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A Review of the Characteristics and Challenges of Electricity Distribution in Ghana: Case Study of the Northern Electricity Distribution Company

Nutifafa K. Fiasorgbor[1*], Robert Aziz Tia Abdulai[2], Mina Antwi-Yeboah[1]

[1]ECOWAS Regional Electricity Regulatory Authority (ERERA), Accra, Ghana
[2]Public Utilities Regulatory Commission (PURC), Ghana, Accra, Ghana
Email: *nukfias@yahoo.com, lordshepi@yahoo.com, minaantwi89@gmail.com

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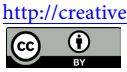

Abstract

This paper presents a review of the characteristics and challenges of electricity distribution in Ghana with an emphasis on the Northern Electricity Distribution Company (NEDCo) in the northern half of Ghana. NEDCo is used as a case study due to the peculiarity of its geographical area of operation and customer characteristics which better highlights the challenges of electricity distribution in Ghana. NEDCo's electricity distribution operations cover approximately 64% of the total landmass of Ghana and contain the most deprived communities and consumers, who are extensively dispersed. In addition to the scattered settlements, NEDCo has a predominantly lifeline customer base that pay tariffs below the average cost of service. These peculiarities, together with regulatory complexities, have contributed to many challenges, such as high system losses, high cost of service and poor network reliability, in the electricity distribution sector in Ghana.

Keywords

System Losses, Electricity Tariffs, Regulatory Regime, Metering and Billing

1. Introduction

Power systems are one of the most critical infrastructures for the socio-economic development of a country. According to [1], Ghana has about 85.33% electricity access rate and continues to extend electricity to unelectrified rural communities to achieve universal electricity access. However, for many years, the power sector has been fraught with many challenges that have compromised the reliability of

Ghana's electricity supply value chain. Despite its high electricity access rate, compared to other countries in sub-Saharan Africa, the challenges do not augur well for the country's socio-economic development. These challenges range from fuel shortage and low dam levels in the generation segment, transmission grid constraints and voltage stability issues, and a myriad of challenges in the distribution segment.

Many studies have assessed Ghana's energy sector challenges and remedies [2] [3] [4] [5], reliability of the energy sector [6], energy policy and reforms [7] [8], tariff and regulatory issues [9] [10] and renewable energy potential and deployment in Ghana [11] [12]. These studies targeted the power system value chain with emphasis on the generation and transmission segments due to the wide range and number of customers affected when they fail. Implementing the recommendations of these studies will help ensure adequate generation capacity, a robust transmission network, and efficient regulatory policies. However, most electricity consumers in Ghana are embedded in the distribution networks and experience many localized challenges, which are not considered major national crises. These situations are widespread in the distribution segment. Without efficient distribution systems hinged on enabling regulatory environment, the investments in the generation and transmission segments may become stranded and ineffective in stimulating the much-needed socio-economic development in Ghana. However, according to [13], for the first quarter of 2021, the distribution sector accounted for about 37% of the total revenue requirement of the power sector, the generation segment about 52%, and transmission about 11%. Therefore, the distribution sector has a significant impact on the overall revenue requirement of Ghana's electricity supply value chain and must be operated efficiently.

Despite these many localized challenges across the distribution network and significant revenue allocation, Ghana's distribution sector's challenges have not been extensively discussed in published literature. There are three distribution companies in Ghana: Electricity Company of Ghana (ECG), Northern Electricity Distribution Company (NEDCo), and Enclave Power Company (EPC). The operation of EPC is limited to the free zones enclave of Tema and has predominantly special load Tariff (industrial) customers. ECG's operations cover the southern half of Ghana and are better resourced than NEDCo in terms of customer base and proximity to the major generation enclaves of Akosombo, Tema and Aboadze. NEDCo's operational area, in the northern half of Ghana, spans approximately 64% of Ghana's total landmass [14] and has the country's most deprived communities [15] and the lowest electricity access rate [16]. **Table 1** gives a brief overview of the characteristic features of the two major distribution companies in Ghana [14] [17].

This paper, therefore, focuses on the characteristics and challenges of electricity distribution with emphasis on the operation of NEDCo in the northern half of Ghana. NEDCo is considered for this study because it better accentuates the

Table 1. Comparison of major electricity distribution companies in 2021.

Parameter	Units	ECG	NEDCo
Geographic Area	%	36	64
Total Customers	#	4,292,000	1,136,050
Industrial customers	#	1852	82
Energy Purchases	GWh	9520	1761
Energy Losses	%	29.84	27.29
Profit	GHS	−178,200,000	−278,220,000

distribution sector's challenges due to its peculiar geographical area and unique customer characteristics and challenges.

2. Background of Electricity Distribution in Ghana

Ghana established its first public power generation system in Sekondi in 1914, using a diesel generator to power its railroad business. From 1922 to 1938, The Electricity Department of the Public Works Department (PWD) expanded electricity supply to other major cities such as Tema, Accra, Kumasi, Tamale and Cape Coast. In 1961, the Government established the Volta River Authority (VRA) to generate, transmit and distribute electricity as a vertically integrated utility. In 1967, the electricity distribution function of VRA was unbundled to establish the Electricity Corporation of Ghana. In 1987, VRA was commissioned to handle the distribution of electricity in the northern half of Ghana, which led to the establishment of the Northern Electricity Department (NED). This limited the business of the then Electricity Corporation of Ghana (ECG) to the southern half of Ghana. NED later evolved into NEDCo and ECG into the Electricity Company of Ghana (ECG) [18]. Areas under NEDCo's jurisdiction are the Northern, North-East, Savannah, Bono, Ahafo, Bono East, Upper East, and Upper West administrative regions of Ghana [14].As a result of power sector reforms in the 1990s, Ghana's power sector was unbundled and now includes power generation, transmission, and distribution segments as separate entities. The reform also led to the creation of two energy sector regulators, the Energy Commission (EC) as the technical regulator and the Public Utilities Regulatory Commission (PURC) as the economic regulator. The Ministry of Energy oversees developing, monitoring, and evaluating the energy sector's policies, programmes and projects. VRA, Bui Power Authority (BPA) (Hydropower), and Independent Power Producers (IPPs) are responsible for power generation. The Ghana Grid Company (GRIDCo) oversees power transmission, and ECG, NEDCo, and EPC are in charge of power distribution.

NEDCo's operations cover about 64% of Ghana's geographic area, but customer density is low, and settlements are extensively dispersed. NEDCo started its operations with a customer base of 17,940 in 1987. This number steadily increased yearly to a customer base of 1,136,050 at the end of 2021. Residential

customers make up 84.96% of the total number of customers. Non-residential customers make up 15.03%, while industrial customers make up only 0.01%. Unfortunately, 46% of the customer population falls under the lifeline category and pays tariffs lower than NEDCo's average cost of service [14].

Despite Ghana's power sector reforms to ensure the reliability and efficiency of the power system [6], the country is still plagued with energy insecurity, as revealed by periodic power outages and load shedding. Since the late 1990s, Ghana's energy demand has steadily increased and occasionally outstripped generation, leading to varying degrees of periodic power crises [8]. According to [2], Ghana's hydropower resource exploitation is an appealing power source because it is renewable, clean, sustainable, and environmentally friendly. However, given the rapid growth in demand, a power crisis is unavoidable if water levels fall due to climate change, and thus the need to diversify supply sources. [7] indicated that there is a need to increase generation capacity to accommodate the rising power demand. Consequently, research into how Ghana's energy portfolio can be upgraded to meet rising energy demand, including the use of renewable energy, is encouraged [11] [12]. However, [10] noted that regulatory and policy issues have hampered Ghana's goal of renewable energy integration into the country's generation mix. If these policies are not amended, Ghana will most likely fail to meet its renewable energy targets. Furthermore, [3] [4] [5] indicated that Ghana has adequate installed generation capacity to meet its domestic demand; however, the major challenges are related to the unavailability of adequate generation capacity due to fuel supply challenges, inefficient distribution systems, high transmission and distribution losses, revenue loss due to non-payment of bills and poor tariff structure. [9] noted that, aside reliability and supply inadequacy issues, Ghana's tariff pricing regime has historically failed to incentivize electricity generating companies due to price distortions.

3. Methodology

The study used a literature review approach to investigate the issues considered. The data for the study was collected from key documents, regulatory agencies and utilities' reports, tariff proposals, official government websites, key stakeholders, and published literature. The unstructured data was transformed into a detailed description of the challenges that impede the efficiency of electricity distribution in Ghana with an emphasis on NEDCo.

The literature reviewed for this study has revealed extensive research on Ghana's energy sector. However, these studies have primarily focused on the generation and transmission segments of the value chain such as energy sector challenges and solutions [2] [3] [4] [5], reliability [6] energy policy and reforms [7] [8], tariff and regulatory issues [9] [10], and renewable energy potential and deployment in Ghana [10] [11]. Though these studies made references to some of the challenges in the distribution segments, no study has highlighted the localized challenges within the electricity distribution sector, which is critical for the holistic assessment of the challenges within Ghana's power sector. Therefore, the

primary focus of this study is to investigate the characteristics and challenges of electricity distribution in Ghana with emphasis on NEDCo, which better accentuates the challenges of the distribution sector in Ghana.

4. Major Challenges

This section of the study underscores the major challenges that impede efficient power distribution by NEDCo in the northern half of Ghana.

4.1. Aged Infrastructure and Deferred Maintenance

NEDCo's main infrastructure for power distribution includes distribution lines, transformers, switchgear, protection and control devices, and other ancillary equipment for communication. Many of these components were designed and installed decades ago [14]. [19] noted that the failure rates of aged and obsolete components increase and affect supply reliability over time. According to [20], aged infrastructure has low reliability and higher operation and maintenance costs due to frequent preventive maintenance on this equipment. Deferring or non-adherence to an effective preventive maintenance regime would lead to equipment failure. The cost for "untreated maintenance faults" and corrective maintenance is relatively high compared to preventive maintenance costs [21].

4.2. High Distribution System Losses

NEDCo's network losses are classified as either technical or commercial losses. Technical losses are inherent in power distribution networks and are largely proportional to the square of the power flow through distribution lines and transformers [22]. Commercial losses are due to electricity theft and non-payment of bills by consumers, including state institutions. Since NEDCo is wholly Government-owned, it is challenging to hold state institutions accountable for electricity used without interference [3]. As of the end of 2021, distribution system losses in NEDCo, including both technical and commercial losses, were about 27.29%. Technical losses constituted approximately 9.2%, and commercial losses were 18.09% [14]. The total losses in NEDCo's network have been consistently above the PURC benchmark of 21.0% as shown in **Figure 1** below. It is evident from **Figure 1** that the year-on-year percentage change in losses are significant, haphazard and unpredictable and does not reveal any firm commitment by stakeholders to reduce losses below the regulatory benchmark.

4.3. Metering and Billing Concerns

NEDCo has both postpaid and prepayment meters in its network in a ratio of 51:49 as of the end of 2021. Postpaid meters are used predominantly in rural areas, and prepayment meters in urban communities. However, many of these meters are either old, resulting in inaccurate reading and billing, faulty or not available for new service connections [14]. Over 28.0% of the complaints received by the PURC were related to metering and billing [24]. Deployment of

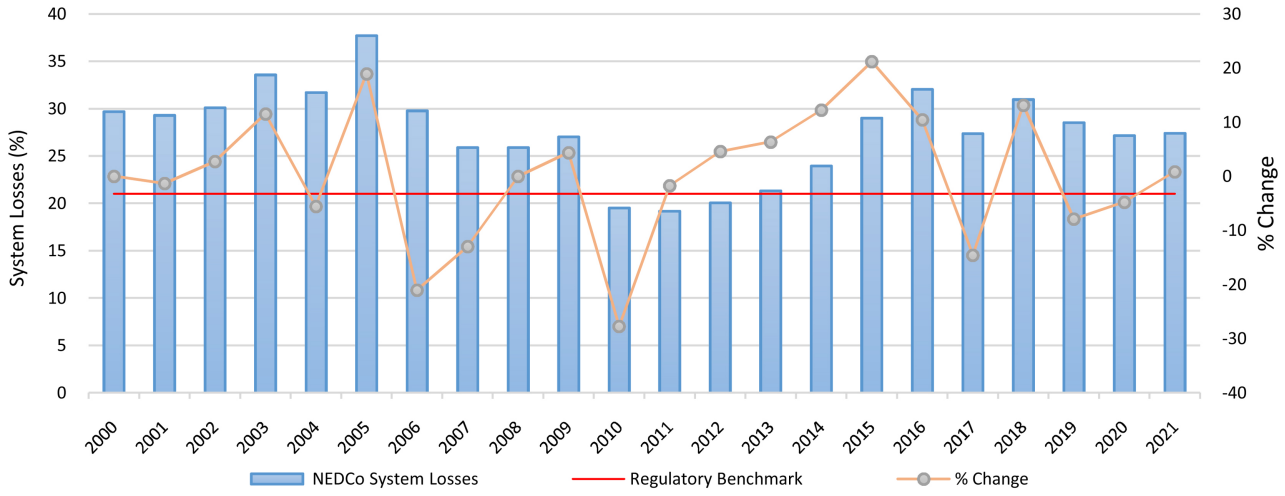

Figure 1. NEDCo's distribution losses. Data source: 2022 National energy statistics, energy commission [23].

postpaid meters in rural communities requires that NEDCo engages the services of meter readers to visit customer premises every month to manually take meter readings, submit for inputting and billing and take the bills back to consumers [14]. From this scenario, coupled with a large lifeline customer base, one can easily infer that the cost for meter reading and subsequent billing could be greater than the revenue generated. As a result, the revenue collection rate has consistently remained below the regulatory cap of 98.0%, customer bills are often estimated for an extended period, and occasionally there are long delays in setting up and processing bills of new customers [14] [25]. The linear trend line in **Figure 2** below reveals NEDCo's consistent improvement in revenue collection from 2017.

4.4. Network Reliability and Power Quality Concerns

The economic regulator, PURC, has rated NEDCo as being non-compliant with its reliability and regulatory benchmarks [26]. The network's reliability and power quality challenges are due to the network configuration and consumer behaviour. Long radial distribution lines dominate NEDCo's distribution network with many lateral circuits. Due to the radial network configuration, many consumers are affected by disturbances or faults at remote locations, which compromises the reliability of the distribution grid. NEDCo, therefore, has a high System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) that exceed the regulatory caps [24]. SAIFI and SAIDI data obtained from the Energy Commission, the technical regulator [23] and NEDCo [14] are inconsistent, which cast doubt on the accuracy of this data.

NEDCo operations are also affected by network hiccups caused by vandalism and accidents, especially on the low voltage (LV) grids where most secondary substations are unfenced. Due to the free access to the unfenced substations, consumers easily interfere with substation protective devices using improvised

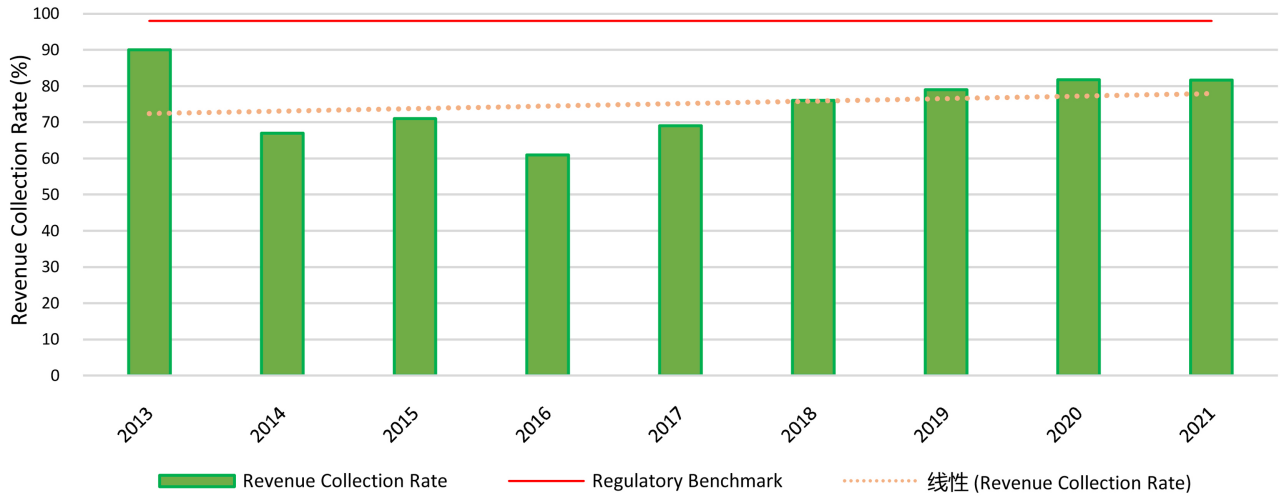

Figure 2. NEDCo's revenue collection rate. Data source: NEDCo 2022 tariff proposal [14] and electricity tariff setting methodology and tariff structure in Ghana: Comparative analysis of DisCos performance, MRC consultants and transaction advisers [25].

fuses with unverified ampacities to close circuits even on sustained faults. Also, consumers often transfer loads from one phase to the other, which changes the load balance of the phases. Phase imbalances result in high losses in both phase and neutral wires and the malfunctioning of protective relays [27]. Additionally, bushfires in the harmattan intended to trap animals destroy many wood poles and plunge communities into darkness. NEDCO bears the replacement costs of these burnt poles and any damaged equipment [28].

4.5. Tariff Structure Bottlenecks

In Ghana, the existing end-user electricity tariff for residential and commercial customers is the Incremental Block Tariff (IBT) and industrial consumers have flat-rate tariffs based on voltage levels. The Public Utilities Regulatory Commission (PURC) conducts tariff reviews based on projected cost and demand forecasts. To improve the efficiency of the tariff process, PURC published in Gazette No. 15 of February 25, 2011, its quarterly Automatic Adjustment Formula (AAF) for minor tariff adjustments in line with variations in forecasted fuel prices, foreign exchange, inflation, and power generation mix. PURC also instituted lifeline tariffs for low-income consumers at tariff levels below the actual cost of service [3] [29].

The Incremental Block Tariff (IBT) structure used by PURC, as shown in **Figure 3** below has not proven to be very efficient in stimulating energy consumption and economic growth in the NEDCo regions. Residential and commercial consumers resort to self-generation when their consumption enters the highest tariff blocks [30]. Self-generation reduces NEDCo's projected revenue required for efficient power distribution. The tariff structure therefore does not incentivise electricity consumption. IBT is also relatively more complicated for NEDCo's consumers, who are largely not literate [15]. As a result, PURC and NEDCo are often inundated with customer complaints on metering and billing

Tariff Category: EUT			Effective 1st September 2022
Residential			
0-30 (Lifeline, Exclusive)	-	(GHp/kWh)	41.9065
Service Charge: Lifeline	-	(GHp/month)	213.000
31-300	-	(GHp/kWh)	89.0422
301-600	-	(GHp/kWh)	115.5595
601+	-	(GHp/kWh)	128.3995
Service Charge:			
Other Residential Consumers	-	(GHp/month)	1073.0886
Non-Residential			
31-300	-	(GHp/kWh)	83.7841
301-600	-	(GHp/kWh)	89.1552
601+	-	(GHp/kWh)	133.0919
Service Charge:	-	(GHp/month)	1242.8245
SLT-LV			
Energy Charge	-	(GHp/kWh)	132.6125
Service Charge	-	(GHp/month)	50000.0000
SLT-MV			
Energy Charge	-	(GHp/kWh)	100.6863
Service Charge	-	(GHp/month)	50000.0000
SLT-HV			
Energy Charge	-	(GHp/kWh)	105.6746
Service Charge	-	(GHp/month)	50000.0000
SLT-HV STEEL COMPANIES			
Energy Charge	-	(GHp/kWh)	74.5315
Service Charge	-	(GHp/month)	50000.0000
SLT-HV MINES			
Energy Charge	-	(GHp/kWh)	263.9705
Service Charge	-	(GHp/month)	50000.0000

Figure 3. Retail tariff rates and structure [32].

[24]. Also, coupled with the large lifeline customer population, the level of tariff increase requested by NEDCo is usually not approved by the PURC, which has impeded NEDCo's efforts to undertake all the planned investments specified in its tariff proposals over the years [3] [14] [31]. Also, over the years, PURC has not strictly adhered to its AAF schedules which resulted in tariff hikes during major tariff reviews and consequent public agitations [3].

4.6. Rural Electrification and Load Growth Concerns

The load in NEDCo's network has been increasing since its establishment due to new service connections and existing consumers increasing their loads with predominantly "second-hand" or refurbished appliances with poor power factors [14] [33]. The load growth is due to many factors, such as the national economy, per capita income, prices of goods and services, and politics. However, unplanned electricity demand growth can affect a distribution grid's reliability and stability if not effectively managed [19].

In the NEDCo area, one of the main drivers for the rapid load growth is Government's rural electrification programmes such as the Self-help Electrification Project (SHEP). Through SHEP, Government has extended the distribution grid to areas that are currently not economically viable to necessitate these extensions. Under SHEP, established in 1989, communities within 20 km from an existing sub-transmission grid will procure all the towers needed for electrification and have at least 30% of houses wired. When the community meets this requirement, the Government provides the rest of the equipment, such as ladders,

pole-top assemblies, and transformers, required for the electrification of the community [34]. The SHEP is undertaken by the Ministry of Energy and handed over to NEDCo upon completion. Most of the consumers acquired through SHEP are unable to pay for the electricity consumed after the pomp and pageantry surrounding the electrification of the community, mainly for political expediency. This is the primary source of NEDCo's predominantly large lifeline customer base. In addition, upon handing over SHEP projects, NEDCo most often than not has to upgrade some network equipment to meet its standards due to its limited involvement in the SHEP project [34]. **Figure 4** below reveals that energy demand has increased over the years in NEDCo's operational area, but the increases have been insignificant compared to the national energy demand growth over the same period in **Figure 5**. This is primarily due to the large lifeline customer base in NEDCo's jurisdiction.

4.7. New Service Connection Application Hitches

In Ghana, a new service connection application process starts with the services of an Energy Commission's (EC) certified electrician, who wires the facility at a non-standardized fee. After wiring, some tests such as earth electrode resistance tests are conducted, and the results are recorded on a new service request form. A certified inspector further verifies the wiring and test values to ensure compliance with regulatory standards before the application forms are submitted to NEDCo for approval and subsequent connection to the grid [35]. However, despite the sparse consumer settlements under NEDCo's jurisdiction, only 15% of certified electricians nationwide are based in the NEDCo area. The total number of inspectors nationwide is about 2% of the certified electricians [36]. Due to the

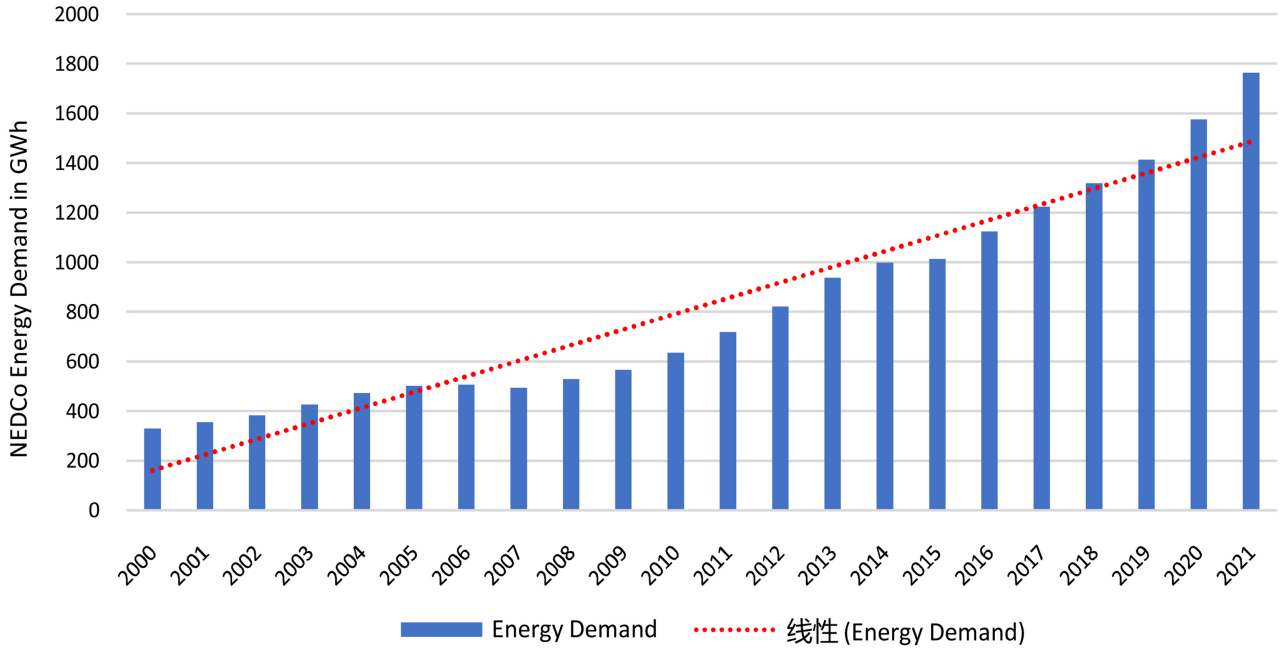

Figure 4. NEDCo load growth. Data source: 2022 national energy statistics, energy commission [23].

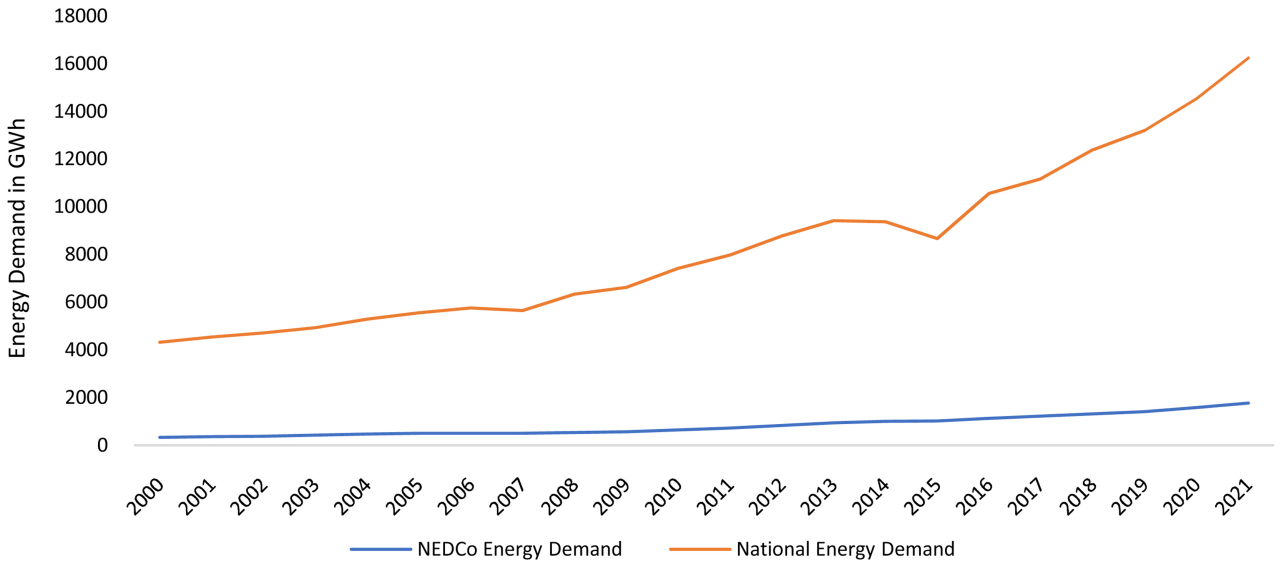

Figure 5. Comparing national and NEDCo load growth. Data source: 2022 national energy statistics, energy commission [23].

inadequate number of certified electricians and inspectors in the communities, test results are occasionally forged.

Additionally, most wiring works in rural communities are undertaken by uncertified electricians but signed off by certified electricians and inspectors without conducting the necessary tests or site visits. As a result, inferior wiring materials are used, leading to fires and equipment damage [26] [36] [37]. Also, due to the inadequate number of certified electricians within the NEDCo regions, there are significant delays in acquiring new service connections. According to [26], NEDCo's compliance with new services connection applications is low, and NEDCo needs to improve the strength of its internal controls to maintain compliance.

4.8. Public Lighting Systems and Management Concerns

Public lighting has caused significant shortfalls in NEDCo's revenue [14]. However, visits to communities under NEDCo's operational areas reveal that public lighting is not efficiently managed in these areas. Most of the lamps used for public lighting are 200 W - 400 W sodium vapour lamps, which remain lit during the day, dissipating energy that cannot be accounted for [26].

5. Proposed Solutions

The challenges noted above require immediate attention to mitigate their impact on NEDCo, customers, consumers and other stakeholders.

5.1. Strict Independent Regulation

As noted above, the EC and the PURC are responsible for regulating Ghana's electricity supply value chain. The EC has developed codes and standards, such as the National Electricity Distribution Code, to ensure quality of service and ef-

ficient electricity distribution but this code has remained as a draft document since 2012 [38] [39]. The PURC on the other hand has developed the PURC Consumer Service Regulations, 2020 (LI 2413) [40] and tariff rate setting guidelines [41] [42] with regulatory caps to mitigate passing inefficiencies through to consumers. In addition to these measures, both EC and PURC have inspectorate divisions to monitor and audit the operations and compliance of utilities. Despite the above efforts, avoidable inefficiencies are still observed in the operations of NEDCo. NEDCo has consistently violated regulatory thresholds for losses and reliability without invoking penalties from sector regulators and tariffs have often been reviewed upwards for investments in the distribution grid without significant improvements in service quality.

[20] noted that to operate the electricity market efficiently, the reliability of individual distribution network components should be considered as part of the cost drivers. Therefore, considering quantitative reliability indices, such as SAIFI and SAIDI, as part of the cost drivers can help to mitigate frequent supply interruptions and their attendant impacts on the grid, consumers and economic activities. However, regulators must closely monitor and validate the accuracy of this data and all other data originating from regulated utilities. Furthermore, the impact of regulatory decisions, such as the mandatory use of EC's certified electricians and inspectors, should be well monitored and constantly evaluated for quality of service. Fees chargeable by certified electricians should be standardized. The EC should also encourage and certify more electricians, especially in the deprived communities of Ghana.

Additionally, PURC and EC must ensure that the findings of their inspectorate divisions are thoroughly investigated and review regulatory caps to reflect the reality on the ground, taking rapid load growth and network extensions into account. Prior to tariff approvals, the PURC should require that utilities justify the impact of proposed infrastructure projects on the quality of service. Also, PURC, as part of its monitoring efforts, should ensure that utilities undertake network enhancements projects specified in their tariff proposals and engage the services of experienced technical experts to assess the impact of these projects on reliability and quality of service before granting new tariffs. This will, however, be a challenge for the PURC since it does not strictly adhere to its quarterly and major tariff review schedules. The PURC has over the years also failed to approve tariffs at levels requested by utilities without proving that the approved levels can generate enough revenue to undertake the specified projects. In its 2022 tariff proposals [14], NEDCo required about 113% rate increase to carry out critical projects to prevent an imminent localized load shedding, increase in technical losses, poor voltage profile and poor supply reliability. However, a rate increase of 27.15% was approved by the PURC [31] without any published technical justifications to indicate that the proposed projects by NEDCo could be undertaken with the level of tariffs approved. PURC should assess the impact of these projects as noted by the utilities and technically ascertain their contribu-

tion to quality of service and efficiency of the distribution grid prior to tariff approvals. The PURC should further establish if the approved rates can really help NEDCo to undertake these projects. In this regard, it is recommended that the PURC engages the services of independent technical consultants to audit regulated utilities in line with their tariff proposals prior to approvals.

5.2. Tariff Structure Review and Cost Reflectivity

PURC is expected to balance the interests of consumers and utilities according to its mandate. However, as a government entity responsible for reviewing and costing the electricity value chain, PURC may sometimes favour affordability over cost efficiency. As a result, the estimated cost of supplying electricity across the value chain may be understated to maintain low tariffs, especially during election years. According to [43], PURC may outsource independent assessment of the electricity supply value chain to facilitate investments in the power sector and accordingly adjust electricity tariffs to recover only prudently incurred cost with significant scientific justifications. Also, PURC should consider introducing flat-rate (a single price per kWh) and Time-of-Use tariffs (ToUs) for residential and commercial consumers while maintaining the lifeline tariff band. ToU tariff will facilitate shifting non-critical loads to off-peak periods and reduce the short-run marginal costs. The short-run marginal costs due to load increase are expensive for NEDCo's operations since the bulk of the supply is transported from the south to the north with inherent high technical losses in the transmission and distribution grids. ToU tariffs would reduce peak demand and the need for expensive additional capacity. A flat-rate tariff is simple and easy to understand by consumers. It would also ensure that consumers remain connected to the grid without resorting to self-generation and manage energy usage to stay within the threshold of their disposable income allocated to electricity. Furthermore, the PURC should endeavour to comply with its tariff timelines and use accurate forecast tools in its projections to ensure stability of tariffs, prevent huge tariff hikes during major tariff reviews and consequently help consumers in their resource planning.

5.3. Network Investments and Reduction of System Losses

Electricity distribution is capital-intensive and requires high fixed costs. Reducing technical and commercial losses in NEDCo's distribution system requires significant investment in the grid, such as replacing obsolete equipment and implementing tamper-proof prepayment smart metering systems, especially in government ministries, departments, and agencies. In addition, NEDCo should be incentivized to install energy meters on poles to mitigate power theft, that is, commercial losses, as stated in its 2022-2027 tariff proposal [14].

NEDCo has launched a mobile payment platform to facilitate payment of bills through mobile phones to help collect revenues [14]. However, further efforts should be made to deploy prepaid meters in all peri-urban and some rural

communities where possible. This will incur additional costs for vending stations at strategic locations and public education on using the new meters. However, these costs will ultimately be offset by the benefits of adequate revenue collection from customers in these remote locations, who depend on meter readers and estimated bills. NEDCo may also implement whistleblower policies to reduce electricity theft rates [44]. In addition, as part of its regulatory efforts to ensure NEDCo's efficiency, PURC can set up a loss reduction programme over a period and equip NEDCo through cost-reflective tariff adjustments to mitigate the levels of its technical and commercial losses. Furthermore, to prevent intrusion into the substation and tampering with protection and control systems, NEDCo needs to fence its secondary substations and effectively coordinate its protection and control systems, including auto-reclosers and sectionalizers, to discriminate in selecting and timely isolating faulted portions of its network efficiently.

5.4. Demand Side Management (DSM) and Renewable Energy

The infrastructure investments required to support the growing demand of NEDCo are huge, coupled with the replacement of aging power system components. "Electricity saved is worth more than electricity generated". DSM consists of energy efficiency, demand response, and strategic load growth programmes [45]. Considering the current state of the NEDCo network, energy efficiency can be easily implemented among these programmes. Implementation of energy-efficiency programmes can reduce demand during peak periods and hence postpone investments in additional capacity and consequently reduce greenhouse gas emissions. In this regard, since its establishment, the Energy Commission has implemented several energy efficiency programmes including but not limited to replacement of inefficient refrigerators, incandescent bulbs with Compact Fluorescent Lamps (CFLs) and energy efficiency standards and labels programmes [46] [47]. These are laudable initiatives, and the Energy Commission is encouraged to explore further energy efficient options to address issues of public lighting and power factor correction, especially at the residential and non-residential levels.

[14] indicated that due to the absence of many industrial consumers within NEDCo's operational area, VRA supplies the power requirement of NEDCo from its hydropower plants as well as from its 2.5 MWp and 6.5 MWp solar generators at Navrongo and Lawra respectively, which are embedded in NEDCo's network. NEDCo, therefore, does not procure power from any independent power producers or renewable energy generators. It is noteworthy that VRA's hydropower plants are in the south and incur high transmission losses in the process. Also, due to the sparse settlements in the region, it is inefficient to use long distribution feeders to serve a small number of households. Consumers at the tail ends of the distribution feeders would experience low voltages, requiring expensive transformer injections. It would, therefore, be beneficial and cost-saving

when many embedded generations are deployed close to load centers and use VRA's hydropower in the south as a backup. It is noteworthy that the integration of embedded generation may impact grid operation, but the benefits will far outweigh the challenges in NEDCo's network regarding the provision of sustained voltage support, reactive power compensation, reduction of losses and reliability [48].

5.5. Efficient Public Lighting Systems

To reduce the extra cost incurred through public lighting, NEDCo recommended the approval of a tariff for public lighting and metering of streetlights [14]. The study agrees that a tariff on public lighting will help to curb the inefficient management of public lighting in Ghana but may also impede the deployment of public lighting, which may give way to criminal activities. Also, tariffs and public lighting metering will not wholly address the problem of dissipating energy during the day. For efficient management of public lighting, NEDCo, in consultation with the district assemblies, will be required to take steps, in addition to already existing measures, to install and effectively monitor photocells to turn off these lights during the day. In addition to using photocells, use of energy-saving and solar-powered lamps should be encouraged through public education and policies. These measures will ensure huge savings on the energy used for public lighting.

5.6. Effective Monitoring of New Service Connection Application Process

NEDCo and EC must ensure that all certified electricians and wired installations are effectively monitored to comply with approved standards. Also, EC should take steps to standardize the cost of new service connection across the country and conduct public education to encourage many youths to venture into these areas in order to increase the number of certified electricians in proportion to the number of customers across the NEDCo areas. Government can also support youths to undertake electrical installation apprenticeships, especially for domestic wiring, and help these apprentices acquire Energy Commission's certifications just as students in the secondary schools who enjoy free education in Ghana.

5.7. Effective Communication and Public Relations

According to [49], public relations and effective communication are essential for companies to survive in the business world. Through effective public relations a company can effectively handle negative perceptions from those outside the company. Therefore, effective communication and public relations would help NEDCo address some of the challenges noted in this study. NEDCo and sector regulators should therefore enhance their public and consumer education programmes, launch events, design and distribute leaflets, brochures and quick ref-

erence cards to educate the various stakeholders on the dos and don'ts regarding efficient electricity use and responsibilities of customers and consumers. Steps should also be taken to enhance social media (e.g. Twitter, Facebook, LinkedIn) handles, mobile apps and websites of NEDCo and sector regulators to make them more interactive and informative to help address billing, vandalism and network interferences. The PURC recently rolled out a tariff recknoner on its website which is very commendable in helping consumers calculate their electricity bills by just keying the customer type, computation preference and consumption [50].

6. Conclusion

This paper reviewed key challenges in Ghana's distribution sector, with emphasis on NEDCo's operations in the northern half of Ghana. Several challenges have been identified to impede the efficiency of electricity distribution in Ghana. These challenges include the use and poor maintenance of obsolete equipment, inefficient tariff structure, and high system losses, among others. To overcome these challenges power sector regulators would have to enhance their monitoring regimes and examine the existing tariff structure which would incentivise electricity consumption required to stimulate the country's expected economic growth and enhance energy efficiency programmes. Also, distribution utilities would have to adhere to their maintenance regimes and undertake investment projects aimed at reducing network losses and improving the reliability of the distribution network. Finally, consumers and customers would have to be law-abiding and desist from engaging in activities that seek to impact the quality of supply and reliability of electricity distribution in Ghana.

Authors' Contributions

NKF collected and analyzed the data and wrote the main manuscript text. RATA provided input on the methodology, content and structure. MAY reviewed the content and technical aspects of the paper. All authors read and approved the manuscript.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not reflect the official position of either ERERA or PURC.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Energy Commission (2021) National Energy Statistics. http://www.energycom.gov.gh/newsite/index.php/reports/category/24-energy-statis

tics

[2] Eshun, M.E. and Amoako-Tuffour, J. (2016) A Review of the Trends in Ghana's Power Sector. *Energy, Sustainability and Society*, **6**, 9. https://doi.org/10.1186/s13705-016-0075-y

[3] Kumi, E.N. (2017) The Electricity Situation in Ghana: Challenges and Opportunities. CGD Policy Paper, Center for Global Development, Washington DC, 30. https://www.cgdev.org/publication/electricity-situation-ghana-challenges-and-opportunities

[4] Nyasapoh, M.A., Debrah, S.K., Twerefou, D.K., Gyamfi, S. and Kholi, F.K. (2022) An Overview of Energy Resource and Future Concerns for Ghana's Electricity Generation Mix. *Journal of Energy*, **2022**, e1031044. https://doi.org/10.1155/2022/1031044

[5] Yamoah Cobbold, E., Owusu, D. and Bathuure, I. (2019) An Assessment of Ghana's Electricity Sector, Challenges, and Remedies. *International Journal of Multidisciplinary Research and Development*, **6**, 242-247.

[6] Ackah, I. (2014) Ghana's Power Reforms and Intermittent Power Supply: A Critical Evaluation. *Journal of Economics and Sustainable Development*, **5**, 267-276. https://core.ac.uk/download/pdf/234646763.pdf

[7] Asumadu Sarkodie, S. and Owusu, P. (2016) A Review of Ghana's Energy Sector National Energy Statistics and Policy Framework. *Cogent Engineering*, **3**, Article ID: 1155274. https://doi.org/10.1080/23311916.2016.1155274

[8] Essandoh, E.O., Akolgo, G.A., Kumi, E.N. and Atta-Darkwa, T. (2021) Review and Analysis of Ghana's Power Sector Policies, Programmes and Reforms. *Journal of Energy and Natural Resource Management*, **7**, Article No. 1.

[9] Acheampong, T., Menyeh, B.O. and Agbevivi, D.E. (2021) Ghana's Changing Electricity Supply Mix and Tariff Pricing Regime: Implications for the Energy Trilemma. *Oil, Gas & Energy Law*, **19**, 1-28. https://www.ogel.org/article.asp?key=3974

[10] Obeng-Darko, N.A. (2019) Why Ghana Will not Achieve Its Renewable Energy Target for Electricity. Policy, Legal and Regulatory Implications. *Energy Policy*, **128**, 75-83. https://doi.org/10.1016/j.enpol.2018.12.050

[11] Aboagye, B., Gyamfi, S., Ofosu, E.A. and Djordjevic, S. (2021) Status of Renewable Energy Resources for Electricity Supply in Ghana. *Scientific African*, **11**, e00660. https://doi.org/10.1016/j.sciaf.2020.e00660

[12] Kuamoah, C. (2020) Renewable Energy Deployment in Ghana: The Hype, Hope and Reality. *Insight on Africa*, **12**, 45-64. https://doi.org/10.1177/0975087819898581

[13] PURC (2020) 2021 First Quarter Electricity and Water Tariffs (AAF). https://www.purc.com.gh/subsub-heading/4837625

[14] Northern Electricity Distribution Company (2022) Tariff Proposal for 2022. https://www.purc.com.gh/attachment/40757-20220427010431.pdf

[15] Ghana Statistical Service (2021) Ghana 2021 Population and Housing Census: Literacy and Education. https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/2021%20PHC%20General%20Report%20Vol%203D_Literacy%20and%20Education.pdf

[16] Bukari, D., Kemausuor, F., Quansah, D.A. and Adaramola, M.S. (2021) Towards Accelerating the Deployment of Decentralised Renewable Energy Mini-Grids in Ghana: Review and Analysis of Barriers. *Renewable and Sustainable Energy Reviews*, **135**, Article ID: 110408. https://doi.org/10.1016/j.rser.2020.110408

[17] Electricity Company of Ghana (2022) Proposal for Electricity Distribution and

Supply Aggregate Revenue Requirement and Tariff.
https://www.purc.com.gh/attachment/145051-20220427120401.pdf

[18] R. C. for E. E. and R. University of Ghana (2005) Guide to Electric Power in Ghana. https://pdf.usaid.gov/pdf_docs/Pnads932.pdf

[19] Fotuhi-Friuzabad, M., Safdarian, A., Moeini-Aghtaie, M., Ghorani, R., Rastegar, M. and Farzin, H. (2016) Upcoming Challenges of Future Electric Power Systems: Sustainability and Resiliency. *Scientia Iranica*, **23**, 1565-1577. https://doi.org/10.24200/sci.2016.2229

[20] Li, Z. and Guo, J. (2006) Wisdom about Age [Aging Electricity Infrastructure]. *IEEE Power and Energy Magazine*, **4**, 44-51. https://doi.org/10.1109/MPAE.2006.1632453

[21] Matse, N., Mashwama, N.X., Thwala, D. and Aigbavboa, C. (2022) A Theoretical Assessment of the Impacts of Poor Maintenance of Public Infrastructure. *IOP Conference Series*: *Materials Science and Engineering*, **1218**, Article ID: 012018. https://doi.org/10.1088/1757-899X/1218/1/012018

[22] Onime, F. and Adegboyega, G. (2014) Determination of Electric Power Losses in Distribution Systems: Ekpoma, Edo State, Nigeria as a Case Study. https://www.researchgate.net/publication/339101585_Determination_of_Electric_Power_Losses_in_Distribution_Systems_Ekpoma_Edo_State_Nigeria_as_a_Case_Study

[23] Energy Commission (2022) 2022 National Energy Statistics: Energy Statistics and Balances. https://www.energycom.gov.gh/files/2022%20Energy%20Statistics.pdf

[24] Public Utilities Regulatory Commission (2021) 2020 Public Utilities Regulatory Commission Annual Report. https://www.purc.com.gh/attachment/634752-20220401120438.pdf

[25] MRC Consultants and Transaction Advisers (2022) Electricity Tariff Setting Methodology and Tariff Structure in Ghana: Comparative Analysis of DisCos Performance. World Bank Group. https://www.purc.com.gh/attachment/229008-20220624020600.pdf

[26] Public Utilities Regulatory Commission (2020) 2019 Public Utilities Regulatory Commission Annual Report. https://www.purc.com.gh/attachment/515595-20210602120604.pdf

[27] Ciontea, C.I. and Iov, F. (2021) A Study of Load Imbalance Influence on Power Quality Assessment for Distribution Networks. *Electricity*, **2**, 77-90. https://doi.org/10.3390/electricity2010005

[28] Dzidzoamenu, I. (2022) E/R: Dozens of Electricity Poles Burnt in Bushfires—Starr Fm. https://starrfm.com.gh/2022/02/e-r-dozens-of-electricity-poles-burnt-in-bushfires

[29] Public Utilities Regulatory Commission (2018) Press Release: Third Quarter 2018 Electricity Tariff Decision Based on Automatic Adjustment Formula. https://www.purc.com.gh/attachment/778103-20201203031251.pdf

[30] Energy Commission (2020) 2020 Energy (Supply and Demand) Outlook for Ghana. http://www.energycom.gov.gh/planning/data-center/energy-outlook-for-ghana?download=76:energy-outlook-for-ghana-2018

[31] Public Utilities Regulatory Commission (2022) Press Release, 2022-2025 Multi-Year Major Tariff Review for Natural Gas, Electricity and Water Services. https://www.purc.com.gh/attachment/459725-20220816110856.pdf

[32] Public Utilities Regulatory Commission (2022) Publication of Electricity Tariffs. https://www.purc.com.gh/attachment/549840-20220902110951.pdf

[33] Ghana Broadcasting Corporation (2022) Energy Commission Warns against Use of Second-Hand Appliances. https://www.gbcghanaonline.com/general/energy-commission-warns-against-use-of-second-hand-appliances/2022

[34] Arthur Energy Advisors (2010) National Electrification Scheme (NES) Master Plan Review (2011-2020)—Draft Report. https://www.mida.gov.gh/pages/view/111/NES_Master_Plan_Review_Executive_Summary_Main_Report.pdf

[35] Energy Commission (2013) Ghana Electrical Wiring Certification Guidelines. http://energycom.gov.gh/files/GHANA%20ELECTRICAL%20WIRING%20CERTIFICATION%20GUIDELINES%20.pdf

[36] Energy Commission (2020) Register of Professionals & Inspectors. http://www.energycom.gov.gh/licensing/electrical-wiring/register-of-professionals-inspectors

[37] Addai, E.K., Tulashie, S.K., Annan, J.-S. and Yeboah, I. (2016) Trend of Fire Outbreaks in Ghana and Ways to Prevent These Incidents. *Safety and Health at Work*, **7**, 284-292. https://doi.org/10.1016/j.shaw.2016.02.004

[38] Energy Commission (2012) National Electricity Distribution Code, Republic of Ghana. http://www.energycom.gov.gh/files/NATIONAL%20ELECTRICITY%20DISTRIBUTION%20CODE-FINAL%20(May%202012)%20.pdf

[39] Energy Commission (2019) National Electricity Distribution Code. http://www.energycom.gov.gh/files/DISTRIBUTION-CODE-NATIONAL-ELECTRICITY-DISTRIBUTION-CODE.pdf

[40] Public Utilities Regulatory Commission (2020) Public Utilities Regulatory Commission (Consumer Services) Regulations, 2020. https://www.purc.com.gh/attachment/721760-20210305060329.pdf

[41] Rate Setting Guidelines for Electricity Distribution and Supply: Methodology, Volume II. 2018. https://www.purc.com.gh/attachment/932496-20201119111143.pdf

[42] Public Utilities Regulatory Commission, Ghana (2017) Rate Setting Guidelines for Electricity Distribution and Supply: Main, Volume I. https://www.purc.com.gh/attachment/438724-20201119111122.pdf

[43] Onyekwena, C. and Ishaku, J. (2017) Electrification in Nigeria: Challenges and Way Forward. 31. https://cseaafrica.org/wp-content/uploads/2017/10/Nigeria-CSEA-Electricity-Project_-1.pdf

[44] Okpare, A.O. and Okreghe, C.O. (2020) Power Energy Distribution and Consumption in Nigeria: The Way Forward for Sustainable Industrial and Commercial Development. *Nigerian Journal of Technology*, **39**, Article No. 3. https://doi.org/10.4314/njt.v39i3.27

[45] Jabir, H., The, J., Ishak, D. and Abunima, H. (2018) Impacts of Demand-Side Management on Electrical Power Systems: A Review. *Energies*, **11**, Article No. 1050. https://doi.org/10.3390/en11051050

[46] Energy Commission (2022) Report on the Enforcement of Energy Efficiency Legislative Instruments (1815, 1932 & 1958) at Ports of Entry (With Relevant Indicators/Statistics). http://www.energycom.gov.gh/files/REPORT%20ON%20THE%20ENFORCEMENT%20OF%20ENERGY%20EFFICIENCY%20LEGISLATIVE%20INSTRUMENTS%20(1815,%201932%20&%201958)%20AT%20PORTS%20OF%20ENTRY%20(With

%20Relevant%20IndicatorsStatistics).pdf

[47] Energy Commission (2021) Regulated Appliances Market Performance Report. http://www.energycom.gov.gh/files/Regulated%20Appliances%20Market%20Performance%20Report%20for%20Ghana%20-%202020.pdf

[48] Sudhakar, P., Malaji, S. and Sarvesh, B. (2018) Impacts of Embedded Generation on Distribution Network Behavior. *International Journal of Reconfigurable and Embedded Systems* (*IJRES*), **7**, 91-103. https://doi.org/10.11591/ijres.v7.i2.pp91-103

[49] Onyiengo, S.I. (2014) Effectiveness of Communication Media Used by the Public Relations Department in Facilitating Effective Internal Public Relations at the Kerio Valley Development Authority in Kenya. *International Journal of Humanities and Social Science*, **4**, 108-117.

[50] PURC Tariff Reckoner. https://www.purc.com.gh/categ/tariffs/subcategories/tariff-reckoner

List of Abbreviations

NEDCo—Northern Electricity Distribution Company;
ECG—Electricity Company of Ghana;
CFL—Compact Fluorescent Lamp;
PURC—Public Utilities Regulatory Commission;
EC—Energy Commission;
DSM—Demand Side Management;
VRA—Volta River Authority;
EPC—Enclave Power Company;
SAIFI—System Average Interruption Frequency Index;
SAIDI—System Average Interruption Frequency Index;
IBT—Incremental Block Tariff;
AAF—Automatic Adjustment Formula;
PWD—Public Works Department;
NED—Northern Electricity Department;
BPA—Bui Power Authority;
LV—Low Voltage;
SHEP—Self-Help Electrification Project;
ToU—Time-of-Use;
DSM—Demand Side Management.