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Research Article

The Choice of Nuclear Energy for Ghana as a Result of Development of Its Energy Production

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Ghana thought of nuclear energy early in the 1960s but has not been able to realize this dream of generating electricity from nuclear power. Ghana's electricity generation dates back to the Gold Coast era where the main source of electricity supply (isolated diesel generators) was owned by industrial establishments, municipalities, and other institutions. The electricity sector has developed over the years and has diversified its power generation development to take advantage of available and sustainable sources of energy, mainly hydro, natural gas, liquefied petroleum products, and renewables. These sources sought to increase the electricity production capacity in the country, but unfortunately, it has not been able to catch up with the rate of economic growth, urbanization, industrialization, and rural electrification projects. This has led to Ghana's persistent energy crisis, with inadequate and unpredictable power supply coupled with erratic and prolonged cuts of electricity to homes, industries, and businesses which is now colloquially referred to in the local parlance as "dumsor." The Government of Ghana and key stakeholders have therefore decided to add nuclear energy to the energy mix of the country to complement the country's two main energy sources being hydro and thermal electricity. The details of the developments in the electricity sector leading to the choice of nuclear energy as the best solution for Ghana have been outlined.

1. Introduction

Electrical energy is one of the key determining factors of the economic prosperity of any nation. Electricity is essential in every aspect of our daily activities such as lighting, food preparation, heating, education, quality healthcare delivery, transportation, communication, mining, and powering machines. Thus, it serves as the foundation on which every sector of a country's economy grows. This underscores how critical and necessary electricity is for quality of life in this modern time.

2. The History of Power Generation in Ghana

The generation power in Ghana dates back to the preindependence era, where the source of power was predominantly from isolated diesel generator plants distributed in the country. Most of the power systems at the time belonged to industrial establishments, municipal assemblies, and other organizations. In 1914, the Gold Coast Railway Administration built the first public power generation plant for the operations of the railway sector in Sekondi [1]. The supply was in 1928 made available to Takoradi. Meanwhile, the Public Works Department that was initially in charge of electricity extension had started power supply in Accra in 1922 from a limited direct current (DC). Subsequently, in 1st November 1924, a large alternating current (AC) project followed the DC source.

Honorable William Omsby-Gore on 1st April 1926 opened another generating plant consisting of three horizontal single-cylinder oil-powered engines installed in Koforidua in the previous year. The extension of power to Kumasi begun in 1926, and it became fully operational on 1st October 1927.

Winneba got a DC supply installed in 1927 which was later changed to AC by bringing an existing supply from Swedru. Power supply was extended to Tamale in the period 1929-1930, then in 1938, a new AC was installed to increase their supply. In 1932, Cape Coast became the next place to enjoy the establishment of a power station.

The Public Works Department was initially in charge of extending electricity to the major cities, but on 1st April 1947, this responsibility was taken over by the Electricity Department which was established under the Ministry of Works and Housing.

In 1948, there were installations of power generating sources at Swedru, Oda, Dunkwa, and Bolgatanga. The construction of an 11,000-volt overhead transmission line from Accra made it possible for Nsawam to get power supply in 1949. Cities like Tema, Accra, Kumasi, Nsawam, Temale, and Bolgatanga received electricity supply by the year 1955. The chief source of power during this time was diesel generator plants.

By the time the Akosombo Dam Project was completed in 1972, there was a total installed capacity of 912 MW. The project was mainly to supply power to the aluminium industry; however, it assisted with the country's switch of major electricity consumed from diesel generators to hydroelectricity. It was at the time that the Volta River Authority (VRA), managers of the Akosombo Hydroelectric Power Station, started selling electricity to countries like Togo and Benin. The installed generation capacity was increased by 160 MW in 1982 when the Kpong Hydroelectric Power Station was commissioned.

Ghana was hit by a severe drought between 1982 and 1984. This caused a long-term shortfall of about 15% in the total inflow into the Akosombo Dam. Ghana at this time, notwithstanding the increase in generation capacity, suffered its first electricity crisis in 1984. Ghana's generation mix saw the introduction of thermal power plants due to the crisis with a 550 MW facility (Tapco and Tico) at the Takoradi Thermal Plant. By the end of 2015, the total installed capacity of thermal power plants in Ghana has increased to 2,053 MW [2]. The peak load of Ghana has been on an ever-increasing path. This necessitated the construction of the 400 MW Bui Hydroelectric Power Station (commissioned in December 2013) to support the peak load.

3. Effect of Ghana's Economic Growth on Its Power Sector

In spite of these increases in the installed and generation capacity, the country's power sector has, over the past decade, been plagued with power supply challenges due to economic growth, urbanization, industrialization, and rural electrification projects [3–5] resulting in considerable impact on the economic situation of the country.

Ghana has experienced an increase of 49.8 percent in peak load over the last 10 years, increasing from 1,393 MW in 2006 to 2,087 MW in 2016 [2, 6, 7]. This translates into an annual increase of 4.29 percent in peak load over the period under review. Generation capacity on the other hand has more than doubled over the same period, from 1,730 MW in 2006 to 3,759 MW in the year 2016, an average annual increase of 8.60 percent. In addition, the installed generation capacity saw a 29.14 percent increase in 2015 over the 2014 figure of 2,831 MW and a further 3.79 percent increase in 2016, whereas demand decreased by 1.88 percent in 2015 before increasing by 7.97 percent in 2016.

In 2017, a total of 9,577 GWh of electricity representing 67% of the national total was generated at the Akosombo, Kpong, Tema, Aboadze, and Navrongo facilities. This is a decrease of 0.7 percent over the 9,387.67 GWh generated in 2016. The Ghana power system recorded a peak demand of 2,192.15 MW on November 13, 2017. This is higher than the peak demand of 2,087 MW recorded in 2016, by about 5 percent [8]. Figure 1 shows the percentage energy supply by sources for the year 2017.

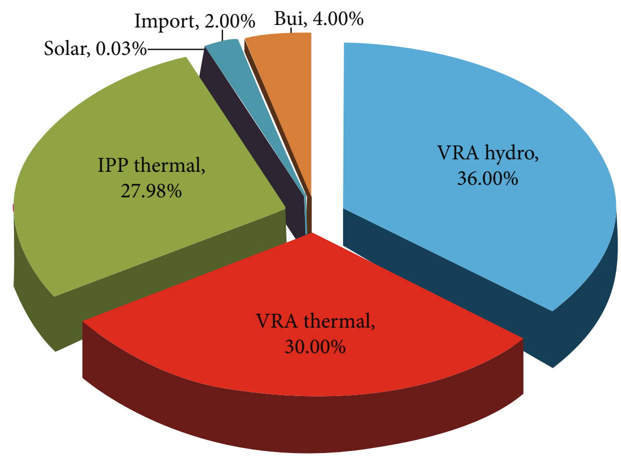

Figure 1: Energy supply by sources for the year 2017 (source: [8]).

4. Ghana's Energy Crisis

The disparity between demand and supply of power is such that the least disruption in the generation setup results in system imbalance and recurrent interruptions in power supply and total blackout in some cases [9]. The electricity crisis has become a household phenomenon in Ghana leading to the adoption of the local word "dumsor" to describe the blackout situation.

Ghana has suffered several episodes of energy crisis in the past, in 1982-1984, 1998-2000, 2006/7, and 2012-2015. In the last few years, however, the situation became terrible. From 1982 to 1984, the country was plunged into a power crisis which was attributed to poor rainfall in the catchment area of the Akosombo Dam coupled with high consumption rates from the Volta Aluminum Company (VALCO) plant. In response to the situation, on a short-term basis, government reduced power supply to VALCO from 370 MW to 20 MW and subsequently reduced power supply to residential, commercial, and industrial consumers. In what may be considered long-term measures, a Volta River Authority- (VRA-) commissioned research recommended the rehabilitation of the Tema Diesel Power Plant and the construction of a new thermal power plant. The Tema Diesel Thermal Plant was

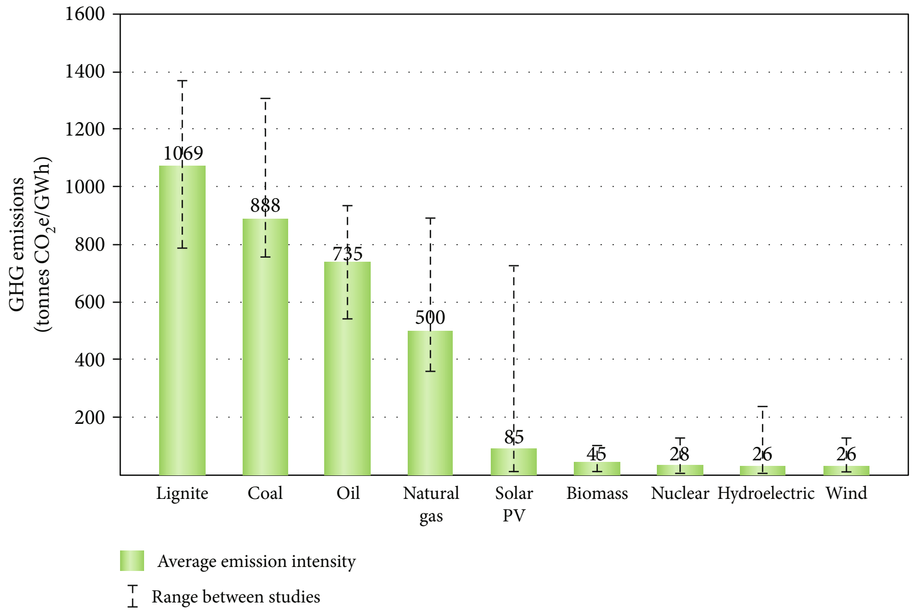

Figure 2: Lifecycle of greenhouse gas emission intensity of electricity generation method (source: [14]).

in operation in 1991. And between 1997 and 1998, the Aboadze Power Plant in Takoradi began operations as was recommended by the 1985 VRA research. Another attempt to solve the energy crisis permanently resulted in the 1995 agreement between Ghana, Nigeria, Togo, and Benin to develop the West African Gas Pipeline (WAGP) to be sponsored by the Economic Community of West African States (ECOWAS). The project commenced 10 years after the signing of the Project Agreement [10].

Despite these initiatives and measures, Ghana was hit yet again by another energy crisis from 1998 to 2000, which was attributed to drought in the subregion due to what is known as the El Nino climatic phenomenon. And between 2006 and 2007, a third crisis was witnessed as a result of poor rainfall and the breakdown of the Aboadze plant. The Government responded to these series of crises by introducing load shedding, leasing out operation of the Transtema power unit, and importing energy saving lamps, among others. In addition, the government also solicited power from La Cote D'Ivoire and speeded up construction of the Tema Thermal Power Plants 1 and 2 (TT1PP). The delayed Kpone Thermal Power Plant which started in 2008 is estimated to be completed in 2015. Ghana also paid its share for the construction of pipelines of the WAGP project in 2005 and had its first supply of gas in December 2008. Other plants such as the Sunon Asogi Power Plant and the Osonor Power Plant (now CENIT of SSNIT) are now operational [10].

Recently, there was another long episode of dumsor which lasted till 2016. Several factors have been attributed to the persistent blackouts: initially, it was ascribed to a faulty pipeline of the West Africa Gas Project (WAGP), which subsequently led to a drastic cut in gas supply from Nigeria to power the thermal plants. But now, the reason has been linked to poor rainfalls between 2012 and 2014, several years of poor maintenance of the thermal plants, and lack of finance to provide fuel for electricity among others [10].

This situation arguably threatened and keeps threatening the social-economic sectors of the country leading to concerns for the socioeconomic stability of Ghana often held as the beacon of peace in West Africa. The energy crisis caused many businesses and industries to fold up, and there were many energy-related problems that the country experienced.

The World Bank ranked electricity as the second most important constraint to business activities in the country and estimated that Ghana lost about 1.8 percent of GDP during the 2007 power crisis [11]. Also, the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana estimated in a 2014 study that Ghana, on average, lost production worth about US $2.1 million per day (or US $55.8 million per month) through the power crisis alone [12]. This means that the country lost about US $680 million (2% of GDP) in 2014 due to the power crisis [13].

As the economy expands coupled with rapid urban sprawl and population growth as well as increase in standards of living, so too will the demand for electricity keep increasing. Hence, it is necessary that Ghana finds new sources of power generation which can help the nation to satisfy this growing demand.

Ghana is looking at the integration of low carbon energy options including renewable energies as shown in Figure 2. Ghana's 2019 energy policy draft is mindful of the intermittent nature of renewable energies, mainly solar and wind, but the policy is aimed at the integration of renewable energy resources in a planned manner to promote the development and use of proven and affordable renewable energy technologies. Renewable energies like biomass, solar, and wind energies are being used in Ghana in small scales. For the energy supply of Ghana to be robust, it is important to consider the contribution of different and reliable sources to the energy mix. Therefore, it is needful and advantageous to integrate all available energy sources into the energy mix.

Figure 3: A typical appearance of a nuclear power plant (source: [16]).

5. The Choice of Nuclear Energy

Mankind will use more energy in the coming years than it has consumed in its entire history. Earlier predictions of energy consumption growth and evolution of energy technologies proved to be wrong as consumption is rising much faster than expected while new sources of energy are not likely to become commercially viable until 2030. Fossil fuels are meanwhile growing short. Opportunities to build new hydropower capacity remain limited, while greenhouse effect prevention measures impose limitations on burning oil, gas, and coal at thermal power stations [15]. A potential response to these challenges is nuclear energy, one of the youngest and fastest evolving global industries. Having realized this, increasingly more countries are embarking on nuclear power. A typical appearance of a nuclear power plant is shown in Figure 3.

The generation of electricity through nuclear energy reduces the amount of energy generated from fossil fuels (coal and oil). This reduction of fossil fuel consumption benefits the situation of global warming and global climate change. By reducing the consumption of fossil fuels, we also improve the quality of the air affecting the disease and quality of life. Currently, fossil fuels are consumed faster than they are produced, so in the future, these resources may be reduced or the price may increase becoming inaccessible for most of the population. Nuclear energy is therefore a perfect alternative to fossil fuels, so the consumption of fuels such as coal or oil is reduced [15, 17].

Another advantage is the required amount of fuel: less fuel offers more energy. One kilogram of 4%-enriched fuel-grade uranium releases energy equivalent to the combustion of nearly 100 tons of high-grade coal or 60 tons of oil. It represents a significant savings on raw materials but also in transport, handling, and extraction of nuclear fuel. The cost of nuclear fuel (overall uranium) is 20% of the cost of energy generated. The reusability of the fuel is also an added benefit of nuclear energy technology. Uranium-235 is not fully burnt up in the reactor and can be reused after regeneration (unlike ash and slag remaining after fossil fuel combustion). With future transition to the closed fuel cycle, the technology will generate zero waste [15, 17].

The production of electric energy is continuous. A nuclear power plant is generating electricity for almost 90% of the annual time. It reduces the price volatility of other fuels such as petrol. This continuity benefits the electrical planning. Nuclear power does not depend on natural aspects. It is a solution for the main disadvantage of renewable energy,

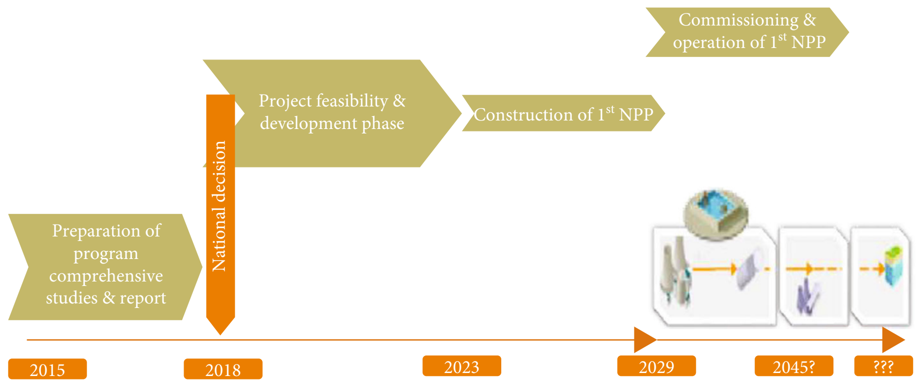

Figure 4: Ghana nuclear power programme roadmap.

like solar energy or eolic energy, because the hours of sun or wind do not always coincide with the hours with more energy demand.

The construction of a nuclear power plant and the entire nuclear energy industry have considerable opposition globally. However, the environmental and renewable energy groups in Ghana do not oppose the construction of nuclear power plant per se due to the contribution of nuclear energy as a low carbon energy source, but there are diverse views or concerns of the safety of a nuclear power plant in relation to waste or spent fuel management. Their conclusions are however largely conjecture.

The Government of Ghana and key stakeholders have therefore decided to add nuclear power as part of a wider project of complementing the country's two main energy sources being hydro and thermal electricity.

Nuclear energy was thought of as early as the 1960s when Dr. Kwame Nkrumah laid a foundation to develop both the institutional and the technological development of nuclear power as a source of electricity to complement the hydropower from Akosombo. The first President of Ghana, Dr. Kwame Nkrumah made the following remarks on November 25th 1964 at the inauguration ceremony the Atomic Energy Project. He said, "we have therefore been compelled to enter the field of Atomic energy, because this already promises to yield the most economic source of power since the beginning of man. Our success in this field would enable us to solve the many sided problems which face us in all the spheres of our development in Ghana and in Africa" [18].

This was not just a farfetched dream but a proper understanding and expectation of how scientific enquiry was essential to our progress and how exploring alternative sources of energy was essential for our country.

Ghana is now working vigorously through the Ghana Atomic Energy Commission (GAEC) and other stakeholder institutions on the introduction of nuclear power for electricity generation. A roadmap has been developed for the commissioning of the first nuclear power plant in 2029 as is shown in Figure 4.

In December 2015, Ghana applied for the IAEA's Integrated Nuclear Infrastructure Review (INIR) mission for the assessment of phase 1 of the nuclear programme. The country then developed the phase1 INIR mission self-evaluation report in 2016. The IAEA conducted the INIR mission in January 2017.

According to the press release by the Ministry of Energy on Thursday, July 2, 2015, upon nuclear power receiving legal backing, Ghana would be the second in Africa after South Africa to produce electricity from nuclear energy, producing 700 MW of electricity in the first phase and then 1,000 MW in subsequent years [19]. The technology assessment strategies have so far dwelt on pressurized water reactors (PWRs), mostly on large reactors, namely, VVER 1200, HPR 1000, and APR 1400 and small modular reactors. Out of these reactors, there is a higher probability that one of them will become Ghana's first nuclear power plant. These reactors are operated using uranium as fuel.

Pursuant to Ghana's nuclear agenda, studies conducted indicated that there are pockets of uranium deposits in some parts of Ghana to serve as nuclear fuel. There are ongoing follow-up studies to assess the commercial viability of these uranium deposits [20, 21]. Ghana's capacity to extract and enrich uranium is still under development. For Ghana to extract and enrich uranium for the first nuclear power plant is not economically viable for now. When Ghana operates a fleet of reactors, then the idea of extraction and enrichment will be of enormous advantage. There is also ongoing discussion and consultation among energy policy experts to draw Niger, a close neighbouring country who has an abundance of uranium, on board. The idea is for Niger to supply the uranium to Ghana in exchange for electricity.

A degree of robustness of the grid is important for the reliable operation of a nuclear power plant. However, Ghana's current grid has a policy not to allow more than 10% of the current grid capacity at 4,000 MW. Therefore, there is an agreement for upgrading the grid system that Ghana currently has to enable it to transport electricity generated by a nuclear power plant.

6. Conclusion

When nuclear power is added to the energy mix, foreign investors will be attracted to invest in Ghana due to the stable power supply that will be available to enhance the smooth operation of their businesses, increasing the income base of the nation through taxes. It can also help Ghana to realize its vision of becoming a power net exporter to many African Nations. This will then strengthen the lower middle-income economy status of Ghana since the energy deficiencies and hindrances would be eradicated.

Nuclear power is a capital-intensive venture for Ghana but seeing what Ghana is likely to gain out of it, it is economically rational that Ghana has decided and is working assiduously on it as an additional source of power.

Since the building of a nuclear plant requires a lot of time and huge capital, the growing energy demand is being satisfied in the meantime with optimal short- to medium-term plans that recommend cost-effective energy options while considering long-term plans with the inclusion of nuclear and other baseload but low-carbon energy technologies as shown in Figure 2.

Data Availability

The data used to support the findings of this study are referenced within the article.

Conflicts of Interest

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

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