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Ghana's Nuclear Energy Programme: Now or Later?

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Abstract
This article explores the feasibility of introducing nuclear energy into the power system of Ghana, a developing nation with increasing energy demand. Examining Ghana's political stability, environmental considerations, and technological advancements in nuclear energy globally, the study evaluates the potential benefits and challenges of developing a nuclear power plant in Ghana. Issues such as public perception, safety, cost of electricity supply and grid reliability, among others, are analysed. Using a literature review approach and data from various sources, the study highlights the need for transparent decision-making, proactive public engagement, and the impact of other alternative energy sources.

Keywords: grid reliability, levelized cost of electricity, safety, public perception

1. Introduction

Nuclear power generation has been a topic of debate for decades, with concerns over safety and environmental impact at the forefront of discussions. While developed countries have been using nuclear power for decades, developing countries are now considering it to meet their growing energy demands. It is generally recognized that within the coming decades, nuclear power is likely to play an important role in many developing countries because, usually, such countries have limited indigenous energy resources and, in recent years, have been adversely affected by increases in world oil prices. Furthermore, the International Energy Agency (IEA) predicts an increase in world primary energy demand by 2035, with over 70% coming from developing countries. Therefore, the world's electricity generating capacity must increase significantly to meet the energy demand. Consequently, a broad portfolio of technologies and energy sources, including nuclear energy and other climate-friendly options, must be considered to address the generation deficit (Semenenko 2021; IEA 2023).

Ghana is one of the few African countries that have shown a keen interest in developing nuclear energy as a source of electricity supply to meet its growing energy demand. The country has been exploring the possibility of nuclear power since the 1960s, and in 2015, the government announced its intention to build a nuclear power plant by 2030. Consequently, in 2017, the

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International Atomic Energy Agency (IAEA) conducted an Integrated Nuclear Infrastructure Review (INIR) mission in Ghana to assess the country's readiness to develop a nuclear power programme. This mission aimed to ensure high safety and reliability in project and plant operations. The review team identified several areas that needed improvement, including the establishment of a legal and regulatory framework, the development of human resources, and the creation of public awareness, enhancing nuclear safety, financing, enhancing the stability of the electrical grid, stakeholder involvement, site and supporting facilities, environmental protection, emergency planning, nuclear fuel cycle and industrial participation among others. In 2019, the IAEA conducted a follow-up INIR mission and noted that Ghana had made progress in addressing the gaps identified in the previous review (NPPO, n.d.; Nuclear Engineering International 2021; International Atomic Energy Agency 2019).

However, the literature review on nuclear power in developing countries reveals a complex landscape. Developing nations with higher population and energy demand growth rates consider nuclear power a viable solution to escalating energy demands. Nevertheless, due to limited resources, a successful introduction of nuclear power in these countries requires specific criteria related to national infrastructure, challenges in technical complexity, substantial investment, and stringent safety standards. Factors influencing nuclear power development include natural and human resource availability, economic development, the political environment, safety, security, and environmental concerns (Csik and Schenk 1987; Sovacool and Cooper 2008).Currently, South Africa is the only African country with a commercial nuclear reactor for power generation, but the continent has an active nuclear science and technology sector with several research reactors. With ten reactors in eight countries, Africa actively engages in nuclear research, training scientists and students in nuclear science, radiation protection, and waste management. Therefore, the need for nuclear scientists and research-oriented personnel is often overestimated, while practical experience is underestimated. Sub-Saharan African countries like Ghana, Kenya, Namibia, Nigeria, Sudan, Tanzania, Uganda, and Zambia are interested in nuclear programmes and have signed agreements with international nuclear power developers, including Russia’s Rosatom, China General Nuclear, and China National Nuclear Corporation(Sah et al. 2018).

This article navigates the complex terrain of introducing nuclear energy into a developing country, with emphasis on Ghana, examining its potential benefits and drawbacks. The methodology employed in this study involves a synthesis of literature review, case study analysis, comparative analysis, critical evaluation, and a policy-oriented approach to provide a comprehensive perspective on introducing nuclear energy in a developing country. The article meticulously explores the technical, economic, and socio-political dimensions, addressing safety issues, public perception, cost-effectiveness, and the impact on national security and the power grid. By contextualizing this analysis within Ghana’s specific energy landscape, including its resource constraints and developmental goals, the article endeavours to ascertain whether nuclear energy is currently a feasible and advantageous solution for the country's burgeoning energy demands. The goal is to present a holistic perspective that aids in informed decision-making, fostering a discourse that balances the promises and perils of nuclear energy in the unique context of Ghana.

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2. Is Nuclear Energy Right for Ghana?

When considering whether nuclear energy is right for a country, it is important to evaluate the specific context and circumstances of the country. Examining Ghana's specific context and circumstances, it is evident that nuclear energy is right for the country. Ghana's political stability, highlighted as one of the most stable in the Sub-Saharan Africa region, forms a robust foundation for implementing nuclear energy projects(Sah et al. 2018). Also, incorporating nuclear power into Ghana's energy mix is underscored by significant environmental benefits. Furthermore, advancements in nuclear technology, with modern reactor designs, including Generation IV reactors and Small Modular Reactors (SMRs), showcasing enhanced safety features, scalability, flexibility, and reduced construction costs, further support this assertion. Fail-safe technologies such as the Emergency Core Cooling System (ECCS) and Passive Autocatalytic Recombiner (PAR) prevent accidents and ensure safe operations. Additionally, modern nuclear power plants integrate diverse safety features, including duplicate emergency cooling systems, advanced control systems, and enhanced containment structures, providing multiple layers of protection. These advancements collectively affirm that nuclear power is suitable and increasingly safe and efficient for Ghana's evolving energy needs, aligning with global progress in nuclear technology (World Nuclear Association 2020; Tan et al. 2023; Hyvärinen et al. 2022; Dehjourian, Sayyareh, and Rahgoshay 2016; Al-Kusayer 1985).

3. Nuclear Energy Now or Later?

Contemplating the role of nuclear energy in Ghana prompts a critical question: Is it a choice for now or a consideration for the future? Undoubtedly, nuclear power holds significant promise for Ghana, particularly with the notable advancements in its technological landscape, emphasizing enhanced safety measures. The assertion is unequivocal: nuclear energy has the potential to substantially bolster Ghana's energy security. However, the decision to embrace nuclear power must be approached carefully, a notion thoroughly explored in the subsequent sections of this article.

3.1 Public Perception

Public perception of nuclear power projects is a complex issue that varies across countries and regions. According to a report by the Economic Research Institute for ASEAN and East Asia (ERIA), public perception and acceptance of nuclear power are influenced by factors such as safety, environmental impact, and economic feasibility. The report also highlights that public opinion on nuclear power is not uniform and varies across countries and regions. For instance, a survey conducted in Japan in 2019 revealed that 44.3% of respondents were in favor of nuclear power, while 29.5% were against it. Similarly, a study conducted in the United States in 2016 found that 68% of respondents supported using nuclear energy (Murakami and Anbumozhi 2020; Jenkins-Smith et al. 2018; NEA 2010).

Evaluation of the public awareness, perception, and acceptability of nuclear power development in Ghana revealed that only 28% of those surveyed were aware of Ghana's nuclear development plan. Despite the limited level of understanding, it was found that roughly 51% of respondents supported Ghana's nuclear development strategy. Most respondents expressed concern over the

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safety of nuclear energy in Ghanaandits potential effects on people or communities should they decide to use it or in the event of accidents. The report recommended that in order to promote and maintain public awareness of Ghana's nuclear power development plan, the government of Ghana and other stakeholders should adopt a communication strategy and awareness initiatives to address the knowledge gap (Odonkor and Adams 2020).

3.2 Nuclear Safety and Security

Nuclear safety and security are two critical aspects of nuclear power. The International Atomic Energy Agency (IAEA) is responsible for fostering a robust and sustainable global framework for nuclear safety and security among its member states. Its mission is to safeguard people, society, and the environment from the detrimental effects of radiation. As outlined by the IAEA, security considerations within the nuclear industry encompass criminal or unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities, or associated activities, which include the threat of nuclear terrorism. Additionally, the IAEA offers guidance on the intersection of nuclear safety and security for various facilities and activities. This guidance addresses the challenges, opportunities, and best practices essential for effective management in the planning and implementation of diverse programmes and activities(International Atomic Energy Agency 2021b; 2021a).

Post-colonial West African countries face bad governance and corruption challenges, leading to economic stagnation, political unrest, and social instability. Scholarly works identify these issues as major causes of violent conflicts in the region. Examples include the Sierra Leonean war, where bad governance, corruption, and poverty were root causes, and Liberia, where greed and corruption were cited as reasons for the civil war. In Nigeria, corruption is linked to conflicts such as the Niger Delta dispute and the Boko Haram insurgency. The Niger Delta, rich in oil resources, remains impoverished due to corruption at the national level, with a significant portion of oil earnings estimated to be stolen. Guinea-Bissau also experiences violence fueled by deep-seated corruption and bad governance, as expressed by the local population. Burkina Faso faces escalating threats and attacks from violent armed groups, leading to severe consequences for civilians, state institutions, and leaders. Since 2014, the country has witnessed consistent attacks by terrorist groups, resulting in military coups, poor leadership, food insecurity, community tensions, population displacement, strained security institutions, limited access to security services, weak oversight, weapons proliferation, election volatility, corruption, and state frailties(Annan 2014; Marc, Verjee, and Mogaka 2015; Okafor et al. 2023; Akinola and Ramontja 2023).

The security situation in West African countries is a matter of concern. According to a report by the United Nations, the region is facing unprecedented levels of security and humanitarian challenges due to operations by armed groups, violent extremists, and criminal networks(United Nations 2020; 2023).It is noteworthy that Ghana has not experienced any direct terrorist attacks like its neighboring countries, but the government of Ghana is on high alert as Sahel militants make their way south after a series of terrorist attacks in the neighboring countries(Aubyn 2021).

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Attacks by terrorists on nuclear installations pose serious threats to national and regional security. Potential risks include the theft of a nuclear weapon, obtaining nuclear components for the construction of explosive devices, the use of radioactive materials in "dirty bombs," and attacks or sabotage on nuclear installations. Mass casualties, long-term environmental harm, and the possibility ofnuclear proliferation could all be effects of a successful attack. Nevertheless, spanning a 50-year timeframe, there have been 91 infrequent occurrences of terrorist attacks perpetrated by non-state actors, specifically targeting nuclear facilities, nuclear scientists, nuclear transport, or other entities associated with the nuclear industry. It is crucial to note that none of these attacks caused a breach in nuclear reactor containment, radioactive fallout, or environmental contamination. Most of these incidents occurred at locations linked to the nuclear industry but did not result in catastrophic consequences(De Cauwer et al., 2022).

Furthermore, nuclear power plants have several fail-safe systems in place to prevent accidents and ensure safety. These systems include redundant safety systems, emergency cooling systems, and backup power supplies to prevent the release of radioactive materials in the event of an accident. Terrorism is one of the major security concerns in the nuclear industry. The International Atomic Energy Agency (IAEA) has identified four potential risks related to nuclear security: the theft of a nuclear weapon, obtaining nuclear materials for the assembly of nuclear explosive devices, the malicious utilization of radioactive sources, and the radiological dangers resulting from an assault on, or sabotage of, a facility. Wile fail-safe systems can help prevent accidents, they may not be sufficient to prevent terrorist attacks on nuclear power plants. It is noteworthy that fail-safe systems are usually designed to increase safety and prevent accidents or lessen their effects in the event of equipment failures, operational mistakes, or unavoidable occurrences like earthquakes. Although they are crucial for safety, they are not intended to thwart targeted terrorist assaults. Defending nuclear installations against terrorist and external military attacks calls for a unique set of security precautions, including military intelligence (World Nuclear Association 2022; International Atomic Energy Agency 2005; Kim and Kang 2012; Smith 2022).

3.3 Levelized Cost of Electricity

The levelized cost of electricity (LCOE) is a metric used to estimate the average cost of generating a unit of electricity over the lifetime of a power plant expressed in terms of cost per unit of electricity produced (usually per megawatt-hour or kilowatt-hour). LCOE is a valuable tool for comparing different methods of electricity generation, as it considers all costs associated with building and operating a power plant spread out over its expected lifespan. The LCOE varies depending on the technology used to generate electricity. The capital costs of nuclear power plants are generally higher than those of coal-fired plants and much greater than those of gas-fired plants. However, the operating costs of nuclear plants are lower than almost all fossil fuel competitors, with a very low risk of operating cost inflation. The LCOE for nuclear energy is estimated to be $70.75 per megawatt-hour (MWh), and that of solar energy is estimated to be about $30.43/MWh. However, nuclear energy has the advantage of being a reliable source of base load power that can operate continuously for extended periods. In this regard, Solar energy

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with battery energy storage systems (BESS) can be a viable alternative to nuclear energy in Ghana. Solar energy is a renewable energy source that has become increasingly cost-competitive in recent years (US Energy Information Administration 2022).

3.4 Network Stability and System Losses

Upon taking ownership of the Ameri Power Plant, the Ghanaian government decided to relocate the Ameri Plant from Aboadze to Kumasi in the Ashanti Region to help stabilize the national grid. The relocation is expected to help address power outages and fluctuations experienced in major parts of the country. The Ministry of Energy has stated that the takeover and relocation of the plant would rake in about $31 million annually from power export and $4 million as savings on transmission loss cutback (Andy Ogbarmey-Tettey 2021; MyJoyOnline 2022).

Ghana's power sector is burdened with high losses in the transmission and distribution grids due to the long distances traversed during these operations. The situation is exacerbated by the fact that with the exception of Bui Generation Station, the major generation units in Ghana are located in the southern half of the country at three major power enclaves, namely, Akosombo including Kpong generation units, Tema and Aboadze power enclaves. Therefore, power must be wheeled over long distances, about 586 kilometers (364 miles) (Accra to Bolgatanga), to serve customers in the country's northern half. The demand in the north of Ghana is comparatively insignificant and usually results in Ferranti Effects on the transmission grid. Ferranti effect is a phenomenon in electrical engineering that describes the increase in voltage occurring at the receiving end of a very long (> 200 km) AC electric power transmission line, relative to the voltage at the sending end, when the load is low, or no load is connected(Deb 2012). To mitigate the impact of this effect and other related reactive power issues due to voltage drops on the long transmission lines to the northern half of the country, the Ghana Grid Company (GRIDCo) has installed Static Var Compensators (SVC) at its 161kVTamale Substation in the Northern Region and other vantage points in its network(Yarlagadda et al. 2022; GRIDCo 2022).The overall resilience and stability of the system will be improved by decentralizing power generation. The ability to load balance and manage power demand more effectively is made possible by setting up several power plants spread across the country.

Fortunately, Ghana has abundant renewable resources, such as solar, wind, and small-hydro sources, which can be harnessed for power generation. These generation units can be installed at strategic grid locations to reduce the substantial losses incurred due to long transmission and distribution lines and enhance grid stability. Therefore, it would be more advantageous, at the moment, to think about renewables with Battery Energy Storage Systems (BESS) and other environmentally friendly and decentralized power production technologies or using distributed generation instead of nuclear reactors, which are likely to be located at Nsuban in the Western Region, which is the preferred option, with Obotan in the Central Region as the backup site as revealed by the Nuclear Power Ghana (NPG)(Takase and Kipkoech 2023; GNA 2023). The need for long-distance transmission is avoided by producing electricity close to demand centres, which lowers transmission losses. It is also noteworthy that expanding generation capacity in the

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south will require additional expenditure to enhance transmission capacity in order to mitigate system losses and worries about system stability.

4. Conclusion

While nuclear energy has advantages, including a high energy density, enhancement in safety and efficiency, and minimal greenhouse gas emissions, it also comes with significant risks and challenges. In Ghana, where there are many other options for producing environmentally friendly electricity, the decision to use nuclear power must consider several factors, including safety concerns, grid reliability and stability, public concerns, and the nation's overall development objectives. Therefore, before deciding whether to pursue nuclear energy as part of Ghana's power sector development strategy, it is imperative for authorities to carefully analyse all these issues in relation to other options, such as renewable energy, the levelized cost of electricity, stability and performance of the grid due to location of the nuclear plant and the health and safety of the environment and society. The ultimate objective is to prioritize the safety and well-being of the population while sustainably meeting the country's increasing energy demand. Public participation and transparency are crucial in this process to ensure that the concerns and opinions of all stakeholders are taken into account.

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