Contingency Planning for Korea's Single-Source Nuclear Fuel Supply Chain

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1. Introduction

All fresh nuclear fuel for Korean reactors is fabricated at a single facility, the KEPCO Nuclear Fuel (KNF) plant in Daejeon. This plant supplies fuel assemblies for every domestic pressurized water reactor (PWR), fuel bundles for the pressurized heavy water reactor (PHWR, CANDU-6 type) units at Wolsong, and export fuel for the Barakah nuclear power plant in the United Arab Emirates (UAE). No second domestic fabrication line exists for either fuel type.

Because fabrication is concentrated in one plant, any disruption at Daejeon, whether caused by equipment failure, fire, a natural disaster, or a regulatory suspension, represents a single point of failure for the entire national fuel supply chain. The consequences of such a disruption would not be limited to Korea's own reactor fleet; they would also extend to an international customer under an active supply contract. Nuclear fuel is, in addition, a long lead time product: procurement, fabrication, and quality release together normally take well over a year from order to delivery [4], so a disruption cannot be resolved simply by placing an emergency order once it occurs.

This paper reviews the structural risk created by this single-source dependency and examines possible contingency measures for domestic reactor operation and for the export fuel commitment. It first reviews the structure of the domestic supply chain and general supply chain resilience practices, then defines the disruption scenarios and assessment criteria used in this study. It next presents the available contingency paths for PWR fuel, PHWR fuel, and the UAE export contract, and finally discusses the trade-offs among the proposed measures and concludes with policy level recommendations.

2. Methodology

2.1. Scenario definition

Two disruption scenarios were considered. Scenario A is a short-term outage, lasting from several weeks to a few months, such as an equipment failure, a fire limited to part of the facility, or a temporary quality hold on a specific production line. Scenario B is a long-term outage, lasting a year or more, such as extensive fire or structural damage, a natural disaster affecting the site, or an extended regulatory suspension of the facility's operating license.

2.2. Assessment criteria

For each scenario, the analysis considered three criteria: (i) whether the existing fuel inventory buffer at domestic reactor sites is sufficient to cover a supply gap before it begins to affect reactor operation, (ii) the lead time required to qualify and license an alternative supplier for each fuel type, and (iii) the contractual exposure created for the Barakah export commitment, including the likelihood of delay penalties or the need for contract renegotiation.

2.3 Comparative framing

The two scenarios and three criteria were then compared against the contingency paths identified in Section 3, to assess which measures address only short-term outages, which measures are necessary for long-term outages, and which measures are relevant to both.

The scope of this dependency can be stated simply. Domestic PWR units rely entirely on enriched UO_2 rod assemblies fabricated at KNF, Daejeon, with no backup domestic line. The CANDU-6 units at Wolsong rely entirely on natural UO_2 bundles from the same facility, again with no backup domestic line. The Barakah export contract relies on the same enriched UO_2 rod assembly line at Daejeon that supplies domestic PWR units, so a disruption of that line would affect both markets simultaneously rather than one or the other.

3. Results

3.1 Domestic PWR fuel contingency

Existing international PWR fuel vendors, including Westinghouse and Framatome, represent a technically credible alternative fabrication source [1]. However, because each Korean reactor core has been qualified and licensed with KNF fuel assemblies of a specific design, loading fuel from an entirely new, foreign vendor would require KINS (Korea Institute of Nuclear Safety) approval of the new fuel design and a corresponding revision to the plant's licensing basis before the fuel could be loaded. No Korean precedent exists for this kind of foreign-vendor switch, so the exact scope and duration of the domestic regulatory pathway cannot be stated with

certainty. Comparable international cases of an outright vendor switch, however, indicate that qualifying and delivering an entirely new fuel design is measured in years rather than months: Westinghouse has supplied all of Ukraine's VVER reactors since 2022, replacing their former Russian-designed fuel supply [2], and a Euratom-funded programme to qualify Westinghouse VVER-440 fuel for European reactors, funded from 2015 with conceptual design completed in 2017, preceded a 2023 supply agreement with the Czech Republic's ČEZ for the Dukovany plant, with deliveries beginning in 2024 [2], [6]. This process would need to begin well before an actual disruption for the measure to be useful as a contingency.

3.2 Domestic PHWR fuel contingency

For the CANDU-6 units, BWXT Canada and Cameco Fuel Manufacturing continue to produce natural UO_2 CANDU fuel bundles for the Canadian fleet and could, in principle, supply the Wolsong units [1]. Because PHWR fuel uses unenriched uranium, this path avoids enrichment related supply constraints entirely. The primary constraint is therefore regulatory licensing and bundle design compatibility verification, rather than fabrication capacity, since decades of independent design evolution on each side may have introduced minor specification differences between Korean and Canadian CANDU bundle designs that would need to be verified before substitution.

3.3 UAE export contingency

A disruption at Daejeon would also affect Korea's fuel export commitment to the Barakah plant. This is not a purely hypothetical concern: in July 2025, Barakah's operator ENEC signed a fuel supply agreement with Framatome as an explicit step in diversifying its fuel supply chain, and Framatome fabricated the first lead fuel assemblies for Barakah by November 2025, drawing on its existing NRC-licensed Richland facility and decades of experience with this fuel type [10]. However, full commercial use still requires a comprehensive fuel qualification testing programme under ENEC's own regulatory framework before the fuel can be integrated into the reactor; fabrication alone does not equal deployment, and this qualification and regulatory approval step remains the longer, multi-year part of the process. Because this qualification falls under the UAE's Federal Authority for Nuclear Regulation rather than KINS, it is a real-world proof of concept for the fabrication side of a vendor transition, but it does not itself establish a Korean domestic precedent of the kind discussed in Section 3.1. A disruption originating at KNF specifically would additionally require contractual renegotiation with the customer, and an extended supply gap could also affect Korea's broader reputation as a reliable nuclear technology exporter, which is a consideration beyond the direct commercial cost of the disruption itself.

3.4 Summary of alternative fabrication candidates

Taken together, the fuel types considered, the internationally available alternative fabrication candidates identified for each, and a qualitative estimate of the regulatory licensing lead time required before an alternative supplier's fuel could actually be used can be summarized as follows. Worldwide LWR fuel fabrication capacity is reported to considerably exceed demand, with overcapacity further increased by countries including South Korea pursuing fuel self-sufficiency [3]; independent market analysis similarly reports that the global fabrication industry supplies annual reload demand with a modest but consistent capacity surplus [9]. These industry-wide figures are the best public evidence available; the spare capacity that any individual vendor could actually offer Korea at a given time still depends on its existing customer commitments and current order book, which are commercially confidential and cannot be independently verified. With this caveat, Westinghouse and Framatome (domestic PWR fuel) and BWXT Canada and Cameco Fuel Manufacturing (domestic PHWR fuel) are identified here as illustrative alternatives on the basis of their listed nameplate capacity [3], rather than as confirmed sources of guaranteed spare capacity; for the Barakah export line, Framatome has already been engaged by ENEC in practice, as described in Section 3.3. Each of these would in any case require a multi-year licensing process (with contractual renegotiation also required on the UAE side). Of vendor capacity and licensing lead time, licensing lead time is therefore the factor that can be assessed with more confidence from public sources, since vendor-specific spare capacity cannot be.

3.5 Evaluation against assessment criteria

Neither KHNP nor KNF publicly discloses the exact size of the on-site or contracted fuel inventory buffer held for the domestic reactor fleet, so the inventory-buffer criterion is evaluated here against a general industry benchmark rather than a Korea-specific figure. Utility-held commercial nuclear fuel inventories are reported to generally cover between one and three years of reactor requirements, held specifically to prevent supply disruptions from affecting reactor operation and to cover fuel-cycle lead times [5]. Because Scenario A is defined as several weeks to a few months, a buffer of this size would comfortably absorb it; because Scenario B is defined as a year or more, a one-to-three-year buffer is of a similar order of magnitude to the multi-year licensing lead time itself, so it delays rather than eliminates exposure as the outage lengthens. Applying the three criteria defined in Section 2.2 to the three contingency paths above yields the pattern summarized in Table 1, evaluated separately for Scenario A (short-term outage) and Scenario B (long-term outage).

Table 1. Qualitative evaluation of the three assessment criteria across the three contingency paths, under Scenario A (short-term outage) and Scenario B (long-term outage).

Criterion	Domestic PWR	Domestic PHWR	Barakah export
(i) Inventory buffer	A: absorbed (buffer ≈1–3 yr [5]); B: same order as licensing time	A: absorbed (buffer ≈1–3 yr [5]); B: same order as licensing time	A: absorbed (buffer ≈1–3 yr [5]); B: same order as licensing time
(ii) Licensing lead time	Years (new design approval + licensing basis revision)	Years (licensing + bundle compatibility verification)	Years (UAE-side qualification + contractual renegotiation)
(iii) Contractual exposure	None (domestic operation only)	None (domestic operation only)	A: low; B: high (penalties, renegotiation, reputational risk)

As Table 1 shows, inventory buffer and contractual exposure both vary in severity across the three fuel lines and across scenarios, but licensing lead time is uniformly measured in years for every path and scenario in which it applies. Because it is the one criterion that is consistently binding rather than situational, licensing lead time is the criterion that most directly confirms the pattern already noted in Section 3.4, and it is the basis for the priority given to advance licensing in Section 4.

4. Discussion

Three measures follow from these findings. First, a larger strategic fuel inventory buffer at reactor sites would extend the time available to activate an alternative supply path before reactor operation is actually affected, and is the fastest measure to implement, though it carries an ongoing storage and carrying cost. Second, advance prequalification licensing pursued in parallel with more than one backup fuel vendor for both PWR and PHWR fuel, rather than with a single vendor, would remove the multi-year licensing lead time from the critical path at the time it is actually needed, while also reducing exposure to the risk that any one pre-qualified vendor lacks spare capacity when actually called upon; independent market analysis reporting a modest but consistent industry-wide capacity surplus [9] suggests that, once multiple vendors are pre-qualified in this way, at least one is more likely to be able to supply fuel while the inventory buffer from the first measure is being drawn down. This combined approach has the highest long-term risk reduction value but also the highest upfront cost and the longest preparation time, scaling further with the number of vendors pre-qualified. Third, future nuclear fuel export contracts, including any future renewal or amendment of agreements such as Barakah, should incorporate alternative sourcing and delay related contingency provisions as a matter of general practice, so that a supply disruption at the fabrication facility does not automatically translate into a contractual default.

These three measures can be related back to the two disruption scenarios defined in Section 2. A strategic inventory buffer is effective against Scenario A and only partially effective against Scenario B, since a long outage can eventually exhaust even a generous buffer; it can be implemented in the short term at a low to medium ongoing cost. Prequalified backup suppliers are not required to address Scenario A but are the single most effective measure against Scenario B, though pre-qualifying more than one requires a longer preparation time and a higher upfront cost than pre-qualifying only one. Export contract contingency clauses are effective against both scenarios and can be implemented in the short term at low cost, since they primarily require legal and commercial negotiation rather than technical qualification.

5. Conclusion

Across all three contingency paths examined, physical fabrication capacity does not appear, from public industry-wide data, to be the primary constraint, since internationally qualified fabricators exist for both PWR and PHWR fuel types and worldwide LWR capacity is reported to exceed demand [3], [9]; however, whether any of these vendors could actually offer Korea spare capacity at a given time cannot be independently verified, so this should be read as an illustrative alternative rather than a confirmed finding. Regulatory licensing lead time, by contrast, is measured in years rather than months in every path considered and cannot be activated only after a disruption occurs, and can be assessed with more confidence from public sources, making it the more consistently verifiable constraint of the two. This indicates that effective contingency planning should focus on preemptive measures rather than reactive ones.

Because prequalification licensing carries a real cost and is unlikely to be pursued without a clear mandate, sustaining a credible backup pathway for Korea's single-source nuclear fuel supply chain may require an explicit national policy decision, rather than a purely commercial one made by the fabricator or the utility alone. Given that the licensing lead time is the common bottleneck across every contingency path examined in this study, the single most consequential near-term action would be to initiate advance licensing discussions in parallel with more than one backup fuel vendor, well before any disruption makes such a step urgent; this would let Korea draw down its existing inventory buffer while realistically expecting at least one pre-qualified vendor to be able to supply fuel, rather than depending on a single, unverified source.

The uncertainty over whether existing foreign vendors could actually supply spare capacity to Korea, noted above, also points to a longer-term policy option that is beyond the scope of this study: constructing a second, geographically separate domestic fabrication line that would remove dependence on foreign vendor capacity and licensing altogether. International precedent suggests this would require a substantial and uncertain commitment of its own. The regulatory review for a newly licensed United States fuel fabrication facility took roughly three years even under an accelerated 30-month schedule [7], while the Savannah River Site's Mixed Oxide Fuel Fabrication Facility experienced a severe construction cost overrun relative to its original estimate before the project was ultimately suspended [8].

Whether a domestic backup facility would be more cost-effective than the measures proposed above is left for future work.

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