**THE ROLE OF SMALL MODULAR REACTORS (SMRS) IN MITIGATING CLIMATE CHANGE AND PROMOTING ECONOMIC GROWTH IN AFRICA:**

**A CASE STUDY OF NIGERIA**

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**Abstract**

Small Modular Reactors (SMRs) are increasingly viewed as a promising solution to meet the rising energy needs in Africa. They offer cost-effective, financially feasible, and quicker completion options compared to traditional methods. Furthermore, SMRs hold the potential to address critical challenges such as fostering economic development and mitigating climate change. This study investigates the role of SMRs in electricity generation, combat climate change, their potential to spur economic growth. The focus is specifically on Nigeria, serving as a case study. In 2019, Africa accounted for around 4% of global CO2 emissions, with the largest contributors being South Africa, Nigeria, and Egypt due to their significant industrial and energy sectors. Achieving the pace of CO2 emissions reductions in line with the Paris agreement requires large increases in efficiency and renewable investment. Investments in SMRs will contribute to climate change mitigation by reducing reliance on fossil fuels and lowering greenhouse gas emissions associated with electricity generation. SMRs present numerous advantages over conventional large-scale nuclear reactors. These include lower initial costs, improved safety features, and scalability, which are especially beneficial for addressing the challenges posed by poor and inadequate grid systems in Africa. Consequently, by offering a reliable and sustainable source of electricity and will help countries in Africa meet their climate targets under international agreements while promoting the transition to a low-carbon economy. Using Nigeria as a case study, this paper analyzes the potential benefits and addresses challenges of developing and deploying SMRs in the energy mix in Africa. It provides insights into policy implications, financing, operation, and maintenance, as well as recommendations for maximizing the socio-economic and environmental benefits of SMR’s in the region. Overall, SMRs offer a promising pathway towards sustainable development in Africa, with significant implications for energy security, economic prosperity, and environmental sustainability to achieve Net Zero.

## INTRODUCTION

Africa faces significant challenges in terms of energy access, economic development, and climate change. About Six Hundred million Africans have very limited access to energy, corresponding to an electricity access rate at just over 40 percent, the lowest in the world. Per capita consumption of energy in sub-Saharan Africa (excluding South Africa) is 180 kWh, compared to 13,000 kWh per capita in the United States and 6,500 kWh in Europe [1]. Nigeria, the most populous country in Africa, exemplifies these challenges. Despite its vast natural resources, Nigeria struggles with energy shortages, economic instability, and environmental degradation. The Nigerian government has established three significant and ambitious targets for its electricity sector to be achieved by 2030, considering the current circumstances. These targets focus on increasing access to electricity, developing renewable energy, and reducing emissions. Specifically, the country aims to ensure that 90% of the population, including both rural and urban areas, will have access to electricity [2]. Nuclear power through Small Modular Reactors (SMRs) could play a significant role in this ambition, particularly in reducing carbon emissions.

2. ENERGY LANDSCAPE IN AFRICA: NIGERIA

Energy is critical for any nation’s economic potential to be achieved, without electricity socioeconomic and industrialization drive is near zero. Most African countries electricity demand is far greater than its generated installed capacity that is why Africa’s energy sector is vital to the continent’s economic prospects; most countries except a few in Africa have been able to achieve the reliable domestic energy supply that its people and businesses require. Energy demand in Africa has been increasing at an annual rate of around 3%, the highest among all continents, but energy supply continues to lag significantly [3]

2.1 Energy Access and Demand in Africa

Nigeria faces a substantial energy deficit, with a significant portion of its population lacking access to reliable electricity. The country’s energy infrastructure is outdated and insufficient to meet the increasing demand. Frequent power outages and reliance on costly diesel generators are widespread, posing obstacles to economic growth and development [4]. It is significant to note that countries like Egypt, Tunisia, Morocco, and Algeria in the northern parts of Africa have the highest electricity access rates, which are above 95%. Other countries, such as Gabon, Ghana, South Africa, Botswana, Kenya, and Senegal, have electricity access rates above 70% [5]. South Africa, the only African country with a nuclear power plant, has an electricity access rate above 84%. Despite its high access rates, recent reports indicate complaints about limited hours of supply due to increased demand, mismanagement, sabotage, and vandalism. Ghana has the highest electricity access in West Africa, with around 85.9%, primarily due to its dominance in hydropower energy. It also has high prospects for natural gas reserves and is embarking on nuclear power development. The country utilizes only approximately 58% of its total capacity, leaving a considerable deficit of 2,375 MW, exacerbated by maintenance-related issues and fuel supply inadequacies [6]. Nigeria, with the largest population and economy in sub-Saharan Africa, faces significant constraints in its power sector that hinder economic growth. Despite being rich in oil, gas, hydro, and solar resources, and having the potential to generate 12,522 MW of electricity from existing plants (excluding off-grid generation), the country often manages to dispatch only around 4,000 MW. This output is inadequate for a nation of over 200 million people [7].

2.2 Nigeria Energy Mix

Electricity is a component of energy production, electricity is produced from, hydro, coal, gas, nuclear and renewable, renewable energies are referred to electricity from wind and solar. Solar and wind energies are fast growing renewable across the world due to its low carbon emission, in combination with nuclear energy they can contribute to decarbonisation of electricity and a step towards low carbon energy system. According to USAID report in 2021 Nigeria has a total installed power generation capacity of 16,384 MW. The majority of this capacity comes from hydro and gas-fired thermal power plants, which generate 2,062 MW and 11,972 MW, respectively (Solar, wind, and other sources such as diesel and Heavy Fuel Oil (HFO) contribute the remaining 2,350 MW. Consequently, the Nigerian government has set an ambitious target to expand its on-grid capacity to 30 GW by 2030, with grid-connected renewable energy contributing 13.8 GW (45% of generation) including medium and large hydropower, and 9.1 GW (30% of generation) excluding them [8]. However, the current plan does not include nuclear energy. Incorporating nuclear energy, specifically through Small Modular Reactors (SMRs), could play a significant role in achieving this expansion target if considered by the government and policymakers.

2.3 Renewable Energy Potential

[Nigeria possesses significant renewable energy potential, especially in solar and hydro power. However, the adoption of renewable energy technologies has faced challenges related to finances, technical aspects, and policy constraints. While renewable play a vital role in the energy landscape, they alone might not fully meet the demand for base load power](https://www.irena.org/Publications/2023/Jan/Renewable-Energy-Roadmap-Nigeria). Efforts to overcome these barriers are essential to unlock Nigeria’s clean energy potential and promote sustainable development. Challenges like inadequate gas and grid infrastructure have impeded the expansion of the traditional power sector. This situation has created a need to move beyond gas-fired power plants and to embrace renewable energy, supplementing on-grid power with off-grid renewable solutions. The low penetration of variable renewable such as wind and solar shows the opportunity that lies in integrating them in the power sector, given the substantial cost reductions of the technologies in recent years and the enormous natural resource that Nigeria has, especially for solar power [9 ].

2.4 Environmental Impact

[Nigeria’s energy sector significantly contributes to greenhouse gas emissions, mainly due to its heavy reliance on fossil fuels. The environmental harm caused by oil extraction and consumption has substantial health and ecological consequences. To address these challenges, a crucial step is transitioning to low-carbon energy sources, which can mitigate climate change and enhance public health](https://www.irena.org/Publications/2023/Jan/Renewable-Energy-Roadmap-Nigeria). Nigeria is a signatory to the Paris Agreement, having submitted its Intended Nationally Determined Contributions (INDCs) on November 28, 2015, signed the agreement on September 22, 2016, and ratified it on May 16, 2017. The country developed and validated its NDC Sectoral Action Plan in July 2018, prioritizing five key sectors: agriculture, industry, power, transport, and oil and gas. Nigeria’s greenhouse gas (GHG) emissions are projected to grow by 114% to around 900 million tonnes by 2030. However, its NDC, aligned with the country’s development policy, targets a 20% unconditional and 45% conditional emission reduction below Business as Usual (BAU) levels by 2030 [8 ]. With the current dependency on fossil fuels and gas-powered stations, Nigeria’s GHG emissions will surpass this projection if the country does not reduce its overdependence on gas for electricity generation. This is exacerbated by the acute shortages of electricity supply across the country, with blackouts lasting several hours a day. Consequently, many households and businesses rely on self-generation of off-grid electricity using diesel and gasoline generators as backup. This situation is unlikely to change soon unless the government invests massively in clean renewable energy. Nuclear power, particularly through Small Modular Reactors (SMRs), could be a game changer in addressing these challenges.

3. THE POTENTIAL OF NUCLEAR: SMALL MODULAR REACTORS (SMRS)

Nuclear, power is an important low-emission source of electricity; it provides nearly 10% of global electricity generation in the world, its complements other renewable energy sources in reducing power sector emissions while also contributing to electricity security as power source [10]. It’s a dependable option for generating low- emission heat and hydrogen .Nuclear energy can reduce the reliance on fossil fuel, which is a major contributor to green gas emission, with around 413 Gigawatts (GW) of capacity operating in 32 countries, it contributes to both goals by avoiding 1.5 Gigatonnes (Gt) of global emissions and 180 billion cubic metres (bcm) of global gas demand a year [10]. Nigeria can also leverage on this in solving its energy shortages. SMRs represent a promising solution to these intertwined issues, offering a sustainable, reliable, and flexible energy source. It offers a much easier alternative , it will help achieve most if not all the goals of building a Nuclear power Plant with less challenges and also achieving the aims of generating electricity for industrial development and sustainability while mitigating climate change through clean energy because Modular Reactor are: less expensive, this can reduce the cost and burden of financing , It is also safer due to its coherent safety ,It is compactable and can easily be moved around to areas where there is grid, Nigeria have poor grid , it can help solve this issue and burden of building new grids .It requires less water, it can be deployed in any part of Nigeria particularly in the North to spur development and industrialization and Job creation [11] .It also has less preparation time to build, compared to a conventional PWR which could help actualize Nigeria’s vision 2030 ambition targets for its improved electricity for industrial development .

3.1 Effects of climate change on Africa

**Africa has started to experience more severe climate change than most other parts of the world, despite bearing the least responsibility for the problem, with** nearly one-fifth of the world’s population today, Africa accounts for less than 3% of the world’s energy-related carbon dioxide (CO2) emissions to date and has the lowest emissions per capita of any region  **such experiences are not limited to** higher temperatures, drought, changing rainfall patterns, increased climate variability, floods, reduced food production, lower economic growth and prosperity these can also be connected to the issues of mass illegal migration and risks of frequent desperate journey to Europe by crossing the Mediterranean sea were hundreds of life’s are lost daily.

4. NUCLEAR ENERGY FOR INDUSTRIAL AND SUSTAINABE ECONOMIC DEVELOPMENT

Nuclear power can play a significant role in the generation of electricity for industrial and economic development while promoting sustainability and mitigating climate change in Africa. It has some advantages; it is reliable and consistent source of electricity, capable of supplying base load power. It offers Energy Security any country with significant nuclear power capacity can reduce their reliance on imported fossil fuels and enhance their energy security, It provides sustainable energy because it produces low gas emissions, which is vital for addressing climate change and achieving sustainable development goals, it also provides long-term sustainability due to its long operational life spans, typically exceeding 40 to 60 years, It assures stable and enduring source of electricity for industrial development and economic growth in the region, and job creation and skill development. The establishment and operation of nuclear power plants will lead to the creation of high-quality jobs and drive skill development in the host country, technology transfer, capacity building, and development of indigenous expertise and capabilities, which will boost Africa's technological advancement. By adopting nuclear power, African countries can improve air quality and public health, and water conservation.

4.1. Economic Growth and Development

Nigeria's inconsistent power supply and the high costs of captive generation adversely affect the economy, impacting both residential and industrial sectors. Households and small and medium-sized enterprises spend two to three times more on kerosene, diesel, and petrol than on grid electricity[8] . This leads to higher business costs, hindering economic growth, discouraging local production, and making importation more attractive. Consequently, manufacturing companies collapse or relocate, resulting in increased unemployment. Deploying Small Modular Reactors (SMRs) in Nigeria can guarantee energy security by providing reliable energy access, a cornerstone of economic development. SMRs can offer consistent and affordable electricity, reducing reliance on costly and polluting diesel generators, thereby spurring industrial growth, improving productivity, and attracting foreign investment. The implementation and operation of SMRs can generate numerous employment opportunities across various fields, including construction, engineering, manufacturing, and maintenance. Additionally, establishing a local nuclear industry can stimulate growth in related sectors and contribute to skill development [12]. This type of development is essential for Nigeria and Africa, helping to employ youth and graduates, prevent crime, and reduce the risks associated with mass illegal migration and dangerous journeys across the Mediterranean Sea, where hundreds of lives are lost daily.

4.2 Challenges and Considerations

While there are several challenges associated with adopting nuclear energy, Small Modular Reactors (SMRs) present unique difficulties, primarily because the technology is still evolving. Although many projects are underway, there is limited operational experience globally. Nonetheless, efforts are ongoing to realize the potential of SMRs. Key considerations for the Nigerian government or any African government include:

1. Establishing a robust regulatory framework to ensure the safe deployment and operation of SMRs.
2. Overcoming public concerns about nuclear safety and waste management.
3. Developing the necessary infrastructure, including grid integration and transportation.
4. Securing financing through innovative funding mechanisms and public-private partnerships.

Financing has been a significant issue for Nigeria and other African governments due to scarce resources and competing priorities. However, despite the substantial initial costs associated with nuclear power projects, SMRs offer a relatively cheaper alternative compared to traditional Pressurized Water Reactors (PWRs), which require more time and resources to complete. SMRs represent a unique opportunity with faster completion times, driving development, creating job opportunities, and yielding quicker returns on investment for governments and financiers.

5. WAY FORWARD

The transformation of Nigeria’s electricity supply system faces significant challenges, including inadequate financing, high investment risks, and policy uncertainty. Specific setbacks in the centralized system include insufficient generation capacity, weak transmission and distribution infrastructure, gas supply constraints, seasonal water level fluctuations, and governance issues. Recent policy initiatives, such as feed-in tariffs for renewable energy and new metering regulations, aim to address these problems. Adopting nuclear energy and building nuclear power plants also present challenges, particularly in financing. New nuclear power plants require substantial government funding and investment from owners or operators. To achieve reliable power supply and improve electricity access, Nigeria's power sector will need significant investment, estimated at USD 34.5 billion by 2030 [9]. There is a considerable opportunity for investment in Small Modular Reactors (SMRs) in Nigeria, as nuclear energy can address many existing challenges, except financing. The Transmission Company of Nigeria (TCN) estimates that grid rehabilitation and expansion will require USD 1 billion annually for the next decade. Ongoing financial interventions include a USD 486 million World Bank credit for the Nigerian Electricity Transmission Access Project and a USD 200 million African Development Bank investment to expand electricity access. Additionally, Nigeria has signed a deal with Germany’s Siemens AG for a project aimed at increasing power to 25,000 MW [9]. While these investments exclude nuclear energy, Nigeria has expressed interest in developing nuclear power to diversify its energy mix. The Nigerian Atomic Energy Commission is exploring the feasibility of deploying SMRs, with site selection, regulatory preparations, and stakeholder engagements underway.

6.0. RECOMMENDATIONS

Nigeria can effectively adopt SMRs, fostering economic growth, creating employment opportunities, and mitigating climate change by taking the following steps:

* Establishing a Robust Regulatory Framework: Develop comprehensive nuclear policies and strengthen the Nigerian Nuclear Regulatory Authority (NNRA) to ensure safe and secure SMR deployment, building public trust and compliance with international standards.
* Securing Financing and Investment: Explore innovative funding mechanisms, such as public-private partnerships and international grants, and provide government support through subsidies and tax incentives to attract private investors and secure capital for SMR projects.
* Investing in Infrastructure and Grid Modernization: Upgrade and expand the national grid to support SMR integration and improve electricity distribution, and develop necessary infrastructure, including transportation networks for nuclear materials.
* Capacity Building and Public Engagement: Invest in education and training programs to develop a skilled workforce for SMR operation and maintenance, conduct public awareness campaigns on nuclear energy benefits and safety, and engage stakeholders to build support and trust.
* Strategic Planning for Economic Growth and Climate Mitigation: Integrate SMRs into Nigeria’s long-term energy strategy to complement renewable energy sources, reduce fossil fuel reliance, meet emissions reduction targets under the Paris Agreement, stimulate economic growth, create jobs, and attract foreign investment.

7.0 CONCLUSSION

Deploying Small Modular Reactors (SMRs) in Nigeria offers a significant opportunity to mitigate climate change and promote economic growth. SMRs offer numerous benefits for industrial, economic, and sustainable development. By providing consistent and affordable electricity, SMRs can reduce reliance on costly diesel generators, spur industrial growth, and attract foreign investment. Key steps include establishing a robust regulatory framework, securing innovative financing, investing in infrastructure, building local capacity, and engaging the public. An integrated energy approach, combining nuclear power with renewable sources, will create a sustainable and climate-friendly energy future for Nigeria can lead the way for other African nations, fostering a prosperous and sustainable future for the continent.

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