African Journal of Emerging Issues
Peer reviewed | Double blind | Interdisciplinary

African Journal of Emerging Issues (AJOEI)
Online ISSN: 2663 - 9335
Available at: https://ajoeijournals.org

STRATEGIC MANAGEMENT

NEXUS BETWEEN SYSTEM LOSSES AND COST OF POWER IN KENYA: A COMPARATIVE ANALYSIS OF KENYA, UGANDA AND TANZANIA

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Publication Date: October 2022

ABSTRACT

Background of the study: Power generation in Kenya has rapidly grown in the past decade. In 2021, generation capacity stood at 2,984MW, with a peak demand of 1,993MW compared to installed capacity of 1,473MW in 2010 and a peak demand of 1,068MW. Vision 2030 aspires to universal access to electricity by 2030, but in 2013 the government revised the target year to 2022 to accelerate the achievement of this goal. Renewable energy generation has shown significant improvement in the total generation mix. The cost of energy determines the competitiveness of goods manufactured domestically to those of imports. High energy costs impede domestic wealth creation, creation of employment and balance of trade.

Problem statement: In Kenya economic activity is crippled by shortages in energy supply alongside the inherent disruptions. Despite the immense geothermal prominent role in reducing the cost of power, the whole effort remains a pipe dream. The impact of increase in power production, transmission and distribution is yet to be felt as the cost of power is still high. The pricing of electricity is affected by various factors with tariffs calculation being pegged on the fuel and non-fuel components. The cost of electricity is also affected by fuel costs which vary with time resulting in high power tariffs. Much of the attention has been on the tariff and weather variations and how they affect the cost of power. However, little focus has been directed on the system losses as an actor to high cost of power. It is against this backdrop that this paper is premised upon. The paper has critiqued on previous articles done by scholars and employed desk statistics from annual reports.

Conclusion and Recommendations: The paper recommends that there is need for converting urban clientele that currently use LPG to power electric stoves by offering ultra-low time-of-use tariffs for cooking in order to increase on consumer bandwidth and revenue generation.

The paper also recommends on the government promoting the uptake of electric vehicles as it has the potential to increase demand of power and increase on the revenue. There is also need for load balancing measures to ensure that each of the three phases of the distribution feeder are equally loaded in order to curb the technical system losses. Installations of specific equipment, sensors, and grid structures is encouraged for efficient detection of NTLs. Intelligent management principles could also contribute effectively to a decrease in technical losses. Technical teams to supervise the meters should be implemented and policies formulated on dealing with cases of power theft. This should be accompanied by installation of tamper-proof meters, reduction of the average number of consumers per transformer and by upgrading of electricity meters to use Smart card technology.

Key Words: *System Losses, Technical Losses, Non-Technical Losses, Cost of Power*

1.1 BACKGROUND OF THE STUDY

Modern society uses electricity as a source of energy, and more attempts are being made to provide enough power to support economic growth (Owusu, Asumadu-Sarkodie & Dubey, 2016). In the twentieth and twenty-first centuries, the manufacturing sector has gradually moved away from the usage of fossil fuels like coal and petroleum. This has been made possible by the increased need to minimize carbon emissions by utilizing renewable energy sources and to stop the ongoing climatic changes, such as global warming, caused by the usage of fossil fuels (Kaygusuz, 2012). Since the COVID-19 pandemic, which had a major impact on energy consumption and peak demand growth in 2019–20, the power sector has been steadily recovering. In contrast to the almost negative growth seen in 2019–20, peak demand increased by 3.5% and energy purchases by 5.6% in 2020–21, reflecting this.

Short-term load forecasting (STLF), medium-term load forecasting (MTLF), and long-term load forecasting (LTLF) are three major categories into which electricity load estimates can be split (Suganthi, & Samuel, 2012). STLF is typically carried out several hours, days, or even weeks in advance. The STLF facilitates day-ahead electricity supply planning through the markets and demand side management (DSM). However, MTLF works with predicting horizons that range from months to even years. The MTLF supports revenue estimation, scheduling of unit maintenance, trading of energy, etc. The predicted horizon for LTLF spans from a few years to even decades in the future (Khan, & Jayaweera, 2018). These forecasts assist decision-makers in planning the expansion of power networks, effectively managing resources, and making more informed decisions.

According to the Least Cost Power Development Plan (LCPDP) Report of 2021– 2030, the amount of energy purchased is anticipated to increase under the Reference Scenario from 12,416 GWh in 2021 to 34,321 GWh in 2041. This indicates a growth rate of 5.22% on average. The average growth rate predicted by the Vision and Low prediction scenarios are 7.97% and 4.50%, respectively. According to the reference scenario, peak demand is anticipated to increase by an average of 5.34% from 2,036MW recorded in 2021 (the base year) to 5,757MW in 2041. Peak demand is expected to reach 9,731MW in the vision scenario and 5,035MW in the low scenario by 2041, which translates to average growth rates of 8.14% and 4.64%, respectively. As the nation strives to achieve universal access to energy, household users are anticipated to have a significant impact on the peak demand rise (LCPDP Report, 2022). New infrastructure in the energy sector was built and fully operationalized in the nation in 2019. The full operationalization of the Lake Turkana Wind Power with a capacity of 310 MW to the national grid and the Garissa 54.5 MW Solar Power Plant by the Rural Electrification and Renewable Energy Corporation were the major highlights within the Electricity subsector (REREC).

In the same year, KenGen's 172MW Olkaria V was put into service. These changes have significantly increased the nation's share of renewable energy (KenGen Annual Report, 2020). With rules and regulatory frameworks to oversee the regulation, efficiency, energy security, and sustainable development in the industry, Kenya's energy sector has seen great growth and development. Tax laws have been utilized in conjunction with renewable energy sources including wind, biomass, and solar energy "to stimulate investment in geothermal exploration and development of hydroelectric power" (National Energy and Petroleum Policy, 2014). KSh 43.6 billion was committed to the energy and petroleum sector in 2014 to increase energy production and lower energy costs (KPMG, 2014).

The Ministry of Energy (MoE) and the Energy and Petroleum Regulatory Authority (EPRA) currently oversee Kenya's electrical sector. The MoE is in charge of overall policy coordination and development in the institutions that make up the energy sector. It also establishes the sector's strategic direction and offers long-term outlooks to all of its participants (MoE, 2016). The second regulator, EPRA, is a self-governing, independent sub-sector regulator that was established in 2006 as part of the Electric Power Act's revision. Electricity Regulatory Commission (ERC, 2019). It also establishes, evaluates, and modifies consumer pricing, approves power purchase agreements, encourages competition in the energy sector institutions, when possible, handles customer complaints, and upholds environmental, health, and safety laws.

As of June 2018, 10.702 terawatt-hours of electricity were produced using 79.42% of total installed capacity and 66.96% of renewable energy (KNES, 2018). The foundation of the government's "Big 4 Agenda" is the provision of affordable and sufficient energy to guarantee the fulfillment of the four pillars of food security, manufacturing, affordable housing, and healthcare. Energy is one of the Big Four Agenda's key enablers since supplying enough electricity to all of its pillars will be essential to its success. Geothermal energy accounts for more than 40% of Kenya's electricity production, making it a world leader in the usage of this affordable renewable energy source. The entire endeavor is still just a pipe dream, despite the enormous geothermal's major role in lowering the cost of power. Universal access to electricity is a goal of Vision 2030, although in order to speed up progress toward this objective, the target year was changed from 2030 to 2022 in 2013.

Kenya's power demand has increased significantly over the last ten years. With a peak demand of 1,993 MW in 2021 compared to 1,068 MW in 2010. Installed generation capacity in 2021 stood at 2,984MW compared to 1,473MW in 2010. KPLC acquires electricity from a number of suppliers, including KenGen, Independent Power Producers (IPPs), the Rural Electrification and Renewable Energy Corporation (REREC), which also oversees the Rural Electrification Programme (REP), and Emergency Power Producers (EPPs). Additionally, over the past four years, it has consistently imported 150–180GWh of electricity from the Ugandan utility UETCL and, to a lesser extent, 1.8–4.5GWh from the Ethiopian utility EEP.

The overall generating mix has significantly improved thanks to the production of renewable energy. In contrast to the 68.5% of total energy generated in 2010/11, renewable energy sources (hydro, geothermal, solar, wind, cogeneration, and biomass) accounted for 92.2% of the total energy generated by KenGen, IPPs, the REP, REREC, and EPPs in the Kenya Power Financial Report for FY 2020/21. Geothermal energy's contribution increased from 20% in 2010–11 to 41.6% in 2020–21, and wind energy's contribution increased from 0.2% in 2010–11 to 14.% in 2020–21. Due to all these increases, thermal (heavy fuel oil (HFO)) plants' contribution decreased from 31.5% in 2010–11 to 7.8% in 2020–21 (KPLC Report, 2020–21).

Power losses, which were 23.95% as of June 2021, continue to be a major concern for the business. Currently, the 400Kv, 220Kv, and 132Kv transmission networks make up the national grid network. The distribution network consists of systems that operate on 66Kv, 33Kv, and 415/240v. Transmission and distribution lines have grown in length, going from 59,322 kilometers in 2014–15 to 255,581 kilometers in 2020–21. The Kenyan government's last mile scheme, which boosted 415/240V and 433/250V lines from 110,778KM in 2014–15 to 168,595KM in 2020–2021, and HV/MV lines from 59,322KM in 2014–15 to 86,986KM in 2020–21, is mostly to blame for the increase.

The capacity of generation substations climbed from 3,025MVA in 2014–15 to 3,878MVA in 2020–21, while the capacities of transmission and distribution substations increased from 3,144MVA to 5,455MVA and 3,572MVA to 4,603MVA, respectively, over the same time period. According to Kenya Power's 2020/21 Annual Report, distribution transformer capacity increased from 6,384MVA in 2014/15 to 8,778MVA in 2020/21. The cost of power remains high despite increases in production, transmission, and distribution.

Numerous factors influence electricity pricing, with tariff calculations based on the fuel and non-fuel components. According to Grainger and Zhang (2017), there are three key factors that determine the purchased power and utilized power, and electrical processes are typically region-specific. The ability of generating businesses to provide produced power, the availability of power generation capacity, and variations in weather patterns are the three elements that have an impact on the price of energy. Additionally, the elements do not affect the price of energy on their own; rather, they interact with other less significant factors to determine whether the cost of power is high or low.

Typically, weather patterns play a major role in determining the production and supply of electricity (Bee, 2016). Due to the ongoing need for power for heating and air conditioning, costs increase by multiples during periods of extreme heat or cold. Similar shifts are also experienced across the African continent, particularly in Kenya, during the wet and extremely hot seasons (Shah, 2019). When there is a drought, less hydroelectric power is produced, which forces producers to use thermal generators to make up the difference, raising the cost.

The price of fuel, which varies over time and results in high power tariffs, has an impact on the price of electricity as well. Furthermore, the Energy Information Administration (EIA, 2018) claims that the cost of maintenance, which includes the cost of repairing system damages or the impact of extreme weather conditions, has an impact on the price of electricity due to transmission and distribution systems. As a result of repairs and maintenance, unreliable infrastructure raises the proportionate cost of power, which is charged according to core tariffs established by power distribution firms (Abotsi, 2016).

When it comes to consumption, the price of mains energy varies depending on customer type, consumption volume, and tariffs for home use are different from those for manufacturing, and the same is true for small and large businesses. Residential and business consumers pay the most for electricity, as it is more expensive to transmit fewer power components, according to Fisher-Vandem, Mansur, and Wang (2015). Nevertheless, industrial electric power users pay lower tariffs because they receive supplies at higher voltages, which are more productive and less expensive (International Energy Outlook, 2016).

In general, the cost of electricity to producers is nearer to the cost of power at wholesale. The annual average cost of electricity in the US, for instance, was 10.54 cents per kilowatt hour (kWh), with the following averages for utility customers: 12.90 cents for residential; 10.68 cents for commercial; 6.91 cents for industrial; and 9.67 cents for transportation (EIA, 2018). The seven categories that make up Kenya's mains power market include both domestic and commercial use (ERC, 2019).

According to the Science Africa Report from 2022, Kenya should pay 0.136 U.S. dollars, or Ksh. 15, for the average cost of electricity. This is not the case, however, as the cost of energy is 0.222 U.S. Dollars, or Kshs. 24.65 per kWh, for families, and 0.170 U.S. Dollars, for enterprises. This price includes all costs associated with electricity use, including production, distribution, and tax costs. The price of electricity is expected to increase from the current 0.22 U.S. Dollars per kWh to 0.24 U.S. Dollars per kWh (kWh). Kenya has a high electricity price of US$ 0.22 per kilowatt hour (KWh), compared to Tanzania's US$ 0.098 per KWh and Uganda's US$ 0.133 per KWh (Business Insider Report, 2022).

According to the Sessional Paper No. 4 of 2004 (International Energy Agency, 2012), system losses caused by technical and non-technical factors are to blame for Kenya's high-power costs, while the Independent Power Producers (IPPs) are to blame for the country's high cost of doing business. In order to lower the high cost of electricity and boost efficiency and the financial sustainability of the power sector, this study aims to determine the instances of system losses in the full chain of a power system, from the generation, transmission, and distribution phase.

1.2 SYSTEM LOSSES OF ELECTRICITY

System losses are primarily defined as differences between the amount of power generated and the amount that is actually distributed to customers, caused by both technical and nontechnical reasons (World Bank, 2016; Klynveld Peat Marwick Goerdeler [KPMG], 2015; Shokoya & Raji, 2019). There are two types of system losses: technical and non-technical. Fixed and variable technical system losses are additional categories of technical system losses (International Energy Agency, 2012).

Losses in the system happen at every stage, from generation through transmission. Following generating, electricity enters high- and medium-voltage networks (100 KV). System losses arise during the transmission phase as a result of technological issues, climatic conditions, and unique geographic circumstances. The systems that distribute electricity to end customers experience system losses throughout the distribution phase as a result of both technical and nontechnical causes. This is referred to as transmission and distribution (T&D) losses.

According to Ofgem (2009), metering process accounts for the majority of electricity wasted during distribution. Physical inefficiencies including hysteresis, Eddy current losses in the iron core of transformers, and the corona effect in transmission lines are the cause of fixed technical system losses. Power current passing through the network's wires, cables, and transformers causes variable technical losses. These losses, which can also be referred to as load losses, series losses, copper losses, or transport-related losses, are inversely correlated with branch resistance and branch current square.

The efficiency effects of energy infrastructure depend on the technology used, the equipment's age, the amount of recurring investment, the level of corruption or weak governance, and the type of maintenance used (Best & Burke, 2018; Gaur & Gupta, 2016; Oyinlola, Adedeji, Bolarinwa & Olabisi, 2020). According to McKinsey (2015), fostering the growth of the power or energy sector has the power to drastically alter African economies. Accordingly, Ebhota and Tabakov (2018) identify the inadequate energy supply as a significant barrier to Africa's economic development, but Shokoya and Raji (2019), Trotter (2019), and Onat (2010) disagree. Despite Africa's enormous capability for electricity production, system losses are thought to be the cause of the continent's high-power costs.

Technical (TL) and non-technical (NTL) losses of electrical energy occur in the power grids at the transmission and distribution level (Depuru, Wang, Devabhaktuni & Nelapati, 2011). In most cases, the computation of TL is required for an accurate estimation of NTL (Costa, Alberto, Portela, Maduro & Eler, 2013). As they occur in the equipment during the transmission and distribution (T&D) process, TLs are unavoidable, but NTLs are characterized as administrative losses that result from unpaid electricity, equipment malfunction, billing error, substandard infrastructure, and unauthorized use of electricity (Sharma, Pandey, Punia & Rao, 2016).

1.3 TECHNICAL SYSTEM LOSSES

Power dissipation in the various components of the energy distribution system throughout the transmission procedures results in technical losses (Sallam & Malik, 2011). Technical losses typically account for 22.5% of energy distributed and are directly influenced by network features and operation mode (Parmar, 2013). Distribution lines that are overhead and subterranean have various physical characteristics that result in several loss mechanisms. Conductor losses, dielectric losses, reactive current losses, and sheath losses are examples of the types of losses that might occur as well as ways to mitigate those losses (Inan, Batson & Scheibe, 2014).

According to Scottish and Southern Energy Power Distribution (SSEPD) 2015, the physical properties of the electrical equipment used in distribution networks directly cause technical losses. These are fixed losses that are unrelated to load and variable losses that are connected to load. All conductors, whether coils in transformers, aluminum or copper wires in overhead lines or cables, switchgear, fuses, or metering equipment, are thought to have an internal electrical resistance that causes them to heat up when carrying electric current. This theory is known as variable losses (Baricevic, Skok, Zutobradic & Wagmann, 2017). These losses are referred to as "variable losses" because they are caused by the dissipation of heat into the environment, which varies with the current running through conductors in electrical networks (Baricevic, et al., 2017). The terms "ohmic losses," "copper losses," "Joule losses," and "resistive losses" are also frequently used to describe these losses (Antmann, 2009). These are the main reasons overhead distribution wires lose power. Although copper is significantly more expensive than aluminum, it is a typical solution to utilize copper for wires instead of aluminum (Raminfard, Shahrtash, Herizchi & Khoshkhoo, 2012).

Overhead wires frequently use air as insulation, whereas underground cables employ dielectric materials. Dielectric materials can result in a minimal current loss in the line, known as dielectric loss, but this loss is frequently so small as to be unnoticeable (Raminfard et al., 2012). Underground cables' phase conductors' magnetic fields cause eddy currents to form inside the sheath, the moisture-blocking outer casing, which leads to sheath losses (Jackson et al., 2015). These are seen as unavoidable and minimal.

In addition, the distribution system's single biggest source of losses is transformer losses. Transformer losses come in two different varieties. Eddy currents and resistive losses in the internal cables are the main causes of load loss, which is inversely proportional to the load on the transformer. Eddy currents generated by the transformer's magnetic core are what cause no-load losses (Jackson et al., 2015). The distribution networks experience larger levels of losses (at lower voltages) (SSEPD, 2015). Additional elements that affect the amount of current flowing through conductors, such as the effect of network imbalance, power factor, and power quality, can also affect variable losses (Suresh & Elachola, 2000).

Additionally, because they vary proportionately to the resistance, variable losses rely on the conductor's length and cross section as well (SSEPD, 2015). As a conductor's cross-sectional area grows, its resistance lowers (Suresh & Elachola, 2000). Larger cable sizes hence lessen the impact of losses. The cross-sectional area of the windings and the materials employed in them have an impact on the variable losses in transformers, according to a similar principle. This type of losses can also be caused by improper connections between network equipment and deteriorating conductors, which can result in the development of hot spots due to an increase in equivalent resistance (Baricevic et al., 2017).

Variable losses typically make up between two-thirds and three-quarters of all technical losses in the power system (Baricevic, 2017). The two main influencing elements (power flows and resistance) can be used to categorize strategies to reduce variable losses. Depending on how they relate to the global system, these measures either attempt to reduce the system power flows or the resistance of the transportation paths. Reduced network resource utilization could be the cause of lower current and resistance. However, expanding network capacity necessitates greater capital expenditures. This results in a direct trade-off between capital investment and the cost of losses.

According to Garcia-Villalobos, Egua, Torres and Etxegarai (2017), the ideal average utilization rate for a distribution network that accounts for the cost of losses in its design might be as low as 30%. Fixed losses occur when electrical energy is lost by network equipment and equipment linked to the network that has been made "active" (energized), such as transformers or wires (SSEPD, 2015). The system experiences losses even if no power is delivered to customers since it is electrically activated (Aten & Ferris, 2009). Because they are unaffected by the amount of electrical energy the network provides, these losses-which manifest as heat and noise-are known as "fixed losses" or "no-load losses" (Garca-Villalobos et al., 2017).

1.4 NON-TECHNICAL LOSSES

Nontechnical Losses (NTLs) The term "lost energy" describes the portion of power losses that cannot be accounted for and take place at the power system's external level. There are many different circumstances that result in non-technical losses. Poor management of the utility running the network is to blame for Non-Technical Losses (Ahmad & Hasan, 2016). Losses that are not technical are frequently connected to the customer management procedure (Antmann, 2009). The explanation for NTLs is that they represent the loads and circumstances that the technical losses computation did not account for (Nagi, Yap, Tiong, Ahmed & Mohamad, 2009).

NTL losses are harder to measure since system operators frequently fail to account for them, leaving no documentation or evidence that can be legally backed up. NTLs are mostly associated with power theft and customer management procedures, since there are numerous ways to purposefully cheat the relevant utility. The NTLs can also be caused by malicious and illegal meter manipulation, such as tampering with or bypassing the meter (Chauhan & Rajvanshi, 2013). The goal is to trick the meter into recording less energy than is actually used (Navani, Sharma & Sapra, 2012).

The vast majority of NTLs in developing nations are attributable to transmission and distribution losses, hence electric utilities must concentrate on reducing NTLs rather than only technical losses (Chauhan & Rajvanshi, 2013). According to Angelos, Saavedra, Cortés, and de Souza (2011), organized crime, regularized corruption, and electricity theft are frequently linked to the dishonest behavior of energy consumers. Therefore, it is impossible to assess such losses properly. The costs associated with these NTL initiatives are typically covered by loyal consumers.

The impact of NTLs is greater in emerging or underdeveloped nations, but it can also have an impact on industrialized economies (Nagi et al., 2009). One of the most recent and practical solutions to the NTL detection issue has been the installation of smart meters (Rengaraju, Pandian & Lung, 2014). However, because of their deployment, running costs, and complex designs, they are not a workable solution for developing economies (Depuru et al., 2011). The installation of particular tools, sensors, and grid structures is another effective method of identifying NTLs (McLaughlin, Holbert, Fawaz, Berthier & Zonouz, 2013). According to Monedero, Biscarri, León, Guerrero, Biscarri, and Millán (2012), system losses can happen when measurement equipment malfunctions, leading to an increase in non-technical losses as a result of excessive electricity use.

1.5 EMERGING TRENDS IN SYSTEM LOSSES OF ELECTRICITY

In East Africa Energy sector, system losses have been recorded albeit with sharp variations in the three countries – Kenya, Tanzania, and Uganda. As at 30th June 2021, the systems losses in

Kenya Power and Lighting Company (KPLC) were at 24% having bought 12,101,000,000 units of power but only sold 9,203,000,000 units. Uganda Electricity Generation Company Ltd (UEGCL) recorded system losses of 18% while the Tanzania Electric Supply company (TANESCO) system losses stood at 15%. An annual report by KPLC, attributed the higher system losses on technical and commercial factors arising from the expanded transmission and distribution network as well as increased electricity pilferages (KPLC Annual Report, 2019/2020). An analysis on the company annual reports, reveal variables that have been contributing to the Transmission and distribution (T&D) losses and subsequent high cost of power in Kenya as compared to the other East Africa countries.

Table 1: Statistics on East Africa Power Annual Reports

Country	**Kenya**	**Uganda**	**Tanzania**
Financial Year	June 30, 2021	December 31, 2021	June 30, 2020
Units Purchased (kWh)	12,101,000,000	4,276,829,268	7,734,000,000
Units sold (kWh)	9,203,000,000	3,507,000,00	6,551,000,000
Revenue USD	1,336,296,755	532,188,827	675,451,741
Revenue/Unit sold (USc)	14.52	15.18	10.31
Cost of units sold (USD	873,620,899	350,870,296	467,450,050
Cost per unit (SUSc.)	7.22	8.20	6.04
No. of customers	8,278,203	1,636,431	1. 2,864,559
No. of Employees	10,177	1,564	7,344
No. of distribution Transformers	8,778	14,833	22,575
System Losses in Units	2,898,000,000	769,829,268	1,183,000,000
System Losses	23.95%	18.00%	15.30%

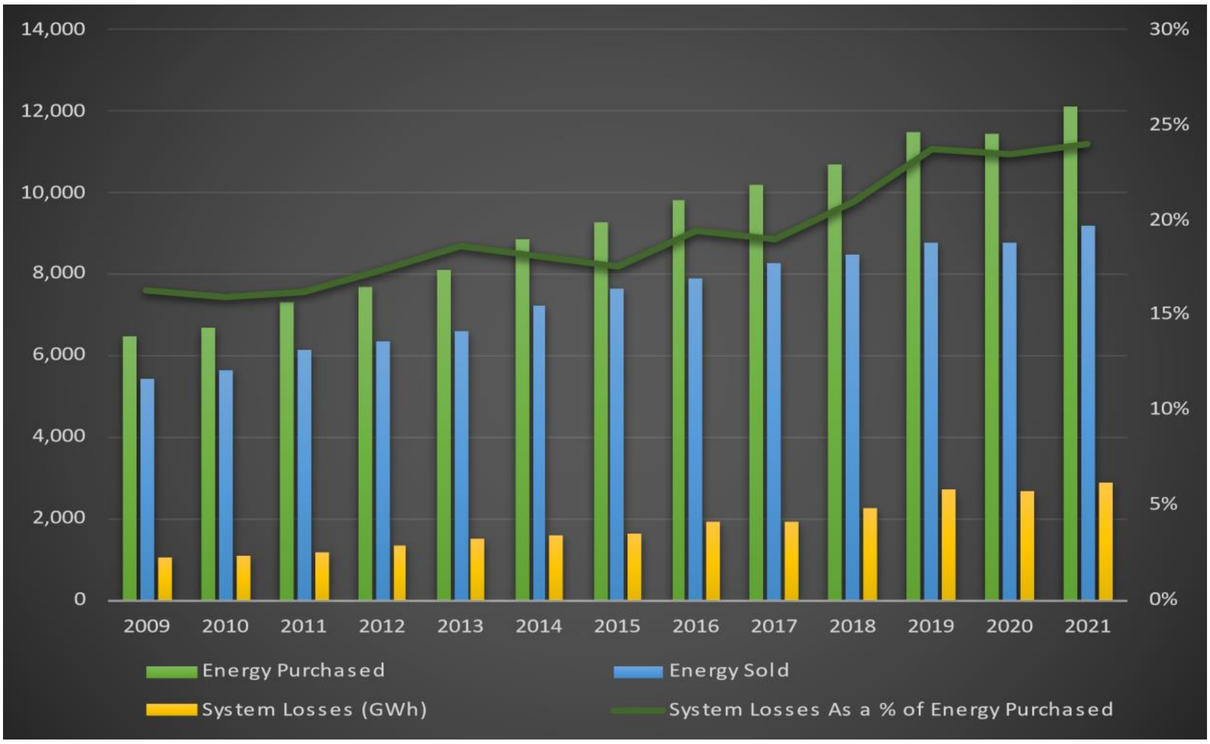
Annual Report and Financial Statements 2020/2021

From the annual report of 2021, KPLC recorded 23.95% in system losses which translates to 2.9 Billion units with a cost value of US$209 Mil. The Energy and Petroleum Regulatory Authority (EPRA) allowed KPLC to recover the losses from consumers. EPRA increased the allowable system losses by 5% from 14.9% to 19.9% with effect from July 2020 (KPLC Annual Report, 2019/2020).

Table 2: Electricity Purchased Vs Electricity Sold (GWh)

Year	Energy Purchased(GWh)	Energy Sold (GWh)	System Losses (GWh)	System Losses As a % of Energy Purchased
2009	6,489	5432	1057	16.3%
2010	6692	5624	1068	16.0%
2011	7303	6123	1180	16.2%
2012	7670	6341	1329	17.3%
2013	8087	6,581	1507	18.6%
2014	8840	7,244	1,596	18.1%
2015	9280	7,655	1,625	17.5%
2016	9,817	7,912	1,905	19.4%
2017	10,204	8,272	1,932	18.9%
2018	10,702	8,459	2,244	21.0%
2019	11,493	8,769	2,724	23.7%
2020	11,462	8,773	2,689	23.46%
2021	12,101	9,203	2,898	23.95%

Source: Kenya Power Annual Report 2009-21



System Losses Report; 2009-21

1.6 POWER OUTAGE AND SYSTEM LOSSES

Existing empirical data demonstrates that electricity generated on-site is more expensive than electricity obtained from the public grid (Adenikinju, 2003; Steinbuks & Foster, 2010; Oseni & Pollitt, 2015). The short-term impact of the high cost of self-generation on capital utilization results in firms reallocating resources, using only the most energy-efficient methods of production, and substituting power for material inputs, which lowers productivity (Fisher-Vanden et al., 2015). This suggests that an increase in electricity costs may cause businesses to change how they use their inputs, preventing them from operating at full capacity. This might encourage businesses even more to make long-term investments in technology that uses less electricity. The type of power outages affects how businesses react to them in some ways.

A company has the option of purchasing backup energy or outsourcing the manufacturing of intermediate inputs that require a lot of electricity. From the limited prior research, it is unclear if power disruptions cause increased electricity efficiency or drive businesses to replace electricity with material input. In this regard, Fisher-Vanden et al. (2015) published a thorough empirical investigation of how Chinese industrial firms react to electricity shortages using a translog cost function. There was a decrease in other non-electricity energy sources, which suggests that these primary energy sources are complementary inputs in producing the intermediate products that have been outsourced in response to electricity shortages, according to a study that used a translog cost function to examine how Chinese industrial firms respond to power outages.

1.7 SYSTEM LOSSES AND ECONOMIC COST

Electricity shortages can drive industrial companies' costs higher, influencing them to avoid energy-intensive technology and raising their overall production costs. Due to the need for alternative methods, which lowers product quality, stops manufacturing, and delays order delivery, this also has an impact on the competitiveness of businesses. A lack of electricity has an impact on location choices for businesses and investments. The growth of a company is adversely affected over time by this. According to Abeberese (2016), firms lack the incentive to either migrate to productivity-enhancing industries or grow larger, since doing so comes with the expense of relying on electricity in nations where the supply of electricity is severely unstable. Given the frequency of power outages, businesses can take a variety of actions to reduce the costs incurred by outages. Investing in self-generation is a popular coping mechanism. Investment in self-generation, however, decreases productivity by making businesses divert money to less productive investments.

Numerous empirical studies have examined how power disruptions affect business performance (Alam, 2013; Scott, Darko, Lemma, & Rud, 2014; Abotsi, 2015; Nyanzu & Adarkwah, 2016). The majority of empirical research have employed a proxy measure of power loss to examine the effect of power outages on firm performance. Fisher-Vanden et al. (2015) used industry-level estimates, the ratio of thermal electricity generated to thermal electricity capacity, while Alam (2013), Andersen and Dalgaard (2013), and Andersen and Dalgaard (2013) used meteorological satellite data lightning density as an instrument for power outages. Allcott et al. (2014) used variations in electricity supply from hydroelectric power availability to instrument electricity scarcity. However, a number of studies (Adenikinju, 2003; Abotsi, 2015; Oseni and Pollitt, 2015) examined the financial impact of power outages and how this affected firm performance.

Many studies have attempted to assess the cost related to power outages using a variety of methodologies. Adenikinju (2003), Steinbuks and Foster (2010), and Oseni and Pollitt (2015), for example, deduced outage costs from business actions. But occasionally, this approach only offers an upper or lower bound on outage cost estimates (Balducci, Roop, Schienbein, DeSteese, & Weimar, 2002). Pasha, Ghaus, and Malik (1989) and Caves, Herriges, and Windle (1992) both employed survey methodologies in their studies and asked businesses to report the losses they incurred as a result of outages. This strategy is appealing since it results in the allocation of outage costs among consumers. Studies that have used a production function approach to calculate the cost of power outages include Castro et al. (2016), for example.

Power outages have a variety of effects on corporate operations. However, their effects vary from one company to the next depending on how vulnerable they are and how much electricity they can generate on their own (Oseni &Pollitt, 2015). The price of power outages varies depending on the size of the company and the sort of economic activity that the company is involved in. Adenikinju (2003) and Moyo (2012) observed that because they can't afford the cost of backup electricity, small businesses are severely hurt by power outages. On the other side, a 2015 study by Oseni and Pollitt revealed that larger businesses suffer more from outages. They indicated that the fundamental reason for this is because larger firms utilize more manufacturing methods that are dependent on machines than do small firms.

The cost of power outages is also influenced by the type of power interruptions a company experiences. There are numerous ways to categorize power outages, including duration, frequency, time of the interruption, and advance notification. The effect of these factors on outage costs has been studied in some research. According to the findings of the Scott et al. (2014) study, frequent power outages are linked to decreased firm production. Due to data limitations, there have been few studies on the effects of timing power outages and advance warnings. The methods used by businesses to lower the costs of outages have been the focus of numerous empirical research. Investment in self-generation has been determined to be the most widely used tactic (Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni & Pollitt, 2015). According to Steinbuks and Foster (2010), firm size, sector, corporate structure, and export have a significant impact on both the motivation to invest in a generator and the capacity of the generator installed.

The degree of power interruption susceptibility of businesses affects the incentive to invest in self-generation (Oseni & Pollitt, 2015). Some businesses are more susceptible to power outages than others due to the nature of their operations. The variation in a firm's level of susceptibility was described by Ghosh and Kathuria (2014) as transaction-specific costs. They demonstrated that there is a comparable transaction cost when a firm has a power outage by treating the provision of electricity as a transaction. They discovered that businesses with high transaction costs are more motivated to invest in their own electricity production.

A firm's adaptation strategy is partially influenced by the type of power outage. Short-term power outages may not encourage businesses to invest in generators, according to Alam (2013). According to Fisher-Vanden et al. (2015), Chinese businesses instead re-optimize their production inputs by replacing materials for energy during power outages rather than producing their own electricity. The goal of empirical studies on power outages in Sub-Saharan Africa (SSA) has been to quantify their financial impact. These studies do not make it apparent, though, whether power interruptions increase electricity efficiency or push businesses to use other resources in place of energy. The following are some ways that this paper is different from past SSA studies. In order to assess whether power outages have an impact on input factor shares, overall productivity, or how firms use their inputs, a cost function is first used to quantify how power outages affect firms' production costs. The use of two rounds of firm-level data, as opposed to one in earlier research in the field, allows for a fuller analysis.

1.8 DRIVERS OF SYSTEM LOSSES

Revenue per subscriber has fallen due to connections that are expanding quickly. Through an ambitious campaign that includes the Last Mile Connectivity Project, Kenya experienced the best yearly percentage growth in access rates in the world between 2010 and 2017, and connections more than doubled between 2015 and 2019. (LMCP). Even though this has increased overall revenue, net income per customer has been severely declining, and total consumption has only climbed by 25% over this time despite a more than 100% increase in connections. Although it is anticipated that the goal of achieving universal access by 2022 will eventually lead to widespread social benefits, it has so far had a negative impact on the utility's financial viability and performance, which has a negative impact on the primary source of electricity required to drive economic growth.

A comparison of electricity purchased and sold showed that a total of 12,102GWh was produced, of which 9,203GWh was sold to customers, resulting in a loss variance of 2,898GWh or 23.95%, which, using the average sale price for the 9,203GWh sold, equates to almost Ksh. 45,382,887,000. Since the industry authorities must recover the loss by charging the consumers 19.9% of power loss as a recovery rate, the 23.95% loss variation has been attributed to system losses resulting from commercial/technical operations. These system losses have increased the cost of electricity on the consumers. Despite raising operating costs, the remaining 4.05% is not passed on to consumers.

Approximately 700 high-consuming, highly profitable core commercial-industrial (CI) clients make up less than 0.01% of the overall clientele but more than 54% of KPLC's total revenues, despite declining revenue from these customers. Yet these anchor CI customers are increasingly leaving KPLC as more affordable and dependable captive solutions, such as solar PV, become more common. Customers of CI include Kapa Oil Refinery Limited, Two Rivers Shopping Center, London Distillers Limited, Williamson Tea, and Garden City Mall, all of which have solar PV systems with peak capacities more than 1 MW. Coal-fired power plants up to 15 MW have been installed by others, such as Devki Steel Limited. Without this dependable, high-consumption customer base, KPLC's business model will crumble very soon. KPLC is making an effort to retain and even grow demand from CI customers in response to this shift by constructing specialized distribution lines, installing smart meters, and offering financial incentives (e.g. ultra-low time-of-use tariffs). As a result, while overall income per sold unit of power has consistently ranged between US$ 0.14 and 0.16 over the past eight years, profit has severely decreased. The utility's problems were exposed by the 92% profit decline that was announced for the fiscal year that ended in 2019. The earnings have been reduced by the cost of sales, poor management, system losses (both technical and non-technical), rapid expansion, decreased revenue per client, and other variables.

1.9 CRITICAL SOLUTIONS

Although the load factor is now below 75%, there are numerous low-hanging fruit chances to boost electrification. Load factor, according to Queiroz, Roselli, Cavellucci, and Lyra (2012), is a variable that links the losses under the conditions of maximum system loading to the overall energy losses for a particular electric network. Growing power production and distribution have improved load factor as a result of Kenya Power and Lighting Company's (Kenya Power) unbundling and partial privatization.

One area that is prime for growth is the conversion of urban customers who currently use LPG to power electric stoves by providing ultra-low time-of-use prices for cooking (similar to previous preferential tariffs granted for water heating). The tea processing business, cement processing companies, edible oil refineries, and other significant thermal energy consumers that currently rely on biomass sources for energy can all be encouraged to transfer some or all of their energy requirements to grid-based electricity. Even if only slightly, encouraging the use of electric vehicles has the potential to boost demand. Between 2016 and 2017, Kenya registered 15,000 automobiles on average each month. About 25% of this fleet might be converted to electric vehicles, which would increase demand by more than 60 GWh and boost utility revenue by close to US$ 10 million annually.

Kenya Power has long-term records of more than 7.5 million customers, with information that could be used as a stand-in for credit rating. These records are in addition to the physical assets that are currently being used to support other revenue streams, such as hosting fiber optic cables and street lighting. Additional financial services, including asset financing, can be provided using this information. Energy sector prospects that are diverse, such as those in energy consultancy, technical services, and energy consumption analytics, provide up additional revenue streams.

Politically motivated decision-making procedures that might not be in line with the utility's longer-term economic goals make Kenya Power vulnerable. For the utility to develop and sustain its relevance over time, there needs to be a balance between the values of the public and private sectors. With the Government expanding its holding in the utility and luring a strategic partner to buy just under 50% of its investment in the utility, the current debt might be converted to equity. The government, a strategic investor, and shares launched on the Nairobi Securities Exchange made up nearly an equal third of the final share spread. This would lessen the exposure to political interest linked to electrification schemes driven by the public sector.

A long-standing strategy for reducing generating requirements is load management, or the reduction of peak loads via active or passive load control. Transmission and distribution networks increasingly rely on load management to reduce specific types of loss (Song, Jung, Kim, Yun, Choi & Ahn, 2012). Reduced system demand can be achieved by demand response and Distributed Generation (DG), which also helps to minimize losses in the distribution system caused by load (Schneider et al., 2010). A heavily laden line can be relieved of load by modifying the topology of the distribution system in real time. This requires the use of larger distribution lines, which naturally have lower losses. However, this necessitates a substantial investment in control systems and system management assets (Schneider et al., 2010).

The distribution feeder's three phases are loaded equally thanks to load balancing. Transformer losses due to uneven phases occur throughout the system and are exponentially correlated to the degree of phase imbalance. In an unbalanced feeder system, resistive losses along the neutral wire that accidentally become loaded are decreased by reducing phase imbalances, as well as transformer losses (Vidhyalakshmi, Zubair & Ramprasath, 2013). Higher voltage lines have fewer losses compared to lower voltage lines carrying the same amount of power because losses are inversely related to the voltage level of the line. The voltage level of the higher side of transformers is frequently unregulated, even if the low voltage side must be maintained at 120 V or 240 V. The total system losses would be decreased by raising the voltage of these lines (Zhang & Zhang, 2008).

The numerous losses that occur at the distribution substation can be reduced in a number of ways. Locating the substation closer to the end-use load can help reduce the resistive losses brought on by long cable runs between the substation and load, which is one of the main strategies for decreasing substation-related losses. Compared to air-insulated substations, gas-insulated substations have a lower footprint and are simpler to locate in constrained spaces near a load (Vidhyalakshmi, Zubair & Ramprasath, 2013).

Reactive power system losses are exacerbated by low power factors for end-use devices, or the ratio between real and apparent power. To make up for the losses brought on by uncorrected power factors, the majority of utilities add a surcharge or adjustment to the bills of large industrial users. Customers that are residential or commercial are typically not charged for their influence on power factors. Although contemporary appliances are equipped with power factor correction technology or additional capacitance to lower the reactive current, the main source of distorted power factors is equipment that uses motors (Litvinov, Zheng, Rosenwald & Shamsollahi, 2004).

1.10 CONCLUSION AND RECOMMENDATION

Researchers and experts in electricity sectors and academia have been trying different methods to address the causes of high cost of power. Technical Losses and Non-Technical Losses in the grid need to be reduced significantly and effectively. The traditional methods utilize the statistical analysis of data to understand the significant indicators of fraudulent behavior, allowing the development of effective policies to address the issue. Other methodologies include the utilization of machine learning algorithms for analyzing the data from meters and the evaluation of consumption patterns that may imply fraudulent activities. Installations of specific equipment, sensors, and grid structures are encouraged for efficient detection of NTLs. Intelligent management principles could also contribute effectively to a decrease in technical losses. Technical teams to supervise the meters should be implemented and policies formulated on dealing with cases of power theft. This should be accompanied by the installation of tamper-proof meters, reduction of the average number of consumers per transformer, and by upgrading of electricity meters to use Smart card technology.

Low inspections, high customer base, and extensive inducement to bribery and corruption has consequently led to an increase in the cost of power hence there is a need for smart grid deployment to curb the cases of pilferage. The cost of power also needs to be brought down by reducing or abolishing the fuel taxes and other charges like fuel energy cost charge and Foreign Exchange Fluctuation Adjustment. Massive electrification of areas with no electricity connection can also discourage the habit of pilferage of power thereby encouraging the customers to pay for power consumed. There is a need to review the Power Purchase Agreements (PPAs) with the Independent Power Producers (IPPs) and ensure that they play within the confines of the contract and that those that commit material breaches of their contracts are terminated. Most of the IPPs operate in almost similar environment hence the cost of power should be renegotiated across all the firms. This will significantly see that the cost of power transmitted to the consumers comes down.

Once the term of operation (PPA) has expired, thorough scrutiny and rigorous forensic audit of any IPP seeking renewal of their contracts should be done. There is need to discourage donor funding or rather over dependence on Public Private Partnership framework without first exhausting the self-funding options. Over reliance on donor funds only increases the tax burden to the power consumers as the investors impose dubious charges like Foreign Exchange Fluctuation Adjustment and other levies on the power sold thereby increasing the cost of power. An improved system management, automation and innovation system needs to be installed in order to enhance supply reliability, efficiency and reduce system losses. In addition, the installed systems may provide incentives that promote conducive environment for growth of industrial customers and their associated energy consumption.

To tackle technical losses, there is need to curb power theft resulting in lost revenues by improving monitoring at a more granular level. Segregation of technical losses in the system, identifying the gaps and methodology for intervention. Improving the accounting, energy balance and accountability for energy in the distribution side. Finally, there is need for increase in demand for power band in order to generate more revenues. This can be done by giving favorable incentives to industrial consumers in order to balance between investment costs borne by the client and the stakes related to the system losses. Grid management solution such as switching off transformers could also be possible in periods of low demand for configurations where multiple transformers are required in a substation to meet peak load or for redundancy.

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