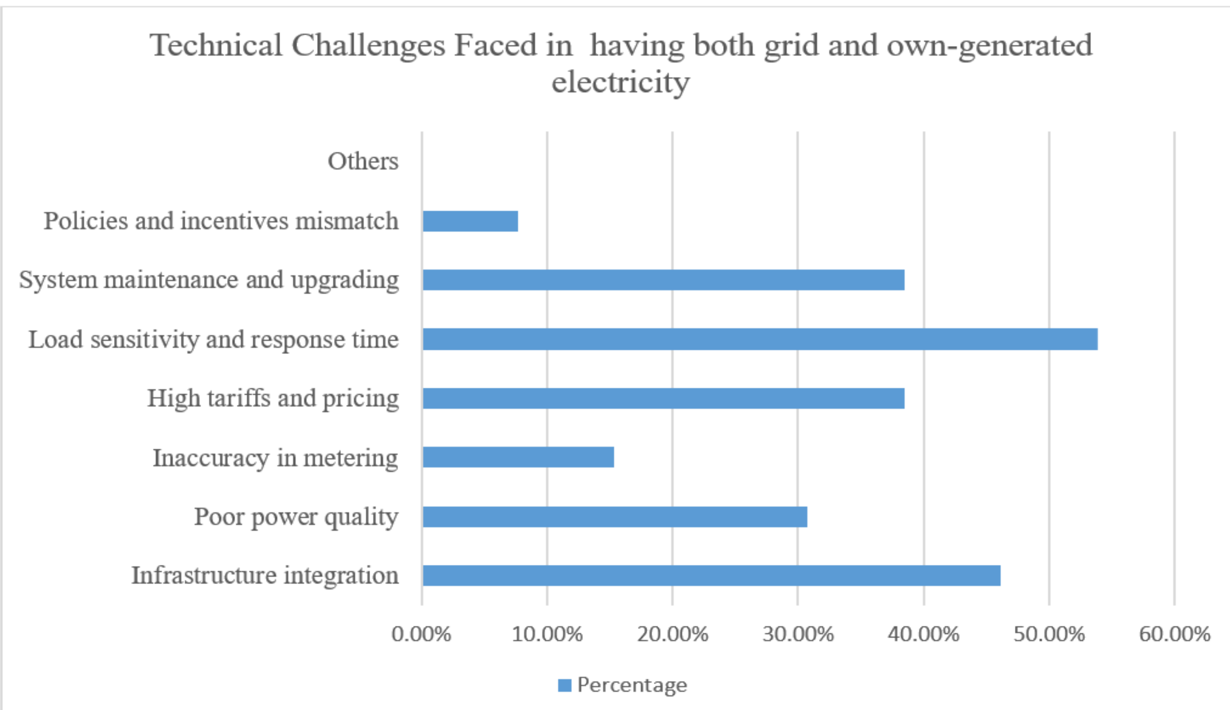

Figure 4. 7: Technical challenges faced by consumers having hybrid systems

From self-generating consumer perspective, a hybrid system offers benefits such as power reliability, availability, and quality. However, integration of the power generated into power systems in attempt to utilise of the resources has had several challenges. These include effect of generated power on the power systems, power quality, power imbalances, and operating costs

(Ibrahim et al., 2011; Nwaigwe, Mutabilwa, and Dintwa, 2019; Al-Shahri et al., 2021). The widespread integration of solar PVs into industrial systems that have many motor drives results in an increase in Total Harmonic Distortion (THD) (Aziz et al., 2018; Shah et al. (2015). The causes number of issues that include overheating of components (switchgears, cables, transformers), nuisance tripping of circuit breakers, resonance of the power system, and inaccuracy in sensor measurements. Collective, the THD has a negative impact on equipment reliability, system operating cost, and operational performance of own-generated electricity. These harmonics result in such the challenges observed that include: load sensitivity, components integration, system maintenance, and power quality.

4.6.4 FIT tariff and Net Metering Agreement

From the findings, only three respondents stated that the firms had agreement with utility provider to supply excess power to the grid (Table 14). One indicating maybe. The rest of the participants saying the firm had no power purchasing agreement with Kenya Power. For those with the agreement, all stated FIT tariffs arrangement and two saying having had net metering agreement.

Table 4. 14: Arrangement to supply Excess Electricity to Grid

Response	Respondents	Percentage
Yes	3	23.08 %
No	10	76.92 %
Maybe	1	7.69 %

Table 4. 15: Relevant Agreement to Supply Excess Electricity to the Grid

Response	Respondents	Percentage
Feed-in-Tariff	3	23.08 %
Net Metering	2	15.38 %
Power Wheeling	0	0 %
Power Purchase Agreement (PPA)	0	0 %
I don’t know	0	0 %
Others	0	0 %

4.6.5 Favourability of the agreement

The participants were asked on the favourability of the agreement to supply excess generated power to the grid. All the respondents stated that they were satisfactory.

Table 4. 16: Favourability of the Agreement

Response	Respondents	Percentage
Highly satisfactory	0	0 %
Satisfactory	3	23.08 %
Average	0	0 %
Disappointing	0	0 %
A lot need to be done	0	0 %

In response to Energy Act (2019), the consumers with own-electricity generating systems can supply excess power to the grid under FIT and net metering agreement. Ndiritu and Engola (2020) argued that while PPA policy have triggered investment interests, implementation of the policy has been ineffective due to its design compounded with low infrastructural and technological support. Other factors cited barriers facing PPA include regulatory shortcomings, very high tariffs, and delays in concluding negotiations. As such one would argue that with proper implementation of the policy, the overall LCoE for the own-generated electricity would reduce significantly.

4.7 Summary

This findings and discussion chapter captures the results from the survey and secondary data from EPRA. The primary data from survey involved administering a questionnaire to participants working in self-generating electricity consumers and EPC in energy sector. The data aimed to capture the electricity generation capacities, utilisation factors, financial element for the system, and factors that led the consumers to opt for self-generation as well as reasons for having both grid and own-generated electricity. The secondary data collected from EPRA provide tariffs and billing structuring for different class of electricity consumers. From the findings, LCoE for own generating systems is relatively high (Ksh 46.49/ kWh and Ksh 40.96/ kWh) for solar PVs and Genset system compared to cost grid electricity (Ksh 22/ kWh). However, the push for grid defection is supported by other myriad factors primarily reliability, convenience, and power quality. The chapter further discusses policies in implemented particularly FIT and net metering focusing on ways it would be instrumental in supporting own electricity generating systems.

Chapter 5: Conclusion and Recommendation

5.1 Conclusion

Over the past decade, the energy sector has experienced a significant transformation that includes increasing reliance on DGs, flexible demand, liberation of the grid system, consumer-oriented demand and supply, increased interconnectedness of the grid, and decarbonise of the energy sector. This is largely driven by technological improvement, push for environmental consciousness in production and use of energy, electricity reliability and availability, and cheaper energy sources. However, with the maturity of RE becoming economically viable, consumers particularly in commercial and industrial sectors have been in forefront in uptake of own electricity generating systems aimed to address the inherent issues of power reliability, cheaper energy, power quality, environmental sustainability, and energy independence. With this uptake, however, little is understood particularly on the economics of defection and supporting factors for both the consumers and traditional utility providers. For consumers, the decision to install own electricity generating systems might be based on myriad of reasons grounded on suggestions and projections but not concrete data and information. As such, this study aimed to conduct a comparative tariff assessment between own consumer generated and grid electricity, a case of study of Kenya. The specific objectives included: performing LCoE for self-generated electricity then comparing to cost of energy from Kenya Power; determining annual energy mix for a typical consumer in commercial and industrial sector; establish and evaluate the factors causing defection from the grid; and lastly propose policy measures aimed to address consumer defection. The scope of the study is commercial and industrial consumers in Kenya.

To addresses the aim and objectives of this study and answer the research questions, a mixed research method comprising of both qualitative and quantitative methods was adopted. Quantitative approach enabled capturing the numerical and statistical aspect of defection particularly the LCoE and energy mix. On the other hand, qualitative approach was instrumental in understanding the factors driving consumers to defect by installing own electricity generating systems as well as policies measures on hybrid systems. The data was collected from both primary and secondary sources. Primary data using a survey questionnaire incorporated gathering data from consumers in commercial and industrial sector who currently have own electricity generating system. The survey respondents were nine consumers and four vendors. Data from secondary sources was obtained from EPRA capturing electricity tariffs and billing between 2013 and 2022. Collected data was analysed using SPSS software and thematic analysis tool.

The LCoE for the own electricity systems varied considerably ranging from as low as Ksh 15/kWh to Ksh 90/kWh (*1 USD = Ksh 110 at the time of writing*). The average energy cost for solar PVs is Ksh 46.49/kWh and that for Genset being Ksh 40.96/kWh. The high difference is attributable to the annual hours the system is in use. With low capacity, the overall cost of the electricity generated by the system is considerably high. On the other hand, electricity from the grid has remained relatively constant over the last ten years. In addition to demand and consumed energy cost, the commercial and industrial consumers are liable to other additional charges that include FERFA, INFA, SSF, WARMA, and Taxes & levies. The demand charges ranges between Ksh 220/ kVA and Ksh 800/ kVA depending on the consumer class. Currently, consumed energy charges are between Ksh 7.80/kWh and Ksh 8.70/kWh, and off-peak charges ranges between Ksh 3.90/kWh and Ksh 4.35/kWh depending on the consumer class. Cumulatively, taking into account the variable additional charges and penalties, consumers in commercial and industrial sectors pay approximately Ksh 22/kWh for electricity to the utility provider. In comparison to the own generated electricity, grip power is considerably cheaper. From the findings, the cost difference is against the held notion that such systems as own generation is cheaper than utility provided power. This is attributable to lack of economies of scale and low utilisation factor.

From the findings, despite installation of own-electricity generating system, consumers still rely heavily on grid power. Approximately 53% of the respondents indicating approximately 26-50% of the total consumed electricity is sourced from own generation, 30% saying 50-75%, and 23% saying 1-25% is from own generation. Notably, none of the respondents said they rely 100% on own generation to meet their electricity needs. According to the findings, there are myriad driving factors leading consumers particularly in commercial and industrial sector to opt for own generated electricity. The leading factor is the push for available and reliable electricity. Kenya is among the countries in the world with high power outages and interruption averaging 25 days annually. Own generation therefore acts to bridge this gap. Cheaper energy source was mentioned by 85% of the respondents but the calculated LCoE show the cost of own-generated electricity being considerably higher than grid power. Other factors highlighted included power quality, environmental and energy sustainability, electricity independence, clean energy, and combating poor customer services.

Although there are number of policies such as FIT and net-metering that are already in place aimed to allow consumers to generate their own electricity and then export excess electricity to the grid, the implementation in Kenya remains slow. According to the findings, response framework from the utility is a major issue. The respondents also argued on high financial requirement, lack of technical support, technological mismatch, low incentives, and monopoly from the Kenya Powers as some factors have derailed uptake of PPAs. Therefore, there is need to have a structured implementation approach involving all involved parties (consumer, utility provider, and policy makers).

5.2 Recommendation

Based on the findings, the following recommendations are made:

For own generation to be truly competitive, utilisation factor need to increase. These can be done through:

i. Effective implementation of FIT, Net-metering, & power wheeling agreements
ii. Enhancing system integration
iii. Making financing and investment on own generation systems more favourable

Future Studies:

i. A research on the correlation between electricity reliability (outages and interruption) and defection
ii. More research is needed on hybrid integration systems. With the increasing uptake of own generation, system integration largely supported by technological differences and system harmonics would cause failures
iii. The efficacy of FIT and Net-metering policy implementation in Kenya

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Appendix

EPRA Tariffs and Billing

<table>
<tr><td></td><td></td><td colspan="4">Energy Charges (Ksh/Unit)</td></tr>
<tr><td>Category</td><td>Year 2013-14</td><td>Year 2014-15</td><td>Year 2015-18</td><td>Year (2018-22)</td><td>Year (2022)</td></tr>
<tr><td>Method DC-Lifeline</td><td rowspan="2">A fixed charge of Ksh 120
Energy charges:
a. Ksh 2.5 /Unit for 0-50 units consumed
b. Ksh 11.62/Unit for 51-1,500 Units consumed
c. Ksh 19.57/Unit consumed above 1,500</td><td rowspan="2">A fixed charge – Ksh 150.00
Energy Charge:
a. Ksh 2.50/Unit for 0-50 units consumed
b. Ksh 13.68/Unit for 51-1,500 Units consumed
c. Ksh 21.57/ Unit consumed above 1,500</td><td rowspan="2">A fixed charge – Ksh 150.00
Energy Charge:
d. Ksh 2.50/Unit for 0-50 units consumed
e. Ksh 12.75/Unit for 51-1,500 Units consumed
f. Ksh 20.57/ Unit consumed above 1,500</td><td>Ksh 12.00/Unit</td><td>Ksh 7.70/ Unit</td></tr>
<tr><td>Method DC-Ordinary</td><td>Ksh 15.80/Unit</td><td>Ksh 12.60/ Unit</td></tr>
<tr><td>Method SC</td><td>a. A fixed charge of Ksh 150.00
b. Energy charge of Ksh 12.00/ Unit for units consumed</td><td>a. A fixed charge – Ksh 150.00
b. Energy charge – Ksh 14.00/ Unit consumed</td><td>a. A fixed charge – Ksh 150.00
b. Energy charge – Ksh 13.50/ Unit consumed</td><td>Ksh 15.60/Unit</td><td>Ksh 12.40/ Unit</td></tr>
<tr><td>Method C11</td><td>a. A fixed charge of Ksh 2,000.00
b. Energy charge of Ksh 8.70/Unit consumed
c. Demand charge Ksh. 800.00/kVA</td><td>a. A fixed Charge of Ksh 2,000.00
b. Energy charge Ksh 9.45 /Unit consumed
c. Demand charge of Ksh 800.00/ kVA</td><td>a. A fixed Charge of Ksh 2,500.00
b. Energy charge Ksh 9.20 /Unit consumed
c. Demand charge of Ksh 800.00/ kVA</td><td>a. Energy charge Ksh 12.00/ unit consumed
b. Energy charge 6.00/ unit supply metered during off peak hrs
c. Demand charge - 800.00/ kVA</td><td>a. Energy charge Ksh 8.70/ unit consumed
b. Energy charge 4.35/ unit supply metered during off peak hrs</td></tr>
</table>

					c. Demand charge 800.00/ kVA
Method C12	a. A fixed charge of Ksh 4,500.00 b. Energy charge of Ksh 7.550/Unit consumed c. Demand charge – Ksh 520.00/kVA	a. A fixed charge of Ksh 4,500 b. Energy charge of Ksh 8.25/ Unit consumed c. Demand charge of 520.00 kVA	a. A fixed charge of Ksh 5,500 b. Energy charge of Ksh 8.00/ Unit consumed c. Demand charge of 270.00 kVA	a. Energy charge Ksh 10.90 /unit consumed b. Energy charge 5.45/unit supply metered during off-peak hrs c. Demand charge 520.00/ kVA demand charge	a. Energy charge Ksh 8.10 /unit consumed b. Energy charge 4.05/unit supply metered during off-peak hrs c. Demand charge 520.00/ kVA
Method C13	a. A fixed charge of Ksh. 5,500.00 b. Energy charge – Ksh 7.00/Unit consumed c. Demand charge Ksh. 270/kVA	a. A fixed charge of Ksh 5,500 b. Energy charge of Ksh 7.75/ Unit consumed c. Demand charge of 270.00 kVA	A fixed charge of Ksh 5,500 Energy charge of Ksh 7.70/ Unit consumed Demand charge of 270.00 kVA	a. Energy charge - 10.50/ unit consumed b. Energy charge - 5.25 / unit supply metered during off-peak c. Demand charge 270.00 /kVA demand charge	a. Energy charge - 8.00/ unit consumed b. Energy charge – 4.00 / unit supply metered during off-peak c. Demand charge 270.00 /kVA demand charge
Method C14	a. A Fixed Charge of Ksh 6,500.00/Unit b. Energy charge – Ksh 6.80/Unit consumed c. Demand charge – Ksh 220/kVA	a. A fixed charge of Ksh 6,500 b. Energy charge of Ksh 7.55/ Unit consumed c. Demand charge of 220.00 kVA	a. A fixed charge of Ksh 6,500 b. Energy charge of Ksh 7.30/ Unit consumed c. Demand charge of 220.00 kVA	a. Energy charge 10.30/ unit consumed b. Energy charge -5.15/ unit supply metered during off-peak c. Demand charge 220.00 kVA	a. Energy charge 7.80/ unit consumed b. Energy charge - 3.90/ unit supply metered during off-peak c. Demand charge 220.00 kVA

Method C15	a. A fixed charge – Ksh 17,000 b. Energy charge Ksh 6.60/Unit consumed c. Demand charge – Ksh 220.00/ kVA	a. A fixed charge of Ksh 17,000 b. Energy charge of Ksh 7.35/ Unit consumed c. Demand charge of 220.00 kVA	a. A fixed charge of Ksh 17,000 b. Energy charge of Ksh 7.10/ Unit consumed c. Demand charge of 220.00 kVA	a. Energy charge Ksh 10.10/ unit consumed b. Energy charge Ksh 5.05/ unit supply metered during off-peak c. Demand charge Ksh 220.00/ kVA	a. Energy charge Ksh 7.60/ unit consumed b. Energy charge Ksh 3.80/ unit supply metered during off-peak c. Demand charge Ksh 220.00/ kVA
Method SL	a. A fixed Charge of Ksh 200.00 b. Energy charge – Ksh 10.50/ Unit consumed	a. A fixed Charge of Ksh 200.00 b. Energy charge – Ksh 11.50/ Unit consumed	a. A fixed Charge of Ksh 200.00 b. Energy charge – Ksh 11.00/ Unit consumed	Energy charge 7.50 / unit consumed	Energy charge 5.50 / unit consumed

Other charges

i. Fuel Charges

$$Fuel\ Energy\ Cost = \frac{1}{1-L} \times \left\{\frac{\sum C_i G_i S_i + \sum P_{xp} + \sum P_i}{G}\right\} \times 100$$

Where

C_i = Actual price in Ksh/kg paid by the company or Electric Power Producers for fuel consumed by Plant i

G_i = All units generated and or purchased by the company from electric power producers' plant i

G = Total units purchased by the company from electric power producer(s), generated by the company and net imports

S_i = Specific fuel consumption in kg unit for particular electricity plants (Appendix 4.1)

P_{im} = Sum of fuel costs for imported units calculated based on respective power import contracts

P_{xp} = Sum of fuel costs for exported units calculated based on respective power import contracts

P_i = Sum of fuel displacement costs and other pass through charges based on power purchased from power plant i.

L = Target System loss factor in transmission and distribution equal to 14.9% in year 2018/19

ii. Foreign Exchange Rate Fluctuation Adjustment (FERFA)

All units billed or purchased is liable to FERFA, and its being calculated using the following below:

$$FERFA = \frac{1}{1-L} \times \left\{\frac{(\sum(F_{t-1} \times Z_t)X_0) + (\sum(H_{t-1} + Z_t)X_0 + (\sum(IPP_{t-1} \times Z_t)X_0)}{G}\right\} \times 100$$

Where:

F_{t-1} = Sum of the foreign currency costs incurred by KenGen

H_{t-1} = Sum of the foreign currency cost incurred by the company other than those costs relating to electric power producers

IPP_{t-1} = Sum of the foreign currency costs paid by the company to electric power producers (except KenGen)

Z_t = Proportionate change in the exchange rate (X_t)

$$Z_t = \frac{X_t - X_o}{X_o}$$

Where:

X_t = CBK mean exchange rate

X_t = CBK mean exchange rate as captured by Forex exchange rate for the month of March 2017

iii. Inflation Adjustment

According to EPRA tariffs and billings structuring, all units are subject to international inflation and it is calculated using the following:

$$INFA_t = \frac{1}{1-L} \times \left\{\frac{INFA_{KenGen} + INFA_{IPP} + INFA_{KPLC}}{G_P}\right\}$$

Where:

$INFA_t$= Total Inflation Adjustment in Kenya cents/ Unit for the half year period t.

L = Target System loss factor in transmission and distribution (14.9% for 2018/19)

G_P= Total projected units generated or purchased by the company from electric power producers for the half-year adjustment period

a. $\boldsymbol{INFA_{KenGen}}$= Sum of specific adjustment in half-year period relating to contracted KenGen plant i ($INFAKP_i$)

$$INFAKP_i = [KP_i \times FOMCR_{bi} + Gk_i \times VOMCR_{bi}] \times \left[0.7 \times 0.5\left(\frac{CIPU_t}{CPIU_b} - 1\right) + 0.3\left(\frac{USCPI_t}{USCPI_b} - 1\right)\right]$$

Where:

KP_i = Contracted capacity for KenGen Plant i in KW

$FOMCR_{bi}$ = The base escalable capacity charge rate for KenGen Plant i in (Ksh/kW/year) /2

$VOMCR_{bi}$ = The base escalable variable operations and maintenance charge rate (Ksh/kWh)

Gk_i = Projected units purchased from KenGen plant i in kWh in half year

$CIPU_b$ = Geometric underlying Consumer Price Index posted by KNBS

$CIPU_t$ = Underlying Consumer Price Index for adjustment effected in the effect period Jan – June every year as provided by KNBS

$USCPI_b$ = Consumer Price Index for the US city average published by the US Department of Labour Statistics

$USCPI_t$ = Consumer Price Index for the US city average adjusted effected in the period July –Dec / Jan – July every year – as provided by the US Department of Labour Statistics

b. $\boldsymbol{INFA_{IPP}}$

$$INFA_{IPP} = \sum INFAIPP_i$$

Where:

$INFAIPP_i$ = Specific Inflation adjustment in half-year period for contracted electric power producers excluding KenGen

$$INFAIPP_i = [IPP_i \times CCR_{bi} + GIPP_i \times ECR_{bi}] \times \left[\frac{USCPI_t}{USCPI_b} - 1\right] *$$

Where:

CCR_{bi} = Base escalable capacity charge rate for IPP plant i in (USD/kW/year)/2

$GIPP_i$ = Projected units purchased from IPP plant i in kWh

ECR_{bi} = Base escalable energy charge rate for IPP plant i in USD/kWh

$USCPI_b$ = 'CPI –U' for the US city average for all items as published by the US Department of Labour and Statistics

$USCPI_t$ = 'adjustments effected CPI – U' published by the US Department of Labour and Statistics

c. $INFA_{KPLC}$

$INFA_{KPLC}$ Specific Inflation adjustment for semi-annual period relating to transmission and distribution O&M costs

It is given by:

$$INFA_{KPLC} = TDOM_b[0.7 \times 0.5\left(\frac{CPIU_t}{CPIU_b} - 1\right) + 0.3\left(\frac{USCPI_t}{USCPI_b} - 1\right)$$

Where:

$TDOM_b$ = The transmission and distribution network O&M costs excluding depreciation of assets and provision for bad debts

iv. Security Support Facility (SSF)

All units billed or purchased is subject to security support computed using the formula:

$$SSF = \frac{1}{1-L} \times \left(\frac{\sum G_{pi} \times SSFR_{pi}}{G}\right) \times 100$$

Where:

$SSFR_{pi}$= Euro cents 1.86/kWh

iv. Water Levy

All units billed/purchased by the consumers is liable to Water Resource Management Authority (WARMA) Levy for water used by hydro power plants. It is calculated using the following formula.

$$WRMA_{LEVY} = \frac{1}{1-L} \times \left(\frac{\sum G_h \times WL}{G}\right) \times 100$$

Where:

G_h = Total units purchased from the preceding moth from hydroelectric power producers with capacity equal/ greater than 1MW

WL = Approved water levy for plant i as per the approved PPA

v. Taxes and Levies

The electricity from the grid is subject to any taxes, levies, or duties imposed by the Kenya government. In 2017, the levied by the government were:

i. 16% VAT charged to:
   a. Demand charge
   b. Inflation adjustment
   c. Fuel energy cost
   d. Foreign Exchange Fluctuation Adjustment
   e. Non-fuel energy cost
ii. Rural Electrification Programme (REP) levy – 5% of revenue from unit sales
iii. Energy Regulatory Commission (ERC –now EPRA) at 3 Ksh/kWh

Off-peak hours

Day	Start (Hrs.)	End (Hrs.)
Weekdays	00:00	06:00
	22:00	00:00
Saturday/Holidays	00:00	08:00
	14:00	00:00
Sunday	00:00	00:00

Survey Questionnaire

Questionnaire Questions – Consumer

Research Topic: ***A Comparative Tariff Assessment between Grid Electricity and Own Consumer Generation: A Case Study of Kenya***

Researcher's Background Information

I am ***George Kimutai Komen***, a MSc. student currently pursuing ***Masters in Energy Management*** at *University of Nairobi, Department of Mechanical Engineering*. I am conducting an academic research on a comparative tariffs assessment between grid electricity and own consumer generation, a case study of Kenya. The aim of this research study is to assess comparatively the tariff of grid electricity and self-generated power with focus of determining the threshold for defection, energy mix, energy savings for consumers, and policy change in energy sector. This questionnaire, aimed to answer research questions, is structured to capture demographics of the participants followed by factors causing consumers to opt to generate own-electricity, cost of producing electricity, and potential policy changes required.

Participant's Background Information

1. Please indicate your gender
   - ☐ Male

- ☐ Female
- ☐ Rather not say

2. Please select category that best describe your highest education level
    - ☐ Primary level
    - ☐ Secondary
    - ☐ College
    - ☐ Undergraduate
    - ☐ Post-graduate level
    - ☐ Others, please state: ___________
3. Which best defines the field you currently work? *(select more than one if applicable)*
    - ☐ Engineering and construction
    - ☐ Independent Power Producers
    - ☐ Industrial maintenance
    - ☐ Utilities
    - ☐ Contractor
    - ☐ Engineering Consulting
    - ☐ Government Regulator
    - ☐ Energy Auditing
    - ☐ Research
    - ☐ Others, please specify: _______
4. Please indicate the category that best describe your job title *(select more than one if applicable)*
    - ☐ Energy Manager
    - ☐ Engineer
    - ☐ Maintenance engineer
    - ☐ Energy Coordinator
    - ☐ Factory manager/ Coordinator
    - ☐ Energy Regulator
    - ☐ Energy Auditor
    - ☐ Consultant
    - ☐ Others, please specify: ________
5. Select category that best describes your years of experience in the field

- ☐ 0 – 3 Years
- ☐ 3 – 5 Years
- ☐ 5 – 10 Years
- ☐ 10 – 20 Years
- ☐ More than 20 Years

6. Which source does your company deploy as electricity source? *(select more than one if applicable)*
    - ☐ From Kenya Power
    - ☐ Solar PVs
    - ☐ Biomass
    - ☐ Coal
    - ☐ Natural Gas and LPG
    - ☐ Briquettes and Charcoal
    - ☐ Diesel Generators
    - ☐ Wind Energy
    - ☐ Geothermal Energy
    - ☐ Biogas
    - ☐ Others: Please specify
7. Of the total electricity consumed by the company, what percentage is self-generated?
    - ☐ 0 %,
    - ☐ 1 – 25%,
    - ☐ 26 – 50%,
    - ☐ 51 – 75%,
    - ☐ 76 – 99%,
    - ☐ 100%
8. In your opinion, what are the factors causing consumers to self-generate own electricity rather than relying on grid? *(select more than one if applicable)*
    - ☐ Electricity Reliability and Availability
    - ☐ Power Quality
    - ☐ Alternative Cheaper Energy Source

- ☐ Energy Sustainability
- ☐ Diversifying Electricity Source
- ☐ Clean and Environmental Driven Source
- ☐ Electricity Independence
- ☐ Poor Customer Service from Utility Provider
- ☐ Other: Please specify ____________

9. In your opinion, what are main factors that led the company to generate own electricity? *(select more than one if applicable)*
   - ☐ Cutting Production Cost
   - ☐ Attain electricity reliability
   - ☐ Cut electricity cost
   - ☐ Seeking alternative clean energy source
   - ☐ To achieve higher power quality
   - ☐ Poor and unreliable customer service
   - ☐ High additional charges and tariffs
   - ☐ Making use readily available energy sources
   - ☐ Others: Please specify _________________

10. Are you still connected to the grid
    - ☐ Yes
    - ☐ No
    - ☐ I don't know
11. If yes to Q10, what are the reasons for having both; grid connection and self-generating systems? *(select more than one if applicable)*
    - ☐ Enhance power quality
    - ☐ High cost of installing full independent electricity source
    - ☐ Ensure power availability throughout
    - ☐ To take advantage of cheaper off-peak tariffs
    - ☐ Reduce cost on storage devices - battery
    - ☐ Enhance electricity reliability

- ☐ Incentives of feed-in-tariffs
- ☐ Reduce cost on infrastructural need
- ☐ Others: Please specify ____________

12. What is the installed capacity of the plant? ________________ (kW)
13. Do you have an estimate initial capital of installing the system? ________ (Ksh)
14. Select the approximate number of hours in a year in which self-generated electricity is likely to be in use
    - ☐ 0 hrs
    - ☐ 1 – 500 hrs
    - ☐ 501 – 1500 hrs
    - ☐ 1501 – 4000 hrs
    - ☐ 4001 – 6000 hrs
    - ☐ 6001 – 8760 hrs
    - ☐ 8760 hrs
15. How did you implement the project?
    - ☐ In-house sourcing
    - ☐ Outsource through procurement
    - ☐ Partnering with vendor
    - ☐ Signed an agreement with private power producers
    - ☐ Others, please indicate: ________
16. How was the project financed?
    - ☐ Bank loans
    - ☐ Internal investment and financing
    - ☐ External investors
    - ☐ Grants
    - ☐ Power agreements
    - ☐ Government grants
    - ☐ International donors
    - ☐ NGO funding
    - ☐ I don’t know

17. In addition to initial capital cost, what other cost have you incurred while self-generating *(select more than one if applicable)*

    - ☐ Cost of storage units (e.g. batteries)
    - ☐ Cost of Metering and Tariffs Equipment
    - ☐ Energy management systems (e.g. SCADA software) cost
    - ☐ Distribution systems and appliances (e.g. transformers) cost
    - ☐ Power regulators and stabilisers cost
    - ☐ Operation and maintenance
    - ☐ Fuel cost (include diesel fuel, biomass, biogas, and coal)
    - ☐ Licensing and insurance cost
    - ☐ Others: please specify: _______________

18. What are barriers faced by the company in switching to own-generation?

    - ☐ High cost energy storage systems
    - ☐ Variability of electricity generation
    - ☐ High initial capital cost
    - ☐ Lack of financial funding – unwillingness of banks to fund
    - ☐ Trained and certified labour forces
    - ☐ Government regulations and policies
    - ☐ Monopoly of Kenya Power discourages investment own power generation
    - ☐ Others, please state: ___________

19. What are some of the technical challenges you have faced by having both self-generation system and connected to the grid?

    - ☐ Infrastructure integration
    - ☐ Poor power quality from utility when in demand
    - ☐ Inaccuracy in metering
    - ☐ Exorbitant tariffs and incorrect pricing
    - ☐ Poor policies such as incentives and FiT
    - ☐ Voltage and current variations,
    - ☐ Load sensitivity and response time
    - ☐ Poor system maintenance and upgrading

☐ Others, please state: ________

20. Do you as a company have any arrangement with Kenya Power to supply any excess generated power to the grid?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know
21. If yes to Q20, select relevant agreement
    - ☐ Feed-in-Tariff
    - ☐ Net metering
    - ☐ Power wheeling
    - ☐ Power Purchase Agreement (PPA)
    - ☐ I don't know
22. Is the rate of the agreement favourable?
    - ☐ Highly satisfied
    - ☐ Satisfactory
    - ☐ Moderately satisfied
    - ☐ Disappointing
    - ☐ A lot need to be done

The End

Thank You for Your Participation

Questionnaire: Vendor

Research Topic: **A Comparative Tariff Assessment between Grid Electricity and Own Consumer Generation: A Case Study of Kenya**

Questions

1. Please indicate your gender
    - ☐ Male

- ☐ Female
- ☐ Prefer not to say

2. Please select category that best describe your highest education level
   - ☐ Primary level
   - ☐ Secondary
   - ☐ College
   - ☐ Undergraduate
   - ☐ Post-graduate level
   - ☐ Other
3. Which best defines the field you currently work? (*select more than one if applicable*)
   - ☐ Engineering, Procurement, and Construction
   - ☐ Independent Power Producers
   - ☐ Industrial Maintenance
   - ☐ Contractor
   - ☐ Engineering Consulting
   - ☐ Government Regulator
   - ☐ Energy Auditing
   - ☐ Research
   - ☐ Others
4. Name of the company you work for? (Optional)

5. Select category that best describes your years of experience in the field
   - ☐ 0 – 3 years
   - ☐ 3 – 5 years
   - ☐ 5 – 10 years
   - ☐ 10 – 20 years
   - ☐ More than 20 years
6. What source of electricity do you, as a vendor, install? (*select more than one if applicable*)
   - ☐ Grid Electricity
   - ☐ Solar PVs

- ☐ Biomass
- ☐ Coal
- ☐ Natural Gas and LPG
- ☐ Briquettes and Charcoal
- ☐ Diesel Generators
- ☐ Geothermal Energy
- ☐ Biogas
- ☐ Other: _________

7. Based on the last installed consumer-own-generated electricity, what is approximate percentage of the total electricity is from own generation?
   - ☐ 0%
   - ☐ 1 – 25%
   - ☐ 26 – 50%
   - ☐ 51 – 75%
   - ☐ 76 – 99%
   - ☐ 100%
8. Select the approximate number of hours in which electricity from the grid is likely to be in use by the self-generating consumer
   - ☐ 1 – 4 hrs
   - ☐ 4 – 8 hrs
   - ☐ 8 – 12 hrs
   - ☐ 12 – 18 hrs
   - ☐ 18 – 24 hrs
9. What is the installed capacity of the own-generation project you did? (*select appropriate*)

   Solar PVs: _____ kW

   Genset/ thermal generators: _____ kVA

10. What is an estimate initial capital for the installation (Q9)? _______ (Ksh)
11. What is the annual operation and maintenance cost for the installed own electricity? ___ (Ksh)
12. How was the project financed? (*select more than one if applicable*)

- ☐ Bank loans
- ☐ Internal investment and financing
- ☐ External investors
- ☐ Grants
- ☐ Electricity purchase agreements
- ☐ NGO funding
- ☐ I don't Know
- ☐ Others: ___

13. In addition to the initial capital cost, what other cost did the consumer incur by implementing own-generation (*select more than one if applicable*)
    - ☐ Cost of storage units (e.g. batteries)
    - ☐ Cost of metering and tariffs equipment
    - ☐ Energy management systems (e.g. SCADA software)
    - ☐ Distribution systems and appliances
    - ☐ Power regulators and stabilisers
    - ☐ Fuel cost
    - ☐ Licensing and insurance
    - ☐ Other: ______
14. What are the reasons for the consumers to having both grid connection and self-generating electricity sources? *(select more than one if applicable)*
    - ☐ Enhance power quality
    - ☐ High cost of installing full independent electricity source
    - ☐ Power availability and reliability
    - ☐ Taking advantage of cheaper off-peak tariffs
    - ☐ High cost of storage devices - battery
    - ☐ Alternative cheaper energy source
    - ☐ Energy sustainability
    - ☐ Clean source
    - ☐ Poor customer service and relation by Utility Provider
    - ☐ Incentives of feed-in-tariffs
    - ☐ Others: Please specify ___________

15. What are some of the technical challenges the consumer faced by having both grid and own-generated electricity? (*select more than one if applicable*)
    - ☐ Infrastructure integration
    - ☐ Poor power quality
    - ☐ Inaccuracy in metering
    - ☐ Exorbitant tariffs
    - ☐ Load sensitivity and response time
    - ☐ System maintenance and upgrading
    - ☐ Policies and incentives mismatch
    - ☐ Other: ____
16. Does the consumer have any arrangement with Kenya Power to supply any excess generated power to the grid?
    - ☐ Yes
    - ☐ No
    - ☐ Maybe
17. If yes to the previous question, select relevant agreement (*select more than one if applicable*)
    - ☐ Feed-in-Tariff
    - ☐ Net Metering
    - ☐ Power Wheeling
    - ☐ Power Purchase Agreement (PPA)
    - ☐ I don’t know
    - ☐ Other: ______
18. Would you consider the agreement favourable?
    - ☐ Highly satisfactory
    - ☐ Satisfactory
    - ☐ Average
    - ☐ Disappointing
    - ☐ Average
    - ☐ Disappointing
    - ☐ A lot need to be done