

NuScale-Based Comparative Analysis of 10 CFR Part 52 Design Approval Frameworks (SDC vs. SDA) and Licensing Strategy Implications for i-SMR

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1. Introduction

In commercial nuclear power plant licensing, regulatory review of design, site, and operational requirements, as well as associated hearing procedures, has historically contributed to schedule delays and cost escalation. To mitigate such uncertainties and reduce schedule and cost risks inherent in the traditional two-step framework under 10 CFR Part 50, the U.S. Nuclear Regulatory Commission (NRC) established 10 CFR Part 52, which provides staged and integrated licensing pathways.

Part 52 offers multiple licensing options, including early site permit (ESP), standard design certification (SDC), standard design approval (SDA), manufacturing license (ML), and combined license (COL). Among these, SDC in Subpart B and SDA in Subpart E share the purpose of pre-reviewing reactor designs but differ in legal enforceability, review procedures, and application flexibility.

Meanwhile, SMRs require phased development and market deployment, supported by modularization and standardization. Accordingly, a licensing strategy capable of flexibly responding to changes in design maturity and business environments is critical. This paper focuses on SDC and SDA and compares their institutional characteristics and intended uses based on NuScale's US600 SDC and US460 SDA cases. It then derives licensing-strategy implications for an innovative small modular reactor (i-SMR) SDA application, particularly regarding early-stage review burden distribution, design change accommodation, and licensing risk management.

2. Overview of the U.S. NRC Licensing Framework (10 CFR Part 50 vs. Part 52)

2.1 Characteristics of 10 CFR Part 50 (Two-Step Licensing)

The Part 50 framework generally adopts a two-step licensing approach separated into construction permit (CP) and operating license (OL). Operational limitations have been raised, including uncertainty in issuing operating licenses, inefficiencies in hearing procedures, construction delays, and increased construction costs.

These limitations of the Part 50 two-step framework are contrasted with the Part 52 approach depicted in Fig. 1.

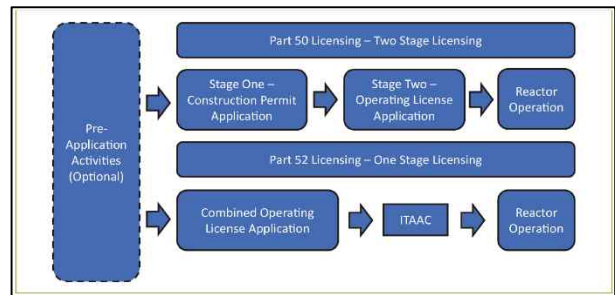


Fig. 1. Two licensing pathways for new commercial nuclear power plants in the United States [1].

2.2 Structure of 10 CFR Part 52 (Staged/Integrated Licensing)

Part 52 provides the following mechanisms with the objectives of distributing licensing risks in advance and minimizing repetitive review of approved matters:

- ESP in Subpart A pre-approves site suitability issues (environmental impacts, emergency planning, security, etc.). Site issues resolved at this stage are, in principle, not re-litigated in subsequent stages.
- SDC in Subpart B certifies a standard design through federal rulemaking, resulting in legally binding design certification rules incorporated by reference in subsequent COL applications [2,3].
- SDA in Subpart E pre-reviews and approves a specific design without federal rulemaking; consequently, it does not establish a legally binding rule and may be subject to re-examination in subsequent COL proceedings [3,4].
- ML in Subpart F allows manufacturing of nuclear plants (or modules) at a location other than the plant site.
- COL in Subpart C integrates construction and operation licensing; commercial operation begins after confirming design conformance and construction completion through inspections, tests, analyses, and acceptance criteria (ITAAC) [3]. The COL is valid for 40 years from the date

the NRC determines that ITAAC acceptance criteria have been met [3].

Figure 1 illustrates the two licensing pathways and highlights how COL and ITAAC enhance regulatory predictability under Part 52 prior to operation.

3. Comparison Criteria and Analysis Method for Design Approval Mechanisms (SDC, SDA)

This paper presents a comparative analysis based on relevant literature and regulatory framework. The comparison criteria are defined as follows:

- Approval method and legal enforceability (whether it involves federal rulemaking and its effectiveness when referenced in COL).
- Review procedures and regulatory burden (including the need for public hearings and the extent to which review scope and materials can be reused).
- Validity period and change allowance (validity, extendability, and ability to revise designs after approval).
- Strategic applicability (distribution of early-stage review burden, schedule/risk management, and staged licensing feasibility).

4. Results: NuScale-Based Comparison of SDC vs. SDA

NuScale first obtained an SDC for the 50 MWe US600 design and subsequently pursued an SDA for the 77 MWe US460 design [5]. This can be interpreted as a strategic choice that maintains the technical foundation of the existing SDC while considering design changes and schedule reduction [5,6].

4.1 NuScale Case Study: SDC for US600 vs. SDA for US460

Table 1. NuScale case comparison of SDC (Subpart B) and SDA (Subpart E)

Aspect	SDC for US600	SDA for US460
Regulatory basis	10 CFR Part 52 Subpart B	10 CFR Part 52 Subpart E
Approval mechanism	Rulemaking-based certification	NRC-issued approval
Legal enforceability	Legally binding; stable COL reference	Limited; possible re-review in COL
Procedure	Includes rulemaking; higher burden	Streamlined; no public hearing
Scope	12 modules x 50 MWe = 600 MWe	6 modules x 77 MWe = 462 MWe
Approval year	2020 [5]	2025 [5]

Validity	15 years (renewable under applicable provisions; §52.55 & 52.57) [3]	15 years (non-renewable; §52.147) [3]
Strategic use	Standardization; minimized re-review	Faster review + flexibility during evolution

4.2 Interpretation of Institutional Differences

Strength of SDC: Improves licensing predictability by ensuring legal enforceability and minimizing re-review at the COL stage [1,2]. It is suitable for repeated application of a standardized design.

Strength of SDA: Can be used when the design is not fully finalized or when a time-constrained, interim/strategic approval approach is needed instead of SDC [4,6]. It allows relatively greater post-approval design modifications and can reduce schedules through reuse of review materials and adjustment of review scope [4].

5. Utilization Approaches and Implications for Korea (i-SMR)

5.1 Distribution of Early-Stage Review Burden and Schedule Management

In the early phase of an i-SMR standard design approval (SDA) process, limited design maturity, insufficient operating data, and evolving modular or shared configurations may favor a staged technical review approach over a single, fully finalized design approval [7]. The NuScale SDA case provides a strategy that distributes early-stage technical review burdens and enables subsequent design supplementation [5,7].

5.2 Balancing Design Change Allowance and Licensing Risk

While SDA provides flexibility, it requires consideration of potential partial re-review when linked to COL. Therefore, from the perspective of domestic application, the following balanced strategy is needed:

- Fix the criteria and basis for design decisions early for core safety functions and major safety systems to minimize re-review potential.
- For areas with high likelihood of change (power rating, module configuration, parts of BOP, etc.), design an approval strategy on the premise of staged review and robust configuration/change management.
- Ultimately, establish a roadmap that converges to an SDC-type approach (or a domestic equivalent of a legally binding standard design approval) at a stage suitable for standardization and repeated deployment.

5.3 Enhancing Operational Readiness Assurance from the COL/ITAAC Perspective

A key feature of Part 52 is that commercial operation is authorized only after design conformance and construction completion are verified through ITAAC. Similarly, domestically, it is necessary to strengthen the clarity of confirmatory criteria ITAAC at the approval stage and the linkage requirements among design–construction–operation.

6. Conclusions

This paper compared the SDC and SDA design approval mechanisms under U.S. NRC 10 CFR Part 52 using the NuScale US600–US460 case. The results indicate that SDC enhances licensing predictability through legal enforceability and reduced potential for re-review at the COL stage, making it suitable for standardized and repeat deployments [2]. In contrast, SDA can be leveraged for schedule reduction and strategic flexibility through streamlined procedures and design supplementation as design maturity evolves [4,7], while acknowledging a potential increase in downstream re-review risk.

For an i-SMR pursuing SDA, a combination of a staged approval strategy to ensure flexibility followed by a final standardization phase with legally binding design approval, considering design maturity and business environments is expected to be effective in managing licensing risks and schedules [7].

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