A Comparative Review of International Safety Case Development for High-Level Radioactive Waste Disposal

Hyeongjin Kim[a,†], Jisoo Jung[a,†], Manwoong Kim[a,b], Jong-Il Yun[a,*]

[a] Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Daejeon 34141, Korea

[b] Department of Advanced Nuclear Engineering, Pohang University of Science and Technology, Pohang 37673, Korea

*Corresponding author: jiyun@kaist.ac.kr

†These authors contributed equally to this work.

Introduction

A safety case integrates assessment results with arguments and evidence for disposal safety [1,2]. As data and designs change, reviewers need to trace the basis for safety claims and assessment revisions. This study compares selected international practices and maps their documentation functions onto Baik et al.'s 2016 framework [3]. Three linked records connect requirements and evidence, uncertainties, and assessment changes to support reassessment and follow-up research decisions.

Background

Scope and comparison method

- The review focuses on post-closure assessment and documentation. Sources cover scenario development [4], Nagra's general-licence methodology [5], NUMO's pre-siting safety case [6,7], and the 2016 KAERI research structure [3]. Their different purposes and stages guide interpretation.

- For each source, the review examines five questions and distinguishes explicit links, topic-level descriptions and procedures not demonstrated in the selected text.

Table 1. Common questions applied to the selected sources

Dimension	Question
Purpose and stage	Which decision and development stage does it support?
Technical connections	How do system information, scenarios and models connect?
Requirements and evidence	What supports the safety claims?
Uncertainty and follow-up	How do uncertainties affect assessment and subsequent work?
Review and updating	How are revisions and their reasons documented?

Review

International scenario-development review [4]

- FEP identification and screening connect the repository description to scenarios and assessment models. The review covers both system-based and safety-function-based approaches.

- FEPs are features, events and processes relevant to system evolution.

Documentation implication

Preserve each screening decision and its rationale. Identify the scenarios and models that represent retained FEPs.

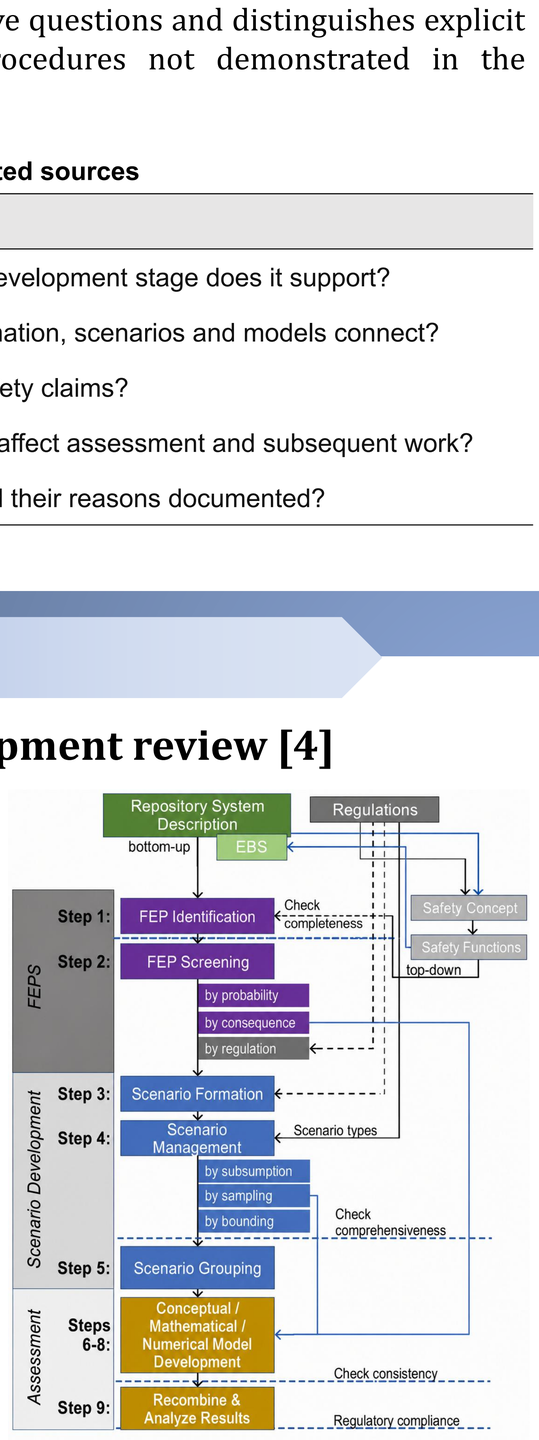


Fig. 1. FEP and scenario-development workflow [4]

NUMO pre-siting safety case [6,7]

- NUMO links representative site descriptive models, repository design and safety assessment with requirements management and quality assurance.

- The NEA review of the 2021 report recommended configuration management and fuller documentation of uncertainty identification [8].

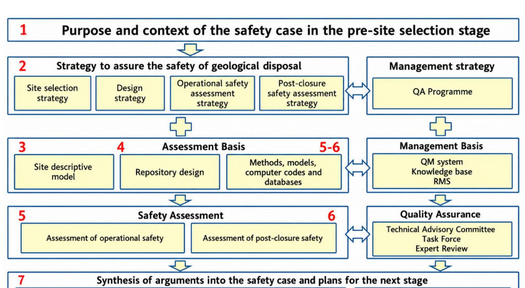


Fig. 2. Structure of NUMO's pre-siting safety case [6,7].

Documentation implication

Identify the data, assumptions and model versions used for each result. Link remaining uncertainties to reassessment and follow-up research decisions.

Nagra general-license methodology [5]

- Nagra distinguishes performance assessment, scenario development, radiological-consequence analysis and the demonstration of post-closure safety.

- The final safety argument combines evidence for safety functions with scenario-specific assessment results.

Documentation implication

Explain how each evidence item supports a safety claim, including its applicability and limitations.

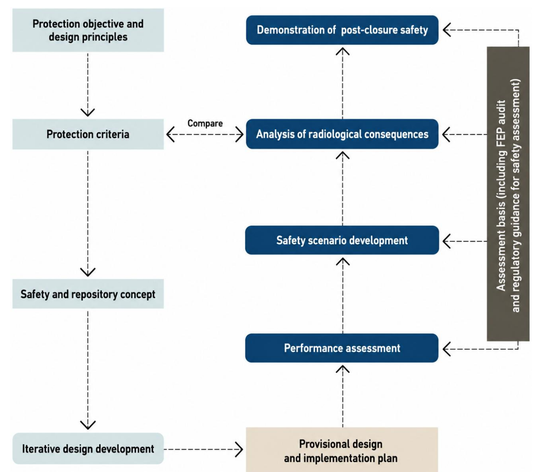


Fig. 3. Nagra's post-closure safety assessment workflow [5].

KAERI research framework (2016) [3]

- Nine technical sections cover the design basis, disposal system, assessment and safety case synthesis. The publication already discusses iteration and uncertainty treatment.

- This historical structure provides the mapping target, without implying deficiencies in current KAERI practice.

Mapping

IV. Engineered Barrier System, V. FEPs and Scenarios, VI. Model and Data, VII. Safety Assessment, and IX. Safety Case Synthesis.

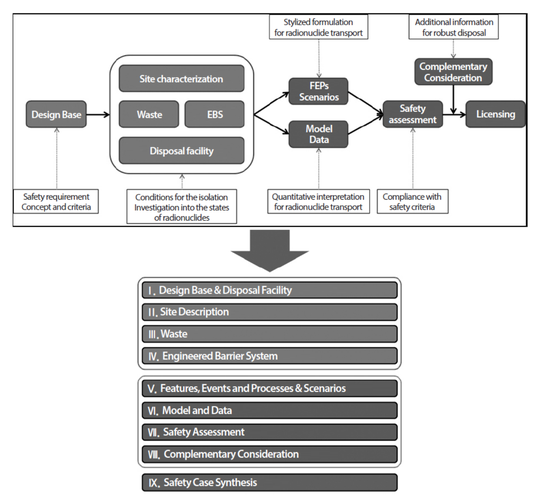


Fig. 4. KAERI's research safety case framework [3].

Basis for the proposed records

- IAEA documentation guidance [2], Korean criteria [9] and CNSC guidance [10] inform the proposal. Record formats are author proposals. Domestic requirements and research assumptions remain distinct.

Table 2. Source findings and proposed documentation fields

Source basis	Proposed record	Fields needed for review
FEP links [4]; safety arguments [5]; limitations [10]	Requirement-to-evidence matrix	Requirement/source; safety function and claim conditions; evidence/argument; limits and conflicting evidence
Uncertainty identification [8]; treatment [10]	Uncertainty register	Affected claim/model; safety significance; follow-up priority, owner, completion criterion and status
Controlled updates [2]; configuration management [8]	Change and configuration record	Data/model versions; affected claims/cases; reassessment decision, reasons and reviewer

Table 3. Illustrative bentonite-data revision

Linked record	Example entry
Matrix: R-01 / C-01 Evidence: E-01 / E-02	R-01: design conductivity range. C-01: saturated-buffer flow within assessed bounds. E-01/E-02: old/new test evidence.
Uncertainty: U-01 → C-01	U-01 links E-02 to C-01. Check applicability and safety significance; assign follow-up work and a completion criterion.
Change: CH-01 / B-01, B-02	CH-01 links E-02/U-01 to affected models/cases. Preserve B-01, assess candidate B-02, and record the decision and rationale.

- Hypothesis: new test data exceed the assessed conductivity range. R-01 is a project design condition. Check applicability and model/case impacts before reassessment. No numerical safety conclusion is assumed.

Conclusions

❖ The review informs linked records for requirements and evidence, uncertainties, and assessment changes.

❖ The illustrative case links new evidence to affected claims and models, follow-up work and reassessment decisions.

❖ Actual revisions are needed to test completeness, traceability and support for review decisions.

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