# Regulatory Gap Analysis Plan for i-SMR Life-Cycle Inspections

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## 1. Introduction

The global nuclear energy sector is experiencing growing momentum in the development and deployment of Small Modular Reactor (SMR) as a next-generation power source. In particular, the Republic of Korea has prioritized the advancement of Innovative SMR (i-SMR), which are anticipated to play a crucial role in achieving both national energy security and carbon neutrality goals. Reflecting this policy direction, the National Science and Technology Advisory Council recently approved the Innovative SMR Demonstration Support Project, designed to support a domestic construction permit application (tentatively targeted for 2029) and to establish a timely regulatory framework, including the development of new regulatory technologies for construction and operation licensing.

According to the 11th Basic Plan for Long-Term Electricity Supply and Demand (2024 draft), the government has set a target for the commercial operation of i-SMR beyond 2034 [1]. These reactors, expected to be constructed domestically, will incorporate innovative technologies such as multi-module systems, integral reactor designs, integrated control rooms, and modular construction methods. While these features represent a major advancement in reactor technology, they also pose significant regulatory and technical challenges that cannot be fully addressed under the current safety inspection framework and technical standards [2].

Therefore, it is imperative to reassess and reorganize the existing legal and technical frameworks governing nuclear safety inspections. Particular emphasis must be placed on areas such as pre-operational inspections, periodic inspections, quality assurance inspections, and supplier inspections, all of which need to be adapted to reflect the unique design and operational characteristics of i-SMR. This study aims to analyze the regulatory gaps associated with life-cycle inspections of i-SMR and propose measures for establishing a robust and future-oriented regulatory framework.

## 2. Research plan and Methods

This research seeks to derive improvement measures by adapting existing inspection standards to the distinct design features of i-SMR compared to large-scale reactors. The project will pursue purpose-oriented R&D specifically tailored to regulatory requirements for life-cycle safety inspections, while reflecting domestic plans for i-SMR construction and operation. The strategy focuses on establishing stepwise regulatory inspection capabilities through the development of regulatory frameworks, enabling technologies, and technology-neutral approaches applicable to SMR inspections. In addition, it aims to strengthen long-term regulatory preparedness through diversified R&D investments and systematic management of anticipated regulatory challenges.

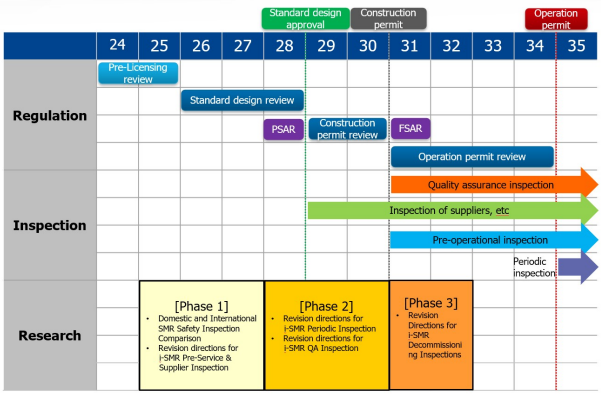


Figure 1. Research plans for i-SMR licensing schedule and life-cycle inspections.

Considering potential inspection exemptions due to unique i-SMR design features, the project will emphasize enhanced pre-design certification and factory manufacturing inspections, while progressively streamlining field inspections, in line with the i-SMR's low accident probability [3]. Due to the modular characteristics of i-SMRs, safety inspections tailored to these features must be implemented, encompassing quality inspections during factory fabrication, on-site installation inspections, integrated testing of shared systems and containment structures, and verification of the integrity of containment and physical connection interfaces. Accordingly, it is essential to establish inspection criteria and to prepare countermeasures to address potential regulatory issues that may arise.

At present, the regulatory authority (KINS, Korea Institute of Nuclear Safety) is conducting preliminary reviews of gap analysis reports addressing multi-module and shared design approaches, secondary reactivity control systems, passive safety systems, and methodologies for multi-failure accident analysis. The licensee conducted an analysis of each applicable safety requirement—derived from relevant laws, enforcement decrees, enforcement regulations, technical standards,

and notifications in relation to the design characteristics of i-SMR. Through this analysis, a total of 36 safety requirement gaps were identified. In addition, two further issues, considered to require improvements to the regulatory framework beyond the identified safety gaps, were also derived and are currently under separate review as items for potential institutional reform.

Following the submission of seven gap analysis and technical reports in October 2023, the developer completed presentations and responses addressing 257 queries raised by the regulatory body, and KINS subsequently issued its review reports in December 2024. Based on the opinions presented in the field-specific review reports from the regulatory body, the licensee aimed to prepare for future standard design approval by developing and revising additional technical reports during the preliminary design stage of the i-SMR.

Furthermore, to resolve the additional gap items, seven technical reports were developed from the latter half of 2024 and submitted for preliminary review by the regulatory expert organization prior to formal review applications. Two technical reports concerning the evaluation methodology for the Emergency Planning Zone (EPZ) and the multi-module and shared system design were submitted at the end of 2024, followed by the remaining five reports in early 2025. In the first half of 2025, the licensee continued efforts to close the identified gaps during the preliminary design stage by developing the remaining four technical reports, along with additional ones newly identified [4].

Such reviews are expected to enable the timely establishment of a regulatory review framework during the standard design approval phase and to proactively resolve potential regulatory issues that may arise. Similarly, if comparable preliminary reviews (gap analyses) and regulatory verification studies on inspection-related aspects are conducted during the inspection phase for construction and operating licenses, it would allow the proactive preparation of technical responses to emerging issues and facilitate the establishment of an efficient and stable safety inspection framework.

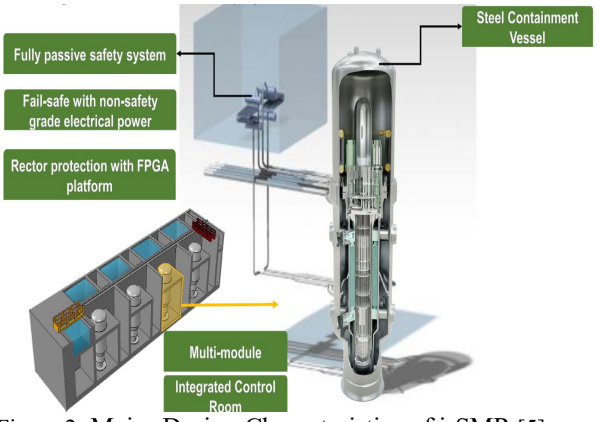


Figure 2. Major Design Characteristics of i-SMR [5].

This project will examine the applicability of pre-service and in-service inspections for safety-grade components newly introduced in i-SMR designs, such as passive safety systems, helical steam generators, and steel containment vessels. Additionally, methodologies for quality assurance and supplier inspections including the regulatory treatment of non-safety systems (RTNSS) are being developed, with the aim of producing a life-cycle inspection technical basis document that can be applied during the licensing stage of i-SMR.

Furthermore, given the global trend toward SMR deployment, international cooperation and harmonization are becoming increasingly important. Through collaboration with the IAEA and CNSC, this project aims to contribute to the development of international SMR standards (e.g., ASME, IEEE) and thereby strengthen the global applicability of Korea's i-SMR safety inspection framework.

## 3. Conclusions

This study proposes directions for strengthening the regulatory framework for i-SMR safety inspections by institutionalizing a life-cycle based inspection system. The outcomes are expected to enhance the applicability of inspection practices, enabling the timely implementation of revised inspection guidelines for the i-SMR scheduled for domestic construction in 2029.

By proactively addressing regulatory challenges specific to SMR safety inspections, this research will significantly improve the reliability and competitiveness of Korea's inspection regime. Moreover, the technical and scientific evidence generated will serve as a regulatory foundation not only for i-SMR inspections but also for addressing potential issues in the life-cycle inspections of operating large-scale nuclear power plants.

## Acknowledgements

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