



ENERGIZING AFRICA SUSTAINABLY: LESSONS FROM GHANA'S ELECTRICITY INFRASTRUCTURE



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ABSTRACT

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Africa's electricity infrastructure shortfall presents an opportunity for sustainable infrastructural investment. This paper assessed Africa's electricity infrastructure for sustainability, through a systems holistic model. To scale down the analytical procedure for specific country application, data was analyzed from Ghana, one of Africa's best examples of high achievements in access to electricity, tipped for universal access by 2030. The study found that Ghana's electricity infrastructure does not satisfy the requirements for environmental, economic and social sustainability. Electricity infrastructure in Ghana has been 453% more fossil fuel based than the recommended global requirement. Also, industry electricity tariffs have gone up by at least 276% since 2011, with worsening externality per capita due to investments in unsustainable electricity infrastructure. Thus, electricity infrastructure has worsened livelihoods in Africa, creating a disincentive for investment and failing to deliver sustainable development. African countries must re-examine their electricity infrastructure investments, not only by kilowatt-hours but also based on sustainability indicators, in order not to further aggravate poverty and deprivation on the continent.

Contribution/ Originality: This paper's primary contribution is finding that Africa's current investment in electricity infrastructure impedes sustainable electricity delivery. It demonstrates the superiority of the strong sustainability paradigm over the currently used weak sustainability paradigm, in determining the type of electricity infrastructure which can secure sustainable development for Africa.

1. INTRODUCTION

Africa's several developmental challenges appear largely connected to its lack of access to sustainable energy services, which depend to a large extent on sustainable energy infrastructure. The lack of access, afflicting about 620 million people has limited economic opportunities and created health and environmental risks, reducing the quality of life and human capital development (International Energy Agency (IEA), 2019; Sy & Copley, 2017).

In 2013 the estimated financing of the energy infrastructure needs in Africa was US\$ 8 billion while the needed funding was about US\$ 63 billion, creating a financing gap of about US\$ 55 billion (Africa Progress Panel (AAP), 2015) which means only about 13% of needed financing was realized. The current need for reliable and affordable electricity for all Africa implies an investment of over US\$100 billion per annum (International Energy Agency (IEA), 2019).

Even though some progress has been made globally over the past two decades, sub-Saharan Africa remains the only region in which the absolute number of people without access to electricity is increasing. Estimates show that

without major policy action and increased investment in the electricity sector, over 600 million people will be living without electricity in Sub-Saharan Africa in 2030 (International Energy Agency (IEA), 2017).

While the lack of electricity access in Africa is immense, it is surmountable. The existing financing gap notwithstanding, there exist deep-seated issues with the provision of electricity infrastructure in Africa. One of the main issues is the sustainability of such infrastructure. On a continent stressed by climate change, poverty and diminishing natural resources, compromising sustainable infrastructure would only spell doom for current and future generations. Sustainable infrastructure, in addition to enabling economic progress also enhances quality of life and helps to protect vital environmental and natural resources, eventually promoting a more efficient use of financial resources. Thus without putting in place sustainable electricity infrastructure, Africa will within a very short period require more external funding than it does today to fix its energy poverty, thereby creating more poverty.

1.1. Rationale for the Study

The global economy has been yearning for a recovery of economic growth alongside charting a sustainable development path, particularly by addressing the risks posed by climate change and the recent COVID-19 pandemic. Investment in sustainable infrastructure would be an important component of meeting this expectation. The need for such investment is all the more crucial given that the current stock of infrastructure is ageing in developed countries while in developing countries rapid urbanization and high population growth calls for urgent action in this direction.

Africa's energy shortfall, though a setback also represents an opportunity for sustainable infrastructure investment. The need for sustainable electricity in Africa, thrives within a global environment with ample means to provide a solution. This is against the background that the electricity deficit is hindering much needed economic development on the continent.

While investors would want to act quickly on African's electricity deficit, they also need to secure their investments so that while they help, they do not end up losing their investments.

While probably the most fascinating aspect of Africa's electricity infrastructure situation appears to be the financing needed, this paper seeks to address a deep-seated issue, which could render all the financing largely unworkable for current and future generations. It seeks to analyze the dynamics of the current electricity infrastructure set up and how they change in value, creating the need for greater funding each time. This will inform policy to ensure future electricity infrastructure investments would serve both current and future generations sustainably. This way, an avenue could be created to make electricity infrastructure work for Africa.

This paper sought to analyze the current dynamics of electricity infrastructure with respect to sustainable development in Africa. It aims at informing policy on how Africa can harness sustainable electricity infrastructure development and funding for total welfare improvement. To scale down the issues for individual country application, the study also specifically assesses Ghana's electricity infrastructure based on its service delivery for sustainable development. Ghana has been a leading African country in electricity access, tipped to be among the first to attain universal access by 2030 (International Energy Agency (IEA), 2019).

The following section presents pertinent conceptual and theoretical issues for sustainable electricity infrastructure. This is followed by an examination of the electricity infrastructure situation in Africa. A holistic model analysis of the Ghanaian situation comes next, followed by a discussion of the findings. The paper concludes by drawing lessons from the findings for energizing Africa sustainably.

2. SUSTAINABLE ELECTRICITY INFRASTRUCTURE

Electricity infrastructure which guarantees long term provision of productive electricity while significantly enhancing the social, economic and environmental well-being of people is sustainable. Such infrastructure will serve

the needs of both current and future generations, thus satisfying the intergenerational and intragenerational equity requirements for sustainability.

For electricity infrastructure to be sustainable, it must be socially, economically and environmentally sustainable. To be socially sustainable, it must be inclusive and respect human rights. Its design should be geared towards meeting the needs of the poor by increasing access, supporting poverty reduction, and reducing vulnerability to climate change. Economic sustainability of electricity infrastructure implies it provides jobs and helps boost national output. Such infrastructure does not burden governments with unpayable debt or consumers with high tariffs. To satisfy environmental sustainability, electricity infrastructure must mitigate carbon emissions and not aggravate local pollution during construction and operation and should contribute to the transition to a lower-carbon economy (Bhattacharya, Meltzer, Oppenheim, Qureshi, & Stern, 2016).

While it is desirable to have economic, social and environmental sustainability in any sustainable electricity infrastructure, the framework within which these three subsystems of sustainability exist will to a large extent determine how sustainable any infrastructural project will be, since sustainability is a systems concept. This means there will be feedback and reinforcing influences from each of the three subsystems and these must be smoothly assimilated without any distortion of the systems' harmony. Thus the institutional as well as cultural frameworks would determine the eventual outcomes generated by the system.

For instance, electricity infrastructure sustainability could result not only from the choice of energy from a renewable source but also from the reliability of energy supply networks and grids. It will also depend on the type of infrastructure, the local context and the enabling environment (Long Finance, 2015). Figure 1 illustrates the system within which sustainable electricity infrastructure operates.

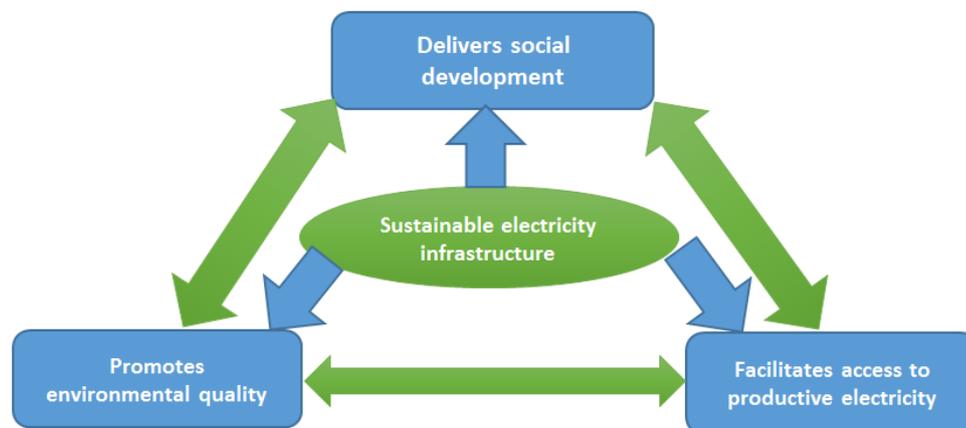


Figure-1. Sustainable electricity infrastructure system.

2.1. Weak Sustainability versus Strong Sustainability Paradigms

The concept of electricity infrastructure refers to electricity capital stock. Viewed this way, two paradigms of sustainable development will have to be considered carefully towards achieving sustainability; the weak and strong sustainability paradigms. To use the weak sustainability paradigm means to ensure that total electricity capital stock is passed on intact to future generations, irrespective of the composition of the electricity infrastructure which will be passed on. The strong sustainability paradigm however insists on the critical natural capital stock composition. Due to the arguments of imperfect substitutability between man-made and natural capital and the issue of irreversibility of loss of critical natural capital, it becomes evident that electricity infrastructure cannot be sustainable if its provision is based on the weak sustainability paradigm. Thus apart from what sustainable electricity infrastructure can do, what it is composed of must be a critical consideration to pass the sustainability test.

2.2. Theoretical basis for Sustainable Infrastructure

Generally, the literature on infrastructure identifies two main types – basic infrastructure and advanced infrastructure. Basic infrastructure refers to roads, electricity and basic telecommunication systems while advanced infrastructure consists of advanced information and communication technologies in general and high speed communication networks in particular (Agenor, Canuto, & Jelenic, 2012). The emphasis of this study is on basic infrastructure, which is what Africa needs urgently. Such basic infrastructure if acquired creates the environment for advanced infrastructure to be meaningfully acquired and utilized.

The stock of basic infrastructure which is generally public capital stock over time (t), can be expressed as

$$K(t+1) = (1 - \delta)K(t) + I(t) \quad (1)$$

Where $\delta \in (0, 1)$ is the real rate at which infrastructure depreciates. Also,

$$K(t + 1) = (1 - \delta)K(t) + \alpha I(t) \quad (2)$$

Where $\alpha \in (0,1)$ is the efficiency or governance indicator.

For infrastructure to be sustainable the most important consideration is the flow of services provided by the stock of public capital, $K(t+1)$ in Equation 1, not the flow of investment $I(t)$. This naturally does not agree with the weak sustainability paradigm which assumes perfect substitutability between man-made and natural capital, which it argues can happen through investment (Turner, Pearce, & Bateman, 1993). Thus once investment is not the most significant issue, with Equation 2, it is argued that the equation conforms with the strong sustainability paradigm where the public capital stock could deliver significantly sufficient services over a long period of time even to the next generation.

Thus irrespective of the stage of infrastructural achievement in an economy, it is possible to assess how sustainable current and future infrastructure could be. This is based on the flow of services and disservices from current infrastructure. Following the concept of sustainability, these flows are categorized into environmental, social and economic dimensions as discussed in the following section.

2.3. Sustainable Electricity Infrastructure and Welfare

Since electricity Infrastructure projects could have huge impact on the environment, some portion of the required infrastructure investment could be committed to making such investment sustainable, by ensuring lower emissions, higher efficiency and resilience to climate change. While this is an additional upfront cost, the net macroeconomic effect of these additional investments (Bhattacharya, Romani, & Stern, 2012). Standard & Poor's found that a 1% GDP increase in infrastructure spending could have a multiplier effect of between 1.0 and 2.5 for G20 countries over a three year period, with greater effect in developing countries (Standard & Poor's, 2015).

Sustainable electricity infrastructure is essential for poverty reduction and societal well-being since it enhances access to basic services and facilitates access to knowledge about work opportunities, thus boosting human capital and quality of life. Sustainable infrastructure helps to reduce poverty, generally improving well-being. For example, distributed renewable power in previously un-electrified rural areas can increase household income and improve gender equality by reducing time spent on household chores (Bhattacharya et al., 2016).

Sustainable electricity infrastructure enhances food security through more efficient resource use and reduces vulnerability. Bad electricity infrastructure can and does kill people on a large scale mainly via faulty services, accidents, and health service failures and puts pressure on resources to an extent that may compromise the viability of future generations and create unsustainable economic burdens in the future (Bhattacharya et al., 2016).

Thus the analytical framework of this study is based on the strong sustainability paradigm. This is the first of its kind downscaled for individual country application in Africa. The strong sustainability paradigm cannot be ignored for African analysis, since the alternative, the weak sustainability paradigm compromises the natural capital stock. This goes against Africa's welfare since about 70% of Africa's livelihoods depend mainly on natural resources. Thus any paradigm which compromises the natural capital stock also compromises the welfare of Africans. If the

natural capital stock gets compromised the any investment to depreciate it would have no sound theoretical basis, remaining highly uncertain.

Most of the current international frameworks for sustainable development unfortunately depend on the weak sustainability paradigm, making them unsuitable for Africa. For developed countries, it makes not much difference since their dependence on natural resources is rather low. The current international inclination towards the weak sustainability paradigm jeopardizes Africa's chances of having accurate assessments and evaluation towards welfare improvement. This paper departs from this trend by offering a strong sustainability paradigm based analysis.

3. ELECTRICITY INFRASTRUCTURE IN AFRICA

The World Bank (2017) estimates that two in three Africans, or about 600 million people, do not have access to electricity. Without electricity, health clinics struggle to provide basic services, children are unable to get a proper education, and businesses cannot grow and thrive in today's global economy. Even when there is electricity, the quality of supply is often poor. A majority of countries in Africa are still experiencing frequent power outages. This reality is at odds with the rising aspirations of the international community and national governments to reach every consumer with reliable, affordable, and sustainable energy solutions by 2030 (World Bank, 2017).

Stern, Burke, and Bruns (2017) noted the lack of success in Africa's electricity infrastructure endeavors. With only 35% of households having access to electricity in 2014 characterized by poor quality, the region was far below other regions of the world (International Energy Agency (IEA), 2016). This led the International Energy Agency (IEA) (2014) to argue that Africa's failure to attain significant development was due to an acute lack of essential electricity infrastructure. Foster and Briceño-Garmendia (2010) have argued that there was no infrastructure challenge greater than the electricity infrastructure issue in Africa. While electricity outages reduced the productivity of firms (Moyo, 2013) they also slowed down economic growth generally on the continent (Andersen & Dalgaard, 2013).

The top three Sub-Saharan African economies in terms of access to electricity, whose populations exceeded one million in 2014 were Gabon, South Africa and Ghana. Gabon had 89% access with poor quality supply and a limited coverage outside urban centers (Stern et al., 2017). South Africa had 86% access but produced insufficient electricity due to power outages, having a heavy toll on economic growth (International Monetary Fund, 2016; World Bank, 2016a). Ghana had 72% access in 2014, however, one of the most cited constraints to growth of the economy had been unreliable electricity supply, compelling 52% of enterprises to own or share a generator (International Monetary Fund, 2014; World Bank, 2016a, 2016b). Oyuke, Penar, and Howard (2016) argued that the real access to reliable electricity in Ghana was 42% in 2014.

The combined length of electricity transmission lines in 38 countries in Africa in 2017 was 112,196 kilometers (km). Brazil has a longer transmission network than Africa, at 125,640 km, and, at 257,000 km, the United States of America has more than twice the length of the African transmission network. Despite its large land mass, Africa also has fewer kilometers of transmission lines per capita than other regions. The length of transmission lines in Africa has been 247 km per million people. If South Africa is excluded, this indicator falls to 229 km per million people. In contrast, Colombia has 295km of transmission lines per million people, Peru has 339km, Brazil has 610km, Chile has 694km, and the United States has 807km (World Bank, 2017).

Africa has to a large extent relied on emergency electricity solutions for too long. Many African countries have always waited till the emergence of crisis, then they begin to seek immediate relief. Under such emergency conditions the temptation has always been to go for infrastructure not well assessed for sustainability. Providing electricity through emergency arrangements has a tendency to double the cost of electricity. The emergency measures usually lead to the installation of new capacity based on fossil fuel systems. The terms of such transactions have always not been favorable for the affected economies financially (Jarret, 2015).

The World Bank declared 32 of 48 nations on the continent to be in energy crisis (Yeboah, 2017). However, the applied solutions so far in Africa do not appear to thread paths of sustainable development. The next section reviews the situation of Ghana as a typical African electricity infrastructure investment example.

3.1. The Electricity Situation in Ghana

Ghana is reputed to be a leading African country in electricity access. Currently, the Energy Commission of Ghana (2020) reports an access to electricity of 85%, tipped to obtain universal access by 2030 (International Energy Agency (IEA), 2019). While installed electricity capacity in Ghana exceeds 4 GW, the actual availability of electricity has rarely surpassed 2,400 MW due to several factors including poor network infrastructure (ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), 2019). It is worth noting that fewer than 20% of firms and 50% of households reported having reliable access to electricity in national surveys (Blimpo & Cosgrove-Davies, 2019).

Ghana's energy situation over the past decade showcased the African condition in several forms, to the extent that the Ghanaian energy term "Dumsor" got documented in the 9th edition of the Oxford Advanced Learners English Dictionary. Dumsor, which emerged out of the peak of Ghana's energy crisis means persistent, irregular and unpredictable electric power outages. This provides a vivid description of what Ghana has been through, resulting in power rationing and leading to a loss of 5.6% of Gross Domestic Product (National Development Planning Commission (NDPC), 2014).

The problem of aging infrastructure contributed to inefficiencies in electricity production, causing the cost of supply of electricity to rise rapidly. For example, the World Bank (2013) noted that Ghana's transmission system was relatively old. This system was constructed in the 1970s and had since seen very little improvement. Also, about half of the country's 161-Kilovolts-transmission infrastructure was constructed in the 1960s, and was long past its recommended retirement age. Ghana's macroeconomic challenges however, could not allow it to find the necessary revenues for electricity infrastructure investment to ease the disruption due to over aged infrastructure.

The cycle of events in Ghana as well as how solutions have been worked out and how these relate to sustainable energy infrastructure provides useful lessons for the whole of Africa. In June 2017, Ghana's energy minister Boakye Agyarko, addressing the maiden Ghana Energy Summit in Accra, summed the outcome of almost one decade long experimented solutions by saying that the implementation of all the over 30 power purchase agreements which Ghana had to embark on to ease its energy crisis was going to cost the country annual extra capacity charges of nearly US\$700 million (Appiah-Adjei, 2017). Among the reforms the minister proposed a review of the over 30 power purchase agreements, placing a moratorium on others and refinancing of energy sector debts (Yeboah, 2017).

In 2015, the performance of the electricity subsector in Ghana was weak, with negative growth of the order of -10.2 percent. The considerable reduction in output of the subsector in 2015 was largely due to severe El Niño weather effect, which considerably reduced the output of the hydroelectric dams due to the reduced volumes of water in their catchment areas. For example, due to the reduced volume of water, only three of the six turbines at the Akosombo Dam were fully operational in 2015, resulting in a shortfall of about 450 MW in electricity production (Institute of Statistical Social and Economic Research (ISSER), 2016).

The government of Ghana undertook various measures to address the power challenges that confronted the industrial sector and the economy as a whole. A new Power Minister was appointed, who pledged to end the power crisis by the end of 2015. This pledge was largely achieved, with improvement in the energy production situation by the end of 2015 (Institute of Statistical Social and Economic Research (ISSER), 2016). During the year, work was completed on the 110 MW TICO expansion and also the 220 MW Kpone Thermal Power Project. The 360 MW Sunon Asogli expansion project was partially completed by the end of the year. The Volta River Authority (VRA) expanded its plant (49.5 MW) by adding 38 MW (Government of Ghana, 2015). Also, an emergency

offshore generation plant assembled in Turkey arrived in Ghana during the fourth quarter of 2015. The rush for emergency power systems shows how desperate the situation was for Ghana. The steps boosted generation capacity, eventually leading to a reported electricity access rate of 85%.

However, acquiring higher generation capacity appears to have deepened Ghana’s woes in delivering electricity sustainably. Currently, Ghana’s dependable power generation capacity of about 4,600 MW exceeds peak demand load by 70 percent. Under take-or-pay contracts with independent power producers (IPPs), Ghana pays about US\$500 million annually for unused power generation capacity. This excessive electricity supply was due to unplanned response to the 2014 energy crisis, when emergency power generation was contracted far above existing demand. Ghana has also contracted for the supply of 750 mmscf of gas per day by 2023 including the importation of large quantities of liquefied natural gas, while demand is projected to reach about 450 mmscf per day (International Monetary Fund (IMF), 2019).

4. METHOD OF STUDY

The study used official data on electricity generation from 10 thermal plants operating between 2010 and 2016 from the Volta River Authority (VRA), Ghana’s main producer of electricity. This was intended to down scale the analysis for easy country specific application. The labels of the VRA plants used were: CENIT ENERGY LTD., TICO UNIT1, TICO UNIT2, TTPP ST1 MOBILE, TTPP ST1 POWER, TTPP ST1 TWIN A, TTPP ST1 TWIN B, TTPS GT1, TTPS GT2 and VRA TEMA ST2. The study also used official reports from the VRA, Ghana Energy Commission, Electricity Company of Ghana (ECG), and Ghana Grid Company (GRIDCO).

It employs quantitative analysis within a systems holistic model framework (Figure 2), using sustainability indicators to assess Ghana’s electricity infrastructure, based on its service delivery.

It begins by identifying the sustainability subsystems taken into account within the set-up (Figure 2). This is followed by identifying indicators which show the extent to which sustainability is operational within the set-up, comprising of generation, transmission and distribution of electricity.

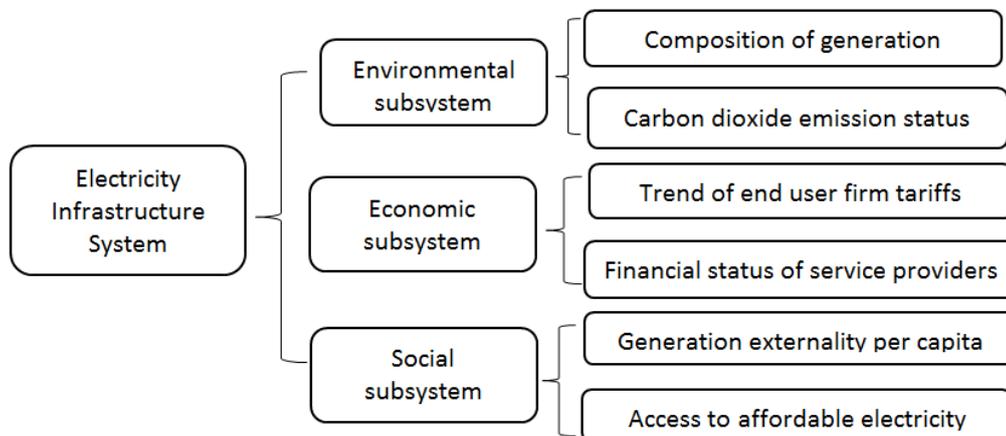


Figure-2. Holistic electricity infrastructure system framework.

4.1. Analytical Framework

Indicators used to ascertain environmental subsystem sustainability were carbon dioxide (CO₂) emissions and the structure of the composition of the sources of electricity. Indicators for the economic subsystem sustainability were the trend of end user tariffs and financial standing of the service providers in generation, transmission and distribution. Indicators for the social subsystem were the trend of the extent to which externalities per capita of electricity generation had improved and whether there had been improved access to affordable electricity.

Based on the assessed outcomes for each subsystem, a conclusion was drawn whether the particular subsystem sustainability requirement had been met. The eventual result was provided by an integration of the outcomes for all the subsystems.

5. RESULTS AND ANALYSIS

5.1. Environmental Subsystem

The environmental dimension for sustainable electricity infrastructure is to ensure the maintenance of the integrity of society's environment which is its life support system. Environmental goods and services must be used in such a way as to maintain the productivity of nature and the overall contribution of environmental goods and services to human welfare. The indicators used here were improvement towards cleaner composition of electricity generation sources and a lower carbon dioxide emission status [Figure 2](#).

5.1.1. Sources of Electricity

Following government interventions to ease Ghana's energy crisis, there had been a shift from hydroelectricity, which provided about 100% of Ghana's electricity before 1993 and over 90% before 1998. By 2016 the share of thermal sources was estimated at 70.33%, while hydroelectricity sources accounted for only 29.49% ([Energy Commission of Ghana, 2016](#)). [Table 1](#) and [Figure 3](#) illustrate the outcomes of the interventions in terms of electricity generation.

Table-1. Grid Electricity generation in Ghana (GWh) and Total Installed Generation Capacity (MW).

Source/ Year	Hydro Generation	Thermal Generation	Renewables Generation	Total Generation	Installed Capacity (MW)
2009	6877	2081	-	8958	1970
2010	6995	3171	-	10,166	2165
2011	7561	3639	-	11,200	2170
2012	8071	3953	-	12,024	2280
2013	8233	4635	3	12870	2831
2014	8387	4572	4	12,963	2831
2015	5844	5644	3	11,491	3656
2016	5561	7435	27	13,023	3795
2017	5616	8424	28	14,067	4398
2018	6017	10,195	33	16,245	4889
2019	7252	10,885	52	18,189	5171.6
% increase from 2009	5.5	423.1	-	103	162.5

[Table 1](#) shows a worsening composition of Ghana's electricity infrastructure in terms of cleaner sources of electricity generation. Thermal generation of electricity increased by 423.1% between 2009 and 2019, with renewable energy sources making up only 0.003% of the total generation of 18,189 GWh in 2019. Installed capacity, which was mainly fossil fuel based also increased by 162.5% between 2009 and 2019. Thus, increasingly, Ghana's sources of electricity generation are becoming fossil fuel based, with a high component of light crude oil, which is not only very dirty but also very expensive as compared to hydroelectricity.

To steer the energy sector toward sustainability, it is estimated that investments in fossil fuel based infrastructure must decrease by about one-third by 2030, while investments in renewable sources of electricity generation must increase by at least a similar proportion to comply with maintaining global average temperature increase less than 2°C ([Global Commission on the Economy and Climate, 2016](#)). Thus Ghana has deviated from decreasing fossil fuel based infrastructure by 453.1% with respect to the recommended sustainability requirement. Therefore, Ghana's electricity infrastructure misses the first sustainability indicator by moving from cleaner sources of generation to dirtier sources.

5.1.2. Carbon Dioxide (CO₂) Emissions

The 10 thermal plants of the VRA were also assessed on CO₂ emissions from 2010 to 2016. The outcomes are illustrated in [Table 2](#) and [Figure 4](#).

Table-2. CO₂ emissions and externality from power generated by 10 VRA thermal plants.

Year	Total Electric Power (GWh)	CO ₂ Emission (MtCO ₂)	Emission Factor (tCO ₂ /MWh)	Externality per capita (US\$)million
2010	3,270.5	2.616	0.8	7.94
2011	2,788.6	2.231	0.8	6.61
2012	3,435.6	2.749	0.8	7.96
2013	3,302.5	2.642	0.8	7.48
2014	3,635.4	2.908	0.8	8.08
2015	4,331.1	3.465	0.8	9.38

Since these plants generate electricity, following the standard conversion rate of 800gCO₂/kWh (International Energy Agency (IEA), 2010; IRENA, 2014) emissions computed due to the electricity generated by the 10 thermal plants increased from 2.616 MtCO₂ in 2010 to 3.465 MtCO₂ in 2015, an increase of about 32.5% with a rising trend as shown in Figure 3.

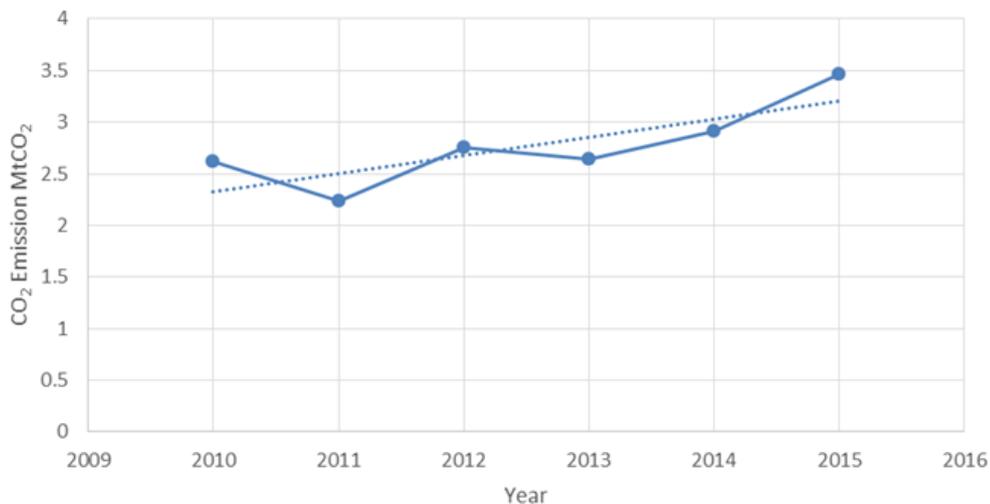
**Figure-3.** Trend of CO₂ emissions from 10 thermal plants of VRA.

Table 2 and Figure 3 show increasing trends in CO₂ emissions from the thermal plants, making the system not compliant with the CO₂ reduction requirement. Instead of CO₂ emissions from the plants decreasing by about 31% based on the global recommendation, these plants had increased emissions by 32.5%, creating a deficit of 63.5% within the study period. In 2009, Ghana's emission factor was 0.57 tCO₂/MWh but the thermal plants from 2010 brought in 0.8 tCO₂/MWh, showing a greater carbon intensity regime of electricity generation by over 40%.

It is also worth noting that between 1990 and 2016 Africa increased its CO₂ emissions per head by 12.6%, while Ghana increased its CO₂ emissions per head by 160.3% in the same period (International Energy Agency (IEA), 2018). Here, Ghana misses the CO₂ emission requirement for sustainable electricity infrastructure. These indicators show the extent to which Ghana's electricity infrastructure does not satisfy the environmental sustainability requirement.

5.2. Economic Subsystem

The economic dimension of sustainable development is supposed to determine whether the operation of electricity infrastructure will help generate a steady stream of income as they are used in the electricity industry. This assessment provides understanding of the degree to which electricity infrastructure will cause economic institutions to strengthen long-term productive capacity, diversify the economic base and enhance the ability to internalize externalities.

Indicators assessed for the economic subsystem were the trend of end user tariffs and the financial standing of electricity service providers. These service providers are mainly the Volta River Authority (VRA) for generation, Ghana Grid Company (GRIDCO) for transmission and the Electricity Company of Ghana (ECG) for distribution.

5.2.1. Trend in End User Tariff

The Energy Commission of Ghana argued that electricity tariffs moved Ghana from a low grid tariff to a very high grid tariff country in Africa. This was based on the classification where low tariffs were 2-9 US cents/kWh, with medium, high and very high tariffs being 10-15 cents/kWh, 18-25 US cents/kWh and 26-35 US cents/kWh respectively. This reduced grid power consumption particularly among commercial, services and industrial customers who were the wealth creation sectors, with negative effects on economic growth (Energy Commission of Ghana, 2016).

According to the Energy Commission, most heavy industries, including the mines require on average tariffs less than 6 US cents per kWh to stay competitive with similar products imported. Light industries could go as high as 10 US cents per kWh to survive (Energy Commission of Ghana, 2016). Thus the current energy tariffs for industries ranging from 15 – 48 US cents per kWh, excluding service charges are on the very high side (Energy Commission of Ghana, 2020). ECOWAS Centre for Renewable Energy and Energy Efficiency (ECEEE) (2019) found that Ghana's commercial electricity consumers paid one of the highest tariffs in the West African region. Since 2011, low voltage non-residential consumers' tariffs had risen by 276%, while high voltage non-residential tariffs had gone up by 321% (Energy Commission of Ghana, 2020).

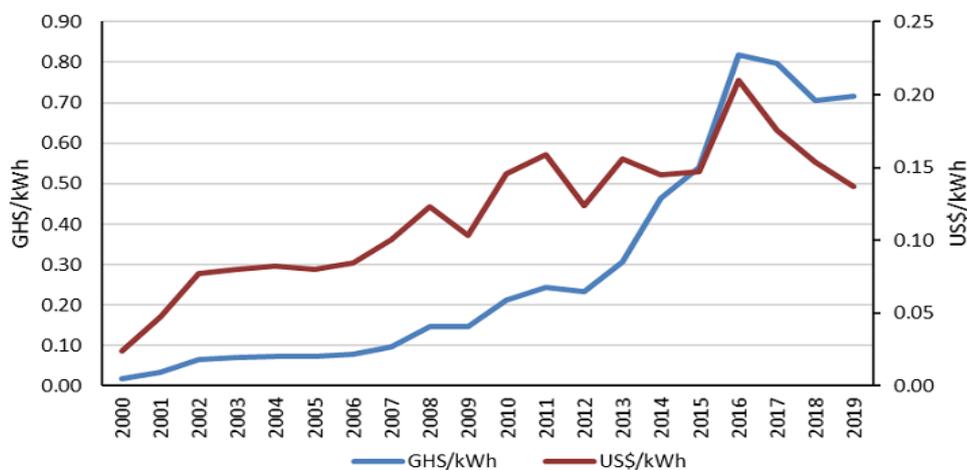


Figure-4. Trend of average end user electricity tariffs in Ghana.
Source: Energy Commission of Ghana (2020).

Under such circumstances, it becomes cheaper for firms to run their own diesel alternative if available and convenient. The situation made some service sector consumers to switch to their backup diesel generators (Energy Commission of Ghana, 2016).

Figure 4 shows a rising trend in end user tariff which the Ghana Energy Commission confirmed moved Ghana from the low tariff to the very high tariff regime, creating uncertain consequences for firms and the economy as a whole. Such a trend is not in line with economic sustainability, since it leads to lower returns to firms and also increases CO₂ emissions due to the switch by firms to their private diesel generation plants. The tariff reduction between 2016 and 2019 in Figure 4 being nominal, since it was the increase due to the rising exchange rate which was effectively absorbed by government, had no significant benefit. This is shown by the fact that the cedi tariff rate beyond 2016 consistently rose above the US dollar tariff rate.

5.2.2. Financial Standing of Electricity Service Providers

A careful examination of annual reports of Ghana's main electricity service providers revealed their very deplorable financial standing. It was found that the VRA and ECG were consistently making losses. The Ghana Grid Company (GRIDCO) made a loss in 2014 but recovered in 2015 and yet still had some funding difficulties which had delayed planned transmission projects.

5.2.2.1. The Volta River Authority (VRA)

The Volta River Authority incurred a net loss for the year ended 31 December 2015 of GH¢1,357million (In 2014, the loss was GH¢996million) and at that date, its current liabilities exceeded its current assets by GH¢1,206million (2014: GH¢433million). The Authority continues to make losses and is unable to settle all its liabilities with available funds.

The continued viability of the Authority is dependent on injection of additional funds by way of debt and aggressive pursuit and recovery of receivables to enable it to operate and generate the necessary cash flows to meet its liabilities as and when they fall due (Volta River Authority (VRA), 2016).

The directors of VRA in conjunction with the Public Utility Regulatory Commission (PURC) were also said to be negotiating with a funding agency to raise a total amount of US\$2 billion to clear the net inter utility debt amongst the players in the power sector, which includes the VRA.

Once that was concluded, all the exposures of VRA up to June 30, 2016 were to be paid and VRA financials restored to normalcy. However, there was going to be a hanging debt, which will get paid eventually by electricity consumers. This is certainly a drag on the welfare of citizens and general economic progress of Ghana's electricity sector.

5.2.2.2. The Electricity Company of Ghana (ECG)

The inadequate power supply to all categories of the ECG's customers in the peak of Ghana's energy crisis affected their corporate image and client confidence. This situation affected the revenue collection performance as customers were unwilling to pay for their power consumption.

At the end of 2014, ECG recorded a loss after tax of GH¢146.70million. This was however improvement over the performance of 2013, which recorded a loss after tax of GH¢206.25 million. Increasing finance cost is one major challenge the company faces. ECG recorded a finance cost of GH¢178.45 million in 2014. In addition, the company recorded some foreign exchange fluctuation losses through power purchases from mainly the Independent Power Producers (IPPs). The issue of foreign exchange fluctuation losses has persisted over the years recording worse performances year after year (Electricity Company of Ghana (ECG), 2016).

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2019) found that the ECG was not financially viable, making Ghana's electricity sector highly dependent on foreign assistance, while improvements had not been forthcoming regarding the quality of electricity supply.

5.2.2.3. The Financial Dilemma

Power sector arrears in Ghana were about US\$2.7 billion in late 2018, of which US\$800 million was owed to private fuel suppliers and independent power producers (IPPs). For 2019, the authorities projected the financing shortfall for the sector to be at least US\$1 billion (1.5 percent of GDP), which they planned to partially finance off budget. The sector's accumulated cost to the government, including current arrears, have been estimated to reach US\$12.5 billion by 2023, driven by a power sector structural deficit and costly liquefied natural gas (LNG) contracts set to become effective in 2020 (International Monetary Fund (IMF), 2019).

The Government of Ghana established an Energy Sector Recovery Program (ESRP) to provide direction on the way out of the current predicament. The ESRP comes along with other arrangements to improve the energy

sector's finances and operations. The government issued bonds through a special purpose vehicle (ESLA plc) to clear some of the state owned enterprises (SOE) legacy debts to its creditors. In March, Power Distribution Service (PDS), a private firm, took over ECG's distribution activities under a concession agreement. This was aimed at improving collections and reducing losses. However, the government terminated the agreement in October 2019 citing fraud (International Monetary Fund (IMF), 2019).

An International Monetary Fund (IMF) (2019) assessment revealed that the core electricity SOEs had generated a negative average return on equity since 2014. Suppliers to the ECG could on average only hope to receive payments after one year. In addition, the time spent by ECG to collect due bills from its customers had increased to more than 200 days. In March 2018 the government reduced electricity tariffs up to about 30%, which aggravated the financial difficulties and fiscal risks of these firms (International Monetary Fund (IMF), 2019).

These institutions constitute the economic backbone of electricity infrastructure in Ghana. They will have to generate the means of acquiring public capital in the sector. If they remain highly indebted and will consistently need government bailouts, then they fail to generate value and hence cannot maintain themselves much more generate resources for investment. Thus from the economic dimension, lower welfare will be generated through electricity infrastructure in Ghana. This is because; the losses accumulated by the main service providers tend to result in higher tariffs and substandard services, reducing well-being. Therefore Ghana's electricity infrastructure does not satisfy the economic sustainability requirement.

Mismanagement of resources and investments has led to considerable waste of public resources and an accumulation of huge debts in Africa. In 2010 for instance, sub-Saharan Africa's energy utilities were operating with deficits estimated at 1.4 percent of regional GDP, some US\$11.7bn. The deficit was equivalent to five times the level of publicly funded investment in the energy sector (Jarret, 2015).

The International Monetary Fund (IMF) (2019) found that electricity service providers in sub-Saharan Africa had excessively high transmission and distribution losses. In addition to low tariffs, which have very low rates of collection, these firms remain generally cash constrained weakening their capacity to raise funds. Kojima (2016) found that in sub-Saharan Africa only about 49% of utility service providers (19 out of 39) received revenues that were enough to cater for operational costs. In addition, only 10% of these firms recovered about 50% of their expenditure on capital (Kojima, 2016). Since these service providers need to partner private investors to raise the needed funding, such precarious financial records make African electricity service providers unattractive to investors who usually have doubts about future payments, and sometimes leads to excessively high lending rates (International Monetary Fund (IMF), 2019). Certainly, this has negative implications for the economic sustainability of Africa's electricity infrastructure.

5.3. The Social Subsystem

The social dimension of sustainable development thrives on equity. The indicators here need to ascertain whether electricity infrastructure provides all citizens the opportunity to have equitable access to minimum standards of security, human rights and social benefits. The indicators for the social subsystem used were the trend of external cost of electricity generation per capita and the extent of improved access to productive and affordable electricity.

5.3.1. External Cost of Electricity Infrastructure

The computation of external cost due to thermal generation of electricity derives from Jacobson and Delucchi (2011) who established that the external cost of producing electricity through the conventional thermal means was 6 cents per kilowatt-hour. This was used to compute the externality that corresponded with the electricity generated by the 10 VRA plants in Table 2.

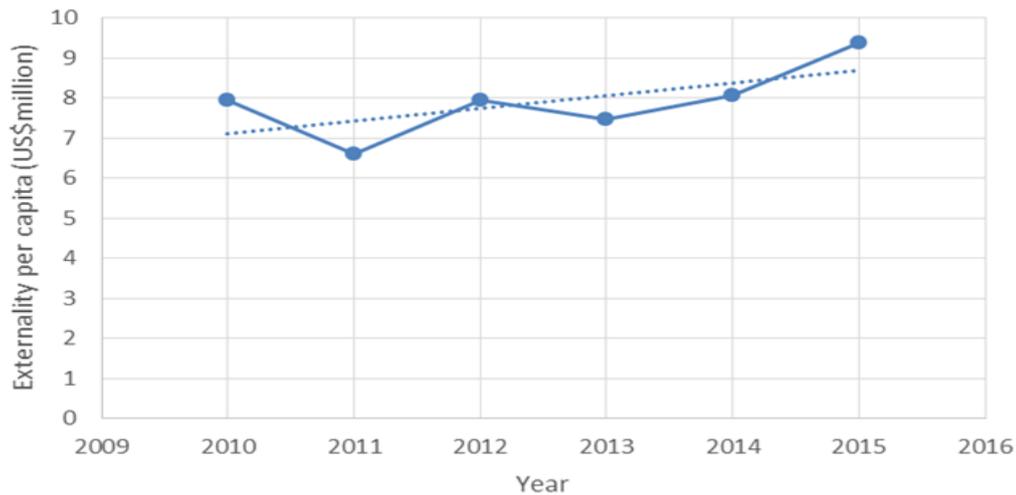


Figure-5. Trend of externality from VRA thermal plants.

The trend of externality data from Table 2 is presented graphically in Figure 5. The trend shows that the externality from electricity infrastructure has been on the increase, thereby rendering the vulnerable more vulnerable. Specifically, the externality per capita from electricity generation from the 10 thermal plants increased from US\$7.94 million per annum to US\$9.38 million per annum between 2010 and 2015. Thus the loss to society through the increase in thermal electricity generation had gone up from US\$7.94 million per capita in 2010 to US\$9.38 per capita in 2015, with no sign of abating. It should be noted that the externality per capita is not all borne by the individual, since the environment through which the externality is suffered is a global public good, serving to transmit the cost globally. However, based on Ghana's population, the values become the contribution per capita to the global externality from unsustainable electricity infrastructure in Ghana. This trend highly violates the social sustainability requirement, making Ghanaians and all other inhabitants of the world socially worse off.

5.3.2. Social Acceptability of Electricity Tariffs

In terms of the social acceptability of electricity tariffs, the move of Ghana from a low tariff regime to a higher one, created uncertainties for businesses and the economy as a whole. Such uncertainties trigger fears which cause anxiety and eventually hurt the economy further, thereby putting the vulnerable in society at risk of job or income losses. In addition, residential tariffs had gone up by over 590% between 2006 and 2015 (Energy Commission of Ghana, 2016) while incomes in the period had only increased by about 250%. Even in recent times, between 2009 and 2019, average electricity tariffs have gone up by over 380% (Energy Commission of Ghana, 2020).

There were some street protests in the past which compelled government to introduce further subsidies for lifeline electricity consumers as a result of tariff increases, showing that the tariffs were not socially acceptable, as the Energy Commission of Ghana. (2016) had feared. Thus, based on increasing negative externality per capita due to electricity generation and the social burden caused by excessively high tariffs, Ghana's electricity infrastructure does not satisfy the social sustainability requirement.

6. DISCUSSION OF FINDINGS AND POLICY IMPLICATIONS

On all counts, electricity infrastructure as exists in Ghana does not meet sustainable development standards. This study found a 453% deviation of electricity infrastructure from the standard global requirement for environmental sustainability. Electricity infrastructure which is increasingly dependent on fossil fuel is self-limiting, and does not respond favorably to the global effort to mitigate climate change through the use of cleaner energy sources. The benefits of current research reveal that renewable energy sources have become cost

competitive compared to fossil fuel sources (IRENA, 2020). Given Africa's endowment of vast renewable energy sources like solar energy and several potential small hydroelectricity generation sites, it would be prudent for decision makers on the continent to begin to invest in renewable energy infrastructure rather than fossil fuel infrastructure. Being a net importer of crude oil, Ghana in 2016 for instance, needed about US\$ 1.18 billion to purchase fuel to power its thermal plants for electricity generation. The cost of fuel and equipment, external costs, as well as exchange rate fluctuations and their attendant complications do not make the increasing dependence on fossil fuels an efficient alternative, given the presence of sustainable backstop technology.

Also, the increasingly high end user tariffs for electricity renders business endeavors in Ghana relatively uncompetitive globally. Basic industrial tariffs increased by 276% to 321% from 2011 to 2019, affecting cost of production of firms significantly. This has the tendency to dampen output since cheap products from abroad could kill local industry, resulting in high levels of unemployment and reduced welfare. The switch of some industrial users of electricity to private diesel generators due to excessive tariffs would worsen the CO₂ emissions and render the national grid generation capacity already acquired idle, causing further financial loss to the distressed state service providers. This gives the impression that real industry tariffs will need to be brought down considerably to achieve economic sustainability.

The precarious financial condition of Ghana's public electricity generation, transmission and distribution institutions makes energy infrastructure planning and execution highly unsustainable. If these firms cannot meet their costs of operating, then how can they find the needed resources for investment? This makes planning for infrastructural development very difficult and full of uncertainty. At the continental level also, there have been some consistent failures. As a result of electricity sector management difficulties Africa has been losing about \$8.2bn yearly. Political expediency has compelled some utilities to sell electricity at tariffs lower than their production cost, rendering them incapable of raising enough revenues to function effectively and invest in infrastructure (Jarret, 2015).

The over dependence of electricity firms on central government appears to be an issue for Africa. African governments have generally been in financial difficulties in recent times. Raw material exports which most of them have depended heavily on are no longer doing well on the international market. This is bound to affect any firm which depends mainly on central government even for debt repayment. The earlier these firms are weaned off government funding, the better it will be for Africa's electricity sector. Transforming utilities, improving the overall governance of the electricity sector and changing wasteful utility practices will be required. In many countries on the continent, electricity utilities have become nexuses for political patronage and corruption. Many of these are now not seen as means for delivering affordable electricity for all, but as rent seeking avenues (Jarret, 2015).

Overlooking the external cost of electricity infrastructure has been one of the greatest omissions of electricity service institutions. This is because it compromises the health and welfare of the people. Increasing externality per capita renders the country less safe for healthy living.

The rush for acclamation for achieving universal access to electricity in Africa has been one of the most deceptive attractions towards investments that yield unsustainable electricity infrastructure. Many governments compete to be seen to have given their people more access to electricity for political advantage. Hence, the rush to enter into any agreement that promises some attractive kilowatt hours of electricity irrespective of its sustainability status.

As much as possible electricity service authorities in Africa will have to seek the welfare of their country above all populist considerations. They will have to ensure due diligence is done in adhering to sustainability standards to save their countries from loss of resources and welfare due to opting for unsustainable electricity infrastructure. A mere high access to electricity based on unsustainable infrastructure constitutes a waste of resources leading to a loss in social, economic and environmental welfare.

7. CONCLUSION

Sustainable energy infrastructure is a must for Africa, to find its way out of poverty to make use of its vast resource endowments. This study sought to assess the sustainability of electricity infrastructure in Africa. To scale down the issues for individual country application, it also examined specific data from Ghana, one of the countries on the continent known to have made much efforts to stabilize a devastating energy crisis, mainly through infrastructure spending (Jarret, 2015). Ghana also happens to be among the top African countries with the highest access to electricity and is tipped to obtain universal access by 2030.

The study found that Ghana's electricity infrastructure does not satisfy the requirements for environmental, economic and social sustainability. Electricity infrastructure in Ghana is 453% more fossil fuel based than the recommended global requirement. Also, industry electricity tariffs have gone up by at least 276% since 2011 with worsening externality per capita due to investments in unsustainable electricity infrastructure. This shows that increasing generation to attain statistical electricity access could worsen welfare in Africa.

The investments made by Ghana, though regrettable, can provide some immediate relief for better planning and urgent execution of sustainable electricity infrastructure. The combined effect of excessive generation capacity and inefficient allocation of electricity has begun showing in the form of constrained economic welfare. Even the much dreaded frequent power outages appear to be gradually showing up occasionally.

Thus the reactive policy making tendency in Africa's electricity sector must give way to a well-thought out sustainable development induced policy framework. This means a purposeful departure from the weak sustainability paradigm which approves of Ghana's approach, to a strong sustainability paradigm which yields sustainable electricity infrastructure.

African countries may invest in electricity infrastructure, but only investments which are in accordance with the strong sustainability paradigm will achieve sustainable electricity infrastructure for Africa.

African countries will need to re-examine their electricity infrastructure with respect to sustainability indicators in order not to further aggravate poverty and deprivation on the continent. Electricity infrastructure which is not sustainable will worsen the plight of Africa. This is because, it will use up scarce resources which have alternative uses and yet not deliver what is socially, environmentally and economically optimal.

Therefore in seeking to increase kilowatt-hours and make a name for attaining universal access to electricity, African governments must not lose sight of sustainability. This will be the most reliable way to secure electricity infrastructure investments for welfare improvement in Africa.

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