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Challenges and risks of nuclear energy investments in Africa

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Abstract

Nuclear power remains a key element of clean energy production, as it can generate continuous, low-carbon electricity while reducing dependence on fossil fuels. Its potential is particularly significant in Africa, where rapid urbanisation and growing energy demand require reliable energy sources. The deployment of nuclear power in Africa faces significant technical, financial, and infrastructural challenges. Public scepticism, high capital investment, and a lack of trained personnel continue to block its deployment. From a geopolitical point of view, nuclear energy development intersects with governance structures, as seen in North Africa, where political stability and transparency are key concerns. The case of Ghana highlights the economic trade-offs between nuclear power and renewable alternatives such as solar power. Russia's nuclear export strategy illustrates both the opportunities and the risks of international nuclear cooperation. Despite technological advances, cost overruns and political instability remain a major threat to nuclear deployment. Addressing these challenges requires a comprehensive regulatory framework, public-private partnerships, and international cooperation to ensure the safe and sustainable deployment of nuclear energy.

Keywords: nuclear energy, African nuclear sector, energy demand in Africa, African energy sector

1. Introduction

The main benefit of nuclear energy is a continuous, low-carbon source of energy that reduces dependence on fossil fuels. Nuclear reactors in operation produce no greenhouse gases, meaning they're a key tool in the fight against climate change. Nuclear energy can also be a game-changer in meeting the increasing energy demands in Africa, powered by rapid urbanization and population growth. In fact, rising energy demand on the continent is expected to grow by 60% by 2040. Moreover, nuclear energy is useful for sectors other than electricity generation, like agriculture, industry, medicine, etc. Nuclear power is also suited to technologies like seawater desalination and industrial heat production. Additional economic opportunities through nuclear energy could arise from regional collaborations and technology exports. Nonetheless, the introduction of nuclear energy to Africa is significantly challenged from both technical and cost perspectives. One single nuclear power plant of 1000 MW can cost between $1.5 billion and $8 billion, which is a difficult time for African countries that do not have adequate money. Another problem is the absence of an adequately trained workforce (nuclear engineers, technicians, researchers, etc.) and the technical capacity to adhere to the potential establishment of nuclear technology. And the new challenge is compounded by a lack of infrastructure — overloaded electrical grids and poorly developed transportation systems. Another key hurdle is public skepticism of nuclear energy. The Chernobyl and Fukushima accidents, coupled with nuclear waste disposal concerns, diminish public acceptance

of nuclear technology [1]. It is important to win public appreciation for the benefits of nuclear energy through engaging communities impacted by the construction of nuclear power plants and awareness programs.

2. Nuclear Expansion

Advancing nuclear energy globally will require broad political and regulatory reforms. African countries must put in place sound laws and regulatory regimes, including safety and waste management standards, based on the milestone approach of the IAEA. Specialized education and training programs will be needed to develop human resources and technical capacity. Funding challenges are best addressed through models from public-private partnerships and buy-in from international financial institutions. Regular educational campaigns that focus on the benefits and safety of nuclear technology can also instill confidence in the public. Nuclear power provides a dependable, low-emission energy source that decreases reliance on fossil fuels. Its geopolitical implications, however, are especially relevant in North Africa [2], where political instability and nondemocracy exacerbate nuclear energy deployment risks. In contrast, the European Union and the United States believe that democracy and transparency should come with a nuclear energy package. The introduction of nuclear energy in rich states such as Algeria, Libya, and Egypt could therefore be seen as a means of cementing political power. From the fossil fuel crisis to the environmental impacts, addressing Ghanaian energy needs in an increasingly sustainable way has come into focus. It analyses the technological and economic feasibility of nuclear energy and solar energy in Ghana as an efficient long-term energy security approach. Plans for Ghana to use nuclear energy go back to the 1960s, but the idea is gaining serious consideration as a solution to the periodic energy crises of the country only in recent years. Construction of the proposed 1200 MW nuclear power plant was estimated to cost between $6 billion and $9 billion, and take up to 12 years. Nuclear energy has low carbon emissions and stable, high-volume energy production. Nonetheless, the implementation of nuclear power is costly in terms of initial investment, waste management, and, critically, safety regulations, placing a burden on the national budget of a country with a debt-to-GDP ratio above 60%.

3. The case study in Ghana

For example, Ghana [3] is blessed with an average sunshine of 3,000 hours of sunlight per year. A 20 MW solar power plant costs just $8 million and can be finished in a few months. The relatively low upfront investment costs of solar energy and brief implementation timeline render it an attractive option for short- and medium-term energy security. The generation cost of solar energy is between 5–12 EUR/kWh, in contrast to an estimate for nuclear energy of 125 EUR/kWh. Solar energy systems provide more flexibility and can be deployed much faster than traditional energy sources of a smaller magnitude. Once the economic situation of the country settles, nuclear energy presents a long-term alternative. Financing models like public-private partnerships can also serve an important role in the implementation of both technologies. But the use of nuclear energy involves higher political and security risks that raise the stakes for its application. As global awareness of safety concerns grew after the 1986 disaster at the Chernobyl nuclear plant, Russia’s nuclear industry generally retreated from the world stage. Restoring credibility and reviving the sector were formidable trials, but beginning in 2007, Russia, as the most prominent Russian nuclear actor, implemented sky-high goals.

4. Role of the Russian nuclear industry

Russia has become a key player in the global nuclear export market thanks to the AES-2006 reactor design and strong political support [4]. The main russian actor is a high-technology innovation-driven corporation. Originally intended for the European marketplace, AES-91 and AES-92 reactor models were later exported to China and India. The reactors included core catchers, greatly improving safety levels. A modernization, the AES-2006 is then equipped with more active and passive safety systems and an increase in power. Then came the VVER-TOI model, which has promised to be built quicker and cheaper, but whose practical performance has yet to be demonstrated. Domestically, the nuclear sector in Russia is hindered by a small internal market and a lack of funds. There have also been considerable delays and technical problems with AES-2006 reactors in Russia that have cast doubt on the technology's reliability. Yet these experiences have yielded lessons that have benefited later export efforts. Russia has managed to secure new trade partners while maintaining its previous alliances. China and India have emerged as some of the biggest clients of Russia, but delays and cost overruns are still major hurdles. Emerging markets like Turkey, Bangladesh, and Vietnam hold great promise, but challenges remain. The "Build-Own-Operate" model, from which the Akkuyu project in Turkey was based, has investment limitations. Vietnam canceled its nuclear program in the end, citing costs and safety concerns. The Russian success, however, seems strategic essentially because it allows low prices as well as the opportunity for financing [5]. Much of the financing has come from the Russian government, encouraging a number of countries to turn toward nuclear technology. But political risks or cost overruns are an ever-present threat to their success. Russia’s nuclear export program illustrates one way a sidelined industry can reemerge in the world. Technological and safety innovations in AES-2006 and other reactors have allowed Russia to provide modern, competitive solutions. Yet, despite frequent delays, cost escalations, and challenges in new markets, the program has yet to realize its full potential. The fate of the Russian export strategy will depend on its ability to navigate technological and financial challenges successfully and to continue to expand its footprint in global markets. If their promises can be fulfilled, new-generation reactors like the VVER-TOI are crucial to a nuclear future.

5. Nuclear challenges in North Africa

North African countries such as Morocco, Algeria, Tunisia, Libya, and Egypt have seen a rapidly growing energy demand in the last few decades. This growth created multiple energy and political challenges related to energy supply diversification and sustainable resource integration. Regional leaders are assessing the importance of nuclear energy in the context of energy security and the import-export structure. [6] Several countries have found nuclear energy to be an attractive solution for enhancing energy security. North African interests have paid particular attention, as energy demands grow, fossil fuels get depleted, and alternative energy becomes imperative. However, the technical dependence is probably the greatest obstacle the adoption of nuclear technology faces. Middle Eastern and North African countries currently have neither the knowledge nor the capacity to independently develop nuclear energy. Thus, all aspects of the construction, maintenance, and fuel supply of nuclear power plants are completely dependent on imported technologies and foreign specialists. This increases costs and decreases energy independence. Constructing the associated nuclear infrastructure is a vastly expensive prospect, especially considering the dependency on imported know-how and the low energy costs of the region. A single reactor can cost billions of dollars, far beyond the budgetary means of most North African countries. The relatively small size of the regional energy systems also does not lend itself to the efficient integration of the output from large nuclear plants, making such investment fairly uneconomic. Another major challenge has to do with safety risks: managing radioactive waste and preventing nuclear accidents require effective regulatory and technical capacities that are not fully developed

in North Africa. Resistance from the public makes the adoption of nuclear energy all the more difficult. Past incidents — Chernobyl and Fukushima, for instance — have profoundly shaped public views, delaying acceptance of nuclear projects. The implementation of such strategies, which emphasize the benefits of nuclear energy, while also communicating safety information, at the same time, will be crucial to gaining public trust.

6. Energy security and risks

Strong interest in nuclear energy is still driven by several factors despite these challenges. Energy security is especially urgent, as countries such as Morocco and Tunisia depend on energy imports, exposing their economies to risks. The Exhaustion of fossil energy resources represents a significant challenge for Egypt, Algeria, and Libya, and there is a need to replace them with new energy sources. Electricity demand in the region is rising at 4–8% per year, which is above the global average, underlining the need for additional energy supplies. Moreover, there is increasing pressure for energy-intensive desalination technology, due to desertification and water scarcity. Energy shortages represent an annual loss of 2–4% of GDP for African countries [7], and stable, reliable energy sources such as nuclear power could help reduce these losses. From a sustainability perspective, one of the biggest advantages of nuclear energy is that it produces almost no carbon emissions and significantly less damage to the environment, compared to fossil fuels. Africa possess a rich endowment of uranium resources, notably in Niger, Namibia and South Africa, giving it a local source to develop nuclear energy with a regard to diminish overreliance on foreign controls in fuelling the nuclear stream. In summary, the development of nuclear energy in North Africa is impeded by multiple factors: technological reliance, financial burden, concerns for safety, and public opposition. Still, the impetus to bolster energy security, meet sustainability targets, and capitalize on indigenous uranium deposits provides compelling motivation for its uptake. Nuclear energy is a potential long-term solution for energy challenges in the region, if countries are able to address comprehensive political and regulatory reforms and secure necessary technological and financial support through international cooperation. Societal acceptance will be critical for success, necessitating clear communication strategies and greater public participation to show how nuclear energy can be beneficial. All North African countries, with different progress, goals, and motivations, plan to use nuclear energy. Egypt plans to build four reactors by 2025 in a bid to meet the needs for 4 GW of power generation. The North African country also plans to develop its first reactor after 2020, and two more units every two years in order to increase its energy generation capacity. Morocco intends to deploy two reactors by the year 2030, with a collective capacity of 2 GW, as it aims to decrease reliance on imported energy. Tunisia also expressed interest in constructing a smaller 900 MW reactor by 2020; however, the relevant small-scale electrical grid within the country presents compelling challenges to integrating such large-scale projects. Libya is in economically better condition, but does not feel itself to be under the same threat as Syria, and has the fossil fuel reserves to leave nuclear energy as a much lower priority.

7. Conclusion

The African energy transition is a massive challenge but also a transformative opportunity. The continent has abundant renewable energy resources, important critical minerals, and unexplored potential for nuclear energy. But the way towards a sustainable energy future is plagued with infrastructural deficits, financing constraints, governance challenges, and socio-economic inequalities.

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