**The Integration of Small Modular Reactors into a National Nuclear Power Programme - A SWOT Analysis of Nigeria INIR Mission**

**Abstract**

*The International Atomic Energy Agency (IAEA) conducted an Integrated Nuclear Infrastructure Review (INIR) Mission for Nigeria in June 2015. The Member State requests an INIR mission. The INIR mission is performed by a team of experts to peer review, using a transparent evaluation methodology, a member State's nuclear power infrastructure development status. The INIR mission evaluated the IAEA's 19 infrastructure elements for deploying large nuclear reactors. Through the lens of strength, weaknesses, opportunity and threat (SWOT), this paper examines the suitability of adopting the result of the 2015 INIR mission for a large nuclear reactor when considering the option of a Small Modular Reactor (SMR). The SWOT analysis shows that the infrastructures required for large nuclear reactors are similar to those for SMRs. Hence, it can be concluded that SMR integration into the Nigerian nuclear power programme is achievable with good planning and an effective implementation strategy.*

**1.0 Introduction**

Growth in the world population has ultimately exposed the inadequacies of relying on fossil fuels as the primary source of electricity generation [2]. For a developing country like Nigeria, it is a challenge to meet the electricity requirement of the populace. Nigeria's population grew from 73.7 million in 1980 to 177 million in 2019, with the available power growing from 783MW  to 3,795MW [22].  Nigeria relies on two primary sources (thermal and hydro) for its public electricity supply. Thermal sources account for about 83%, and hydro sources about 17% [22]. These electricity supply sources can only be complimented by other sources in a mix to meet the electricity demand for socioeconomic development [6]. The decision about the strategies for this mix requires that Nigeria consider factors noted by [4], such as electricity demand, economic and technological development, and available natural and human resources. Nuclear energy can serve as a base load as a member of this mix with its comparative advantages [23].

The deployment of nuclear energy for electricity generation, either as "Large Nuclear Reactors" or "Small Modular Reactors (SMR)", is governed by set rules outlined by the International Atomic Energy Agency (IAEA). The IAEA uses three phases with a structured milestone approach consisting of 19 infrastructure issues for each milestone to assess, monitor and evaluate State Parties interested in building Nuclear Power Plants as an integral part of their energy mix [26].

To underscore the importance of these infrastructure issues, the IAEA undertakes an Integrated Nuclear Infrastructure Review (INIR) Mission on request from a Member State. The INIR mission is an international and professional review of nuclear power infrastructure development status. The IAEA nominates and coordinates a team of experts who will conduct a peer review assessment to assist the Member State in determining the status of its nuclear power infrastructure development. An INIR mission is holistic, and the evaluation methodology is transparent and reflects the best practices of the nuclear industry [14].

This study used the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to investigate the 2015 IAEA INIR Missions to Nigeria. This paper assesses the lessons learned and their adaptability for deploying SMRs in Nigeria.

1. **Lessons Learned from the Mission**

According to [24]

*"the period of development of the Self-Evaluation Report creates an opportunity for genuine soul searching and enthrones some degree of realism".*

The infrastructure issues developed by the IAEA that were subjected to the INIR process were for large nuclear reactors. Preparation for the INIR Mission created an environment that enabled practical cooperation and partnership among national stakeholders. The INIR Mission revealed that planning and successfully implementing a nuclear power program for a newcomer country is an enormous task. It showed that it is vital to subject national programmes to transparent peer-review scrutiny. Furthermore, the INIR process highlighted that strict adherence to strict nuclear safety and security regimes must be carefully considered and established. It also emphasized that no nation can embark on the journey of a nuclear power program alone. It entails having both multilateral and bilateral partnerships because of the level of technological involvement. The 2015 INIR Mission team to Nigeria made 43 recommendations with 10 suggestions and identified 6 good practices.

Using the INIR report recommendation and suggestions as a guide in deploying SMRs, it is important to note that large nuclear reactors generate more than 700 MW of electric power. SMRs, on the other hand, are nuclear reactors with an equivalent electric power of less than 700 MW [7]. SMRs are made to order with several advantages, such as simplification [8], modularity [12], lower financial risk [28], factory manufacturing and assembly [20], and stand-alone off-grid applications [13]. [ 27] noted that the problems and issues that must be overcome for massive SMR deployment to be possible are technology choice; supply chain and trained human resources; public perception and acceptance; finance, investment, and political support; proliferation risks (safeguards and security) and; nuclear fuel cycle and approach to spent fuel remediation. These problems and issues are all embedded in the 19 infrastructure issues needed for a large nuclear reactor.

1. **Methodology**

The SWOT analysis used in the study was the method used by [16][25]. It is a decision-making tool investors have accepted for planning purposes in the energy sector. Researchers who used similar SWOT as an analytical tool to conduct their studies include [17] [18] in the renewable energy sector and [1] in nuclear energy.

1. **Results and Discussions**

The IAEA produced a plan for developing 19 infrastructure issues needed for a nuclear power program [15]. These 19 nuclear infrastructure issues, which require specific actions during the three phases, are present in Table 1 and are not listed as priorities.

**Table 1: Infrastructure issues**

|  |  |  |
| --- | --- | --- |
| National Position  | Radiation Protection | Environmental Protection  |
| Nuclear Safety  | Electrical Grid  | Nuclear Security  |
| Management  | Human Resource Development | Emergency Planning  |
| Funding and Financing  | Regulatory Framework | Nuclear Fuel Cycle  |
| Legal Framework  | Stakeholder Involvement  | Radioactive Waste Management  |
| Safeguards  | Site and Supporting Facilities  | Industrial Involvement  |
| Procurement |  |  |

The SWOT analysis of the activities in Table 1, based on the recommendations, suggestions, and current status of the 2015 INIR report, is presented in Table 2.

**Table 2: Result of the SWOT analysis for 2015 IAEA INIR Missions to Nigeria**

|  |  |  |  |
| --- | --- | --- | --- |
| **Strengths** | **Weaknesses**  | **Opportunities**  | **Threats** |
| National Position | Management | Funding and Financing | Legislative Framework |
| Safeguards  | Site and Supporting Facilities | Electrical Grids | Regulatory Framework |
| Radiation Protection | Nuclear Safety | Environmental Protection | Procurement |
| Human Resources | Nuclear Fuel Cycle | Stakeholder Involvement | Industrial Involvement |
| Emergency Planning | Radioactive waste management |  |  |
| Nuclear Security |  |  |  |

The SWOT approach is a flexible, easy-to-use and understandable tool that evaluates the internal factors of strengths and weaknesses and the external aspects of opportunities and threats that affect the strategies for developing and managing a project [1][25]. The internal factors are the roles and responsibilities of the operators and regulators (Nigeria Atomic Energy Commission (NAEC) and Nigerian Nuclear Regulatory Agency (NNRA)). In contrast, the external factors are the roles and responsibilities of other stakeholders that will impact the activities of the nuclear power programme.

***Strength***

With its effort to add nuclear energy to its energy mix, Nigeria has the prospect of achieving the set objective.  Since the INIR Mission of 2015, Nigeria has developed policies and programmes based on the recommendations and suggestions of the INIR team's report. Nigeria has agreed to the establishment of the Joint Stock Company. It has also agreed with ROSATOM to build a nuclear power plant [3] based on the financing model of Build Own Operate and Transfer (BOOT). Both agreements are waiting for the approval of the Federal Executive Council. Nigeria has commenced the development of Integrated Management Systems (IMS) for relevant organizations.  NAEC conducted an IAEA expert mission for IMS in the first quarter 2024. Human resources and domestic technical capabilities are two factors required to manage nuclear reactors [10]. Nigeria has conducted a comprehensive national human resources development analysis and is reviewing the organizational structures of NAEC and NNRA. The training plans for initial and continuing training are undergoing development. In the area of safeguards, Nigeria has developed the necessary competencies needed for communicating information relevant to safeguards and facilitating IAEA in-field activities.  The National Nuclear and Radiological Emergency Plan has been developed and is being reviewed by the IAEA. The Design Basis Threat has yet to be developed, but Nigeria has the mechanism for the national threat assessment in place. Mismanagement of radioactive waste would pose health risks and affect the environment negatively. Concerns for radioactive waste are usually resolved by the nuclear fuel cycle [1]. Nigeria developed a fuel cycle and radioactive waste management strategy to produce a draft Radioactive Waste and Fuel Cycle Policy. The draft policy document has been sent to the IAEA for review.

***Weakness***

Shortage of qualified nuclear workforce and limited research and development capacity in areas such as nuclear safety are of significant concern for newcomer countries desirous of nuclear energy [10]. Nigeria has confronted the nuclear safety issue by completing the capacity building programme for site licensing as it concerns nuclear safety. However, the training and qualification programme is yet to be implemented. Long-term vendor support that should address the Intergovernmental Agreement (IGA) or the contract still needs to be implemented. A national programme on radiation protection has yet to be implemented because of inadequate capacity. The nuclear fuel cycle and approach to radioactive waste management is a challenging topic for countries embarking on developing and deploying nuclear energy [19 ]. Nigeria has identified sites for low- and intermediate-level waste, and one has been constructed at the Nuclear Technology Centre, Sheda. However, the following activities have yet to be done: updated site selection information, complete site characterization, and plan for site construction, including on- and offsite infrastructure. An impractical environmental impact assessment could impede the adoption and successful implementation of nuclear energy programmes [3][11. Nigeria has yet to conduct and send an environmental impact assessment report for the preferred sites for approval.

***Opportunities***

Lack of adequate financing and investment is a challenge for projects in Africa. The initial costs associated with nuclear power plants are considerable [5], and a greater part of the financing requires long-term upfront investments [23][3]. Through the NNRA, Nigeria has stipulated licensing fees, which are anticipated to cater for the cost of inspection and oversight. Despite agreeing with ROSATOM on BOOT as a financing option, the financing structure and risk management plan are yet to be developed. A robust and efficient electrical grid is needed to evacuate power from the nuclear power plant. [9], noted that insufficient or moribund electricity grid systems are a major hindrance to deploying nuclear energy. Nigeria has begun capacity-building activity for grid integration but has yet to conduct detailed grid studies and develop implementation plans for grid enhancement and associated funding. Given that the grid system is interconnected to other countries, Nigeria has not communicated the influence of NPP to grid operators that the Nigerian National Grid serves. Compared to other energy sources, nuclear energy is relatively unfamiliar and associated with wars and destruction [3]. Nigeria has developed a stakeholder involvement strategy and plan to improve the public perception and acceptance of nuclear energy. However, the national Public Information and Communication Strategy and communications action plan are not yet developed.

***Threats***

A functional regulatory framework is the anchor upon which a successful nuclear energy deployment rests [26]. The different laws establishing NAEC and NNRA had been reviewed by the IAEA and forwarded to the national legislature for their consideration. When it comes into effect, the reviewed laws will delineate responsibilities and adequate provisions for safety, security, safeguards and civil liability for nuclear damage. The IAEA provides Nigeria with the necessary capacity-building assistance to enhance the regulatory framework. Nigeria has yet to develop a comprehensive plan for developing NPP regulations. Nigeria still needs to create a programme for inspection regarding site evaluation, construction and manufacturing of safety components. Nigeria has drafted a strategy for industrial involvement. The role of nuclear technology in facilitating industrial non-power generation activities [9][26] must be considered by newcomer countries. The assessment and requirements for industrial involvement still need to be completed. Nigeria is developing a stakeholder-based procurement plan. This plan will be handed over to the JSC when it is formed.

1. **Conclusion**

The IAEA's plan detailing the activities to be undertaken in phases for milestones to be attained was used by the INIR team in 2015 to conduct Nigeria's INIR Mission. This study conducted a SWOT analysis to assess the possibility of adopting the 2015 INIR report for a large nuclear reactor when considering a small modular reactor. The "Strength" was found to be in national position, safeguards, radiation protection, human resources, emergency planning and nuclear security. However, the implementation of the issues needs a timeline. The perceived "weaknesses" observed relate to management, site and supporting facilities, nuclear safety, nuclear fuel cycle, and radioactive waste management. The implementation process should include constant evaluation and monitoring with related feedback to ensure that the weaknesses are overcome. The identified opportunities would strengthen other national institutions and assets needed to deploy a nuclear reactor for electricity generation. The threats are evident, with the Legislative and Regulatory Framework issues at the top of the list. These threats are surmountable with commitment by all parties involved.

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