

Considerations for Safety Classification of Structures, Systems and Components of Non-LWRs

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1. Introduction

The core of safety regulation for Non-Light Water Reactors (Non-LWRs) lies in establishing a new regulatory framework capable of encompassing diverse design characteristics that diverge significantly from those of conventional large-scale Light Water Reactors (LWRs). This safety regulatory system is centered on the rational assessment of risks and the subsequent gradation of regulatory requirements based on such evaluations.

While South Korea has prior experience in Non-LWR R&D and corresponding regulatory reviews, there is a need to incorporate recent technological advancements and global regulatory trends, such as 10 CFR Part 53. Currently, the domestic level of experience with Risk-Informed Performance-Based (RIPB) licensing frameworks, even for large LWRs, remains relatively low, leading to various challenges in applying these frameworks to light-water Small Modular Reactors (SMRs).

Given that Non-LWRs possess fundamental design concepts distinct from LWRs, it is anticipated that legal consistency must be considered starting from the highest levels of the licensing hierarchy. As the maturity of the regulatory methodology will naturally be proportional to the technical readiness of the Non-LWRs under domestic development, it is necessary to monitor the status of technological development at each stage and adjust the scope of application and development for Structure, System, and Component (SSC) classification methodologies, which is one of the underlying distinctiveness.

With the recent enactment of the "Special Act on the Promotion and Support of SMR Development," the foundation has been laid to take the first step toward the research and commercialization of not only LWRs but also Non-LWRs. Building on the research described above, this paper seeks to propose essential considerations for the safety classification of Non-LWRs.

2. Analysis of the domestic and international status of licensing systems for Non-LWRs

2.1. International Guidelines for Non-LWRs (Focusing on Safety Classification)

IAEA Safety Standards [1] have published a series of hierarchical documents regarding safety classification. Figure 1 provides an overview of these documents

categorized by their regulatory hierarchy, including Safety Fundamentals (high-level principles), Safety Requirements (mandatory requirements), and Safety Guides (technical applications and guidelines).

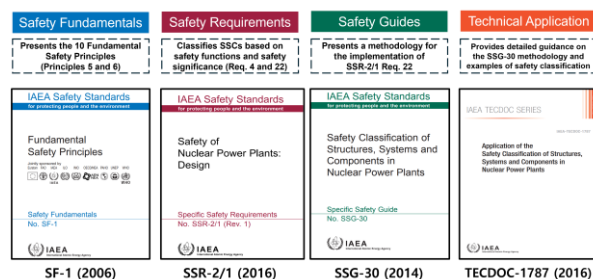


Fig 1. Short description about International Guidelines

IAEA SSR-2/1 Requirement 4 addresses Fundamental Safety Functions (FSFs), while Requirement 22 stipulates provisions for Safety Classification. To classify safety significance, it recommends a deterministic analysis-based approach, supplemented by Probabilistic Safety Assessment (PSA) as necessary. IAEA SSG-30 provides specific recommendations and guidance on fulfilling the requirements established in the overarching document, SSR-2/1. Furthermore, Safety Guide 2.12 outlines considerations for using probabilistic methods, and Safety Guide 2.14 qualitatively specifies the methodology for determining the safety classes of Structures, Systems, and Components (SSCs). IAEA TECDOC-1787 elaborates on the methodologies of SSG-30 and supplements guidance for practical implementation. Specifically, Chapter 2 details design factors for safety classification, FSFs, and the categorization of functions, complemented by concrete examples.

2.2. Analysis of U.S. and Canadian Experience

The U.S. nuclear regulatory framework can be classified into 10 CFR Part 50 [2] (introduced in 1956), 10 CFR Part 52 (introduced in 1989), and 10 CFR Part 53, which is targeted for introduction in 2027. Table I provides a summary of the details for each regulatory framework.

Table I: Regulatory Framework in U.S.

10 CFR Part 50	A two-step licensing framework consisting of a Construction
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	Permit (CP) and an Operating License (OL).
10 CFR Part 52	A regulatory framework utilizing the Combined License (COL) process.
10 CFR Part 53	A Technology-Inclusive, Risk-Informed, and Performance-Based (TI-RIPB) regulatory framework.

Currently, in the United States, challenges exist in directly applying the existing LWR-centric licensing frameworks, namely 10 CFR Part 50 and Part 52, to Non-LWRs. To address this, the U.S. Nuclear Regulatory Commission (NRC) allows for the utilization of Regulatory Guide (RG) 1.233 even within the Part 50 and Part 52 pathways, enabling a more flexible approach for Non-LWR licensing. Furthermore, the NRC is proactively developing 10 CFR Part 53 (technology-inclusive, and risk-informed regulatory framework) specifically designed to provide a dedicated licensing path for advanced reactors.

The Canadian Nuclear Safety Commission (CNSC) is currently conducting the licensing process for the BWRX-300, a type of Small Modular Reactor (SMR). Regarding SMR regulation, the CNSC emphasizes risk-informed decision-making that utilizes Probabilistic Safety Assessment (PSA) information, as well as the implementation of graded regulation based on such insights. Furthermore, the CNSC reviewed the BWRX-300 safety strategy in collaboration with the U.S. NRC and published a joint report on the findings in 2023 [3].

2.4. Analysis of South Korea's Experience

Regulatory activities concerning Non-LWRs in South Korea have historically been limited. While research on the TI-RIPB framework itself has been conducted by the Korea Institute of Nuclear Safety (KINS) [4], there are virtually no practical licensing precedents. Recently, in 2025, the Nuclear Safety and Security Commission (NSSC) hosted the "Nuclear Safety Roundtable" with developers of non-light water SMRs. This event marked the first official communication channel between the NSSC and Non-LWR developers; it was established to gather diverse feedback from industry players and research institutes leading Non-LWR development and to incorporate these insights into the regulatory framework.

3. Key Regulatory Priorities and Issues

Since the safety classification of Structures, Systems, and Components (SSCs) significantly impacts various sections of the Safety Analysis Report (SAR), including accident analysis, and serves as a critical factor throughout the entire lifecycle from design and construction to operation, it is imperative that safety

regulations incorporate methodologies and outcomes that reasonably reflect the unique characteristics of Non-LWRs. This study aimed to identify R&D elements based on literature reviews and expert consultations regarding technical standards for SSC classification, comparative analyses of Korean and U.S. Non-LWR regulatory frameworks, and the specific role of Probabilistic Safety Assessment (PSA). The following sections provide a summary of selected considerations specifically related to legal and institutional frameworks among the identified R&D elements.

3.1. Definitions for Non-LWR Characteristics

In order to integrate the safety regulation of Non-LWRs into the Nuclear Safety Act, it is essential to establish legal provisions that can comprehensively encompass the concepts, characteristics, and various types of Non-LWRs. In this regard, the precedent of the United States conducting licensing for Non-LWRs under 10 CFR Part 50 and 52, corresponding to the South Korean Nuclear Safety Act or Enforcement Rule on Technical Standards for Nuclear Reactor Facilities, Etc., can serve as a valuable reference.

3.2. Grounds for Exemptions, Alternatives, and Graded Approaches

To achieve the "principle of proportionality," a General Act on Public Administration, it is necessary to implement regulatory frameworks that account for variations in risk levels based on specific design characteristics. Relevant provisions should be established in higher-level legislation to ensure that these reviews are conducted with a solid legal basis. From a technical perspective, it is essential to provide detailed methodologies that enhance the contribution of risk quantification (achieved through probabilistic methods) to the decision-making process.

3.3. Introduction to ARDC and PDC

The current "Rules on Safety Classes and Standards for Nuclear Reactor Facilities" are extensively optimized for large-scale LWRs. Consequently, even with an established basis for a graded approach, there is a high probability that these rules will remain insufficient for resolving the specific licensing challenges of Non-LWRs. Therefore, it is necessary to establish a regulatory process and basis that allow regulatory agencies to set Advanced Reactor Design Criteria (ARDC) and to accept the Principal Design Criteria (PDC) proposed by applicants that are equivalent to the ARDC.

3.4. Legal Connectivity with Other Acts

There is a strong consensus that, for example, decommissioning waste reduction and physical protection (including cybersecurity) must be integrated

into the design phase of new reactor types, so called "Something by Design". Although these aspects fall under the "Act on Physical Protection and Radiological Emergency," they inherently influence the safety design regulated by the "Nuclear Safety Act." Consequently, a coordinated mechanism is required to ensure that amendments to one act are interlocked and reflected in the other.

Furthermore, it is well recognized that marine transportable or propulsion reactors are subject to the "Maritime Safety Act." The recently promulgated "Framework Act on the Development of Artificial Intelligence and the Creation of a Foundation for Trust" also covers regulations for AI technologies applied to nuclear reactors. Therefore, it is necessary to establish provisions that enable statutory coordination with other relevant laws based on the specific application and functional scope of the reactor.

3.5. Development of the F-C Curve Reflecting Domestic Conditions

The regulatory environment in South Korea differs significantly from that of the United States, where dozens of private-sector-led reactor designs are undergoing the licensing process and sufficient resources exist for practical rule-making. Consequently, it is currently considered uncertain whether U.S. Regulatory Guide (RG) 1.233 will be directly adopted for domestic Non-LWRs safety regulation. Instead, a transitional phase is anticipated for South Korean safety regulation - one that resides between the current deterministic safety classification and a hybrid approach incorporating selective concepts from RG 1.233.

Nevertheless, as an essential first step toward implementing the TI-RIPB framework for Non-LWRs, it is necessary to develop an F-C Curve tailored to the domestic context and facilitate a deliberative process among stakeholders. In this regard, independent research should be conducted on F-C Curves that specifically account for the legal interplay with other statutes, as discussed in Section 3.4.

4. Conclusions

We have preliminarily completed an analysis of the domestic and international status of Non-LWR licensing systems, along with a gap analysis of these frameworks. The findings confirmed that the United States leads in both policy direction and technical maturity regarding Non-LWRs licensing. In contrast, while the Korea Institute of Nuclear Safety (KINS) has conducted research on TI-RIPB and Non-LWRs, the legal gap analysis highlighted the necessity for standardized licensing procedures capable of encompassing diverse Non-LWR reactor types.

As future works, we aim to analyze safety assessment methodologies for Non-LWRs. This will involve a comprehensive review of both deterministic safety

analysis and Probabilistic Safety Assessment (PSA) methodologies. Additionally, we plan to select a representative reactor type to perform a preliminary PSA. Through collaboration with domestic Non-LWR development agencies, we will select one representative reactor type during the second phase and conduct a Level 1 PSA for full-power internal events.

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