THE PERSISTENCE AND CHALLENGES OF A HYDRO-THERMAL DOMINATED ELECTRICITY GENERATION MIX IN WEST AFRICA: A CASE STUDY OF GHANA, 1966 - 2015

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Abstract
There is a markedly clear consensus among scholars that the presence of a reliable and efficient electricity generation infrastructure and its concomitant reliable power supply has a positive effect on economic development, and that the lack of enough of it effectively retards the pace of economic growth and development. In the absence of a good and efficient electricity generation system to produce the needed electricity, the sectors of a modern economy such as manufacturing, health, construction, communication, entertainment, education etc will shut down. The need to generate more electricity to meet up with the ever-rising demand cannot therefore be overemphasized. However, power supply in West African countries, including Ghana, is notoriously inadequate and unreliable despite continuous upgrading of the generation capacity. This has had a lot of negative economic consequences and still portends a bad omen for the country. Finding the real cause of this unpleasant situation with the view of getting lasting solution to it has therefore been a serious concern among scholars, the government and the people at large. While acknowledging other challenges pointed out by other researchers such as finance, this paper emphasizes that the major problem with electricity generation in Ghana is the persistence of the undue dominance of hydro-electric and thermal generation in Ghana's electricity generation mix. The study adopts a historical method, using secondary sources of information drawn from various fields of study. These are analyzed, using a qualitative approach. The paper finds, that given the high vulnerability of hydro generation to climatic variation and the excessive costliness of running thermal plants, not to talk of the scarcity of their fuel which makes them perform well below their installed capacity, the way out of the wood is for the country to properly diversify its generation sources, in order to have a more balanced and healthier generation mix.
Key Words: Electricity, Hydroelectric Generation Thermal Generation, Diversification, Economic Development

Introduction

After the effective occupation of Africa started, the provision of all it took to maximize the exploitation of the continent was not treated with a kid glove. The colonial government saw the supply of basic infrastructure like transport and electricity as crucial to the development of Africa for its maximum exploitation. The line of reasoning of stalwart colonial officers went *pari pasu* with this belief. Although Fredrick Lugard had argued that the material development of Africa was heavily dependent on transport infrastructure,[i] (other infrastructures like electricity were not held in lower esteem; concern for them was fully expressed among colonial chiefs during the colonial era.[ii]

For one thing, the availability of electric energy and other infrastructural facilities made the extractive process easier; it eased off some administrative challenges and made life more comfortable for the colonizers (both the administrators and the industrialists).[iii] These are apart from its envisaged role in combating or at least reducing city crimes like burglary activities, which were being comfortably perpetrated in the unlit streets in the nights.[iv] It was also in the interest of the colonial masters to listen to the prevailing opinion of people in the print media, the majority of which were expatriates, calling for the building and introduction of electricity infrastructure. Thus by the late 1890s, the building of power plants in Africa, including Ghana, had begun.[v] It must however be noted that the colonial Government of the Gold Coast (now Ghana) though initiated policies to develop and grow the electricity infrastructure, was largely mean and cautious about embarking on large-scale power development especially towards the end of the colonial period.[vi] The generation capacity of the country was therefore very low. Scholars have recognized the indispensability of energy in developing economies and have characterized it as "the pillar of wealth creation"[vii] Electric energy is a very crucial form of energy needed in modern economies. The electricity industry of any country is normally composed of three different major sectors or aspects – the generation, the transmission and the distribution. Generation activity is the activity of producing electricity through a generator; transmission involves the transporting or the movement of bulk electricity at a very high voltage over a long distance to the distribution points and distribution is the aspect of electricity that involves the carrying of electricity at a stepped down or low voltage to the consumption points. Out of the three aspects, generation is very important. The transmission and distribution infrastructures are as a matter of fact, fed by the generation infrastructure. It is therefore a very strategic aspect of electricity in any country. There is no doubt that one of the chief challenges confronting Ghana in her developmental efforts is the generation of adequate, reliable and affordable electricity to meet speedily rising demand.[viii]

The new independent government of Ghana was also convinced that if rapid industrialization, which the colonialists had tactically restrained was going to be achieved at all; and if rising demand caused by urbanization and population growth was going to be met; there was need to expand the generation capacity and supply of electricity in the country. Therefore, with political independence attained in 1957 ,the new government began to implement strategic policies, to ensure large-scale development of electricity generation infrastructure, to sustain Ghana's fledging industrialization and meet the ever- growing demand for electric power in the country. Rather than expand the existing thermal plant at Tema bequeathed by the colonial government, the new government chose to focus on developing hydroelectric power generation, using the water power of the Volta River. The government was actually basing its decision on the feasibility study carried out during the colonial era, which ascertained the potentials of the Volta River for electric power generation and the best way to go about it. The building of the dam and the hydroelectric power plants at Akosombo marked a turning point in the history of electricity in Ghana. With the commissioning of the country's first hydroelectric plant (the Akosombo plant) in 1966, hydro generation began to take the centre stage in the country's generation system. Since then, the electric power sector of Ghana has been growing rapidly and hydro-electric generation has been dominant in the generation mix. With the introduction of the thermal complementation era in the early 80s, thermal generation joined hydro generation to form a duet domination of Ghana's electricity generation system.

Although generation capacity has improved with time, the rate and nature of its growth and supply has not kept up with that of demand. In Ghana, demand for electricity has been growing over the last two decades by 10 – 15 percent per annum.[ix] On the supply side, generation size has not measured up to ideal expectation. Although the government has continuously believed that the major solution is to increase generation capacity, and has therefore continued to make conscientious efforts to upgrade the generation capacity largely drawn from hydro sources and recently hydro and thermal, erratic power supply has remained. Also, the Electric Company of Ghana (ECG), has been nicknamed "Electricity Comes and Goes," a name that says enough of the erratic power supply situation in the country. Finding the major cause of the existence of this vicious circle in Ghana's generation system has been a serious concern among scholars and administrators.

It has been suggested that the preponderance of the hydro generation means in Ghana's generation system is the major explanation for the country's generation woes. The present writer has also observed from his studies, that even the thermal generation means, which dominated the country's generation system during the colonial era, recently gained much importance in the country's generation system, and which is fast crawling up the generation capacity mix ladder, has not proved very dependable.

Although scholars have written on power generation issues in Ghana. For instance Paul Kuruk (1989)[x] decried the poor performance of Electric Utilities in developing countries, focusing the Ghanaian and Nigerian experiences. Ebenezer Nyako Nkumi (2017) wrote on challenges and prospects in Ghana's electricity sector.[xi] Most of the works focus on the general and specific challenges as well as prospects and what can be done to better the situation of the electricity energy sector of the country. Some have also specifically focused on the need to diversify the electricity generation mix of the country to meet future demand. Ishmael Ackah (2021) specifically advocated for the re-jiggling of Ghana's energy mix to include nuclear energy and other sustainable energy sources to meet up future demand.[xii] Making the sector sustainable to meet future demand has recently become the concern of many energy scholar, even n Ghana. It is against this backdrop that this paper examines the implications or problems of the dominance of hydroelectric and thermal generation for the country's generation system, with the view of advocating for the diversification of the country's generation mix to make it more sustainable.Unlike most of the existing works it shows in many ways how the predominance of the hydro-thermal generation means is problematic starting from 1966 when the Akosombo Dam came to be heavily relied on as a generation means. The study is terminated in 2015 when a government report showed that hydro-thermal generation means still dominated the generation mix by over 50 percent.

The paper is divided into four sections. In the first section, the paper traces the history of the dominance of the hydro and thermal generation sources in the country. The second shows how the dominance has persisted; the third highlights the implications of the persistence of the duet domination on electricity generation and supply in the country and the fourth section proffers solution to the problems created by the undue dominance of hydro-thermal generation. Conclusions are made thereafter.

The History of the Dominance of the Hydro and Thermal Generation Sources in Ghana's Generation System

The history of the dominance of hydro and thermal generation methods in Ghana's generation mix cannot be understood without recourse to the history of electricity generation in Ghana. their use in Ghana. . The history of

electricity in Ghana can be easily divided into three major important eras.[xiii] The first period falls within the colonial period and extends a little to the post-colonial era, while the remaining two are situate within the post-colonial era. The first era called "Before Akosombo" or the Pre-hydro era lasts from the late 1890s when the first power plants (thermal) were built in the country by the colonial government, up to 1966. The second period is the Hydroelectricity or Akosombo era (1966-1982), when the Akosombo Hydro-electric power plants were built by the post-colonial government, and the third period is the Thermal Complementation era (1982 to date).
It is obvious from the short breakdown of the history of electricity generation in Ghana, that thermal and hydro have played domineering role. In the first era, generation was based only on thermal; in the second era, hydro took over the lead and 'benched' thermal generation and recently a hybrid- domination by the two has been the situation.

At the early phase of industrialization, coal was the fuel used to generate energy. Electricity came to be generated by it too using the thermal generation means. The increase in the demand for electric energy led scientists to begin the earnest search for alternative sources of electricity generation. The invention of the electric dynamo and the water turbine in the late 19th century, which can be used to generate energy from water bodies was a major breakthrough for scientists in their quest for more means of generating electric energy. With this invention, scientists and inventors began to look for ways of harnessing and transmitting the energy of great water bodies.[xiv]Sir William Siemens, while addressing the Iron and Steel Institute of Great Britain in 1877, discussed the possibility of generating electricity using water- power based on his personal study of earlier scientists. By 1895, eighteen years later, Niagara Falls was used to generate electricity.[xv] The first hydro-electric plant in the world built by Nikola Tesla and George Westinghouse at the Niagara Falls was officially opened two years later, January 1897.[xvi]Thus, the use of hydro-electricity in the West, nay the origin of it in the modern world, can be traced to the late 19th century.

The colonial government however bequeathed only the thermal generation facilities on African countries. It means then that thermal generation played a domineering role in Ghana's electricity generation during the colonial era. After independence, and in the wake of industrialization in Africa, policy makers deemed it fit to improve electricity generation, largely with the view of increasing capacity. Improvement of electricity generation however took two different forms in newly independent African states. While in some states the improvement took the form of expanding the already existing thermal generating facilities bequeathed by the colonial government (e.g. Nigeria), in other states, the development of alternative generation sources like hydroelectricity became the chosen course.[xvii] The later alternative was Ghana's choice. This was going to be the beginning of the domineering role that hydro generation was going to play in the county's generation history and the temporary 'benching' of thermal generation. While the history of hydro-electricity in the West dates back to the late 19th century, the use of it in Africa is more recent.

Although the use of hydro electricity in Ghana was a matter of nearly late 20th century, the conception of the idea goes farther back into the very early 20th century, during the colonial era. The role of Sir Albert Kitson, who was appointed in 1913 by the British Colonial Office, to establish what was known as the Geological Survey Department, must be noted. It was he, who identified the hydro potentials of the Volta River while on voyage on the river in 1915, and later outlined a scheme for harnessing the water-power and mineral resources of the then Gold Coast in an official bulletin.[xviii]Kitson's proposal was later taken up by Duncan Rose, who became interested in the possibility of the idea of a hydroelectric aluminium scheme. While the contributions of these two Europeans towards the realization of the hydro-electric scheme in Ghana should be acknowledged, it must be noted that the efforts and determination to see the idea translated to reality must be credited to the post-colonial African leaders. Although the Gold Coast Colonial Government commissioned the British firm of consulting engineers William Halcrow in 1949 to study the feasibility of the proposed power scheme and the wider aspects of the development of the Volta River for navigation, health and communication, the power scheme was not implemented until much later. By 1951, when the Halcrow study was reported, Ghana was already becoming self-governing. By this time, a new government with an African majority came to power, but the commencement of the power project was still under way.[xix]

Two years later, the Volta River Preparatory Commission was established under Commander Jackson, in fulfillment of the promise made to the people by the new government to harness the power of the Volta for electricity. By the time the commission gave in its report in 1956, the country was practically (though not ceremonially) independent. It must however be also noted, that the skills of Europeans were also used to carry out the project. For example, the engineering study of Willam Halcrow (1955) and its independent assessment/review by Kaiser Engineers (1959) all helped to establish the most appropriate point on the Volta to build the dam used for the hydro-electric power plant. The site finally chosen was Akosombo. The point remains however that, it was

the post-Independent African governments in Ghana, that saw to the building of the dam and the hydro power plant after the many years of foot-dragging by the colonial governments.

With the enactment of the Volta River Development Act of 1961 by the newly independent African government, the Volta River Authority (VRA) was established, with President Nkrummah as chairman.[xx] He was to work with six board members. The VRA was charged with the duties of generating electricity by means of the water power of the Volta River and by other means, and of manning the transmission and supply of electricity in the country. It was also saddled with the responsibility of constructing the Akosombo dam and a hydroelectric power station near Akosombo and resettling the people living in the lands to be inundated as well as the administration of lands to be inundated and lands adjacent thereto.[xxi] It needs to be mentioned that the much overlooked opportunity cost of the Akosombo Dam and its ancillary power plants is the displacement of thousands of Ghanaians, and peoples of other nationalities.[xxii] The Volta Lake created by 1969 following the completion of the Akosombo Dam had claimed a large land area of about 8,500 km^2 ,displacing a lot of people.

With assistance from US government and the World Bank secured, the Volta River Developmental Project, (VRDP) which included the construction of the Akosombo Dam, and other projects, was commissioned also in 1961. The construction of the dam alone was to cost about seventy million dollars.[xxiii] The construction of the dam actually commenced officially in 1962. This was the year that the long and tiring rounds of negotiation between Ghana's VRA and Volta Aluminum Company, Valco, (a Ghana-based aluminum expatriate firm) which culminated in the Master Agreement was eventually concluded. The Master Agreement, actually a power supply agreement, was signed in 1962 by Dr Osagyefo Nkrumah on behalf of Ghana and Mr Elgar Kaiser of Kaiser Industries Corporation on behalf of Valco.[xxiv] What the Ghanaian government intended to achieve by the agreement with Valco was to secure a reliable market or a bulk buyer of the bulk electricity that was to be generated by the Akosombo Hydroelectric Dam that it wanted to build before embarking on the project. Valco on the other hand, which owned an aluminum smelter, wanted a guarantee of constant supply of power, and that at a very cheap rate, which should not be upwardly reviewed for a specific long period of time. The two parties had to reach an agreement on the matter and put the terms of their agreement on black and white, and that was done by the signing of the "Master Agreement."

The completion of the dam by VRA with the installation of four generating units with total capacity of 588 MW in 1965 and formal commissioning of same on 22nd of January 1966, marked the completion of the first phase of the VRDP. Valco's smelter was connected to the grid of the new hydroelectric system in 1967, the same year it was completed.[xxv]With two additional generating units installed in 1972, the total installed generation capacity was upgraded to 912 MW.

With the view of ensuring power security up to 1985, a study by Kaisser Engineering was commissioned. The report of the study, which recommended the building of another hydro power plant at Kpong, having gone through review by Acres International of Canada in 1974, was implemented. The Kpong power plant was finally commissioned in 1982 and it added another 160 MW to the already existing installed generation capacity. The Kpong operates directly downstream of Akosombo and plays the major role of optimizing the extraction of energy from the Volta Lake. These two hydroelectric power plants sited at the Akosombo and Kpong on the Volta River came to make up the core of Ghana's generation system, and the single largest generation facility in the country and accounted for 1,020 MW installed capacity, more than 80% of total national installed capacity.[xxvi]

Shortly after the switch over to the Akosombo hydro power plants, the power sub-sector seemed to have become insulated from generation challenges. There was enough power to supply to major electricity users and also meet up with Valco's self imposed demand. Indeed, it was thought that the new hydro generation means was enough for the country at least for the foreseeable future. Thus, after the Akosombo Hydroelectric power plants started working, the government came to over-rely on it. This over-reliance on the new hydro generation source manifested in the government's decision in 1967(just a year after the switch on of the hydro plants), to switch all major customers off the diesel-run thermal power plants already in place in the country and to connect them to the Akosombo hydro plant.

In addition, the country thought it was then mature enough to begin to play the big- brother- role to some of its neighbouring countries by exporting electricity to them. In 1969, Ghana signed a Power Supply Agreement with the Commutate Electricite de Benin (CEB), a power company owned by Togo and Benin to start supplying power to the two countries. In 1972 precisely, Ghana's Volta River Authority started supplying electricity to these neighbouring countries via a newly constructed 205 kilometre 161-kv transmission line from Akosombo to Lome (Togo).[xxvii] The bulk of electricity exported to these countries was increased in 1983.[xxviii] Thus, the switch over to hydro generation and the outstandingly great results it yielded at the outset lured the government into a sense of

false security of electricity, and made it become outward-looking rather than first consolidating its internal generation system. These foreign countries were still fed from the Akosombo Hydroelectric plants, and no effort was made to diversify the generation source.

As a result of the drought which drastically reduced the immediate capacity of the hydroelectric power plants in1983, VRA undertook a comprehensive expansion study that year as earlier mentioned, the Ghana Generation Planning Study (GGPS) to ascertain the way forward. This engineering planning study, which was completed in 1985, observed that there was a need for a thermal plant to provide a reliable complementation to the hydro generating plants at Kpong and Akosombo. The natural vulnerability of the hydro plants to frequent reduction in capacity output due largely to variable inflow of water from year to year into the Volta was seen as the major reason for complementing them with the thermal plants. The Volta River had manifested over 10:1 variation in inflow between its highest inflow in1963 and its lowest in 1983.[xxix]

Rather than plan a comprehensive diversfication, The GGPS recommended that the old thermal power plant at Tema be brought back to life, and that new ones be constructed to reliably complement the hydroelectric power plants. The logic was that in time of insufficient rainfall, resulting in little inflow into the Volta, the thermal plants would be used to meet the shortfall in demand resulting from reduction in generation from hydroelectric source. The conclusion of the expansion study therefore, was that by adding thermal complementation, the high vulnerability of the single- hydro generation system would be essentially reduced. The study also recommended that the 30MW Tema power station built and installed in 1961 be rehabilitated as an immediate measure to support the operation of the hydro plants and thus reduce the risk of drastic reduction of power being generated in the country. With all these in place, thermal generation started playing an increasingly important role in Ghana's power generation mix.[xxx] From that period, the expansion of old power plants and the building of new ones (majorly thermal and hydro) came to significantly characterize the development of electricity generation facilities in the country.

Persistence of Hydro and Thermal-Power- Dominated Generation in Ghana

Many years after the hydro period and the 1983 crisis that trailed it, over-dependence on the hydro and thermal plants for electricity generation persisted. Electricity generation in Ghana was still dominated by these two generation means during the period of this study despite much talk about broadening the generation base. Research has shown that as late as the end of 2013, hydroelectricity from the Akosombo, Bui and Kpong and thermal plants, still dominated the generation mix. Hydro generation accounted for more than 50% (53.8%) of total generation capacity available for use. Also, thermal generation accounted for 45.9%. Renewable energy provided only 0.1% while LPG (Liquified Pure Gas) provided the remaining 0.2%. This means that Ghana's generation mix was unhealthy, relying on only two generation sources which proved to be volatile in nature. .

The power generation projection for the following year, 2014, also speaks volumes. The energy outlook and projection for the year went thus: 55% from hydroelectricity, about 45% from thermal, and less than ½% from solar energy.[xxxi] Moreover, this was just the projected generation capacity not the firm or dependable capacity. A 2015 record shows that the dominance went beyond 2013. The table below shows the capacity of each of Ghana's electricity generation sources as at January 2015.

Table 1: Showing the capacities of the various generation plants as at January 2015

VRA Hydro	47%
VRA Thermal	36%
VRA Solar	0.1%
IPP Thermal	12%
Bui Hydro	5%

Culled from "Thinking Big" and Reforming Ghana's Energy Sector.[xxxii]

The table shows that hydro generation sources managed by the VRA and Bui altogether accounted for 52% of total generation, while thermal accounted for 38% altogether. This means that hydro and thermal generation altogether accounted for 90% of total generation as of January 2015. This explains the frequent power crisis the country always found itself in.
The table below Table 2 shows the various power plants that have been built over the years in Ghana, their phase out year, their installed capacity, their reliable capacities and the type(s) of fuel used for the generation.

Table 2: Showing InstalledGeneration Capacity in Ghana

Name	Owner	Phase Out (Year)	Installed Capacity (MW)	Reliable Capacity (MW)	Fuel 1	Fuel 2
Akosombo	VRA	2065	1020	900	Hydro	
Kpong	VRA	2042	160	140	Hydro	
BUI	BPA	2065	260	120	Hydro	
Aboadze T1	VRA	2011	330	300	NG	LCO
Aboadze T2 (TICo)	IPP[1]	2013	220	220	NG	LCO
Tema TT1PP	VRA	2014	126	110	NG	LCO
TEMA TT2PP	IPP[2]	2035	49.5	45	NG	Diesel
OSONOR (CENIT)	IPP	2037	126	120	NG	LCO
Tokaradi 3	VRA	2038	132	120	NG	LCO
Tema Mine Reserve Plant	IPP[3]	2032	80	40	NG	Diesel
SunonAsogli	IPP	2035	200	180	NG	

Culled from Ghana Energy Situation,[xxxiii] *(VRA= Volta River Authority; BRA= Bui River Authority; IPP= Independent Power Producer)*

The table above confirms that there has been continuous addition to the country's generation capacity. However despite the continuous addition to the generation capacity, generation challenge still persists. It is very clear from the table also that the additions have been more or less the increase of the country's hydro and thermal generation capacity, rather than improvement of actual or balanced generation capacity. This is the reason for the persistence of generation bottlenecks. The truth is that as long as the dominance of hydro and thermal generators in Ghana's generation mix persists, generation challenges will continue, and may get worse rather than get better.

Another issue that has to be pointed out is the nature, form and dimension that th esaid dominance has assumed. The nature of the dominance is that, of the two domineering generation sources, hydro source, which has proven with time in Ghana to be very problematic and highly unreliable, has remained dominant. Despite the increasing introduction of thermal generators, and the much talk about the thermal complementation era, hydro generators are still more heavily relied on in the country. Even the coinage *thermal complementation* has an implication that the hydro generation means would continue to dominate the generation mix, and would only be complemented by thermal generation which by implication would have to play the second fiddle. This indeed has been the position of things, and so the generation system in Ghana has remained vulnerable to 'drought attack' and consequent frequent reduction or fluctuation of actual generation capacity.

Although thermal complementation era can be said to have started in 1983, when the generation expansion study was commenced, the country was still practically dependent on only the hydro generation means until 1993 when the refurbishment work on the Tema diesel-run thermal power station was eventually concluded. The rehabilitation of the Tema diesel plant faced serious delays, and was not completed until 1993.[xxxiv]Even though the study had recommended that the refurbishment of the plant be commenced in 1985 when the study report came out, and be concluded the following year in 1986, the work did not start until almost a decade after, 1991, and was concluded and put to use between 1991 – 1993. The country thus kept depending majorly on the hydro plants for a decade after the formal introduction of the thermal complementation era.

However,the government commenced the building of a 330 MW combined cycle thermal power plant at AboadzeinTakoradi in 1999.[xxxv]Another thermal power plant was built on the same site the following year (2000) as an expansion of the former. The second plant Takoradi 2, was built by joint venture arrangement between the VRA and CMS Energy of USA, and was a plant with 220 MW capacity.[xxxvi] This brought the Takoradi plants to a total capacity of 550MW. The second plant of Takoradi is well placed to be upgraded by 110 MW once gas is available. Apart from the Takoradi, the Tema plants altogether provide 213MW. These two, Takoradi and Tema, make up Ghna's major thermal plants.With these two power plants in place, thermal generation began to play a significant role in Ghana's generation mix, accounting for about 40% of total national capacity.

Another dimension to the dominance of the hydro and thermal generation can be seen when one looks at the phase- out years for the country's power plants in the table above. The plants with higher dominance tend to have longer years before phase out year. The table reveals that hydro and thermal have longer useful years than any other, and this suggests strongly that the dominance of the two generation sources is still incontestable. It is also clear that hydro generation source still has more hold on the country's generation system, because while other existing generation sources will soon be phased out, it will continue to be heavily depended upon for many years to come.

Also, this era of thermal complementation has seen the opening up of the generation sub-sector to private participation for the very first time, as a strategy to ameliorate the power crisis in the air. Transmission and distribution have always been handled by the government and not open to private participation, the status-quo has remained. Given the government low financial capacity to expand generation, funding through private finance has become mandatory. Although during the colonial era there were few standalone generators owned and used by private firms and industries, the operators of the generators were using the facilities for themselves and not for the public use.

The thermal complementation era saw the growth in private participation in electricity generation for sale to the public. The introduction of private participation in electricity generation was however in line with the government privatization policy adopted in 1994/95.[xxxvii]In 1995, the Power Sector Reform Programme (PSRP), which aimed at restructuring the power sector and thereby attracting private investors, was initiated.[xxxviii]It was in line with this policy that the government contracted two emergency power producers, namely, Aggreko Ltd and Cummin Ltd both of the UK, to produce and sell up to 30 MW each into the distribution grid in Tema.[xxxix] Also government's VRA had to enter into a Joint Venture Arrangement (JVA) with CMS Energy of USA to expand the Takoradi Thermal power plant from 330MW to 550MW.[xl]Subsequently, CMS' stake in the JV was taken over by TAQA of Abu Dhabi. The argument however is that the private investors have focused attention on thermal and hydro generation, and this has increased the hydro-thermal dominance.

Ghana eventually started using Independent Power Producers (IPPs) to complement its efforts in producing or generating electric power. As at 2011, there was up to three IPPs operating in the country with their own generation units already in place, and more were planning to do same. The three that operated in that year were Takoradi International Company (TICo), owned by the Abu Dhabi National Energy Company; SunonAsogli power plant, owned by the Shenzhen Group of China and CENIT, owned by CENIT Energy Limited.The fourth IPP, Cenpower, received assent by Ghana's parliament in October 2012.[xli] However, where the worry lies is the fact that the Independent Power Producers contracted have been producing majorly using the hydro and thermal means, and thus perpetuating the hydro-thermal- dominance.

Although private finance has contributed to power generation projects to boost generation, its contribution has remained limited,[xlii]making the government to try other means like regional approach, but this has also unfortunately perpetuated the hydro-thermal dominance. The West African Gas Pipeline Project (WAGPP) and the West African Power Pool (WAPP) are regional initiatives aimed at improving power generation and supply. Although this is a promising approach to solving Ghana's power generation problem, its efforts so far has been geared towards securing cheap and reliable fuel (natural gas) for mostly thermal generation. This has made the WAPG's member countries to keep relying on thermal generation means. This is apart from the fact that the WAGP has lived below its promises to ensure that natural gas is always available. Pipeline vandalization, the issue of militancy in the Niger Delta region of Nigeria from where most of the gas is obtained and increased demand for the fuel locally in Nigeria which is given priority have combined to make the noble goal of making the availability of the fuel to member countries like Ghana guaranteed almost impossible. Thermal generation, the only significant source of complementing the notoriously volatile hydro plants in Ghana therefore remained also volatile and unreliable. The situation thus was one where the unreliable was used as a back-up for the unreliable.

The power situation in Ghana therefore for a long time remained prone to crises. From the building of the first hydro power plant in Akosombo, the country witnessed several power crises as would be seen in the next section of this paper. The scarcity of gas and other fuels for thermal generation has also clipped the wings of the thermal plants from soaring and hitting the peak of their expected performance.

Problems of Hydro-Thermal-Dominated Generation

One major problem of hydroelectric generation is its vulnerability to 'drought attack.' Dams are normally used to run the hydroelectric plants, and these plants need a steady inflow of reasonable quantity of water, in order to function effectively. Whenever there is drought, often characterized by low water inflow into the hydroelectric

dams, an economy largely dependent on hydroelectricity will be thrown into severe electricity crisis. Ghana has faced several drought-related electricity crises over the years. A large fraction of Ghana's electricity is generated from hydroelectric dams as we have shown before now, as a result, the Ghanaian economy has continued to face serious electricity challenges.[xliii]

Between 1982 and 1984, a great drought hit the Volta lake from which electricity was generated, and this compounded the already declining power consumption in the country. During this period, the amount of water that flowed into the reservoir of the Volta Basin was less than 15 percent of the expected total inflow. Thus there was no enough water for the hydroelectric plants to work at their optimum capacities. Generation level therefore fell drastically. Having all their eggs put in one basket, the country suffered a severe unexpected shock. Owing to the fact that the country was operating hydroelectric generation plants for the first time and were consequently not used to its susceptibility to drastic reduction caused by drought, the occurrence therefore threw Ghana's electricity system into unenviable crisis. This resulted into shutting down of companies and industries in Ghana. The country was getting the result of its over-dependence on the hydro generation source, and it was not a good result.

The crisis, coupled with the numerous power supply commitments of the VRA to industrial and foreign consumers, made the situation of electricity in the country during this period more pitiable. The large power requirements by Valco, the aluminum smelter that was by the Master Agreement entitled to 370MW,[xliv] above 40 percent of the total generation capacity, became a hard bone to chew, not to talk of the supply agreement made with foreign neighbouring countries. Being majorly a "rain-fed" system, Ghana's electricity has continued to suffer severe power failures. Over the last three decades, Ghana has experienced five major power crisis resulting from poor rainfall into the Volta. The first, which we have already mentioned, occurred in between 1982-84, followed by the second, between 1997-98, the third between 2002-03, the fourth between 2006-07(when electricity was shut off for 12 hours every two to three days and business entities had to purchase private generators to meet their needs because the Akosombo hydroelectric plant, which generated two thirds of Ghana's power supply was operating at only a third of its capacity due to drought) and the fifth between 2012 and 2014.[xlv] The implication of this is that the amount of power supplied in a year is influenced by the amount of rain that falls in that year.

One major strategy used to ameliorate the problem of drought attack on the hydro plants was the strategy of load-shedding, but this strategy only blew cold air and bit at the same time like a dangerous rat. Actually, the history of load shedding goes back to the colonial era when the power plants available were badly insufficient, and electricity generation was in its infant stage. It was this strategy that the government of Ghana adopted to tackle the drought effect on electricity generation failure. This strategy however did not leave the electricity system without some economic losses. Supply to VALCO was curtailed after much debate and negotiation. The contractual value of 370MW was reduced to 20MW,[xlvi] less than 6 percent of what was hitherto supplied. The 20 percent was just what was required to maintain the smelting equipments, for lightening and other less power-consuming activities. But the company had to suspend its operation until the crisis was over due to the large power requirement that their operation demanded, and which the VRA could not afford to provide given the crisis.The government of Ghana lost huge amount of money as power supply to Valco and other customers were cut significantly. According to Databank Financial Services Ltd, the power outages compelled companies to incur unplanned operating costs of about $62 million per month or $744 million per annum due to the use of privately acquired generators.Export supplies to Togo and Benin were also significantly sliced.[xlvii]Power supply to residential, commercial and industrial entities was also curtailed. The curtailment programme remained in place until 1985 when the crisis was put under control.

Unfortunately, thermal generation, which is meant to complement hydro generation also has its problems. One major problem that thermal generation faces in Ghana is the unavailability or scarcity of fuel to power the thermal plants. Although the Takoradi and the Tema plants can run on LCOs or NG, they are at present, due to the scarcity of NG, operated on LCOs obtained majorly from Nigeria. The fuel is not really available in a large quantity in Ghana, and is very expensive in the international market.[xlviii]The Ghana Growth and Development Platform (GGDP) economic analysts have posited that, Ghana's current electricity generation trouble has more to do with fuel unavailability to power the plants to generate up to the installed capacity, than with low installed generation capacity.[xlix] This is not peculiar to Ghana. At a time the Brazilian National Electric Power Agency (Aneel), recognized this problem and had to take off the thermal plants from the generation system.[l]There was no gas to power them and they were just occupying space. Today, Brazil uses thermal plants as mere complements to other generation means, they have learnt not to rely on it at least until they will be sure of good and reliable source of fuel for the plants.

Probably, Ghana also realized this problem and thus originally introduced the thermal plants to complement the hydro plants. However, due to the scarcity of fuel, the introduction of thermal generation means to complement the hydro means in Ghana has only helped in a limited way to reduce generation challenges in Ghana. This should not sound surprising as the Ghana Generation Planning Study had already hinted that it would be so. The study had concluded that thermal complementation would only **reduce** the vulnerability of Ghana's electricity generation system to the shock of sudden reduction in capacity output often occasioned by low water inflow into the Volta (Ghana's main water body for electricity generation), not remove it entirely.[li]

This prediction proved rather true. After the belated completion of the refurbishment of the Tema power plant, which lingered for more than a decade, the thermal plant did not function optimally largely due to its huge cost of operation (cost of obtaining fuel to run it) and for the fact that the plant was not perfectly refurbished due to the problem of getting new spare parts to replace its ancient and outdated parts. The contribution of the Tema thermal station was therefore very negligible during that era.Affliction thus arose the second time. The country had to battle with power shortage starting from1997, and this became very disturbing in 1998. The country was thrown into the 1998-2000 power crisis as a result. In its characteristic manner of responding to issues only when they become very critical, the government quickly took some measures to address the situation. Arrangement has however been made for natural gas to be brought in commercial quantity into the country from Nigeria through a regional integration scheme, the West African Gas Pipeline project. Yet, supply has not been reliable due to some factors which include militancy in Nigeria's Delta Niger where the fuel is mostly procured. The power crisis in Ghana became worse in 2003 and reached a critical point in 2006–2007 when electricity was shut off for 12 hours every two to three days.It is however worrisome that Ghana has been for some time now tending towards relying so much on the thermal plants, and the result has not been pleasant, and will not as long as the issue of fuel is notfirst soundly addressed.

The problem of unavailable or scarce fuel generally based on the fluctuation of climatic condition for hydro and fluctuation of supply for thermal, due to either rising price or real scarcity, has made the plants to function well below their installed capacity. Hardly has any of these plants functioned at any time close to its ideal or installed capacity. Taking a look at the working levels of the existing plants as at 2009 from the table below, one would gain insight into how far below their optimum capacity they performed.

Plant	Owner/ Operator	Installed Capacity* (MW)	Maximum Capacity (MW)	% Of Existing Capacity
Akosombo Hydroelectric Plant	VRA	1,023	1,020	52.7%
Kpong Hydroelectric Plant	VRA	160	152	7.9%
Takoradi Thermal Power Plant-T1 (TAPCO)	VRA	364	330	17.0%
Takoradi Thermal Power Plant-T2 (TICO)	TICO	241	220	11.4%
Tema Thermal Power Plant-T1 (TT1PP)**	VRA	113	113	5.8%
Mines Reserve Plant (MRP)	VRA	80	50	2.6%
Tema Thermal Power Plant-T2 (TT2PP)	VRA	50	50	2.6%
TOTAL		**2,031**	**1,935**	**100.0%**

Table 3: *Table showing the performance levels of the existing plants in 2009, culled from a power report.*[lii]
From the table above, it would be seen that total of the existing (functional/working) capacity was less than 50% of the total installed capacity. This explains why the power shortage remains a sad reality.

Another problem of hydro-thermal generation is locational problem. Hydro generation plants and even thermal ones are normally located closer to river drainage basins than tomarkets,[liii]the plants' closeness to coastal areas being the need to secure easy fuel like water for hydro and shipment of gas and diesel from outside, into the country, for thermal. Apart from this, thermal plants are often located to the coast because of their cooling needs. A great deal of water is needed to cool the heat generated at the steam condensers. The distance between the generation point and the consumption point thus becomes rather long. The effect of this far distance between the plants and the consumption points is that the cost of distribution and transmission increases.

Apart from the increase of cost of distribution and transmission, which alone is enough disadvantage, the amount or bulk of electricity lost through line loss, increases with longer distance. Electricity dissipates in the form of heat to the atmosphere along transmission and distribution lines.[liv]The loss of electricity through this medium is

called line loss. In 2001 for example, 14% of electricity generated in Ghana was lost through line loss (11% during distribution and 3% during transmission).[lv] It is logical to see that more electricity is lost during distribution than transmission because distribution takes more time and electricity during distribution travels through longer distance. Although line loss can be caused by technical factors like lack of well maintenance of the lines, which in some cases lose resistivity and go out of shape, dangling in sagging position, but distance do to a large extent contribute to line loss.

Another problem which is peculiar to hydro generation, is the over-flooding of large areas through the dams usually created for the purpose of generation. The result has always been the relocation of large number of people. The economic cost of relocating a large number of people is enormous. Apart from the economic consequences, such relocation also has psychological, cultural and social effects on the people thus moved. Thriving relationship networks are severed, businesses are also interrupted etc. When the Akosombo dam was constructed for the Akosombo hydroelectric plants, a large expanse of land was claimed by the dam, thus necessitating a mass relocation of people, which cost the government a fortune. By 1969, the Volta Lake created following the completion of the Akosombo dam, had covered an area of about 8,500 km^2 and could hold over 150,000 million m^3 of water at its full supply level.[lvi]The lake was about 400 km long and covered an approximate area of 3,275 square miles, i.e 3% of Ghana. Apart from that, the drainage area of the lake also claimed another large portion of land approximating to 398,000 km^2, stretching from Ghana to portions of Togo, Mali, Benin and Cote d'Ivoire.[lvii] This effectively forced the displacement of about 80,000 people.[lviii] In 2000, the World Commission on Dams estimated that 40-80 million people were physically displaced worldwide.[lix]

It is incontestable to assert that every electricity generation method has one environmental disadvantage or the other. However, some have more disadvantages than the other, and the area of disadvantage also matters a lot. The environmental disadvantages of thermal and hydro generation methods are very grave. Thermal generation contributes significantly to air pollution which sometimes results to climate change. The estimated CO2 emission from the world's electricity power industry, majorly from thermal is 10 billion tonnes per annum.[lx]This usually results in an increase in the level of carbon dioxide released into the earth's atmosphere, which facilitates the green house effect and contributes to global warming.

Apart from this, the need to cool off the thermal plants lead to heat being emitted into water bodies continuously, this leads to temperature change to which water animals may quickly respond, by relocating, and some may even die. Hydro generation affects water and the plants and animals living in those water bodies majorly by sending them away from their original habitat. The process of building the dam could also lead to the decimation of some of those animals. Damming interrupts rivers' flow, and can harm local ecosystems. Hydro dams thus have great negative effects on water bodies and distort biodiversity by decimating wildlife too.[lxi] Already in Brazil environmental activists have started movements against the great space consumption of hydro dams and their other negative environmental effects.[lxii]

Another problem that hydro generation method has created for mankind, which has often been overlooked is the great disasters that take place with dam failures. Owing to the fact that large conventional dammed-hydro facilities hold back large volumes of water, a failure due to poor construction can lead to disaster. Dam failures have been responsible for some of the biggest man-caused disasters in history. Large number of people die in the event of such disasters. The Bangiao Dam failure in Southern China directly led to the death of 26,000 people, and another 145,000 people who died of epidemics resulting from the dam failure.[lxiii] Millions were also left homeless. Other examples of dam failure in the world, which also led to the loss of lives include the 1963 Vajont Dam failure in Italy, the 1959 Malpasset Dam failure in France etc. It is true that life is full of risk, but such risks must be minimized where possible, and this case is applicable, hence, the strong opinion of the present writer for a serious de-emphasis on the hydro generation method, despite its acknowledged advantages.

It was predicted in the late 60s that for the future of West Africa, (obviously looking ahead to the 20th century) that there would likely be a big increase in hydro-electric power generation.[lxiv] That prediction has been fulfilled in the 20th century; today, hydro-electric generation dominates energy generation in West Africa. However, given the increasing awareness of its many shortcomings, it is increasingly becoming unfashionable to operate a generation system largely dominated by hydro-electric plants. Forecast therefore has it that the future of electricity generation will gravitate more towards a well-diversified generation system in which newer means of energy generation, largely renewable energy, with lesser negative impact on the environment will play bigger roles. It is therefore unwise to continue to build on what would soon become unfashionable and out of trend.

Panacea for Ghana's Power Generation Challenge

Given the situation painted above, there is need to find the way of taking Ghana's electricity generation out of the wood. It is the strong opinion of the present writer that the way out is for Ghana to look into how to diversify its electricity generation mix.

To raise dependable generation capacity, rather than keep increasing the installed capacity of thermal and hydro sources indiscriminately, the government should begin de-emphasizing the two 'almighty' generation sources and increase the generation base (its breadth and depth) by diversifying generation sources. Ghana has in abundance, wind, solar, biogas and other renewable energy sources.[lxv] These energy sources should be tapped into and less emphasis should be placed on the hydro and thermal sources given their volatile, problematic and undependable nature. Over-reliance on the thermal and hydro power sources which has done a lot of harm to the country should be discontinued. Between 2006 and 2007 for example, hydroelectricity, which accounted for two-third of Ghana's total electricity generation, was forced to function at a third of its normal generation capacity by the drought that hit the country.[lxvi]

It is a fact that broadening or diversifying the generation mix is capital intensive, and will consume a lot of money which may not be readily available to the government. Finance is therefore one of the biggest challenges that has kept Ghana's actual power generation capacity low.[lxvii] However, the issue of finance can also be sorted out. First, one of the main causes of lack of funds is the fact that energy pricing in the country has not been cost effective; and the VRA has not been recovering its cost of power generation let alone making profit. The pricing and rate collection systems should be reviewed. Second, private capital can be used to supplement available government's energy generation fund. What the government should do first is to woo private investors (both local and foreign) through investors-friendly energy policies.

The government is already encouraging private investors to invest in the energy sector by using Independent Power Producers (IPPs), a form of partial privatization. This may appear to be a slow approach to privatization, but is commendable. Chile and New Zealand have achieved full privatization, but all did it gradually. It has been observed that hasty privatization leads to a situation where the wealth of the nation is thrust into few greedy hands.What is worrying however, is the fact that these IPPs are concentrating on the thermal and hydro generation. The government should mandate any IPP it wants to contract to focus on developing other generation sources especially renewable energy sources.

The government can also solve the problem of funding by using regional integration approach. It must be realized by African countries that the future of electricity in Africa, is to a large extent tied to their ability to get neighbouring African countries to pool their resources and harmonize their energy policies for their common good. The fact is that the unexploited energy resources of the African countries, especially the sub-saharan region, are concentrated in a few of the countries that are geographically far from the centres of power demand.[lxviii]Co-operative approach is therefore very crucial. Indeed, a lot of problems can be solved using the regional integration approach. For example, the issue of drought can be reduced if there is co-operation. Not all the droughts are caused by poor rainfall, which is a natural cause, there is also an external as well as artificial cause. The construction of dams in Burkina Faso on an important water source to the Volta for example has blocked some channels from which water flows from there to the Volta, thereby contributing to the frequent drought affecting Ghana's power.[lxix] Ghana has to go into dialogue with Burkina Faso and indeed all her neighbouring countries to agree to work together for the development of their power sectors and not work against each other. It is a pointer to the fact that, the success of the power sector of any African country in this new dispensation of globalization, lays in the integrative approach to power infrastructure development. Joining the West African Gas Pipeline Project (WAGPP) and the West African Power Pool (WAPP) is a step in the right direction. However, regional integration schemes that will contribute to the broadening of the generation base by focusing more on the renewable energies should be formed. The Ghanaian leaders should key more into such co-operative schemes in order to build up the nation's power generation capacity.

Available funds should also be used wisely, especially for the maintenance of the plants that are working. Lack of maintenance is a serious issue leading to poor power generation in Ghana and in many African countries. Mechanical faults/problems with some of the turbines and machines being used contribute to the weakness of the power sector of Ghana. Most of the plants are spoilt and thus not working at all or properly because of some mechanical problems. Economically speaking, building plants with a lot of money and leaving them non-functional for one reason or the other is uncalled-for. Increased installed capacity,which is not reflected in actual generation is a waste of resources, considering the time value of money. The economic rationality of such a decision is indeed questionable. The money used for such wasteful projectsshould have been used to develop other more reliable generation sources.

Summary and Conclusions

Research has it that fast-industrializing developing countries, to which Ghana belongs, must cope with extremely rapid growth in power demand which can be as high as gross domestic product (GDP) growth.[lxx] Demand for electricity has indeed increased significantly since the early post-colonial era in Ghana. Government has struggled to meet up with the sky-rocketing demands. Worsening this situation is the problematic nature of the two generation sources which have dominated the country's generation mix- hydroelectric generation method and the thermal method. While the former is vulnerable to climatic fluctuation, the latter has suffered from scarcity of fuel and high cost of maintenance. The cost of thermal generation is as a matter of fact over 100% more expensive than hydro.[lxxi]This has resulted in serious power deficits that have led to persistent power outages and serious load-shedding programs. This underscores the need for the government to braze up to the challenge of expanding its generation base, so it can meet up with the ever-increasing power demand.

The researcher recommends that Ghana should leave the era of thermal complementation and move on to an era of proper diversification of its generation sources. The government must begin to seriously explore and exploit alternative sources of energy, especially renewable energy (some of which have been highlighted in this paper) for electricity generation. Special attention should be given to the solar energy in the light of the 2007 discovery of natural gas in Ghanaian waters. Recent research has shown that the utilization of local gas reserves in Ghana for power generation will prove to be an economically superior strategy compared to the export-oriented utilization approach.[lxxii] While it is commendable to utilize regional co-operative schemes, the country must not rely fully on that, but try to also exploit the resources within for power generation. The quantity of gas that Nigeria is supposed to be supplying to Ghana through the WAGPP arrangement has not always been met. For example, in 2013, a total of 11.6 trillion standard cubic feet (Tscf) of gas was delivered by the WAGP for thermal generation. This was 25% less than the gas delivered in 2012, and less than a third of the contract volume of about 45 Tscf.[lxxiii] The time the supplies arrived was also almost always very late.

The building of electricity generation infrastructure for development is very important, but the right mix of infrastructure must be built, otherwise the result would be counter-productive. There is no doubt that the pace of economic development in Africa, and in any other place is to a reasonable extent, dictated by the level of development of the electricity infrastructure put in place there. It has been argued that for the country on the take-off stage into the middle- income status, the wrong configuration of generation sources will definitely constitute a drag on the country's economic development initiative as it has done in Ghana.[lxxiv] The dream of economic development cannot therefore be realized if the right mix of electricity generation infrastructures are not put in place to support Africa's fast-industrializing economies.

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