International Regulatory Frameworks for Nuclear Fuel Cycle Facilities: Institutional Features and Implications for Korea

Young A Suh*, Kyun-Tae Kim, Sujin Jung
Korea Institute of Nuclear Safety
**sya@kins.re.kr*

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1. Introduction

The rapid expansion of artificial intelligence (AI) applications and energy-intensive digital infrastructure has contributed to a significant increase in global electricity demand. At the same time, advancements in small modular reactors (SMRs) and next-generation reactor technologies have heightened policy interest in securing stable nuclear fuel supply chains and strengthening spent fuel management systems. Against this backdrop, nuclear power has regained attention within broader energy policy discussions. In particular, uranium enrichment and spent fuel reprocessing facilities are increasingly regarded as key elements of a stable nuclear fuel supply chain, in light of their significance for fuel supply assurance and effective management of the back-end phase of the nuclear fuel cycle.

In the Republic of Korea, the Nuclear Safety Act establishes a licensing framework primarily for nuclear power reactors and related facilities, institutionalizing procedures and requirements to ensure safety. Commercial enrichment and reprocessing facilities, however, are not currently operated domestically. Activities related to enrichment and reprocessing are managed within the procedural framework of the revised 2015 ROK-United States Agreement for Cooperation Concerning Peaceful Uses of Nuclear Energy [1]. In November 2025, the leaders of the Republic of Korea and the United States reached an agreement permitting the Republic of Korea to pursue uranium enrichment and spent fuel reprocessing domestically, and follow-up consultations are currently underway to implement the terms of this understanding.

Future changes in energy policy direction, technological developments in the nuclear fuel cycle, and evolving international cooperation environments may give rise to institutional discussions concerning enrichment and reprocessing facilities. In this regard, a comparative analysis of licensing frameworks in major jurisdictions may offer a useful analytical foundation for potential future policy deliberations.

This study examines the licensing frameworks for nuclear fuel cycle facilities in the IAEA context as well as in the United States, Japan, and France. By analyzing their institutional structures and regulatory approaches, the study aims to identify elements that may be considered in future domestic discussions. The analysis does not presuppose the adoption of any specific institutional model but seeks to provide a structured comparative perspective.

2. Regulatory Framework for Nuclear Fuel Cycle Facilities in Korea

In the Republic of Korea, uranium enrichment and spent fuel reprocessing activities are subject to a dual regulatory structure composed of domestic legislation and the Korea–United States nuclear cooperation agreement. The Nuclear Safety Act establishes construction and operating licensing procedures for nuclear reactors and nuclear fuel cycle facilities [2], and requires the submission of safety analysis reports, the establishment of quality assurance programs, and the conduct of radiological environmental impact assessments to ensure safety.

With respect to enrichment, however, the Act does not provide an explicit statutory definition, and related activities are addressed within the broader framework governing internationally controlled special nuclear materials. Reprocessing is regulated under the category of “spent fuel treatment” and is therefore treated as one type of nuclear fuel cycle facility. In addition, the Act on Physical Protection and Radiological Emergency defines “nuclear material” and “nuclear facilities” as regulatory objects, which would encompass commercial enrichment or reprocessing facilities should they be introduced domestically in the future.

Meanwhile, the Korea–U.S. nuclear cooperation agreement requires prior written consent from the United States for enrichment and reprocessing activities and enrichment beyond certain levels is, in principle, restricted [1]. As a result, any domestic institutional design concerning enrichment and reprocessing must operate within the scope permitted by the agreement.

3. International Regulatory Frameworks for Nuclear Fuel Cycle Facilities

3.1. IAEA

The International Atomic Energy Agency (IAEA) provides regulatory requirements and guidance for the safety of nuclear fuel cycle facilities through its Nuclear Safety Standards Series. The Safety of Nuclear Fuel Cycle Facilities (SSR-4) establishes comprehensive requirements covering the entire lifecycle of fuel cycle facilities—including conversion, enrichment, fuel

fabrication, and reprocessing—from site evaluation and design to construction, commissioning, operation, decommissioning, and release from regulatory control. SSR-4 also outlines key elements of regulatory oversight, including licensing conditions, inspection, enforcement, emergency preparedness, and nuclear material control and accounting [3].

In addition, facility-specific Safety Guides further elaborate technical and regulatory considerations. These include guidance for conversion and uranium enrichment facilities (SSG-5), mixed oxide (MOX) fuel fabrication facilities (SSG-7), spent nuclear fuel storage (SSG-15), and nuclear fuel reprocessing facilities (SSG-42), thereby providing detailed criteria for safety demonstration and regulatory review. Physical protection and material control requirements are also linked to international instruments such as the Convention on the Physical Protection of Nuclear Material (CPPNM), INFCIRC/225 recommendations, and safeguards agreements under INFCIRC/153, which are incorporated into national regulatory frameworks.

3.2. United States

In the United States, uranium enrichment facilities are primarily regulated under 10 CFR Part 70, which governs the domestic licensing of special nuclear material [4]. Depending on facility characteristics, additional regulatory provisions may apply, including 10 CFR Part 40 (Source Material), Part 73 (Physical Protection of Plants and Materials), and Part 74 (Material Control and Accounting of Special Nuclear Material) .

A key feature of the U.S. regulatory framework is the performance-based safety requirement set forth in 10 CFR 70.61. Applicants must conduct an Integrated Safety Analysis (ISA) to demonstrate adequate control of radiological, criticality, and chemical hazards associated with facility operations. During the licensing review process, the Nuclear Regulatory Commission (NRC) evaluates facility design, operational processes, emergency planning, security measures, and material control and accounting systems. Sensitive technical information may be reviewed through non-public procedures pursuant to 10 CFR Part 2. Although reprocessing facilities are classified under 10 CFR Part 50 as a type of “production facility”, commercial reprocessing is not currently permitted as a matter of U.S. policy.

3.3. France

France regulates nuclear facilities under the Code de l’environnement, which classifies nuclear installations as Basic Nuclear Installations (Installations Nucléaires de Base, INB/BNI) [5]. Both reactors and nuclear fuel cycle facilities are managed within this unified legal framework.

The Georges Besse II enrichment facility is designated as a BNI and is subject to licensing and safety requirements applicable to that category. The La Hague reprocessing site consists of multiple BNIs, each subject to facility-specific licensing, safety analysis, periodic safety review (PSR), and regulatory oversight requirements. France incorporates IAEA safety standards into its domestic regulatory system, and civilian nuclear materials are subject to IAEA safeguards and the Euratom framework, while defense-related materials are regulated separately.

3.4. Japan

Japan regulates nuclear fuel cycle activities comprehensively under the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors [6]. The statute covers refining, fabrication (including enrichment), storage, reprocessing, and disposal activities.

Under the Act, “fabrication” is defined in the English version as “fabrication and enrichment,” thereby incorporating enrichment activities within the regulatory category of fabrication. Enrichment activities are therefore regulated under Chapter III (Regulations Concerning Fabricating and Enrichment Activities), which includes provisions on licensing, licensing criteria, approval of design and construction plans, pre-operational inspections, periodic inspections, security measures, and physical protection requirements. In contrast, reprocessing activities are governed under Chapter VI, which establishes a separate regulatory framework including business designation, licensing criteria, design approval, inspections, physical protection measures, safety enhancement evaluations, and decommissioning requirements. In addition, enrichment activities above certain levels are subject to prior consent procedures under the U.S.–Japan nuclear cooperation framework.

4. Comparative Analysis of Regulatory Frameworks

The IAEA provides an international reference framework for nuclear fuel cycle facilities through comprehensive safety standards such as SSR-4 and facility-specific safety guides(SSR-5, SSR-7, SSR-15, SSR-42) [3]. Physical protection and material control requirements are further supported by separate international instruments, which are incorporated into national regulatory systems. The United States structures its regulatory framework around graded requirements based on the quantity and enrichment level of special nuclear material (SNM), emphasizing performance-based safety criteria supported by Integrated Safety Analysis (ISA). France applies a unified classification system under the Basic Nuclear Installation (BNI/INB) framework, assigning facility-

specific regulatory requirements within that structure. Japan regulates enrichment within the broader category of "fabrication" while maintaining a distinct regulatory framework for reprocessing activities. This comparison suggests that facility classification, licensing units, and the integration of safety, security, and material control considerations constitute key design variables in national regulatory systems.

Table I: Comparison of Regulatory Frameworks for Nuclear Fuel Cycle Facilities.

Category	United States	Japan	France
Legal Basis	Atomic Energy Act	Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors	Environmental Code (Code de l'environnement)
Licensing for Enrichment	10 CFR Part 70 (Special Nuclear Material License)	Business Licensing System (Fabrication/ Enrichment)	Basic Nuclear Installation (INB) License
Licensing for Reprocessing	10 CFR Part 50 / Part 70	Business Designation System	INB License
Review of Sensitive Information	Formal security review procedures; non-public review mechanisms	Limited disclosure procedures	Protection of classified/ national security information
Incorporation of IAEA Standards	Actively referenced and applied	Actively referenced and applied	Integrated within the regulatory framework

The table above compares the licensing frameworks of the United States, Japan, and France in terms of legal foundations, licensing types, treatment of confidential information, and incorporation of international standards. Although the three countries operate under different legal traditions and administrative systems, they share a common approach of incorporating nuclear fuel cycle facilities into their broader nuclear regulatory frameworks rather than establishing entirely separate legal regimes.

From the perspective of legal foundations, the United States regulates nuclear fuel cycle facilities under the Atomic Energy Act and detailed provisions in Title 10 of the Code of Federal Regulations. Japan applies the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors, utilizing business licensing and designation mechanisms. France relies on the Environmental Code, under which nuclear fuel cycle facilities are included within the category of Basic Nuclear Installations (INB). Despite institutional differences, all three systems manage fuel cycle facilities within the general legal framework governing nuclear installations.

In terms of licensing structure, enrichment and reprocessing facilities are incorporated into existing regulatory categories in each country. The United States applies special nuclear material licensing under Part 70 or relevant provisions for production facilities under Part 50/52. Japan utilizes a business licensing system for fabrication (including enrichment) and a designation system for reprocessing. France manages both enrichment and reprocessing facilities within the INB licensing framework. This indicates that, rather than enacting entirely separate statutes for fuel cycle facilities, these countries extend or adapt existing regulatory structures to address facility-specific characteristics.

Regarding the handling of sensitive technical information, all three countries maintain procedures that restrict public disclosure of certain design details while preserving the regulatory authority's verification function. The United States operates explicit security review procedures, while Japan and France apply limited disclosure or national security protection mechanisms. This demonstrates an institutional effort to reconcile technological confidentiality with rigorous safety and security oversight.

Furthermore, in all three countries, their licensing processes systematically incorporate considerations of safety, nuclear non-proliferation, and physical protection. Requirements for safety analysis reports and periodic safety review mechanisms are common features. Each country also incorporates IAEA safety standards into its domestic regulatory framework in varying forms.

Overall, while differences exist in legal structure and administrative implementation, the comparative analysis reveals a shared tendency to regulate nuclear fuel cycle facilities within existing nuclear regulatory systems and to maintain consistency with international safety and non-proliferation standards.

5. Implication for Korea

International experience indicates that enrichment and reprocessing facilities are generally not regulated as entirely separate domains but are incorporated into existing nuclear regulatory frameworks, with differentiated requirements reflecting facility-specific characteristics. In this regard, should related discussions arise in Korea, a key institutional design question would be whether to establish distinct licensing categories for enrichment and reprocessing or to refine and expand the existing nuclear fuel cycle facility framework. This issue is closely related to considerations of legal stability, regulatory predictability, and systemic consistency.

Another important consideration concerns how to balance the protection of technologically sensitive information with the regulatory authority's substantive verification function. Major nuclear countries have institutionalized non-public review procedures for confidential information while maintaining rigorous oversight of safety, non-proliferation, and physical protection requirements. If such facilities were to be discussed within the domestic regulatory sphere in the future, the appropriate institutional balance between transparency principles and the protection of national security and industrial technology would likely become a relevant policy issue.

In addition, the degree of alignment with IAEA safety standards, the integration of material control and accounting (MC&A) and physical protection requirements, and the structural linkage among licensing stages may constitute further elements in the policy direction for regulatory framework. These considerations extend beyond the introduction of specific licensing criteria and relate to the broader question of how to construct a regulatory framework capable of ensuring both safety and compliance with international obligations. Rather than prescriptive recommendations, these issues may be understood as analytical points for consideration in the event that future policy discussions take place.

REFERENCES

[1] Agreement for Cooperation Between the Government of the Republic of Korea and the Government of the United States of America Concerning Peaceful Uses of Nuclear Energy, 2015.
[2] Nuclear Safety Act of the Republic of Korea, Act No. 18972, as amended.
[3] International Atomic Energy Agency, Safety of Nuclear Fuel Cycle Facilities (SSR-4), IAEA Safety Standards Series, Vienna.
[4] U.S. Nuclear Regulatory Commission, Title 10, Code of Federal Regulations, Part 70: Domestic Licensing of Special Nuclear Material, Washington, DC.
[5] Autorité de sûreté nucléaire (ASN), French Nuclear Safety and Radiation Protection Framework, Paris.
[6] Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Japan), as amended.