ACHEAMPONG, T., MENYEH, B. and AGBEVIVI, D.E. 2021. Ghana's changing electricity supply mix and tariff pricing regime: implications for the energy trilemma. *Oil, gas and energy law* (OGEL) [online], 19(3), pages 1-28. Available from: https://www.ogel.org/article.asp?key=3974

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ACHEAMPONG, T., MENYEH, B. and AGBEVIVI, D.E.

2021

www.ogel.org

ISSN : 1875-418X
Issue : Vol. 19 - issue 3
Published : May 2021

This paper is part of the OGEL Special Issue on *"Review of the Energy Sector in Ghana"*

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by T. Acheampong, B. Menyeh, and D.E. Agbevivi

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Ghana's Changing Electricity Supply Mix and Tariff Pricing Regime: Implications for the Energy Trilemma

Theophilus Acheampong[*], Bridget Okyerebea Menyeh[**], Doris Edem Agbevivi[***]

Abstract

This article reviews recent developments in Ghana's electricity market, examining regulatory structures, consumption trends and tariff pricing. It further assesses the implications of the country's changing generation mix from hydroelectric to thermal power production on the energy trilemma: that is, energy security, energy equity, and environmental sustainability. Our findings show that thermal generation will continue to form the backbone of Ghana's electricity mix over the next ten years (2021-2030), driven by recent increments in thermal supply. This success in generation security, evidenced by excess grid capacity, has been by virtue of government's strong policy focus since 2015 on meeting current and future demand. Nonetheless, our analysis shows energy security in the Ghanaian context is often viewed as being about power generation and not one that encompasses the entire value chain. So, although there is excess grid capacity, there is lack of investment in distribution infrastructure, evidenced by the persistent 25% losses of all power purchased compared to a Sub-Saharan African average of 12%. This increases susceptibility to persistent power outages, which is a major energy security issue that needs addressing. Furthermore, despite the considerable 85% improvement in access in terms of grid connection, the electricity tariff structure masks inefficiencies in the distribution system by offloading the price burden on to some consumer categories while also creating unintended consequences of unpaid bills and electricity theft. Finally, at a sub-regional level, a comparison of electricity tariffs with some neighbouring West African countries shows that the cost of power in Ghana remains relatively expensive, especially for industry. This can negatively impact the country's competitiveness given that cheaper power is a critical determinant in attracting both domestic capital and FDI inflows and meeting SDG Goals 7 and 13, especially modern energy services.

1. Introduction

Ghana's rapid economic expansion since 2010 has been driven by the development of the country's oil and gas industry and expansion of the services sector of the economy, which now constitutes about 50% of economic activity measured by GDP. This development has been catalysed by rising electricity demand, which is estimated to be growing at 7-10% per annum since 2010, based on Ghana Energy Commission statistics. For example, in 2019, Ghana recorded a 10.2% year-on-year increment in peak demand at 2,613 megawatts (MW) compared to 2018.[1] In line with the established energy-economic growth nexus literature, Ghana's economic development is directly linked to the reliable provision of electricity.

[*] Aberdeen Centre for Research in Energy Economics and Finance (ACREEF), University of Aberdeen, United Kingdom. Corresponding author: Email: theophilus.acheampong@abdn.ac.uk
[**] Modern Energy Cooking Services Programme, School of Social Sciences and Humanities, Loughborough University, UK.
[***] Energy Commission, Accra, Ghana.
[1] Ghana Energy Commission (2020). Energy Outlook for Ghana. Available at http://energycom.gov.gh/planning/data-center/energy-outlook-for-ghana?download=105:energy-outlook-for-

However, access to reliable power has consistently been identified as one of the most significant constraints to business activities in Ghana. It is estimated that Ghana lost about 1.8-2% of GDP during the 2007 and 2014-2016 power crisis.[2] Ghana loses between 2-6% of GDP annually due to insufficient wholesale power supply, not including several indirect costs.[3] Similarly, estimates also show that the cost of generating power can account for over 30% of total firm production costs in some Sub-Saharan African countries, and average losses due to electrical outages can also account for 16% of total annual sales.[4] This multiplier can be considerably larger for micro, small and medium-sized enterprises, which provides over two-thirds of all jobs.[5]

Hence, inadequate power supply negatively affects business operations, forcing companies in several sectors to reduce output and eliminate jobs as part of cost-cutting measures. Other consequences of the lack of electricity include high unemployment, increased crime, and the general despondency of the populace, resulting in anti-government unrests.[6] It can also result in Ghana becoming uncompetitive within the West African sub-region, reducing investment destination attractiveness, especially as a manufacturing hub.[7]

Ghana has historically been highly dependent on hydroelectric power from the Akosombo Dam to provide base generation capacity until erratic rainfall patterns starting the mid-1980s to date caused a fundamental shift in energy policy. Policy advances since the 1990s have been geared towards the development of thermal energy to boost generation capacity and energy security. The Government of Ghana has contracted several independent power producers (IPPs) under a public private partnership (PPP) model to build and operate thermal plants to add to the existing power generation sources. These thermal plants operate on single or dual cycle combustion mechanisms, using both light crude oil, heavy fuel oil or natural gas.

Following years of inadequate natural gas supplies, Ghana initiated steps to develop new supply sources to support local demand growth for electricity generation and domestic consumption. The discovery of significant gas resources since 2007 changed gas supply dynamics, prompting Ghana's policymakers to consider utilising these gas resources to fast-track inclusive economic growth and development. At the same time, some small-scale

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ghana-2020-final-draft (Accessed: 1 March 2021); Acheampong, T., & Ankrah, F. (2014). Pricing and deregulation of the energy sector in Ghana: challenges and prospects. Ghana Energy Situation Report, Q1 2014.

[2] Ackah, C (2015). "Electricity Insecurity and its impact on Micro and Small Businesses in Ghana". Presentation at
Institute of Statistical Social and Economic Research (ISSER), University of Ghana.

[3] Power Systems Energy Consulting (2010). "Ghana Wholesale Power Reliability Assessment". Available at: http://www.ecowrex.org/system/files/repository/2010_ghana-wholesale-power-reliability-assessment-gridco.pdf (Accessed: 3 September 2020)

[4] Jewell, M. (2006). Connecting the Dots: Wasted Energy Everywhere. Energy & Power Management, 8; Arlet, J. (2017, March). Electricity Tariffs, Power Outages and Firm Performance: A Comparative Analysis. In *Proceedings of the DECRG Kuala Lumpur Seminar Series, Kuala Lumpur, Malaysia* (Vol. 23).

[5] Oversees Development Institute (2014). "Electricity insecurity and SMEs". Available at https://assets.publishing.service.gov.uk/media/57a089e1ed915d622c000441/61270-Electricity-Insecurity-Briefing-170914.pdf (Accessed: 3 September 2020); Scott, A., Darko, E., Lemma, A., & Rud, J. P. (2014). How does electricity insecurity affect businesses in low- and middle-income countries. Shaping Policy for Development, 1-80.

[6] Acheampong, & Barkers-Okwan, A. (2015). "Ghana: Economic Policy & 2015 Outlook Report". Available at: https://ghanatalksbusiness.com/wp-content/uploads/2015/05/Ghana-and-the-IMF_Africa-Economics-Report_Final.pdf (Accessed: 3 October 2020).

[7] Acheampong, T., 2016. The implications of changing power generation mix on energy pricing and security in Ghana. *Available at SSRN 2763284*.

renewable energy projects were championed and brought on-stream to diversify the generation mix further. As a result of all these actions, including the relatively high electricity tariff for non-residential and industrial users (prompting the installation of more cost-effective alternative or back-up generation), the country is currently at a stage where there is more than enough supply to meet demand. This raises a fundamental question: how has the switch from hydroelectric power to thermal power impacted energy security, energy equity (access), and environmental sustainability of Ghana's energy systems? How will the interplay of global and local factors impact the development of Ghana electricity markets, including the challenges and risks for potential investors and host governments?

For many countries, including Ghana, the test of a healthy and viable energy system rests on the ability to balance the often-competing dimensions of the Energy Trilemma, namely energy security, energy equity (poverty) and environmental sustainability (climate change mitigation). Balancing these dimensions is often a challenge for governments but getting it right signals an energy system that is robust and fair to the population and the environment.[8] In this context, energy security means the "management of primary energy (electricity) supply from domestic and external sources, reliability of energy (electricity) infrastructure, ability to meet current and future demand"[9]; energy equity (access) means "affordability of energy (electricity) supply across the population"[10] driven by the underlying need for electrification and industrialisation; and environmental sustainability means "the reduction in energy and CO2 intensity" driven by the transition to renewable and low-carbon energy (electricity) sources".[11]

Against this background, this paper analyses the implications of this changing power generation mix for electricity pricing in Ghana considering new capacity additions to the generation mix and tariff pricing structure. The paper makes the following contributions to the literature: firstly, it reviews Ghana's electricity and gas markets, examining the market structure and generation, capacity and consumption trends, as well as the institutional and regulatory structure and competitive landscape. Secondly, the paper assesses the conditions needed to ensure the success of developing the country's electricity and gas markets by identifying contextually relevant in-country issues that need addressing. This includes critical issues related to financing and the role of the state in providing regulatory certainty. Others include the choice of the tariff pricing mechanism, including contractual commitments in securing domestic gas and electricity off-takers, thereby improving project profitability.

The remainder of the paper is structured as follows: Section 2 reviews electricity production and consumption trends in Ghana, highlighting the change from hydroelectric to thermal generation and consumption patterns driven by elasticities of demand and supply. This is followed by Section 3, which analyses electricity tariffs in Ghana at a component level. Section 4 critically discusses how the changing power mix impacts energy security, energy equity and environmental sustainability. Section 5 summarises the paper by providing conclusions and implications for Ghana's energy market.

[8] Heffron, R.J., McCauley, D. and de Rubens, G.Z., 2018. Balancing the energy trilemma through the Energy Justice Metric. Applied energy, 229, pp.1191-1201.
[9] World Energy Council (2020). World Energy Trilemma Index. Available at: https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-index (Accessed: 4 October 2020).
[10] ibid
[11] ibid

2. Characteristics of Ghana's Electricity sector

2.1 Electricity market reforms in Sub-Saharan Africa

In line with developments in other emerging markets, SSA countries have started to unbundle (decouple) their mostly vertically integrated electricity utilities as part of more comprehensive structural adjustment and economic transformation policies. This follows years of poor financial and technical performance of their power sectors. Such unbundling aims to primarily introduce competition by allowing for private sector participation (via IPPs or joint ventures) and creating independent regulators. Over the past thirty years, the outcome of such reform programmes has been a hybrid market with the co-existence of public-private investments.[12]

In line with the above, several African countries such as Namibia, Nigeria, South Africa, Mozambique, Ethiopia and Ghana, have unbundled their power sectors in various ways by decoupling generation (G), transmission (T) and distribution (D) as indicated in Figure 1. Nonetheless, some countries still have state-owned and vertically integrated utilities with no private sector participation. There were 21 such countries on the continent as of 2014, although these are mostly smaller countries in population size.[13] All the more significant markets like Nigeria, South Africa and Ghana have vertically integrated state-owned utilities participating at the generation level in addition to IPPs. At the same time, transmission infrastructure is often state-owned due to its natural monopoly status.

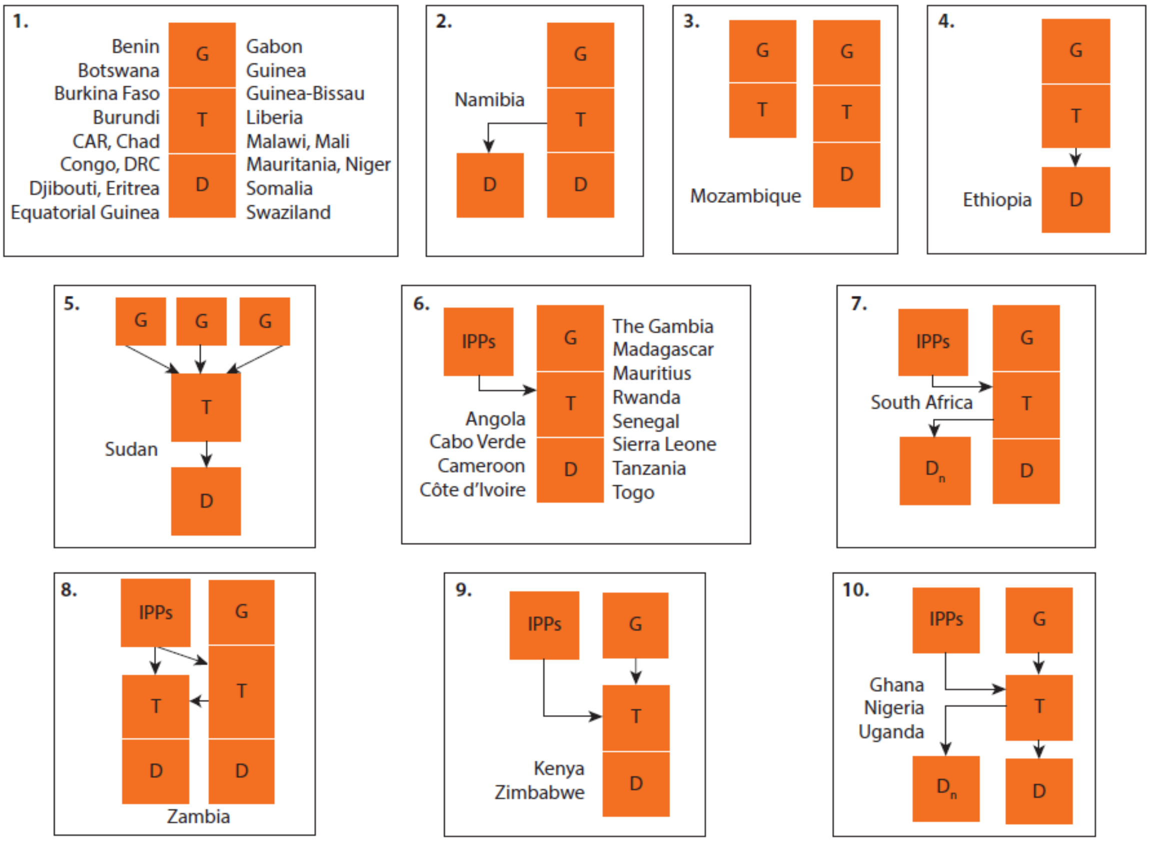
Some of the key policy tools that have been used to support the development of IPPs in the power mix include streamlining procurement and contracting processes, ensuring the financial health of distribution (end-user) off-taker utilities and planning the expansion of least-cost generation based on a merit-order dispatch model.[14]

[12] Fritsch, J. and Poudineh, R., 2016. Gas-to-power market and investment incentive for enhancing generation capacity: An analysis of Ghana's electricity sector. *Energy Policy*, *92*, pp.92-101; Eberhard, A., Gratwick, K., Morella, E. and Antmann, P., 2017. Accelerating investments in power in sub-Saharan Africa. *Nature Energy*, *2*(2), pp.1-5; Nagayama, H., 2009. Electric power sector reform liberalization models and electric power prices in developing countries: An empirical analysis using international panel data. *Energy Economics*, *31*(3), pp.463-472.

[13] Eberhard, A., Gratwick, K., Morella, E. and Antmann, P., 2016. Independent power projects in Sub-Saharan Africa: Lessons from five key countries. The World Bank.

[14] Eberhard et al., 2016 (n 11); Trotter, P.A., McManus, M.C. and Maconachie, R., 2017. Electricity planning and implementation in sub-Saharan Africa: A systematic review. *Renewable and Sustainable Energy Reviews*, *74*, pp.1189-1209; Eberhard et al., 2016 (n 9).

Fig 1: Electricity market structures in Sub-Saharan Africa



Note: Includes vertical integration or unbundling of generation (G), transmission (T), and distribution (D) and presence of IPPs.

Source: Eberhard, A., Gratwick, K., Morella, E. and Antmann, P., 2016. Independent power projects in Sub-Saharan Africa: Lessons from five key countries. The World Bank.; pg 33.

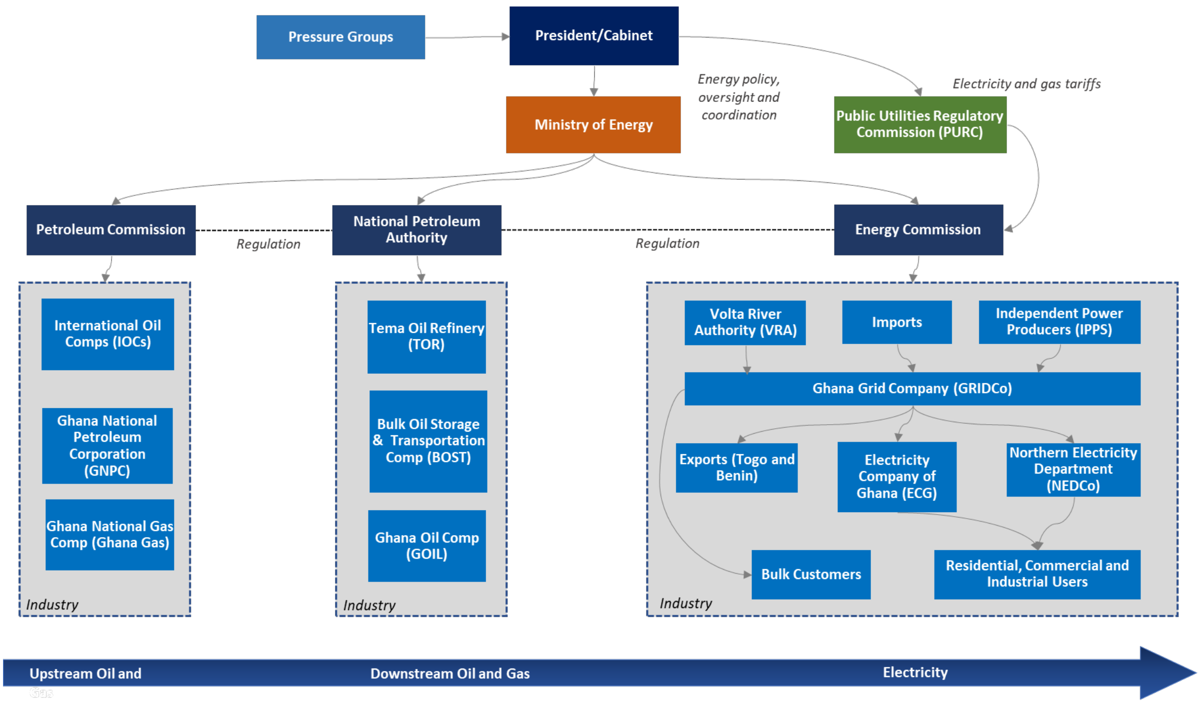
2.2 The Institutional and Regulatory Framework in Ghana

Responsibility for management (energy policy formulation, implementation, monitoring and evaluation and coordination of agencies) of Ghana's power sector falls under the auspices of the Ministry of Energy. The regulatory bodies are the Public Utilities Regulatory Commission of Ghana (PURC) and the Energy Commission (EC). PURC is an independent body set up by the Public Utilities Regulatory Commission Act, 1997 (Act 538) to regulate and oversee electricity tariffs and encourage retail and wholesale competition. In contrast, the EC (set up by Act 541) acts as the licensing authority for service providers in the electricity and downstream natural gas sectors (Figure 2).

Power generation is controlled by the Volta River Authority (VRA), a state monopoly with about 49% market share, augmented by several Independent Power Producers (IPPs). VRA has a mix of hydro, thermal and renewable plants with a total installed capacity of 2,520 MW out of 5,172 MW total installed capacity as of December 2019.[15] Before 2006, VRA had additional responsibility for power transmission, but under the new deregulated framework, this was taken over by Ghana Grid Company Limited (GRIDCo). GRIDCo is the sole operator of Ghana's electricity transmission network and charges a transmission tariff to carry electricity through its network.

Electricity distribution is done on a zonal basis by the Electricity Company of Ghana (ECG) in southern Ghana and by the Northern Electricity Distribution Company (NEDCo) in northern Ghana. ECG supplied most of the demand centres in Ghana located within the Accra-Tema, Kumasi and Takoradi enclaves and was responsible for supplying about 90% of all power purchased in Ghana in 2019. Both ECG and NEDCo are state-owned firms operating under the purview of the Ministry of Energy. Its heavily centralised organisational structure and political interference in operational decisions have resulted in a poor track record on revenue collection, mismanagement and high technical losses estimated at 25% of total power purchased.[16]

Fig 2: Institutional setup and political drivers of Ghana's energy sector value chain



Source: Authors' construct

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[15] Volta River Authority (2020). Power Generation: Facts & Figures. Available at https://www.vra.com/resources/facts.php (Accessed: 3 August 2020); Energy Commission Ghana (2020). National Energy Statistics (2000-2019). Available at http://www.energycom.gov.gh/files/ENERGY%20STATISTICS-2020.pdf (Accessed: 3 August 2020).

[16] Mathrani, S., Santley, D., Hosier, R., Bertholet, F., Braud, A., Dawson-Amoah, G., Mathur, S., Amissah-Arthur, H., Garcia, R., Adam, M.A. and Matthews, B., 2013. Energizing economic growth in Ghana: making the power and petroleum sectors rise to the challenge (No. 79656, pp. 1-83). The World Bank.

2.3 Electricity Generation (Supply) Trends

Historically, a significant proportion of baseload for power generation came from the Akosombo hydroelectric dam until dwindling rainfall around the mid-1980s caused a strategic rethink of ways to ensure the security of supply the national energy policy and planning.[17] This ushered in the Power Sector Reform Programme (PSRP) in 1995 to liberalise a part of the market to bring competition and efficiency through the expansion of electricity generation capacity and efficiency improvements through performance contracts, IPP competition and cost; that is, moving tariffs toward full cost recovery.[18]

Power generation in Ghana has gone through several phases: starting with diesel generators and stand-alone electricity supply systems owned by industrial mines and factories, to the hydro phase following the Akosombo dam construction and is currently centred on a thermal complement phase powered by natural gas and or crude oil derivatives. Hydroelectric power has over the years been usurped by thermal power generation as the primary source of electricity.

According to Ghana's Energy Commission, the installed capacity available for grid supply at the end of December 2019 was 4,695 megawatts (MW) (Figure 3). This comprised of 29% hydroelectric generation (from Akosombo, Bui and Kpong), 70% thermal generation from the dual-fuel plants located within the Tema and Takoradi (Aboadze) power enclaves and 1% renewables (Figure 4 and Figure 5). In 2019, the total electricity for gross transmission was 17,886 gigawatt-hours (GWh) against 15,960 GWh in 2018. The net grid electricity supplied to the country was about 4.7% more than in 2018. The total (maximum) system peak on the transmission grid was, however, 2,804 MW; this was about 11% more than in 2018 (Figure 6). This high growth in peak demand is driven by the increased availability of natural gas for thermal generation, especially in the western corridor and is coupled with an increase in exports, facilitated by the construction of a 330 kilovolt (kV) transmission circuit.

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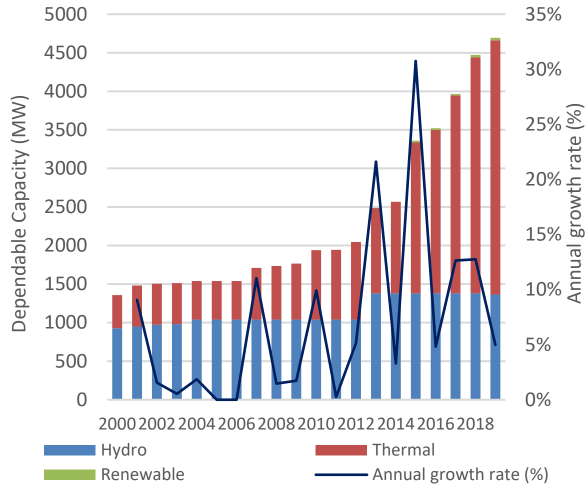
[17] Amin-Adam, M. (2015). "Chronology of power crisis and lessons for ending the current crisis". Available at: https://www.myjoyonline.com/opinion/chronology-of-power-crisis-and-lessons-for-ending-the-current-crisis (Accessed: 3 October 2020).

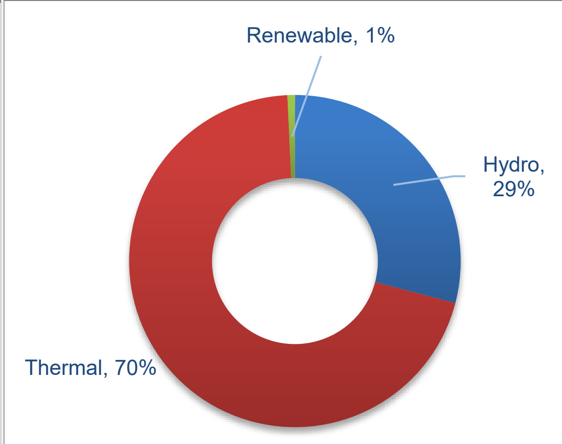
[18] Keener, S., & Ghosh Banerjee, S. (2005). Ghana: Poverty and social impact analysis of electricity tariffs. World Bank

Fig 3: Dependable capacity, MW (2000-2019) and growth rate



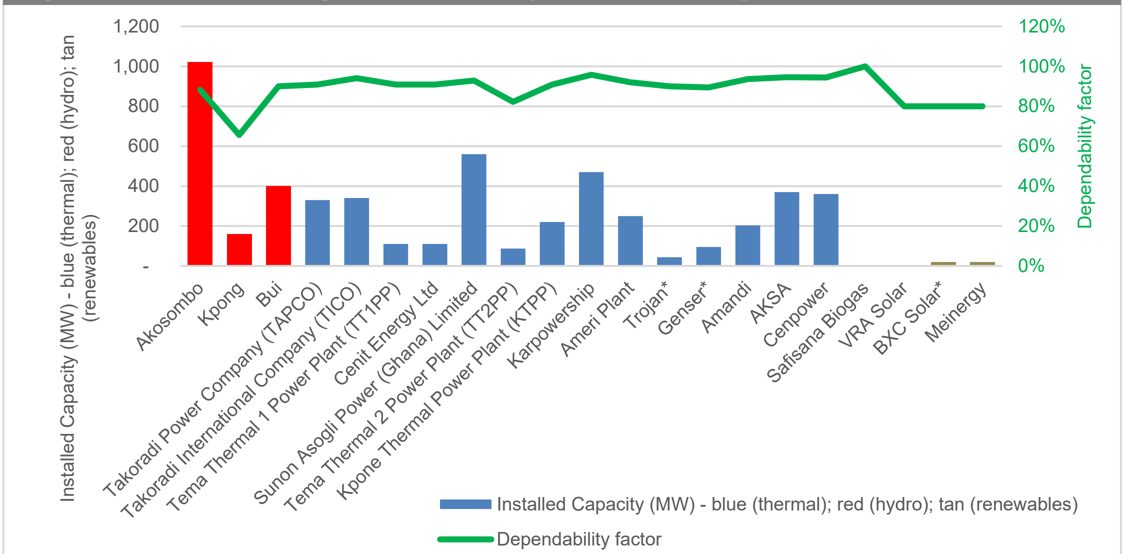
Data: Ghana Energy Commission 2020

Fig 4: Dependable capacity as at December 2019 (MW)



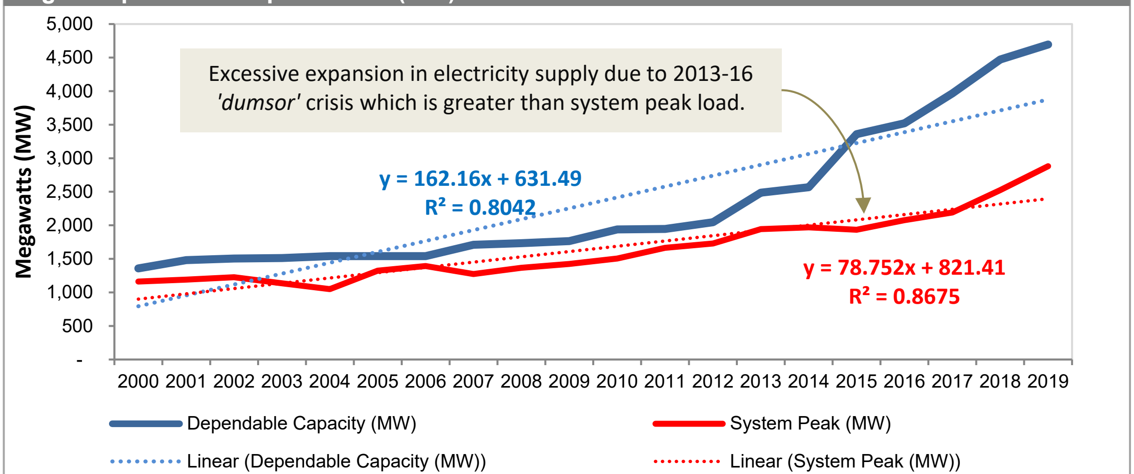
Data: Ghana Energy Commission 2020

Fig 5: Total 2019 installed generation capacity and dependability factor



Data: Ghana Energy Commission 2020

Fig 6: Capacities and peak loads (MW) 2000-2019



Data: Ghana Energy Commission 2020

Electricity generation comes from multiple stakeholders: state-owned Volta River Authority (VRA) owns and operates the Akosombo Hydro Power Station, Kpong Hydro Power Station, and the Takoradi Thermal Power Plant (TAPCO) situated at Aboadze in the Western Region. VRA is also a minority joint partner with TAQA, a private sector company, which owns and operates the Takoradi International Power Company (TICO) thermal plant, also located at Aboadze. At present, VRA accounts for about 50% of total electricity supplied to the power system (compared to 88% in 2010). The remaining 40% of the generation comes from independent power producers (IPPs) such as Sunon Asogli, CENIT, Karpower, AKSA, and Cenpower, among others.

2.3.1 Boosting Output with New Thermal Capacity Amidst Diversified Fuel Supply Sources

Ghana has been through two power crises in the past two decades, namely in 2007 and 2014-2016, in which power supply lagged demand, leading to load-shedding - locally known as *'dumsor'* or on-off. An outcome of the 2007 crisis was the construction of the 400 MW Bui hydroelectric power plant funded by China. The crisis of 2014-2016 likewise was addressed by more IPP investments by the then administration promising to add 3,800 MW of mostly new thermal capacity within five years.[19]

Considering the power supply challenges, the government procured the following IPP emergency power contracts:

- **Karpowership:** This was procured as an emergency power badge from Turkey to temporarily address the country's then power crisis. The badge with a capacity of 450MW initially run on Heavy Fuel Oil (HFO) but is now running on natural gas following its towing to Takoradi from Tema.

- **AKSA Power**: The 370 MW plant, located in Tema, was built by Turkey's Aksa Enerji and runs on Heavy Fuel Oil (HFO) under a five-year build own operate and transfer (BOOT) arrangement.

- **Africa Middle East Resources Investment Group (Ameri) Project:** This is also a 250 MW combined-cycle gas turbine emergency plant under a short-term BOOT arrangement initially for five years. The PPA terms were subsequently restructured into a standard IPP, allowing it to be extended for an estimated 15 operational years. The plant is located at Aboadze in the Western Region and runs on natural gas.

- **Early (Bridge) Power Project:** This is a proposed 450 MW project with consortium partners comprising Sage Petroleum Limited Ghana and US-based Endeavor Energy and General Electric (GE). The plant is in Tema. LPG will be used as the primary feedstock fuel for the plant for the first five years before switching to natural gas as its primary fuel once it becomes available.

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[19] Ghanaweb.com (2015). "Mahama can't add 3,800MW in 5yrs as promised – ACEP". Available at: https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Mahama-can-t-add-3-800MW-in-5yrs-as-promised-ACEP-357103 (Accessed: 15 August 2020).

- **Expansion Projects:** Projects such as the 220MW Kpone Thermal Power Project (KTPP) and the 360MW Sunon Asogli Phase 2 project, and the VRA TT2PP (38 MW) were also expanded.

Also, the *'dumsor'* crisis necessitated a search for cheaper sources of fuel for thermal power generation. Ghana over the period, discovered significant associated and non-associated gas resources from the Jubilee, TEN and Sankofa fields, significantly changing fuel supply dynamics. Domestic gas is likely to meet Ghana's base-case demand through the mid-2020s but needs to be supplemented by LNG imports from the mid-2020s (Gas Master Plan, 2016). The TEN and Sankofa fields came onstream in 2016 and 2018, respectively, considerably boosting gas supplies and energy security via the Atuabo gas processing plant. This then meant imports of gas from Nigeria through the West Africa Gas Pipeline (WAGP), which have historically been unreliable and inefficient, could now be a thing of the past. This is despite the fact that some plants in the Tema-enclave, such as Sunon Asogli were reliant on WAGP supplies in the absence of being able to evacuate domestic gas in the western part of the country to demand centres in the east.

The discovery of large amounts of natural gas in the Western region and the location of the majority of power plants in the East (Tema) required establishing a connection between the west and the east to facilitate the transportation of fuel to the plants. In this vein, Ghana, in August 2019, completed the Takoradi –Tema Interconnection Project (TTIP), which reverse flowed gas from Takoradi to Tema via the WAGP.[20] This now allows the West African Gas Pipeline Company Limited (WAPCo), operator of the WAGP, to transport natural gas from the west to the east at the request of customers – both power and non-power demand users. The reverse flow project was financed by the Ghana National Petroleum Corporation (GNPC), Ghana's national oil company.[21]

Also, to support gas medium-term demand growth, Ghana is considering LNG import proposals. The Tema LNG project, which is a floating storage and regasification unit with an expected capacity of 250 million standard cubic feet (mmscf) per day, is due to be completed and ready for use in 2021.[22] With GNPC's 12 years agreement signed with Rosneft for the supply of LNG, it is estimated that upon completion, the Tema LNG project will supply an expected 75 mmscf per day to meet the country's growing demand for fuel for power generation.

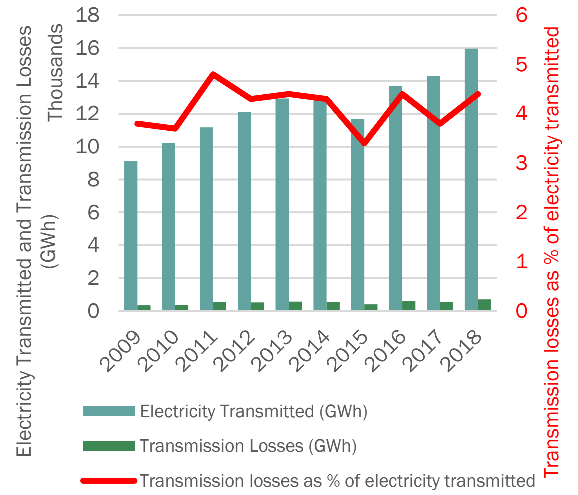
2.3.2 Transmission and Distribution Losses

Transmission and distribution losses in Ghana form a significant proportion of electricity supplied to the economy. Over the years, these losses have become significant in proportion to the electricity transmitted and contributed to the increased cost of electricity to the consumer. Figure 7 shows transmission losses of around 3-4% of electricity transmitted. Distribution

[20] WAPCo (2020). "WAPCo Begins Reverse Flow Transportation of Gas from Western Region of Ghana to the East, Wagpco.com." Available at: https://www.wagpco.com/74-news/2019-news/227-wapco-begins-reverse-flow-transportation-of-gas-from-western-region-of-ghana-to-the-east-2 (Accessed: 2 October 2020).
[21] Africreport.com (2019). "GNPC Finances the West to East Reverse Flow of Natural Gas in Ghana - Africa's premier report on the oil, gas and energy landscape." Available at: https://africaoilgasreport.com/2019/08/gas-monetization/gnpc-financesthe-westto-east-reverse-flowof-natural-gasinghana (Accessed: 2 October 2020).
[22] Offshore Energy (2018). "CHEC Pens Construction Deal for Tema LNG Terminal". Available at: https://www.offshore-energy.biz/chec-pens-construction-deal-for-tema-lng-terminal (Accessed: 3 October 2020).

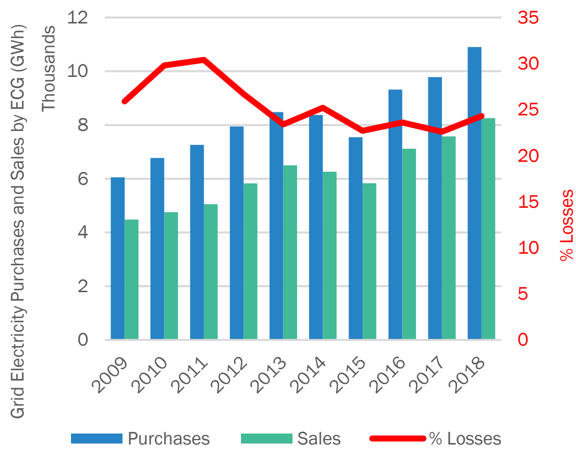
losses comprising technical and commercial losses, on the other hand, is persistently high at 25% of all power purchased and has barely come down since 2013 (Figure 8). On the other hand, electric power transmission and distribution losses (as a percentage of output) in Sub-Saharan African averages 12% as of 2014, according to World Bank data.[23] The inability to reduce distribution losses over the past years has significant implications for electricity tariffs, as we show in Section 3.

Fig 7: Electricity transmitted and transmission losses



Source: GRIDCo

Fig 8: Grid electricity purchases and sales by ECG (GWh)



Notes: Technical and commercial losses
Source: GRIDCo, VRA and ECG/PDS

2.4 Consumption (Demand) Trends

Various studies have established a strong relationship between real GDP growth rate and electricity consumption.[24] Figures 9 and 10 illustrate Ghana's case showing how the population growth rate and rapid urbanisation have increased electricity consumption. With Ghana's population growth at 2.16% per annum, the electricity supply market has an estimated 7-10% year-on-year demand driven by a pressing need for new generation capacity to meet the demands of a growing economy. Thus, new generation capacity must increase by at least the same percentage every year in order to support expanding industrial, institutional, commercial, household and other needs as the country grows and develops.

Growth in total energy demand more than doubled between 2003 and 2019. Annual non-residential demand growth has risen from an average of 9% in 2000-2010, nearly doubled to 16.5% in 2010-2013, and doubled again to 33% in 2013. Residential demand growth has increased overall by 6.2% per year during the last decade, increasing by 15.4% in 2013 alone.[25] The rapid growth in the services sector as a source of economic growth from 29% of GDP in

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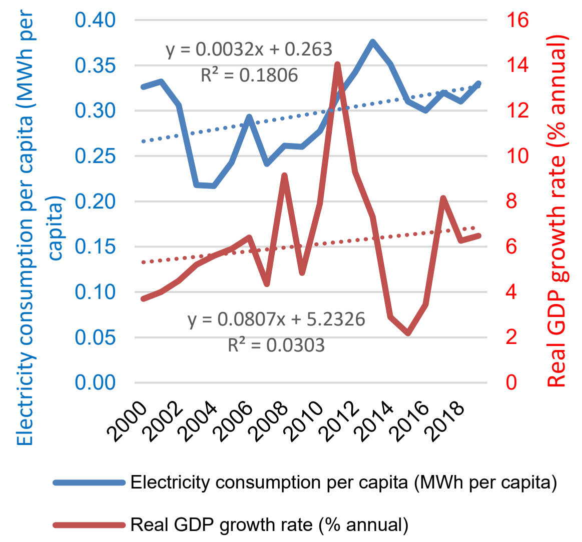
[23] World Bank (2018). "Electric power transmission and distribution losses (% of output) - Sub-Saharan Africa". Available at: https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?locations=ZG (Accessed: 2 October 2020).

[24] Narayan, P. K., & Prasad, A. (2008). Electricity consumption–real GDP causality nexus: Evidence from a bootstrapped causality test for 30 OECD countries. Energy policy, 36(2), 910-918; Lawal, A. I., Ozturk, I., Olanipekun, I. O., & Asaleye, A. J. (2020). Examining the linkages between electricity consumption and economic growth in African economies. *Energy*, *208*, 118363.

[25] Amoako-Tuffor, J., & Asamoah, J. (2015). "Thinking Big' and Reforming Ghana's Energy Sector'. submitted to the African Center for Economic Transformation (ACET), Accra.

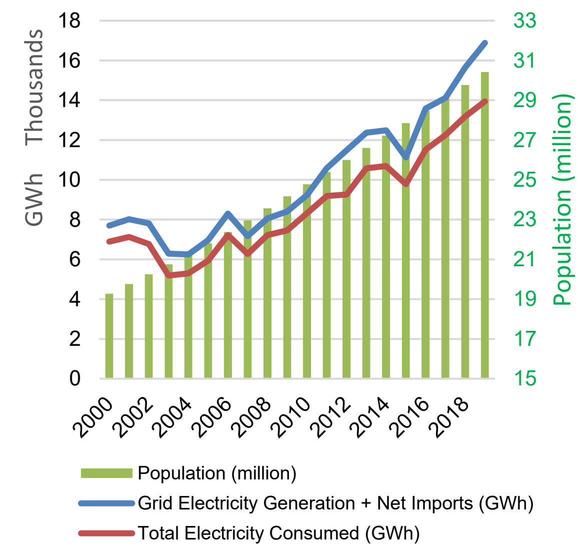
2000 to 44.14% in 2019 in part explains the growth in electricity demand over the past decade. This growth has been fueled by expansion in information and telecommunication, SMEs and financial and business services.

Fig 9:Total electricity generated per capita and GDP growth rate 2000-2019



Data: Ghana Energy Commission 2020

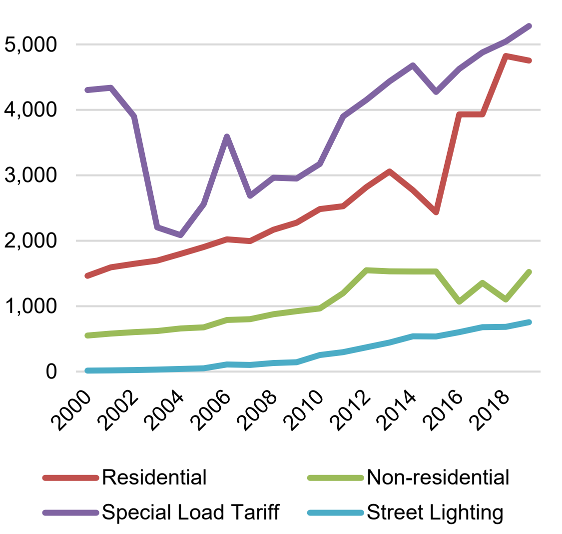
Fig 10: Electricity generation, consumption and population growth 2000-2019



Data: Ghana Energy Commission 2020

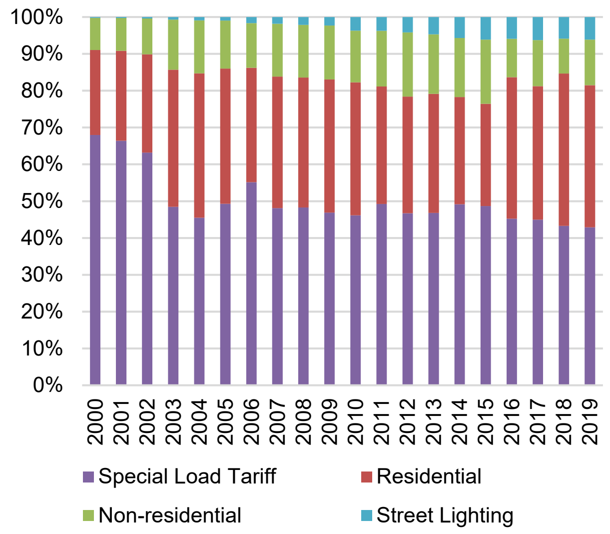
Figure 11 below further illustrates this increase in demand by the services sector through their consumption pattern. Sales by customer classes show a large proportion due to special load tariff customers made up of industry and service classes; this is closely followed by the residential. It is worthy to note the reduction in sales of special load tariff customers relative to the increase in residential. This could be explained by the relatively high tariff vis-à-vis the cost of the embedded generation most of the consumers in these customer classes are faced with – this is explained in greater detail in Section 3. Residential customers, on the other hand, will have to pay almost the actual cost of electricity given the relatively high cost of embedded generation in that class. Figure 12 clearly shows how electricity consumption by the residential class has increased gradually since the 2000s while that of industry has decreased. It is, therefore, safe to project that increments in residential consumption in the medium term are likely. In contrast, industry consumption might decrease, indicating a widening gap in electricity consumption between residential and industrial users.

Fig 11: Utilities electricity sales by customer class (GWh)



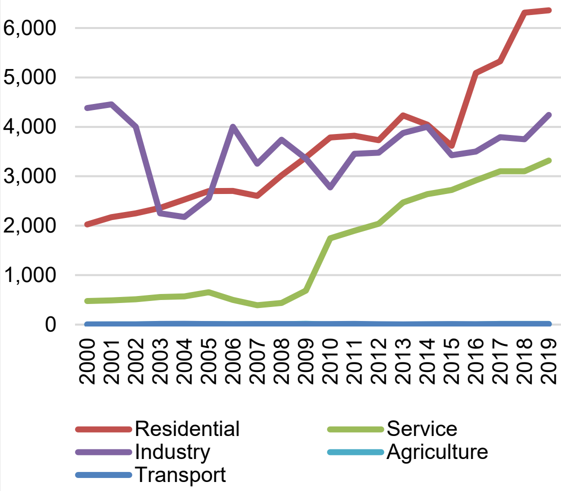
Data: Ghana Energy Commission 2020

Fig 12: Utilities electricity sales by customer class, %



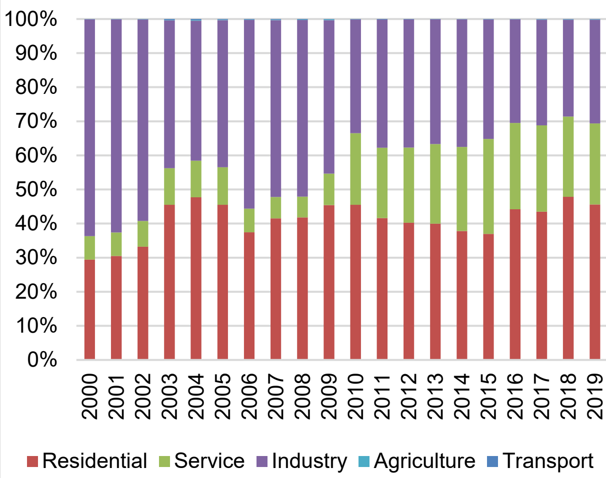
Data: Ghana Energy Commission 2020

Fig 13: Electricity consumption by sectors (GWh)



Data: Ghana Energy Commission 2020

Fig 14: Electricity consumption by sectors, %

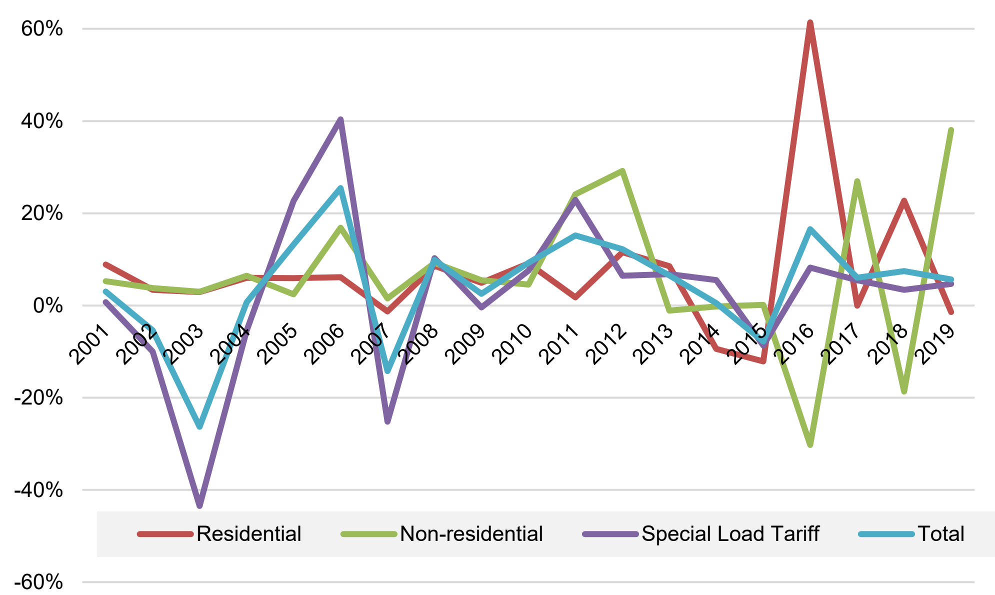


Data: Ghana Energy Commission 2020

The average annual percentage growth by sectors as represented in Figure 15 below shows that growth in electricity demand has been most significant in the residential sector as opposed to industry. Although we see a decrease in residential demand below zero in 2014 and 2015 which can be explained by load shedding hence residential consumers relying on other sources of power such as generators, the subsequent spike in demand not only speaks to residential being the sector with the highest growth but also the amount of demand that was embedded between 2014 and 2015.

In recent years (2016-2019), however, the growth in electricity demand has seen an increase in the non-residential sector although the cumulative compounded annual growth rate since 2000 shows residential sector still as the sector with the highest growth rate as earlier explained. The compounded residential growth rate since 2000 is 6.07% as compared to the non-residential compounded growth rate of 5.21%, shown in Table 1 below.

Fig 15: Average annual percentage growth in demand ([t1-t0]/t0)



Data: Ghana Energy Commission 2020

Table 1: Compounded annual growth rate (CAGR) in demand

Year	Residential	Non-residential	Special Load Tariff
2000-2005	4.49%	3.47%	-8.30%
2006-2010	4.19%	4.10%	-2.44%
2011-2015	-0.73%	5.01%	1.84%
2016-2019	4.87%	9.28%	3.37%
Overall	**6.07%**	**5.21%**	**1.03%**

Source: Author's construct

3. Tariff Pricing Analysis

3.1 Tariff Frameworks and Methodologies

Ghana's Power Sector Reform Programme (PSRP), which commenced in 1995, envisaged the setup of Public Utilities Regulatory Commission (PURC) as the body responsible for setting tariffs to ensure competition and international best standards. To ensure fairness in price setting, the Public Utilities Regulatory Commission Act, 1997 (Act 538), which set up the PURC under Section 2, sets up a governing board with various stakeholders comprising a representative of the Trades Union Congress, Association of Ghana Industries (AGI), domestic consumers and other persons with knowledge in matters of the Commission. However, the effective working of the Commission has often been curtailed by political measures over citizens' agitation on electricity price hikes and the limited consultations in pricing decisions broadly.

The change in the generation mix from hydro to thermal power generation has fundamental implications on the economics of power generation: that is, how power is priced, and ultimately, end-user tariffs. Supply typically comes from two plant types: Type 1 plants that provide the baseload to cater to minimum underlying demand based on a daily demand schedule, and Type 2 plants provide peak or mid-merit load. Plant Type 1 have high fixed capital expenditure (capex) and low marginal operational costs as they often use relatively cheaper fuel sources, while Plant Type 2, on the other hand, have lower fixed costs and higher marginal operational costs. Power procured by the government through the IPPs are Type 2 plants utilising thermal generation. Although Type 2 plants provide greater flexibility and reliability, their generation costs outweigh Type 1, such as the Akosombo hydro plant. The configuration of these plant types and their ranking on the merit-order has an impact on end-user tariffs. For example, the estimated fuel costs in 2019 for utilising combined-cycle generation was US$7.4-8.84 per MMBtu for natural gas and US$13.79 per MMBtu for light crude oil (LCO) (Table 2). The estimated costs for heavy fuel oil (HFO) and diesel were US$9.68 per MMBtu and US$18.73 per MMBtu, respectively.

Table 2 Indicative fuel costs by plant type

Type	Indicative Fuel Costs US$ per MMBtu
Natural gas (Average Delivered Ghana Gas price)	7.4-8.84
Liquefied Natural Gas (LNG)	6.0-8.50
Heavy fuel oil (HFO)	9.68
Light crude oil (LCO)	13.79
Diesel	18.73

Source: Adapted from Energy Commission (2020, Asiedu et al. (2019)[26]*and ESRP (2019)*[27]

The Automatic Adjustment Formula (AAF)

Ghana has been applying the quarterly AAF to compute end-user tariffs, which was initially introduced in July 2002 but later revised in 2011.[28] The AAF incorporates fuel mix (crude oil, natural gas, distillate fuel), Ghana Cedi-US dollar exchange rate, the hydro-thermal generation mix, and changes in the consumer price index, demand forecast and chemical cost in arriving

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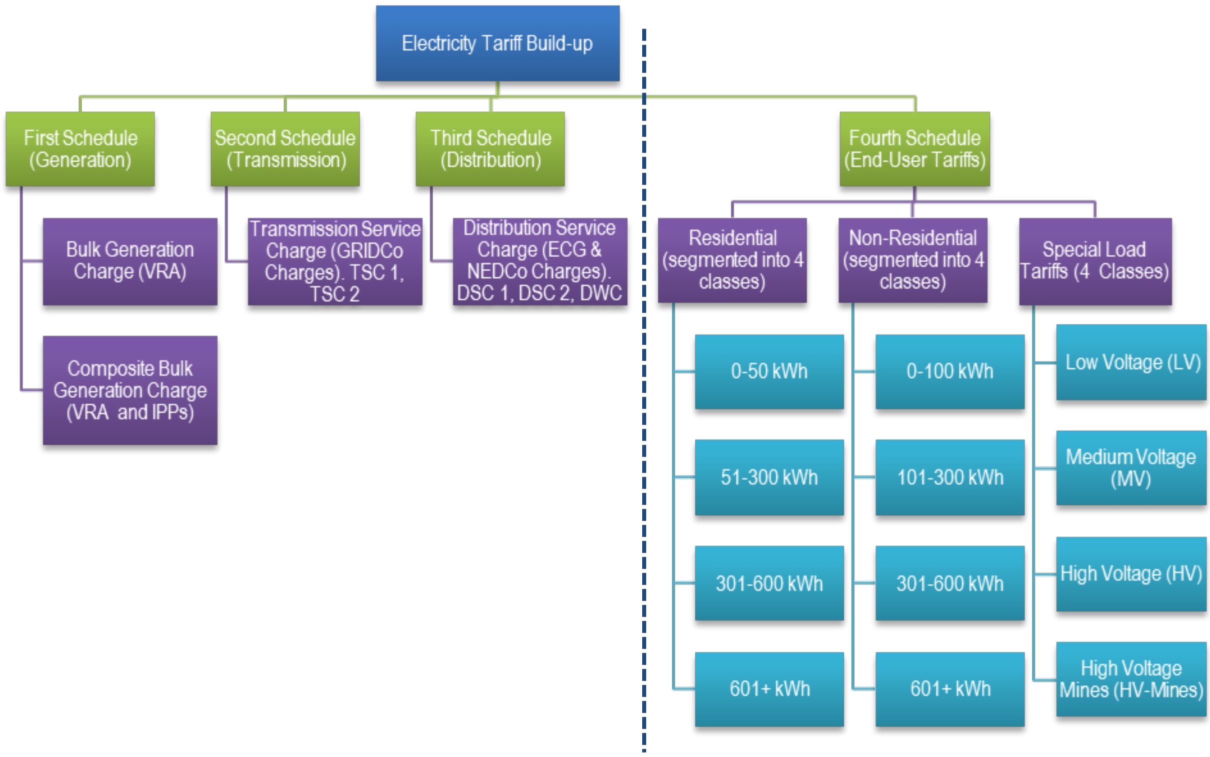
[26] Asiedu, N., Adu, P., Anto, E.K. and Duodu, A., 2019. Energy economics and optimal generation mix of selected power plants technologies in Ghana. Scientific African, 2, p.e00015.
[27] Ministry of Energy Ghana, 2019. Energy Sector Recovery Program, p.15. Available at: http://energycom.gov.gh/files/2019%201111%20ESRP%20ESTF_Clean_v3.0redacted%20final.pdf (Accessed: 7 April 2021).
[28] Public Utilities Regulatory Commission (2011). "Automatic Adjustment Formula (AAF)". Available at: http://www.purc.com.gh/purc/sites/default/files/aprilautomaticadjustmentformula2011_0.pdf (Accessed: 3 October 2020); Public Utilities Regulatory Commission (2011). "Explanatory notes to revised automatic adjustment formula for setting electricity and water tariffs". Available at: http://purc.com.gh/purc/sites/default/files/revised_aaf_implementation_notes.pdf (Accessed: 3 October 2020).

at tariffs.[29] The final electricity tariff build-up is comprised of four schedules, as shown in Figure 16 below. Before 2011, the AAF was not fully implemented because of government interference in the market price-setting mechanism under the guise of absorbing the price mark-up instead of passing it to end-users under-recoveries in the electricity sector.

Hence, the tariff pricing regime failed to incentivise electricity generating companies (both state-owned such as VRA and other IPPs) to make economic returns while ensuring investments in equipment to safeguard energy security. This inefficient market structure created a situation where recovery of full operational costs became a challenge as there is no guarantee that the tariff set by PURC will fully reflect costs. Attempts in the current PURC pricing mechanism have largely addressed this imbalance; the cost of power generation excluding distribution and transmission service charges is below average end-user tariffs.

Fig 16: Ghana electricity tariff components



Source: Authors' Construct.

Adapted from Public Utilities Regulatory Commission (2020). "Approved Electricity & Water Tariffs for the year 2020". Available at: http://purc.com.gh/purc/node/7813 (Accessed: 1 October 2020)

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[29] Acheampong, T. and Ackah, I. (2015). Petroleum Product Pricing, Deregulation and Subsidies in Ghana: Perspectives on Energy Security. Deregulation and Subsidies in Ghana: Perspectives on Energy Security (August 14, 2015); Kumi, E.N. (2017). *The electricity situation in Ghana: Challenges and opportunities*. Washington, DC: Center for Global Development.

3.2 Bulk-Generation, Transmission and Distribution Tariffs Analysis

Under the first schedule, the Bulk Generation Charge (BGC) is defined as the weighted average rate at which electricity distribution companies (DISCos)[30] procure electricity from generation sources in respect of their operations in the regulated market.[31] The generation sources here comprise IPP thermal generation and VRA hydro, with the latter being priced much lower. Since 2014, the composite BGC sources has been below US$0.10 per kWh and is 54% of the total cost makeup (Figures 17 and 18). However, this increases by almost 100% to over US$0.15 per kWh when transmission and distribution service charges are added on to the BGC.

The next item following the BGC is the Transmission Service Charges (TSC) in the second schedule, payable to GRIDCo, the National Interconnected Transmission System (NITS) operator. Historically, Ghana applied only one TSC for all electricity transmitted, but this was decoupled in December 2015 with the introduction of another line item under the second schedule called Ancillary Service Charge (ASC). ASC was imposed on Bulk Customers directly purchasing electricity from the IPPs excluding ECG. The amounts were to be used to pay for "voltage control, operating reserves, black-start capability and frequency control".[32] ASC was imposed at about US$0.80 per kWh (GHp 3.15 per kWh) for three years until it was abandoned in 2017 and replaced. In 2018, the TSC was further decoupled into two new classifications: Transmission Service Charge 1 (TSC 1) and Transmission Service Charge 2 (TSC 2). TSC 1 is the rate payable to GRIDCo to recover the cost of its transmission network operations (includes a regulatory levy), while TSC 2 is the rate payable to GRIDCo to recover transmission losses. As can be seen, an attempt has been made to earmark which transmission costs are identifiable to network operations and transmission losses, respectively. Both of these are currently added in estimating tariffs. Overall, the transmission charges are a relatively small component of the cost makeup (averaging 11% of the total costs), as shown in Figure 17.

Distribution Service Charges (DSC) are the third schedule in the tariff build-up architecture. Here again, Ghana applied only one DSC for all electricity distributed until 2016 when a Distribution Wheeling Charge (DWC) was introduced. DWC is the charge payable to DISCos (ECG and NEDCo) to use their networks by third parties such as bulk customers. Under the liberalised market principles, third parties who have negotiated their supply with a wholesale supplier are required to pay the DWC.[33] This ensures that DISCOs are compensated for the cost of service of using their facilities to transmit power from one system to another. This is, in essence, the third party costs of delivering electricity for these class of customers.[34]

The DSC was further decoupled in 2018 into two line items: Distribution Service Charge 1 (DSC) and Distribution Service Charge 2 (DSC 2). DSC 1 is the rate that DISCos charge to recover the cost of distribution network operations, while DSC 2 is the rate to recover

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[30] Namely Electricity Company of Ghana (ECG), Northern Electricity Distribution Company Limited (NEDCo) and Enclave Power Company Limited (EPCL)

[31] Public Utilities Regulatory Commission (2020). "Approved Electricity & Water Tariffs for the year 2020". Available at: http://purc.com.gh/purc/node/7813 (Accessed: 1 October 2020).

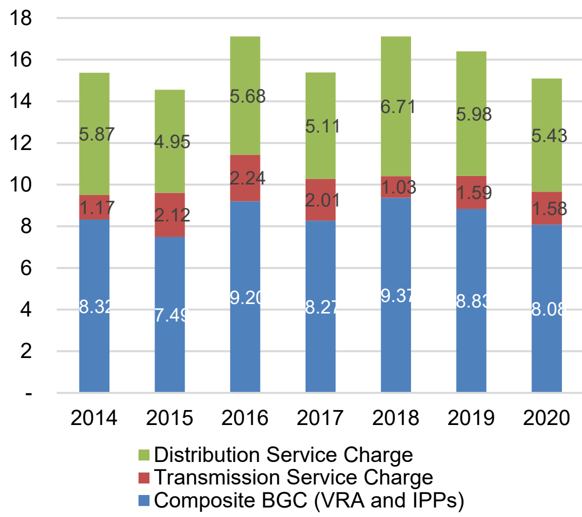
[32] Public Utilities Regulatory Commission (2015). "2015 Major Tariff Review". Available at: https://www.purc.com.gh/subsub-heading/2819573 (Accessed: 07 April 2021).

[33] Energy Commission Ghana, 2019. 'National Electricity Distribution Code'. Available at http://www.energycom.gov.gh/files/DISTRIBUTION-CODE-NATIONAL-ELECTRICITY-DISTRIBUTION-CODE.pdf Accessed: (3 March 2021)

[34] USAID, 2015. 'Partnership for Growth, Ghana TOU Tariff Analysis and Program Development'. Available at https://pdf.usaid.gov/pdf_docs/PA00SX87.pdf Accessed: (18 March 2021)

distribution losses. According to the PURC, bulk customers who are embedded in the distribution network but procure and pay fully the total cost of the electricity purchased from the wholesale market (including TSC 1 and TSC 2) are only eligible to pay DSC 1 to the DISCo.[35] On the other hand, bulk customers who procure electricity directly through a DISCo must not only pay TSC 1 and TSC 2 but DSC 1 and DSC 2 (the DWC). In essence, bulk customers directly procuring power under a wholesale contract from a generating company pay DSC 1, which covers recover the cost of distribution network operations, excluding distribution losses. However, those procuring power from the DISCOs pay both DSC 1 and DSC 2, collectively referred to as DWC, with the latter covering distribution losses. DSC's represent an average 67% mark-up over bulk generation costs since 2014 (Figure 19). Despite these distribution charges being collected, there is a persistent inability to bring down distribution losses in Ghana, which still hovers around 25% of all power purchased. This raises two interesting questions: (1) are the amounts collected being invested into the network to reduce these distribution losses, and or (2) are the amounts collected too small to cover the distribution losses fully?

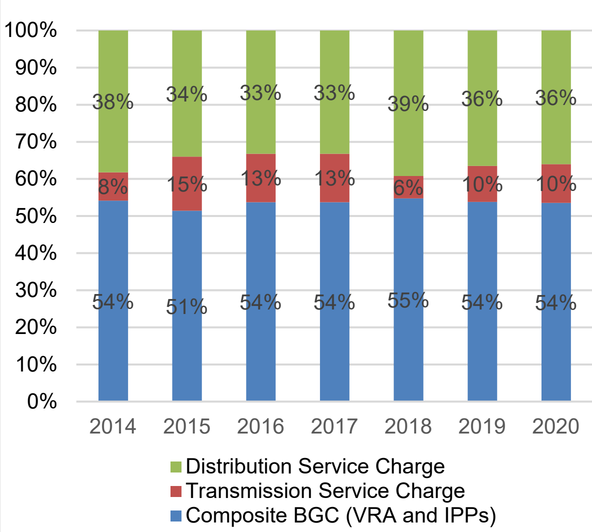
Fig 17: Composite bulk generation, transmission and distribution charges (US¢/kWh)



Note: Published PURC quarterly tariffs are averaged for the year and converted from Ghana cedis to dollars at prevailing year-end exchange rate.

Data: PURC

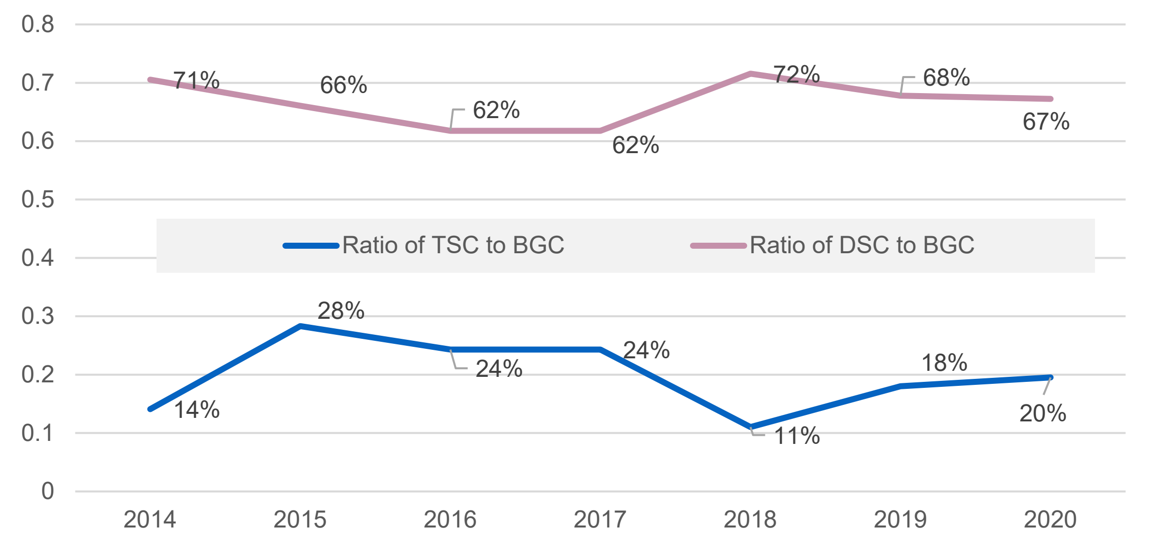
Fig 18: Composite bulk generation, transmission and distribution charges (%)



Data: PURC

[35] Op cit (n 31)

Fig 19: Ratio of transmission and distribution charges to bulk generation charges



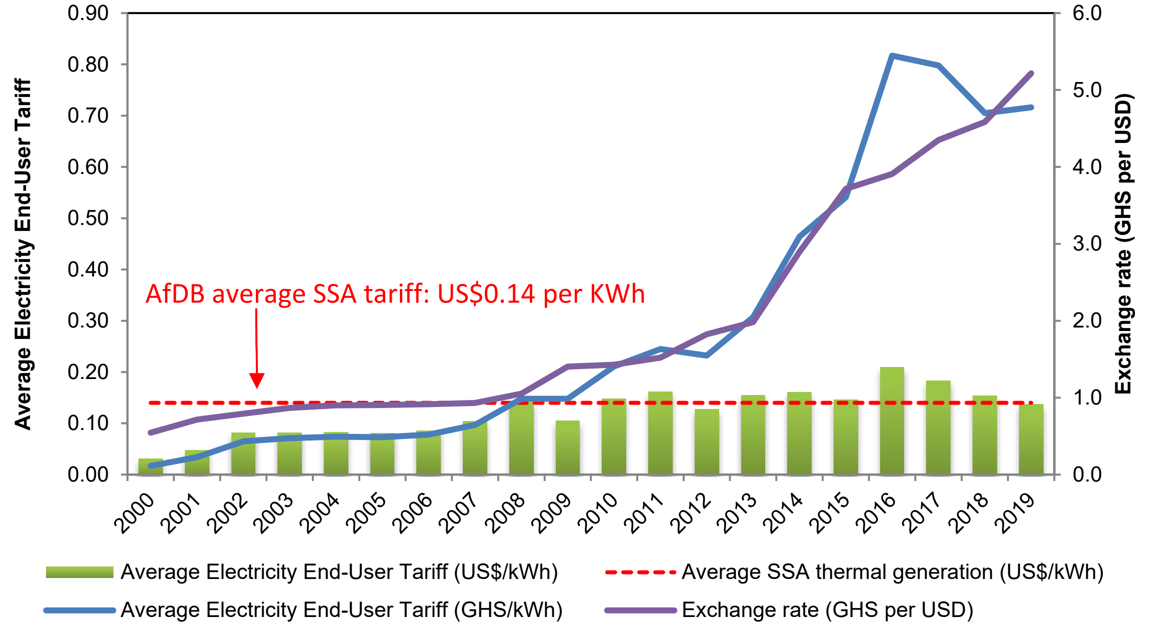
Data: PURC

3.3 Retail Electricity (End-User) Pricing Analysis

Average electricity end-user tariffs in Ghana have grown at an average of 9.6% per annum since 2000 from US$0.024 per kWh to US$0.14 per kWh in 2019, which is indicative of the growing diversification of the generation mix from hydro to thermal over the period (Figure 20). The growth, however, has been about 22% per annum in cedi terms, which also reflects the perennial depreciation of the local currency (the Cedi) to the dollar. Interestingly, average electricity end-user tariffs have reduced by about 30% since 2016 to about US$0.15 per kWh. This is mainly attributable to the coming on stream of other domestic gas supplies and the renegotiation of some of the expensive emergency IPP contracts procured to mitigate the power crisis, which has reduced the cost of power supply.[36]

[36] Ackah, I., Auth, K., Moss, T., & Kwakye, J. (2021). A Case Study of Ghana's Power Purchase Agreements. Available at: https://www.energyforgrowth.org/wp-content/uploads/2021/03/A-Case-Study-of-Ghanas-Power-Purchase-Agreements.pdf (Accessed: 7 April 2021).

Fig 20: Trends in Average Electricity End User Tariffs



Data: Ghana Energy Commission 2020

The breakdown of tariffs by the different consumer classes reveals a much more interesting and nuanced story on Ghana's differential tariff pricing. Residential customers (segmented into four classes based on consumption from 0-50 to 601+ kWh) pay the lowest end-user tariffs, averaging US$0.14 per kWh from 2014-2020 (Figure 21). This is in addition to an average monthly fixed service or access charge of US$1.19. Non-residential customers (also segmented into four classes based on consumption from 0-50 to 601+ kWh) pay an average end-user tariff of US$0.23 per kWh and a fixed monthly service charge of US$2.32.

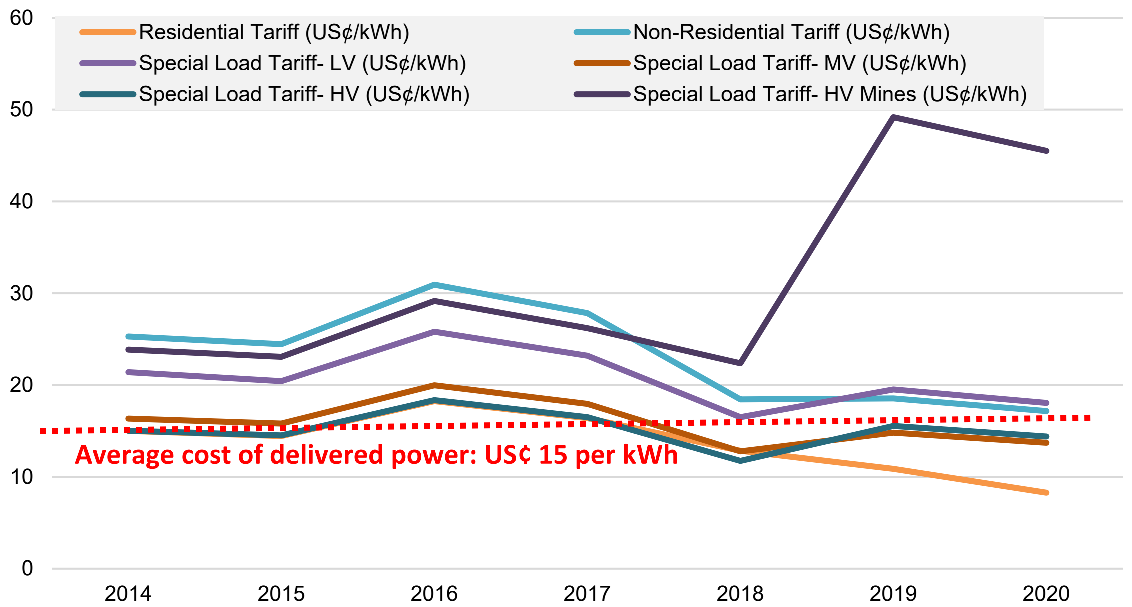
Within the Special Load Tariff (SLT) category, high voltage (HV) customers excluding the mines pay on average US$0.15 per kWh, followed by medium voltage (MV) customers at US$0.16 per kWh, low voltage (LV) at US$0.21 per kWh, and finally high voltage -mines (HV-Mines) at US$0.31 per kWh. All SLT customers also pay a service charge averaging US$9.27 for LV and US$12.98 for MV, HV and HV-mines, respectively. Ghana's current tariff structure reflects a developing electricity market similar to developments in other Sub-Saharan African countries applying different treatment for customers. This is through different tariff features such as schedules for large customers, time-of-use pricing, demand charges, sector-specific tariffs, and block tariffs.[37] Nevertheless, non-residential consumers, SLT-LV and SLT-HV mines consumers in Ghana pay much higher tariffs than the delivered cost of power of US$0.15 per kWh (Figure 21).

In the case of SLT-HV mines, this is almost twice the cost of delivered power. The government of Ghana acknowledges this problem in its Energy Sector Recovery Programme by noting that "end-user electricity and fuel tariffs for the commercial and industrial sectors are relatively

[37] Kojima, M. and Han, J.J., 2017. Electricity Tariffs for Non-residential Customers in Sub-Saharan Africa. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/26571/114848-BRI-PUBLIC-LWLJfinalOKR.pdf (Accessed: 7 April 2021); Trimble, C., Kojima, M., Arroyo, I.P. and Mohammadzadeh, F., 2016. Financial viability of electricity sectors in Sub-Saharan Africa: quasi-fiscal deficits and hidden costs. The World Bank.

expensive when compared to tariffs in other developing countries" such as South Africa (US$0.08-0.10 per kWh), South East Asia (US$0.04-0.07 per kWh) and Even Cote d'Ivoire (US$0.15 per kWh).[38] On a continental basis, effective electricity tariffs have averaged US$0.14 per kWh against US$0.18 per kWh in average production costs since 2010, according to the African Development Bank.[39] However, this is still much higher than in South Asia (US$0.04 per kWh) and East Asia (US$0.07 per kWh).[40] At a sub-regional level, a comparison of electricity tariffs in Ghana and neighbouring West African countries from 2018-2019 shows that the cost of power is still relatively expensive compared to Nigeria and Cote d'Ivoire (Figure 22). Both these regional economic giants are keen on pursuing resource-based and import substitution-led industrialisation, much as Ghana. The cost of power is a key determinant in attracting domestic and foreign direct investment (FDI) inflows.

Fig 21:Average residential, non residential and special load tariffs (2014-2020)

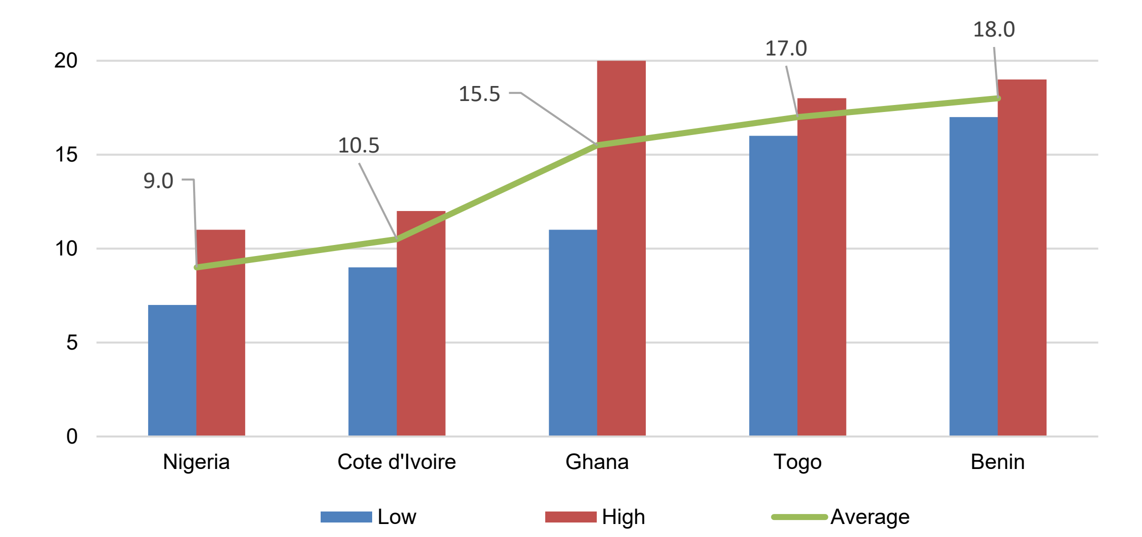


Note: Published PURC quarterly tariffs are averaged for the year and converted from Ghana cedis to dollars at prevailing year-end exchange rate.

Data: PURC

[38] Ministry of Energy Ghana, 2019. Energy Sector Recovery Program, p.15. Available at: http://energycom.gov.gh/files/2019%201111%20ESRP%20ESTF_Clean_v3.0redacted%20final.pdf (Accessed: 7 April 2021).
[39] AfDB, 2013. The High Cost of Electricity Generation in Africa. Available at: https://blogs.afdb.org/blogs/afdb-championing-inclusive-growth-across-africa/post/the-high-cost-of-electricity-generation-in-africa-11496 (Accessed: 7 April 2021).
[40] Op cit (n 38)

Fig 22: Electricity tariff ranges in Ghana and neighbouring countries from 2018-2019



Data: Ghana Energy Commission 2020

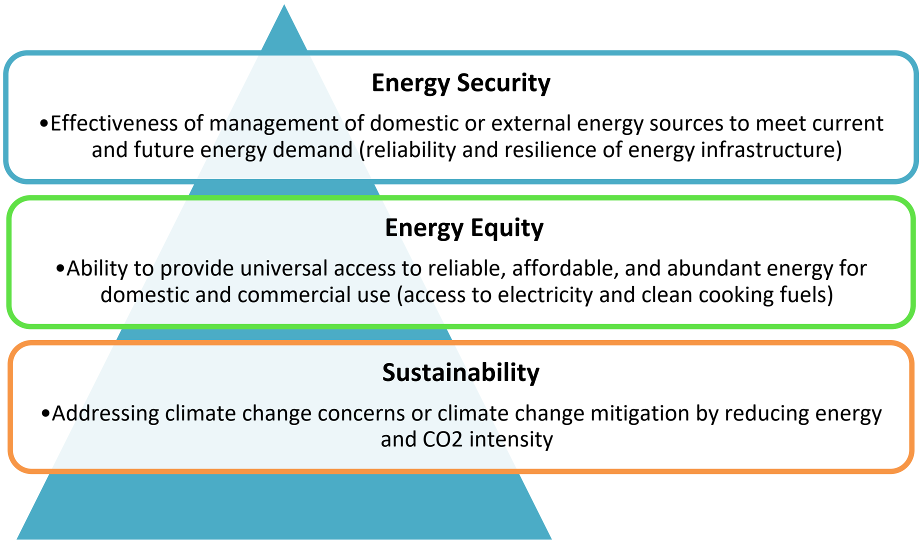
4. Discussion

4.1 What Does This Mean for the Energy Trilemma in Ghana?

As indicated earlier in Section 1, balancing the often-competing dimensions of the energy trilemma is often a challenge for governments. It is the central challenge of energy governance and impacts how different nation-states with different energy profiles address this.[41] In the current climate of increasing discussions on the transition to a low carbon economy, an ideally balanced energy system needs to have high energy security, attain universal access at affordable prices and have low carbon emissions. Thus, we argue that the energy transition in the developing countries, including in Africa, need to be viewed through a more comprehensive or composite energy trilemma lens – that is, the competing demands of energy security, climate change mitigation and energy poverty (Figure 23). It is, therefore, not necessarily about decarbonisation or decarbonising the energy sector. Hence, policy responses by governments should be driven by these considerations as tensions between the horns of the trilemma can help explain energy policy choices that developing countries make. It is essential to mention that this sort of balance emanates from deliberate electricity planning and balancing needs over time.

[41] Gunningham, N., 2013. Managing the energy trilemma: The case of Indonesia. Energy Policy, 54, pp.184-193.

Figure 23: Energy trilemma lens



Source: Author's construct based on the Energy Trilemma Index (ETI)

The World Energy Council's annual Energy Trilemma Index (ETI)[42] attempts to comparatively rank countries on their ability to satisfy or balance the three (3) dimensions, and Ghana is ranked 103 out of 128 countries in the world, and 12 out of 29 African countries surveyed in the ETI. The country is noted to have shown significant improvement from 2000 to 2019 in two of the three trilemma dimensions, namely energy security and energy equity. The country is ranked as one of the top ten overall improvers alongside Kenya and Eswatini in Africa, demonstrating that modest gains have been made overall, especially on these two fronts. However, what does the current tariff pricing structure mean for Ghana's ability to continue to balance the three dimensions going forward?

Regarding energy security, the procurement of fuel for power generation from non-domestic sources such as the West African Gas Pipeline (WAGP) has significantly reduced due to the increasing availability of domestic gas – for example, from the Jubilee, TEN and Sankofa gas fields.[43] The current 4,695 MW dependable capacity of electricity supply outstrips the 3,457 MW system peak demand (including a 20% reserve margin) by 36%, indicating the success achieved as a result of the strong policy focus by the Ghanaian government since 2015 on meeting current and future demand. However, energy security is not just about power availability or generation but should be looked at as systems level – that is, from generation, transmission through to distribution. Although there is significant or even excess grid capacity in Ghana's case, our analysis clearly shows that the lack of investment in the distribution infrastructure, evidenced by the persistent 25% losses, is a major energy security issue. Such losses signal significant underinvestment in the grid infrastructure, which has implications for integrating other variable renewable energy sources and increases susceptibility to persistent power outages. Research indicates that ageing grid infrastructure in the developing world is an

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[42] World Energy Trilemma Index (2020). Available at: https://www.worldenergy.org/publications/entry/world-energy-trilemma-index-2019 (Accessed: 3 September 2020).
[43] Ghana Energy Commission (2020). Energy Outlook for Ghana. Available at http://energycom.gov.gh/planning/data-center/energy-outlook-for-ghana?download=105:energy-outlook-for-ghana-2020-final-draft (Accessed 11 January 2021)

issue that requires urgent attention if a greater proportion of renewables are to be incorporated into the grid.[44] A 2015 survey by accountancy firm PwC found ageing or badly-maintained infrastructure as one of the big challenges in Africa's power industry over the next five years.[45]

Additionally, the significant distribution losses by the DISCOs (ECG and NEDCo) continues to affect their financial viability negatively and subsequently the IPPs. For example, although DISCOs collected an average distribution service charge of about 6 cents per kWh — which should have been used to cover the cost of distribution network operations (DSC 1) and recover distribution losses (DSC 2) — Ghana still has distribution losses above 20% of all power purchased. These losses have barely changed since 2010. It thus begs the question: where have the monies gone to? This indicates that these monies are not being invested back into improving the grid or are inadequate to make a substantial improvement in distribution grid capacity. Regarding the former, interviews with some industry insiders on the distribution charges indicate that they could have been used to cover or pay some of the excess capacity charges that have been incurred resulting from the over-procurement of power during the 2013-2016 power crises. More poignant is that capacity charges for excess capacity are not included in the current PURC tariff methodology, meaning that these costs will have to be paid using other budget lines. Furthermore, even some IPPs have threatened to shut down their operations in Ghana over unpaid debts that government owes them. For example, in November 2020, the industry body, the Chamber of Independent Power Producers, issued a letter to ECG and the Government of Ghana saying they will shut down operations if their overdue receivables were not paid.[46]

Also, this drive to meet current and future demand has resulted in additional unintended consequences concerning the affordability of power (energy equity: basic access to electricity and clean cooking fuels and technologies). From 2000 where electricity access stood at around 44%, data from the Energy Commission[47] shows that the access rate stood at 85% in 2019, making Ghana one of the countries in the African region most likely to achieve 100% access by 2030. In spite of the considerable improvement in access in terms of grid connection, the tariff structure masks the inefficiencies in the distribution system by offloading the price burden on to some consumer categories while also creating unintended consequences of unpaid bills and electricity theft.[48] This results in under-recoveries of costs, negatively impacting investments that can improve the quality and reliability of electricity. For example, the System Average Interruption Frequency Index (SAIFI), which measures the number of times that a customer is interrupted in an operational year, shows that there was an average of 49 interruptions, down from 86 interruptions in 2015. This improvement is, however, still below the regulatory benchmark of six (6) maximum outages permitted per year as per the Electricity

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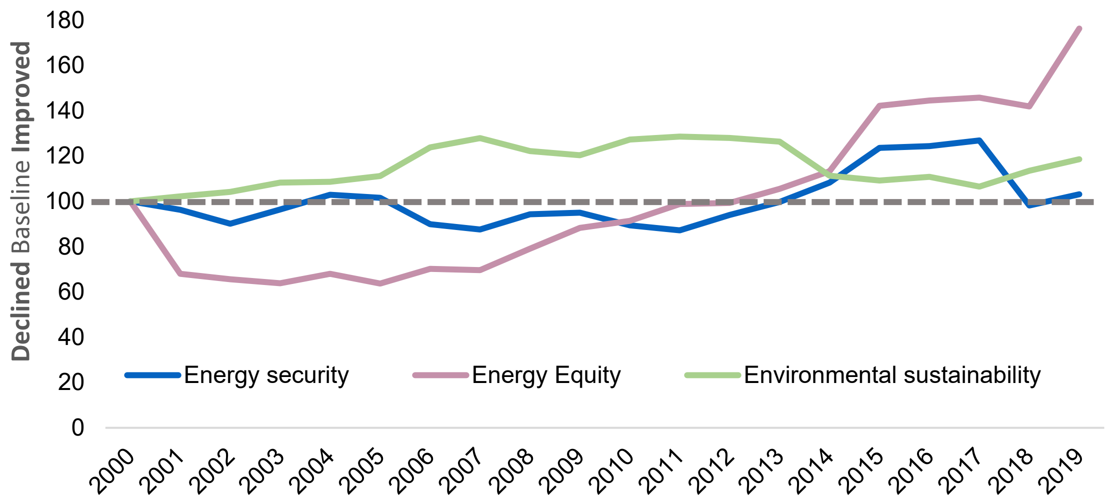
[44] IEA (2020), World Energy Investment 2020, IEA, Paris. https://www.iea.org/reports/world-energy-investment-2020 (Accessed: 23 March 2021)
[45] PWC (2020), A new Africa energy world A more positive power utilities outlook. Available at: https://www.pwc.com/gx/en/utilities/publications/assets/pwc-africa-power-utilities-survey.pdf (Accessed: 23 March 2021)
[46] Dumsor Looms as Independent Power Producers Threaten to Withdraw Power Supply Over $1b Debts (2021). Available at: https://www.modernghana.com/news/1042418/dumsor-looms-as-independent-power-producers-threat.html (Accessed: 23 March 2021).
[47] *Ibid*
[48] Yakubu, O., Babu, N. and Adjei, O., 2018. Electricity theft: Analysis of the underlying contributory factors in Ghana. *Energy policy*, *123*, pp.611-618; Kumi, E.N., 2017. *The electricity situation in Ghana: Challenges and opportunities* (p. 30). Washington, DC: Center for Global Development.

Supply and Distribution (Standards of Performance) Regulations 2008 (L.I.1935).[49] By addressing the electricity system's inefficiencies, fewer losses could mean more power available for industries and other services, including improving access to modern energy cooking services. Presently, only 28% of Ghana's population have access to clean cooking fuels.[50] In other words, about 70% of Ghana's population lack access to clean cooking fuels (mostly cook with biomass), with severe implications for health, gender, and the environment. Addressing the inefficiencies will reduce the need to price in such losses and enhance affordability for promoting cooking with electricity, especially where the country has a substantial electricity supply surplus.

On environmental sustainability, the country's performance— a composite of final energy intensity, low carbon energy generation and CO_2 emissions per capita — remains above average with marginal improvements compared to the 2000 baseline (Figure 24). Whereas hydro formed a significant (68%) portion of the power mix in 2000, the country has gradually increased thermal generation capacity, which, as expected, has been occasioned by increases in CO_2 emissions. There has also been less room for low-carbon energy generation, as observed over the period. On-grid renewable electric power generation has remained static, making up less than 1% of the total generation mix compared to a 10% target by 2020, which has now been extended to 2030. Although there appeared to be significant interest in renewable energy power generation evidenced by the number of provisional licences awarded, the supply overcapacity has led to reduced or no production within the RE sector, increasing investor risk due to some sunk costs incurred. Some companies have been awarded final licences and even signed PPAs but are not yet producing, and it is mainly due to the overcapacity in the system. Additionally, the pricing tariff is symptomatic of an infrastructure needing attention and maintaining the status quo signals difficulty integrating a higher percentage of variable renewables.

Fig 24: Ghana's energy trilemma trends



Note:Trend lines track the country's performance in each dimension, beginning with a baseline of 100 in year 2000
Data Source: World Energy Council (2020)

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[49] Ghana Energy Commission (2019). National Energy Statistics 2009 - 2018. Available at http://energycom.gov.gh/files/ENERGY_STATISTICS_2019_Updated.pdf (Accessed 11 January 2021)
[50] IEA, IRENA, UNSD, World Bank, WHO. 2020. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. World Bank

4.2 Options for Improving Ghana's Energy System

The major challenges in Ghana's electricity market include:

i. Transmission system constrained by underinvestment.
ii. Distribution system that is obsolete and inefficient, with almost 25% of all power purchases lost through technical and commercial losses.
iii. Reinforcing these challenges in Ghana's power sector is the weak financial position of the utilities, especially ECG and NEDCo – all state-owned monopolies.

Table 3 below summarises the challenges and opportunities in Ghana's electricity sub-sector.

Table 3: Ghana's electricity sector challenges and opportunities

Value Chain	Challenges	Opportunities
Generation	1. **Fuel supply:** despite improved gas flows from WAGP, Sankofa and other sources, there is a lack of adequate rainfall which affects water inflow into the Akosombo, Bui and Kpong hydro dams. Additional rainfall would bring down the base generation costs as hydro is cheaper than gas or other liquid fuels.	1. **Economic growth: s**trong economic growth will increase the demand for electricity and thus open the power market for further development. Improved sub-regional cooperation in energy will also open the sub-regional market for enhanced electricity trading through WAPP. 2. **RE power generation:** Investments in especially RE power generation projects to add capacity and balance the national grid to meet projected demand and for regional exports under WAPP. Strong government commitment to private sector-led economic development provides an incentive to increase their participation in the power subsector. Solar and wind energy projects would be beneficial in the long term to reducing grid consumption. Renewable energy provides great prospects for enhancing Ghana's energy security and access. 3. **Public private partnerships (PPPs) in distribution**: There are opportunities for public-private partnerships to manage and invest in the distribution sector in either a joint venture with ECG or as a private utility competing with the state monopoly. This will ensure critical network upgrades and maintenance schedules are adhered to and revenues collected cost-effectively.
Transmission	1. **System harmonisation:** Another challenge facing transmission is ensuring that the provisions of the Ghana Grid Code do not conflict with the West African Power Pool (WAPP) operating manual in terms of syncing interconnections and system frequencies. This is being partly addressed with recent interconnection upgrades such as the Ghana-Burkina Faso under the International Transmission Hub Project of the WAPP (APL3).[51] 2. **Financing:** The majority of Ghana's extensive transmission infrastructure has deteriorated over the years due to inadequate upgrades and maintenance. There is a lack of required financing to expand and upgrade power systems to meet increasing demand, while also ensuring the reliability and quality of operations.	
Distribution	1. **Weak and Obsolete Equipment, and Outages:** The rapid energy demand growth together with inadequate capacity upgrades causes frequent overloading of distribution equipment and lines, leading to frequent network outages. Weak and obsolete equipment coupled with poor revenue collection have resulted in distribution losses of over 20%. 2. **Lack of credible offtaker:** ECG continues to run at a financial loss, which has adversely impacted it as a credible and creditworthy offtaker for IPP ventures.	

[51] World Bank (2021). Increasing Access to Stable, Reliable, and Affordable Energy for the Citizens of the Economic Community of West African States. Available at: https://www.worldbank.org/en/results/2021/01/05/increasing-access-to-stable-reliable-and-affordable-energy-for-the-citizens-of-the-economic-community-of-west-african-states (Accessed: 7 April 2021).

5. Conclusions

This article reviewed Ghana's electricity-gas markets, examining generation and consumption trends, tariff pricing regime, and the institutional and regulatory structures. We further assessed the implications of the country's changing electricity generation mix away from hydroelectric production to thermal power production on energy security, energy equity, and environmental sustainability – the energy trilemma. The critical factor in the economics of power generation, and its viability, is the cost of natural gas or liquid fuels, and this looks particularly attractive if the cost of fuel, particularly natural gas, is low.

We find that electricity generated from thermal sources will continue to form the backbone of Ghana's electricity mix over the next ten years (2021-2030). Nonetheless, Ghana's tariff pricing regime historically failed to incentivise electricity generating companies due to price distortions leading to persistent under-recoveries and state subsidies, thus negatively impacting energy security. This has been corrected in recent years. Average electricity end-user tariffs in Ghana have grown at an average of 9.6% per annum since 2000 from US$0.024 per kWh to US$0.14 per kWh in 2019, which is indicative of the growing diversification of the generation mix from hydro to thermal over the period.

Also, growth in total energy demand more than doubled between 2003 and 2019. However, while electricity consumption by the residential class has increased gradually by 6% compounded annual growth since the 2000s, that of industry comprising non-residential and special load customers is only 5.21% and 1.03%, respectively. This could be explained by the rather high tariffs paid by industry compared to embedded generation costs. For example, we find that non-residential consumers, SLT-LV and SLT-HV mines consumers in Ghana pay much higher tariffs than the average delivered cost of power. Ghana's current tariff structure reflects a developing electricity market, which is similar to that of other Sub-Saharan African countries through the use of different tariff features such as schedules for large customers, block tariffs and demand charges.

Finally, at a sub-regional level, a comparison of electricity tariffs with neighbouring West African countries shows that the cost of power in Ghana is still relatively expensive, negatively impacting the country's competitiveness given that power is a critical determinant in attracting both domestic capital and FDI inflows as well meeting sustainable development goal (SDG) 7. This raises an interesting question: how can Ghana improve its energy trilemma with 2030 being a significant target for the attainment of SDG 7? On energy access, enhancing access to modern energy cooking services and connecting remaining rural communities to electricity will further improve access scores. Undoubtedly, doing it with renewable energy will ensure gains on the diversity indicator and low carbon energy generation indicators on environmental sustainability, all things being equal. Affordability will be the most difficult challenge to address, requiring a thorough consideration of the cost of fuel used and sector reform.