

Assessment of Nuclear Safety Regulatory Effectiveness in Nigeria: A Comparative Analysis of Legal Frameworks, Institutional Capacity, and International Safety Standards

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Received: 16 May 2026/Accepted: 19 July 2026/Published: 28 July 2026

Abstract: Nigeria has a statutory nuclear and radiation safety regulator, a body of sector-specific regulations, and participation in major international nuclear safety instruments. The unresolved question is whether these formal arrangements provide the institutional conditions needed for effective regulation. This article assesses Nigeria's nuclear safety regulatory framework through doctrinal and comparative legal analysis. It examines the Nuclear Safety and Radiation Protection Act 1995; the mandate and public institutional record of the Nigerian Nuclear Regulatory Authority (NNRA); International Atomic Energy Agency (IAEA) safety standards; and selected regulatory models in Canada, the United Kingdom, the United States, India, France, and Japan. Regulatory effectiveness is assessed through six indicators: legal authority, functional independence, authorization and enforcement capacity, technical competence, transparency, and international alignment. The evidence shows that Nigeria possesses a functioning regulatory structure with licensing, inspection, and enforcement powers, as well as an extensive radiation-safety regulatory portfolio. The NNRA also reports continuing oversight activity; for 2025, it reported 741 regulatory inspections and 1,472 authorizations. These figures demonstrate workload but cannot, without data on staffing, quality, and enforcement outcomes, establish the adequacy of regulatory capacity. The main legal concern is structural independence. The statutory and institutional arrangements place high-level executive and sectoral actors, including the Nigerian Atomic Energy Commission, within the NNRA governing structure, while IAEA standards require effective independence and functional separation from organizations whose

responsibilities or interests could unduly influence safety decisions. This article does not infer actual interference from institutional design alone. It instead argues for legislative modernization, clearer safeguards for decisional and financial independence, systematic publication of regulatory performance indicators, stronger transparency regarding technical capacity, and regular peer-review follow-up. Nigeria's regulatory system should be judged not merely by the existence of statutory powers but by whether those powers can be exercised independently, competently, consistently, and transparently.

Keywords: Nuclear regulation; Radiation protection; Regulatory independence; Institutional capacity; IAEA safety standards; Nigeria; Nuclear law.

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1.0 Introduction

Nuclear safety regulation requires more than the existence of legislation and a formally designated regulatory authority; it also requires institutional arrangements that enable safety decisions to be made independently, competently, consistently, and transparently (Leotlela, 2021). Because failures in nuclear and radiation safety can have consequences extending beyond individual facilities or licensees, the effectiveness of the regulatory system is a critical component of national safety governance. (Bowen, & Ponangi, 2026). The IAEA's Fundamental Safety Principles assign the prime responsibility for safety to the person or organization responsible for the

facility or activity, while the state must establish an effective legal and governmental framework for safety (Alvarez, 2014; IAEA, 2006). GSR Part 1 (Rev. 1) further develops the institutional requirements: the regulator must possess adequate authority, competence, and resources, and be effectively independent in safety-related decision-making (IAEA, 2016a). These international requirements provide an appropriate benchmark for assessing national regulatory systems, although conformity with IAEA safety standards should be distinguished from their direct incorporation into domestic law. In the Nigerian context, the relevant question is therefore not simply whether national legislation reproduces international principles, but whether the domestic legal and institutional framework provides effective conditions for their implementation.

Nigeria's contemporary nuclear sector is broader than nuclear electricity generation. Radioactive sources and ionizing radiation are used in medicine, industry, research, agriculture, education, and oil-field services. The country also operates a research reactor and maintains institutions concerned with atomic energy development. The central regulator is the Nigerian Nuclear Regulatory Authority (NNRA), established under the Nuclear Safety and Radiation Protection Act 1995 (NSRPA). The Act and subsidiary regulations provide the legal basis for licensing, inspection, enforcement, radiation protection, and related controls (Federal Republic of Nigeria, 1995; NNRA, 2026a). Consequently, the scope of nuclear and radiation safety regulation in Nigeria extends across diverse activities with different levels of radiological risk, requiring the regulatory authority to maintain appropriate licensing, inspection, enforcement, technical assessment, and radiation-protection capabilities.

Regulatory effectiveness, however, cannot be inferred solely from the existence of statutory powers or the volume of regulatory activity. It concerns the extent to which the regulatory authority possesses and can effectively exercise the legal authority, institutional

independence, technical competence, resources, enforcement capability, and transparency necessary to achieve its safety mandate. A legal framework can nevertheless be comprehensive on paper and still perform unevenly in practice. Nuclear regulatory scholarship has repeatedly shown that effective independence is a problem of institutional relationships as well as statutory wording. Andrews-Speed and Putra (2024), examining France, Japan, and India, show how networks of political, bureaucratic, and industrial actors can weaken or complicate the creation of an independent safety regulator. Ram Mohan, Gopakumar, & Smith (2020), by contrast, demonstrate that *de facto* independence may sometimes develop even where formal legal independence is contested. These studies caution against equating a single structural feature with regulatory failure. They also support a more disciplined assessment of Nigeria: the inquiry should identify legal risks and evidentiary gaps without assuming facts not demonstrated.

A broader nuclear law literature reinforces that distinction. Matthews & Park (2013), in a comparative survey of national nuclear regulatory regimes, treat independence as a composite institutional problem involving organizational location, statutory authority, funding, enforcement powers, and functional separation from nuclear development bodies. Their approach is useful for Nigeria because it avoids treating the word "independent" in a statute as conclusive. The relevant inquiry is whether institutional design supplies practical safeguards against direction or dependency at the points where safety decisions are made. That framework also supports a comparative method focused on design features rather than a simple league-table comparison among regulators.

Despite the growing literature on nuclear regulatory independence and institutional design, there remains limited systematic assessment of Nigeria's nuclear safety regulatory effectiveness that simultaneously considers legal authority, functional independence, authorization and enforcement capacity, technical competence, transparency,



and alignment with contemporary IAEA safety standards. Existing discussions tend to emphasize the existence of the statutory framework or individual aspects of institutional structure, with less attention to how these elements collectively shape the conditions for effective regulatory decision-making in Nigeria. Moreover, comparative evidence from established regulatory systems has not been sufficiently integrated with an assessment of Nigeria's specific legal and institutional context. This study addresses this gap by applying a structured comparative framework to examine both the formal regulatory architecture and the publicly available evidence concerning its institutional capacity and regulatory practice.

The significance of this study lies in its integration of legal, institutional, technical, and comparative dimensions of nuclear safety regulation in Nigeria. Rather than assessing regulatory effectiveness solely from the existence of legislation or the number of regulatory activities undertaken, the study examines whether the institutional framework provides the conditions necessary for safety decisions to be made with appropriate independence, technical competence, enforcement authority, transparency, and consistency with international standards. The analysis is relevant to legislative and regulatory modernization because it identifies areas in which statutory provisions, institutional arrangements, regulatory capacity, and public reporting may require clarification or strengthening. It also contributes to comparative nuclear law and regulatory scholarship by providing a structured assessment of Nigeria against internationally recognized regulatory principles without assuming that institutional differences necessarily indicate regulatory failure. The findings may therefore provide a useful evidence base for policymakers, regulators, researchers, and other stakeholders concerned with strengthening nuclear and radiation safety governance in Nigeria. Against this background, this article addresses three questions. First, to what extent does Nigeria's legal and institutional

framework reflect contemporary international requirements for effective nuclear and radiation safety regulation? Second, what can be established from publicly available evidence about the NNRA's institutional capacity, regulatory activities, transparency, and enforcement practice? Third, what comparative lessons can be drawn from jurisdictions that have developed institutional arrangements intended to separate nuclear promotion from nuclear safety regulation? These questions are examined through six analytical dimensions: legal authority, functional independence, authorization and enforcement capacity, technical competence, transparency, and international alignment. The objective is not to rank national regulators, but to identify features of Nigeria's regulatory framework that are legally sound, require clearer institutional safeguards, or remain insufficiently evidenced to support a definitive conclusion.

2.0 Materials and Method

2.1 Research design and sources

The study adopts a doctrinal legal research design complemented by comparative legal analysis. The doctrinal component examines the content, scope, and institutional implications of Nigeria's nuclear and radiation safety legislation and related regulatory instruments, while the comparative component examines selected foreign regulatory frameworks to identify differences and common principles concerning regulatory authority, independence, institutional capacity, enforcement, transparency, and international alignment. Primary sources include the NSRPA, applicable Nigerian subsidiary regulations and official NNRA instruments, relevant international conventions to which Nigeria is a party, and applicable IAEA Safety Standards. International conventions are treated as treaty-based legal instruments, while IAEA Safety Standards are used primarily as internationally recognized regulatory benchmarks rather than as substitutes for domestic law. Comparative statutory and institutional materials are drawn from Canada, the United Kingdom, the



United States, India, France, and Japan. These jurisdictions were selected because they represent different institutional approaches to nuclear safety regulation and provide useful comparative evidence on regulatory independence, legal authority, technical capacity, enforcement, transparency, and the separation of nuclear development from safety oversight.

Sources were selected on the basis of their legal or institutional authority, relevance to nuclear safety regulation, and usefulness for evaluating the six analytical indicators. Primary legal sources were prioritized for determining statutory powers and institutional responsibilities, while regulatory reports, official institutional materials, international instruments, and peer-reviewed scholarship were used to contextualize implementation, regulatory practice, and comparative institutional arrangements.

Peer-reviewed scholarship on nuclear regulatory independence, regulatory governance, safety culture, and post-Fukushima reform is used to test and refine the legal analysis.

The study does not treat regulatory activity counts as direct proxies for safety outcomes. Where the NNRA reports the number of inspections or authorizations, those figures are used only as evidence of activity and workload. No inference is made about inspection quality, staffing adequacy or compliance trends unless the underlying source supports it. This distinction is necessary because an effective regulator is defined by the quality and independence of its decisions, not by volume alone.

Where discrepancies arise between secondary literature and primary legal or official institutional sources, the latter are given priority for establishing the content of legislation, institutional mandates, and documented regulatory actions, while secondary literature is used to provide interpretation, context, and critical analysis.

The analysis covers the statutory and regulatory framework in force during the study period and publicly available institutional and regulatory information

through 2025, with later materials used only where necessary to clarify the current institutional position.

2.2 Analytical framework

Six indicators structure the assessment. The first is legal authority: whether the regulator has a clear mandate and sufficient powers to authorize, inspect, enforce, and require corrective action. The second is effective independence, including functional separation from organizations involved in nuclear promotion or utilization. The third is institutional capacity, particularly access to qualified staff, technical support, and stable resources. Where quantitative information on staffing, technical resources, budgetary allocation, or specialist capacity is unavailable, the assessment records the evidentiary limitation rather than inferring adequacy or inadequacy from the absence of publicly reported information. The fourth is regulatory practice, including authorization, inspection, enforcement, and emergency-related functions. The fifth is transparency and accountability, including publication of rules, regulatory information, and performance evidence. The sixth is international alignment, which refers to the relationship among domestic law, treaty obligations, IAEA standards, and peer-review mechanisms. Independence and institutional capacity are treated as analytically distinct dimensions: independence concerns the regulator's ability to make safety decisions without inappropriate influence, whereas capacity concerns whether it possesses the human, technical, financial, and organizational resources required to perform its functions effectively.

Each indicator is assessed using defined documentary evidence. Legal authority is examined through statutory provisions establishing the regulator's mandate, licensing powers, inspection authority, enforcement powers, and ability to require corrective action. Effective independence is assessed through institutional location, governing-board composition, reporting relationships, financial arrangements, and functional separation from organizations



responsible for nuclear development or utilization. Institutional capacity is assessed from available evidence concerning staffing, technical expertise, training, financial and technical resources, and access to specialist support. Regulatory practice is examined through documented authorization, inspection, enforcement, emergency preparedness, and related regulatory activities. Transparency and accountability are assessed through the availability of legislation, regulatory guidance, licensing information, inspection or enforcement information, institutional reports, and other publicly accessible performance evidence. International alignment is assessed by examining treaty commitments, incorporation or implementation of relevant international principles, use of IAEA Safety Standards, and participation in international peer-review mechanisms.

These indicators are derived principally from GSR Part 1 (Rev. 1), the Convention on Nuclear Safety, and comparative regulatory literature. The approach follows the distinction in nuclear governance scholarship between formal independence and practical regulatory autonomy (Ram Mohan et al., 2020; Andrews-Speed & Putra, 2024). It also incorporates the OECD Nuclear Energy Agency's emphasis on leadership, accountability, open communication, learning, and self-assessment within an effective regulatory safety culture (NEA, 2016).

2.3 Comparative approach and jurisdictional selection

The comparative analysis examines Canada, the United Kingdom, the United States, India, France, and Japan. The jurisdictions were selected to provide variation in institutional structures, regulatory traditions, nuclear programme maturity, and approaches to the separation of nuclear development from safety regulation. The comparison does not seek to identify a universally applicable regulatory model or rank the selected jurisdictions. Instead, each jurisdiction is examined against the same core dimensions used for the Nigerian assessment, namely

legal authority, regulatory independence, institutional capacity, regulatory practice, transparency and accountability, and international alignment.

Comparative analysis is undertaken by identifying the relevant statutory provisions, institutional arrangements, regulatory responsibilities, and publicly documented regulatory practices in each jurisdiction. Particular attention is given to the institutional relationship between bodies responsible for nuclear development or utilization and those responsible for nuclear safety regulation. The comparative findings are then used to identify institutional features that may provide relevant points of reference for evaluating Nigeria's regulatory framework, while recognizing differences in constitutional structures, legal systems, nuclear programmes, and administrative contexts.

3.0 Results and Discussion

The findings are interpreted in accordance with the six analytical dimensions established in the methodology: legal authority, effective independence, institutional capacity, regulatory practice, transparency and accountability, and international alignment. Because publicly available evidence does not provide comprehensive measures of safety outcomes, the analysis evaluates the legal and institutional conditions associated with regulatory effectiveness rather than treating regulatory activity alone as direct evidence of safety performance.

3.1 Legal mandate and regulatory coverage

The NSRPA provides Nigeria with a distinct statutory authority for nuclear safety and radiological protection. NNRA materials describe the Act as the legal basis for regulating practices involving ionizing radiation and nuclear material, supplemented by the Nigerian Basic Ionizing Radiation Regulations and sector-specific regulations (NNRA, 2026a). The regulatory portfolio covers medical exposure, nuclear medicine, radiotherapy, diagnostic and interventional radiology, radioactive sources, industrial radiography, transport, radioactive waste, well logging, naturally occurring radioactive



material, and industrial irradiators. This breadth is consistent with the diversity of radiation and nuclear-related practices subject to regulatory control in Nigeria and provides a broad formal basis for preventive safety oversight.

The legal mandate also reflects an important principle of nuclear law: regulation must cover the full life cycle of regulated activities rather than focus only on accident response. Authorization, inspection, transport, waste, occupational exposure, public exposure and source security all contribute to preventive safety. Čavoški (2013), writing after Fukushima, emphasized that treaty compliance cannot be reduced to the presence of legislation; implementation must address site, design, emergency, and regulatory deficiencies in a systematic way. The same reasoning applies to countries without commercial nuclear power reactors. A radiation-safety regime can fail if regulatory attention is fragmented across medical, industrial, and research applications.

A modernization issue nevertheless arises from the principal statute's age. The NSRPA dates from 1995. The age of the legislation should not, by itself, be interpreted as evidence of regulatory inadequacy; rather, it provides a basis for examining whether the statutory powers and institutional arrangements remain sufficiently comprehensive to address developments in technology, safety, security, and regulatory practice. Since then, international practice has developed substantially in nuclear security, cybersecurity, digital instrumentation and control, safety culture, emergency preparedness, decommissioning, and advanced reactor technologies. These developments have progressively expanded the scope of contemporary nuclear regulatory expectations and reinforce the need for periodic review of primary legislation against current international safety and security requirements (IAEA, 2025). A statute need not be rewritten whenever technology changes, but primary legislation should provide sufficiently clear authority for the regulator to control new classes of safety-

significant digital and automated systems. Legislative review is therefore justified even if the existing Act continues to support substantial regulatory activity.

3.2 Authorization, inspection, and enforcement capacity

The NNRA publicly identifies authorization and enforcement as core functions. Its Authorization and Enforcement Department is responsible for categorizing and authorizing practices and for enforcing statutory, regulatory, and license requirements (NNRA, 2026b). The Authority has also published examples of enforcement action, including closure of non-compliant health facilities after corrective measures were not implemented (NNRA, 2023). These examples are relevant because regulatory effectiveness requires more than advisory capacity; the regulator must be able to impose consequences where safety requirements are not met.

Recent workload information provides another part of the picture. In an official 2026 communication, the NNRA Director-General reported that the Authority conducted 741 regulatory inspections and issued 1,472 authorizations during 2025 (NNRA, 2026c). The figures indicate an active regulatory programme across a sizeable field of licensed and authorized practices. They do not show whether the inspections were risk-prioritized, how many inspectors were available, the average duration and complexity of inspections, the number of significant findings, or the rate at which corrective actions were closed. Those additional indicators would be necessary before inspection volume could be used to assess adequacy.

Accordingly, the reported figures support a finding of substantial regulatory activity and workload but do not provide sufficient evidence to determine whether regulatory resources are proportionate to risk or whether regulatory interventions have produced measurable improvements in compliance or safety performance. This point matters because regulatory performance can be distorted by simple quantitative targets.



Nuclear oversight depends heavily on expert judgment, and higher numbers do not necessarily mean better safety. An inspection of a complex research reactor or high-activity source facility cannot be equated mechanically with a routine administrative authorization. Effective regulation, therefore, requires a risk-informed allocation of effort and a record that allows outsiders to understand the relationship between workload and safety significance.

3.3 Institutional competence and technical support

GSR Part 1 requires a regulatory body to employ sufficient qualified and competent staff and to obtain technical advice where necessary without transferring its regulatory responsibility (IAEA, 2016a). The NNRA's published departmental structure shows specialization in medical applications, radiological safety, nuclear research reactor safety and safeguards, nuclear safety and security, authorization and enforcement, and technical support functions (NNRA, 2026d). This organizational specialization is consistent with the range of practices under regulation. The existence of specialized departments demonstrates organizational differentiation, but it does not by itself establish that staffing levels, specialist expertise, training, technical resources, or financial capacity are sufficient for the regulator to discharge its responsibilities effectively.

The harder question is whether the available resources are adequate. The public sources reviewed for this article do not provide a current, sufficiently detailed dataset on staff numbers by technical discipline, vacancies, turnover, training hours, inspection-to-staff ratios, budget execution, or reliance on external technical support. That gap prevents a reliable quantitative judgment. It would be methodologically unsound to infer either adequacy or inadequacy from organizational charts alone. The appropriate conclusion is therefore not that NNRA capacity is inadequate, but that publicly available evidence is insufficient to make a reliable quantitative assessment of capacity.

Peer-reviewed work on nuclear regulators shows why competence is not merely a staffing issue. Willis et al. (2024) found that nuclear regulators influence safety culture through a combination of enforcement, partnership, and advisory roles, with professionalism, transparency, and balance in the regulator–regulatee relationship. Those functions require personnel who can exercise technical authority without becoming dependent on the licensee for knowledge. A regulator also needs institutional memory and the ability to challenge technically sophisticated submissions. For Nigeria, public reporting on specialist capacity would strengthen confidence while avoiding disclosure of security-sensitive information.

3.4 Effective independence and functional separation

The most significant governance issue concerns independence. IAEA GSR Part 1 requires the regulator to be effectively independent in safety-related decision-making and functionally separated from organizations whose responsibilities or interests could unduly influence its decisions (IAEA, 2016a). The Convention on Nuclear Safety includes a related requirement for effective separation between regulatory functions and organizations responsible for the promotion or utilization of nuclear energy (Convention on Nuclear Safety, 1994).

The NNRA is institutionally identifiable as a distinct regulator, but its governing structure warrants examination. The Authority's official information lists a board composed of high-level government and sectoral representatives, including the Nigeria Atomic Energy Commission (NNRA, 2026e).

The presence of government and sectoral representatives does not, by itself, establish actual interference with NNRA decisions; rather, it raises a structural question concerning the extent to which the governing arrangement provides adequate safeguards for independent safety decision-making. The Authority is institutionally identifiable as a distinct regulator, but the composition of its governing board warrants examination because it includes senior executive and



sectoral representatives whose institutional responsibilities may intersect with nuclear and radiation policy. NAEC has responsibilities associated with the development and promotion of atomic energy. The formal presence of a promotional institution within the safety regulator's governing arrangement, therefore, raises a structural question when measured against the functional-separation principle.

That observation must be framed carefully. It does not establish that NAEC or any minister has interfered with a specific NNRA safety decision.

Regulatory-independence scholarship warns against treating *de jure* structure as a complete account of *de facto* behaviour. Ram Mohan et al. (2020), in their study of India, found that a regulator may exercise meaningful practical independence even when formal arrangements are contested. Conversely, Andrews-Speed and Putra (2024) show that formal reform can be constrained by entrenched networks of political and industrial influence. The legal objective should therefore be preventive: to reduce the channels through which safety judgment could be compromised, while preserving accountability to government and the law.

The relevant issue under the IAEA framework is therefore not whether government representatives participate in regulatory governance *per se*, but whether the institutional arrangement provides effective functional separation and protects safety-related decisions from inappropriate influence.

The post-Fukushima nuclear-law literature adds a further reason for preventive design. Reyners (2013) describes the internationalization of nuclear safety as historically reactive, with major accidents repeatedly prompting stronger expectations of international scrutiny and domestic regulatory reform. The lesson for a state developing or expanding nuclear activities is that independence safeguards are most valuable before a crisis tests them. Clear legal separation, protected technical judgement and transparent accountability can reduce the

need to reconstruct regulatory legitimacy after an accident or serious event.

A revised Nigerian statute could address the issue directly by stating that safety decisions are not subject to direction by any body responsible for nuclear promotion, establishing conflict-of-interest rules, clarifying appointment and removal criteria, protecting access to technical expertise, and providing a predictable funding mechanism. Effective independence does not mean isolation. As the NEA (2016) emphasizes, an effective regulator must communicate, learn and remain accountable while protecting the integrity of safety decisions.

3.5 Transparency, accountability and regulatory safety culture

Transparency in nuclear regulation has two functions. It allows regulated organizations to understand what is required, and it permits the public and government to evaluate how regulatory authority is used. The NNRA publishes regulations, institutional mandates, licensing information, notices, and selected enforcement information. These practices support accessibility. The next step is deeper performance reporting.

The available reporting evidence also indicates an opportunity to strengthen the public presentation of regulatory performance. The study therefore recommends that future annual regulatory reporting distinguish regulatory activity from regulatory outcomes

A useful annual regulatory report would distinguish activity from outcome. Such reporting should remain subject to appropriate security and confidentiality restrictions, while providing sufficient non-sensitive information to permit independent assessment of regulatory workload, risk coverage, enforcement activity, and institutional performance.

It could publish the number of regulated facilities and sources by category, inspection coverage by risk class, significant findings, enforcement actions, corrective action closure rates, major rulemaking projects, staff training, international peer review activities,



and selected performance indicators. Sensitive security information should be excluded. Such reporting would allow researchers and legislators to evaluate whether resources and regulatory efforts align with the regulated sector's risk profile.

Table 1 summarizes the assessment of Nigeria's nuclear safety regulatory effectiveness across six dimensions: legal

mandate, functional independence, authorization and enforcement, competence and resources, transparency, and international alignment. It highlights existing regulatory strengths, identified structural concerns, and areas where available public evidence remains insufficient for definitive conclusions.

Table 1: Assessment of Key Dimensions of Nuclear Safety Regulatory Effectiveness in Nigeria

Dimension	Assessment
Legal mandate	NSRPA 1995 establishes the NNRA, and subsidiary regulations cover diverse radiation and nuclear practices. This is a substantial formal foundation, but the primary statute should be modernized against current IAEA standards and newer digital risks.
Functional independence	Nigeria has a dedicated regulator, but its governing structure includes senior executive and sectoral actors, including NAEC representation. This creates a structural separation issue; it is not evidence of actual interference.
Authorization and enforcement	Published licensing, inspection and enforcement functions and reported enforcement actions show active practice. The 741 inspections and 1,472 authorizations reported for 2025 indicate workload, not by themselves regulatory adequacy.
Competence and resources	Specialized departments and technical support arrangements are publicly identified. Public data are insufficient for a quantitative judgment on staffing, expertise, retention or budget adequacy.
Transparency	Rules, institutional information and selected enforcement notices are public. Systematic annual reporting on risk-class inspection coverage, significant findings, corrective actions and non-sensitive staffing indicators would strengthen accountability.
International alignment	Nigeria participates in major nuclear safety and liability instruments. Treaty participation should be matched by continuing domestic implementation, legislative review and transparent peer-review follow-up.

Regulatory safety culture is also relevant. The NEA (2016) identifies leadership for safety, individual responsibility and accountability, cooperation, open communication, and continuous improvement as principles of an effective regulatory body. Willis et al. (2024) similarly show that professionalism and transparent interaction influence the safety culture of licensees. These findings do not justify a softer approach to enforcement. They show that a regulator's effectiveness depends partly on whether regulated organizations

perceive its decisions as technically credible, consistent, and safety focused. Nigeria's regulatory modernization should therefore combine enforcement authority with institutional learning and public explanation of regulatory reasoning.

3.6 International alignment and peer review

Nigeria is party to the Convention on Nuclear Safety and the Joint Convention, and it participates in the wider international nuclear legal framework through instruments addressing liability, emergency notification,



assistance, and physical protection (IAEA Office of Legal Affairs, 2026). International participation provides standards, reporting processes, and opportunities for peer review. It does not automatically establish domestic compliance.

Post-Fukushima scholarship illustrates the importance of implementation. Čavoški (2013) argued that the Fukushima accident exposed weaknesses in regulatory independence and the practical application of the Convention on Nuclear Safety obligations. Andrews-Speed and Putra (2024) similarly identify the political and institutional difficulty of separating safety regulation from promotional networks. These lessons support continued Nigerian engagement with IAEA review mechanisms and transparent follow-up. Where peer reviews identify recommendations or suggestions, public action plans and progress updates—subject to security constraints—can help translate international engagement into domestic institutional improvement.

3.7 Comparative institutional lessons

Canada, the United Kingdom, and the United States illustrate different statutory methods of separating safety regulation from nuclear promotion. Canada's Nuclear Safety and Control Act establishes the Canadian Nuclear Safety Commission and assigns it regulatory objectives concerning health, safety, security, and environmental protection (Canada, 1997). For consistency, the jurisdictions are examined using the same core dimensions applied to Nigeria: legal authority, functional independence, institutional capacity, regulatory practice, transparency and accountability, and international alignment.

The United Kingdom's Energy Act 2013 establishes the Office for Nuclear Regulation on a statutory basis, with responsibilities for nuclear safety, security, safeguards, and transport (United Kingdom, 2013). In the United States, the Energy Reorganization Act of 1974 separated the former Atomic Energy Commission's promotional and regulatory functions and created the Nuclear Regulatory Commission to regulate civilian nuclear activities (United States, 1974).

Japan provides a different lesson because the reform followed a major accident. Post-Fukushima restructuring created the Nuclear Regulation Authority with a stronger claim to institutional independence. Andrews-Speed (2020) describes the reforms as a major change in Japanese nuclear governance, while Andrews-Speed and Putra (2024) place the reform within the wider problem of dismantling entrenched regulator–industry–government relationships. The implication for Nigeria is not that an identical agency design should be copied. It is that institutional separation is easier to defend when the law makes the division between promotion and regulation visible and difficult to circumvent. Comparative practice also shows that independence must be paired with competence and accountability. A formally autonomous regulator with inadequate expertise may be ineffective; a technically strong regulator without transparent legal safeguards may remain vulnerable to perceptions of influence. Nigeria, therefore, needs a combined approach: legal separation, stable resources, professional capacity, enforceable powers, and public accountability.

Table 1 synthesizes the principal documentary evidence, identified limitations, and implications arising from the six analytical dimensions used in the study.

3.8 *De jure independence, de facto independence, and accountability*

The comparative literature shows why regulatory independence should not be reduced to a binary question. Formal or de jure independence concerns the legal rules governing appointment, tenure, reporting, financing, and decision-making. De facto independence concerns how the regulator actually behaves when government, licensees or other interested institutions prefer a different outcome. Ram Mohan et al. (2020) demonstrate that the two may diverge: India's Atomic Energy Regulatory Board has faced criticism regarding its legal position within the atomic-energy establishment, yet the authors identify judicial treatment and



regulatory practice that suggest a meaningful degree of practical autonomy. That finding does not remove the case for clearer formal safeguards; it shows that institutional performance must be assessed with evidence rather than inferred solely from organizational location. These comparative findings provide an analytical basis for interpreting institutional independence but do not constitute direct evidence of the NNRA's actual behaviour or decision-making autonomy.

The opposite problem is equally important. A formally independent agency can be weakened by unstable funding, shortages of specialist staff, political appointment practices, or dependence on the regulated industry for technical information. Andrews-Speed and Putra (2024) show that restructuring a regulator does not automatically dissolve networks of influence. Regulatory independence is therefore best understood as a bundle of protections that support independent judgment: legal authority, secure resources, competent staff, conflict controls, access to independent expertise, transparent reasons, and freedom to impose unpopular safety decisions.

Accountability should not be presented as the opposite of independence. A regulator with major coercive powers must remain accountable to law, courts, audit institutions, and the public. What nuclear safety standards seek to prevent is the direction of technical safety decisions by bodies with promotional, political, or commercial interests. The appropriate institutional design is consequently one in which the regulator explains its decisions and use of resources while retaining final technical authority within its statutory mandate. Clear reasons, published procedures and judicial review can strengthen rather than weaken regulatory independence because they reduce the space for informal influence.

For Nigeria, this distinction suggests a targeted legislative approach. Reform should not merely label the NNRA independent. It should identify which decisions are protected from external direction, state the permitted

grounds for removal of senior regulatory officials, address conflicts of interest, establish access to independent scientific advice, and clarify the budgetary process. Those safeguards would allow independence to be evaluated against concrete legal provisions rather than broad institutional claims.

Table 2 presents a comparative assessment of Nigeria and six selected nuclear regulatory jurisdictions across the six dimensions used in this study: legal authority, functional independence, institutional capacity, authorization and enforcement, transparency, and international alignment. The comparison is intended to identify relevant institutional and regulatory practices rather than to rank the jurisdictions or establish a direct measure of regulatory effectiveness.

The comparison indicates that the jurisdictions examined generally combine statutory regulatory authority with institutional separation, technical capacity, authorization and enforcement powers, transparency mechanisms, and international engagement. For Nigeria, the comparison highlights the need to modernize the statutory framework, strengthen safeguards for functional independence, improve publicly available information on regulatory capacity and performance, and link international peer-review findings more clearly to domestic regulatory development.

3.9 Emergency preparedness, security interfaces, and digital change

Regulatory effectiveness also depends on how well the legal framework manages interfaces between safety, security and emergency preparedness. These functions are related but not identical. Safety regulations seek to prevent accidental exposure and unsafe operation; nuclear security addresses malicious acts; emergency preparedness governs arrangements for events that nevertheless occur.



Table 2: Comparative Assessment of Nuclear Regulatory Effectiveness

Dimension	Nigeria	Canada	UK	USA	India	France	Japan
Legal authority	NSRPA 1995; broad regulations	NSCA 1997; CNSC	Energy Act 2013; ONR	Energy Reorganization Act 1974; NRC	Atomic Energy Act 1962; AERB	Dedicated nuclear safety framework; ASN	Post-Fukushima nuclear safety framework; NRA
Independence	Statutory regulator; institutional safeguards require review	Strong statutory separation	Clear regulatory separation	Clear regulatory separation	Independence has been debated	Dedicated regulatory authority	Separation strengthened after Fukushima
Capacity	Specialized units; limited public data	Established technical capacity	Strong technical capacity	Extensive technical capacity	Specialized technical structure	Strong technical capacity	Strong technical capacity
Authorization/ Enforcement	Licensing, inspection and enforcement	Licensing and inspection	Licensing and inspection	Licensing and inspection	Licensing and inspection	Licensing and inspection	Licensing and inspection
Transparency	Regulations and selected regulatory information published	Extensive public information	Public guidance and enforcement information	Extensive public information	Regulatory information available	Public decisions and reports	Public regulatory information
International alignment	International participation; implementation requires continued assessment	Strong international engagement	Strong international engagement	Strong international engagement	International engagement	Strong international engagement	Strong international engagement
Key observation	Modernization, independence and performance transparency remain important	Mature regulatory structure	Strong separation and oversight	Strong separation and technical capacity	Institutional independence remains an area of discussion	Dedicated independent regulation	Post-Fukushima institutional strengthening



Fragmented responsibilities can create gaps where more than one institution assumes that another has acted. GSR Part 1, therefore, emphasizes clear allocation of governmental responsibilities and coordination among authorities (IAEA, 2016a).

Nigeria's regulatory framework addresses a wide range of radiation practices, and its international commitments include instruments on early notification, emergency assistance and physical protection. The public materials reviewed here do not provide enough evidence to assess the operational quality of inter-agency emergency exercises or cyber-response arrangements. That limitation should be acknowledged. A modern statutory review should nevertheless ensure that the NNRA's authority to require emergency arrangements, cyber protection of safety-significant digital systems and coordination with security and emergency agencies is explicit.

Digital change makes this issue more immediate. The relevance of these developments is prospective rather than evidence that such risks are currently inadequately regulated in Nigeria; the available public evidence does not permit such a conclusion. Safety-significant instrumentation, remote monitoring, automated analysis, and artificial intelligence can create new dependencies on software, communications networks, and external vendors. The regulator requires authority not only to inspect physical equipment but also to demand software assurance, configuration management, cybersecurity controls, validation evidence and records sufficient to reconstruct automated decisions. These requirements are consistent with the broader IAEA principle that the regulatory framework must remain adequate for facilities and activities under its jurisdiction, even as technology changes.

The law should avoid prescribing a single technical solution. These considerations point to a legislative modernization priority rather than establishing a current regulatory deficiency. Technology develops more quickly than primary legislation. The better

approach is to provide clear statutory powers and principles, leaving detailed technical requirements to regulations and guides that can be updated through transparent procedures. In this way, legal modernization can strengthen regulatory adaptability without creating a statute that becomes obsolete when the next generation of digital systems is introduced.

3.10 Public participation, reason-giving and confidence in regulation

For purposes of this study, public participation is treated as a component of transparency and accountability rather than as a separate analytical indicator. Regulatory effectiveness also has a legitimacy dimension. Nuclear safety decisions frequently involve technical judgments that cannot be resolved by public preference alone, but this does not remove the need for explanation and participation. Open procedures can improve the quality of decisions by exposing assumptions, identifying local information, and making the basis of regulatory action visible. They also help distinguish independent technical judgment from unexplained administrative discretion.

The comparative literature after Fukushima is instructive. Čavoški (2013) linked regulatory weaknesses to broader failures of governance and argued for stronger mechanisms to test whether states actually implement safety obligations. Andrews-Speed (2020) likewise shows that post-Fukushima reform in Japan involved not only institutional restructuring but also efforts to rebuild confidence in nuclear governance. These studies do not imply that public acceptance is a legal test of safety. They show that durable regulation requires procedures through which the regulator can demonstrate the evidentiary basis and consistency of its decisions.

For Nigeria, this supports publication of major regulatory guides, consultation on significant rule changes, accessible explanations of licensing and enforcement processes, and public summaries of important safety decisions where security permits. Reason-giving is particularly important where the regulator departs from previous



practice or imposes new technical conditions. Such practices would strengthen accountability without transferring technical authority away from the NNRA.

Public participation scholarship in nuclear law points in the same direction. Mlynarkiewicz (2013), examining stakeholder engagement in nuclear regulation, treats public awareness and participation as part of the institutional environment in which technically complex decisions acquire legitimacy. Participation cannot substitute for specialist safety analysis, but consultation and accessible reasons can improve the evidentiary record, expose implementation concerns, and make it easier to distinguish independent technical judgment from unexplained discretion. For Nigeria, this supports a graded approach in which major rulemaking and significant licensing policy changes receive more structured consultation than routine administrative actions.

3.11 Reform priorities for Nigeria

Based on the documented findings and the identified evidentiary limitations, five reform priorities emerge from the analysis. The first is legislative modernization. A replacement or substantial amendment of the NSRPA should state regulatory independence in direct terms, define the relationship between the NNRA and promotional institutions, and update statutory authority for digital and cyber-related safety issues. The law should also clarify appointment, removal, conflicts of interest, and the regulator's access to independent technical advice.

The second is greater transparency on capacity. The absence of public staffing and performance data does not prove weakness, but it prevents external evaluation. Annual reporting should include non-sensitive indicators for specialist staff, training, inspection coverage, enforcement, and corrective action closure. This would allow institutional capacity to be assessed on evidence rather than assumption.

Third, Nigeria should institutionalize regular legislative and regulatory conformity reviews

against current IAEA standards and treaty commitments. A 1995 statute should not be presumed inadequate simply because of its age, but neither should age be ignored where technology and international standards have changed materially.

Fourth, peer review should be linked to public follow-up. IAEA review missions can identify strengths and areas for improvement, but domestic value is realized when recommendations are translated into assigned actions, timelines, and measurable evidence of completion.

Fifth, reform should preserve the operator's primary responsibility. Stronger regulation does not make the regulator an operational guarantor. GSR Part 1 and the Fundamental Safety Principles maintain a deliberate division: the operator is responsible for safety, while the regulator establishes and enforces the framework within which that responsibility is discharged (IAEA, 2006; IAEA, 2016a). This division will become more important as operators and regulators introduce AI and other digital decision-support systems.

Taken together, the evidence indicates that Nigeria has a substantial formal regulatory framework and demonstrable regulatory activity, but publicly available evidence remains insufficient in several areas to establish regulatory effectiveness conclusively. The principal areas requiring continued attention are institutional safeguards for functional independence, transparency of regulatory capacity and performance, legislative alignment with evolving international requirements, and systematic follow-up of international peer-review findings.

The findings should therefore be interpreted as an assessment of the legal and institutional conditions associated with effective regulation rather than as a direct measurement of nuclear or radiation safety outcomes.

4.0 Conclusion

Nigeria has the essential legal and institutional components of a functioning nuclear and radiation safety regulatory system. The NNRA has a statutory mandate,



a substantial body of subsidiary regulations, authorization and enforcement functions, specialized organizational units, and an active programme of inspections and authorizations. Nigeria also participates in the principal international nuclear safety framework. These features are significant and should be acknowledged.

The current analysis indicates that Nigeria has established a formal legal and institutional framework with substantial regulatory authority and documented regulatory activity, but the available evidence is insufficient to determine conclusively whether the framework delivers regulatory effectiveness across all six dimensions examined in this study: legal authority, functional independence, institutional capacity, regulatory practice, transparency and accountability, and international alignment.

The evidence nevertheless supports reform in four areas. First, the 1995 primary legislation should be modernized. Second, the law should clarify functional separation and safeguards for regulatory judgment, particularly where institutions involved in nuclear development are represented in regulatory governance. Third, the NNRA should publish fuller non-sensitive performance and capacity information so that claims about effectiveness can be evaluated. Fourth, international peer review should be connected to transparent domestic implementation.

The analysis does not establish that Nigeria's regulator lacks independence or technical competence. It identifies structural issues and evidentiary limits that prevent stronger conclusions. That distinction is important. Nuclear regulation should be assessed with the same discipline that regulators require from licensees: claims should be traceable to evidence, uncertainties should be stated, and safety-significant institutional weaknesses should be addressed before they contribute to failure.

For policy, the immediate priority is a modern statutory framework that combines independence with accountability. For scholarship, future work should examine

NNRA staffing and budget trends, inspection outcomes, regulatory decision-making, licensee compliance, and stakeholder perceptions using data that are not presently available in sufficient detail. Such evidence would permit a more complete assessment of de facto regulatory effectiveness in Nigeria.

5.0 References

- Alvarez, D. E. (2014). *Fundamental safety principles and roles of organizations in the development of disposal facilities* [Presentation slides]. Regional Workshop on Management and Safe Disposal of Radioactive Waste, Tunis, Tunisia. International Atomic Energy Agency & Arab Network of Nuclear Regulators.
- Andrews-Speed, P. & Putra, N.A. (2024). Breaking the iron triangle around nuclear safety regulation: The cases of France, Japan, and India. *Regulation & Governance*, 18, 1246-1263. <https://doi.org/10.1111/rego.12577>
- Andrews-Speed, P. (2020). Governing nuclear safety in Japan after the Fukushima nuclear accident: incremental or radical change? *Journal of Energy & Natural Resources Law*, 38(2), 161-181. <https://doi.org/10.1080/02646811.2020.1741990>
- Bowen, M., & Ponangi, R. T. (2026). *The importance of an independent nuclear safety regulator: Roundtable summary*. Center on Global Energy Policy at Columbia University.
- Canada. (1997). Nuclear Safety and Control Act, S.C. 1997, c. 9, as amended.
- Čavoški, A. (2013). Revisiting the Convention on Nuclear Safety: Lessons learned from the Fukushima accident. *Asian Journal of International Law*, 3(2), 365-391. <https://doi.org/10.1017/S2044251312000331>
- Convention on Nuclear Safety. (1994). Adopted 17 June 1994; entered into force 24 October 1996.
- Federal Republic of Nigeria. (1995). Nuclear Safety and Radiation Protection Act No.



- 19 of 1995, Cap N142 Laws of the Federation of Nigeria 2004.
- International Atomic Energy Agency (IAEA). (2006). *Fundamental Safety Principles*. IAEA Safety Standards Series No. SF-1. Vienna: IAEA.
- International Atomic Energy Agency. (2025). *Integrated Regulatory Review Service (IRRS) mission to Hungary* (IAEA Report No. IAEA-NS-IRRS-2025/06). Department of Nuclear Safety and Security.
- International Atomic Energy Agency (IAEA). (2014). *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*. IAEA Safety Standards Series No. GSR Part 3. Vienna: IAEA.
- International Atomic Energy Agency (IAEA). (2016a). *Governmental, Legal and Regulatory Framework for Safety*. IAEA Safety Standards Series No. GSR Part 1 (Rev. 1). Vienna: IAEA.
- International Atomic Energy Agency (IAEA). (2016b). *Leadership and Management for Safety*. IAEA Safety Standards Series No. GSR Part 2. Vienna: IAEA.
- International Atomic Energy Agency, Office of Legal Affairs. (2026). *Country Factsheet: Nigeria, Federal Republic of*. IAEA treaty status database.
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. (1997). Adopted 5 September 1997; entered into force 18 June 2001.
- Leotlela, M. (2021). Establishing an effective nuclear regulatory regime: A case study of South Africa. *Science, Technology & Public Policy*, 5(1), 1–18. <https://doi.org/10.11648/j.stpp.20210501.11>
- Matthews, T.P. & Park, E.K. (2013). Regulatory independence and accountability: A survey of international nuclear regulatory regimes. *International Journal of Nuclear Law*, 4(1), 5-19. <https://doi.org/10.1504/IJNUCL.2013.052041>
- Mlynarkiewicz, L.D. (2013). Public awareness and stakeholder engagement in India's nuclear energy regulatory process. *International Journal of Nuclear Law*, 4(1), 78-94. <https://doi.org/10.1504/IJNUCL.2013.052046>
- Nigerian Nuclear Regulatory Authority (NNRA). (2023). NNRA Shuts Down Erring Facilities in Niger State. Official enforcement notice, 24 July 2023.
- Nigerian Nuclear Regulatory Authority (NNRA). (2026a). *Legal Framework and Regulations*. Official institutional materials.
- Nigerian Nuclear Regulatory Authority (NNRA). (2026b). *Authorization and Enforcement Department*. Official departmental mandate.
- Nigerian Nuclear Regulatory Authority (NNRA). (2026c). NNRA DG Flags Off First In-House Seminar for 2026. Official news release reporting 2025 inspections and authorizations.
- Nigerian Nuclear Regulatory Authority (NNRA). (2026d). *Departments and Technical Functions*. Official institutional materials.
- Nigerian Nuclear Regulatory Authority (NNRA). (2026e). NNRA Governing Board. Official institutional page.
- Nuclear Energy Agency (NEA). (2016). *The Safety Culture of an Effective Nuclear Regulatory Body*. Paris: OECD Publishing. <https://doi.org/10.1787/9789264252967-en>
- Ram Mohan, M.P., Gopakumar, K.V. & Smith, T. (2020). Nuclear energy safety, regulatory independence, and judicial deference: The case of the Atomic Energy Regulatory Board of India. *Administration & Society*, 52(7), 1053-1081. <https://doi.org/10.1177/0095399719882640>
- Reyners, P. (2013). A new world governance for nuclear safety after Fukushima? *International Journal of Nuclear Law*, 4(1), 63-77. <https://doi.org/10.1504/IJNUCL.2013.052045>
- United Kingdom. (2013). *Energy Act 2013*, c. 32, Part 3.



United States. (1974). Energy Reorganization Act of 1974, Pub. L. No. 93-438, 88 Stat. 1233.

Willis, S., Holman, D., Clarke, S. & Hartwig, A. (2024). Understanding the regulator-regulatee relationship for developing safety culture. *Risk Analysis*, 44(4), 972-990. <https://doi.org/10.1111/risa.14214>

Zakaria, M. (2026). Advancing nuclear regulatory effectiveness: Integrating leadership for safety into nuclear oversight functions. *Science and Technology of Nuclear Installations*, 2026, 5535689. <https://doi.org/10.1155/stni/5535689>

Compliance with Ethical Standards

Declaration

Ethical Approval

Not Applicable

Competing interests

The author declares no known competing financial interests.

Funding

No external funding was received for this doctrinal and comparative legal research.

Author's Contribution

The author conceived the study, conducted the legal and comparative analysis, verified the sources, and prepared the manuscript.

