TRILATERAL ENERGY SECURITY COMMITTEE

TRILATERAL PATHWAYS TO SMR DEPLOYMENT: A STRATEGIC FRAMEWORK FOR U.S.-SOUTH KOREA-JAPAN COOPERATION

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Contributors

To inform this report, we conducted interviews with a diverse group of experts representing a range of sectors and all three countries central to this study, the United States, Japan, and South Korea. These contributors included:

- **Leading Think Tank representatives (2)**
- **Academic Experts (1)**
- **Industry Professionals (4)**
- **Prominent Research Institute researchers (1)**

Their insights and perspectives were instrumental in shaping the analysis and recommendations presented in this report. We gratefully acknowledge their time and expertise.

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Trilateral Pathways to SMR Deployment:

A Strategic Framework for U.S.-South Korea-Japan Cooperation

The development of Small Modular Reactors (SMRs) represents a significant opportunity for transforming energy generation, particularly in addressing the increasing demand for flexible, reliable, and sustainable 24/7 power. However, there are still a number of challenges and international cooperation among allies will be key to unlocking the potential of this frontier technology in a timely manner. This white paper examines cooperation among the United States, South Korea, and Japan (hereafter "the Triad") on establishing standardized SMR designs, exploring a joint design pre-licensing system, and addressing regulatory framework harmonization challenges. It concludes that the Triad should establish a joint standard and engineering/safety protocol framework for SMRs, enabling project deployment across borders without requiring (if not, limited) separate national approvals.

Economic and Supply Chain Challenges

Standardizing SMR designs is essential for cost reduction and market entry speed as it would enable off-site manufacturing and transportation, which will significantly reduce construction time and costs together with some diversification of risks. This modularity in construction also allows for incremental capacity expansions, providing the flexibility necessary to meet fluctuating energy demands and making initial capital investment more manageable. Additionally, the smaller size of SMRs lowers the inventory of radionuclides, which mitigates safety concerns and regulatory hurdles. Although some estimates currently expect SMRs to have higher costs per megawatt (MW) and megawatt-hour (MWh) than large reactors, they are particularly suited for specific applications that do not require the amount of power produced by traditional plants, such as replacing retiring coal plants, and costs can be recovered when utilizing the high-temperature heat produced in industrial processes (Khan & Nakhabov, 2020; DOE, 2024b).

To unlock the full economic potential of SMRs, especially given that their levelized cost of electricity (LCOE) is currently anticipated to be on the higher side (around 20% above conventional alternatives by 2030 without tax incentives or subsidies) an adequate promotion strategy for certain levels of demand or procurement (e.g., fleets of 10-20 units) and streamlined regulatory reviews will be key. Meanwhile, the modular-based construction approach may also help mitigate potential site-specific project delays and contribute to diversifying various project risks, further enhancing the feasibility and attractiveness of SMR deployment.

The transition from First-of-a-Kind (FOAK) to Nth-of-a-Kind (NOAK) projects is crucial for understanding the cost dynamics of advanced nuclear technologies. FOAK projects typically incur higher costs due to a lack of experience and economies of scale. However, as more plants are constructed, costs tend to decrease due to learning effects and improved processes. The LCOE is expected to decline as efficiency improves across all energy technologies (DOE, 2023). Notably, a two-year delay in the construction of a nuclear power plant can increase the final cost of electricity by approximately 15% (Sovacool, Gilbert, & Nugent, 2014). Therefore, timely construction and the transition from FOAK to NOAK projects are essential for minimizing costs and cooperation will accelerate these transitions.

Regulatory Harmonization and Pre-Licensing

In terms of regulatory frameworks, the collaboration between the Triad presents both opportunities and challenges. Each country has competitive strengths. For example, the United States government is making substantial investments in SMR technology, focusing on safe deployment and regulatory processes (DOE, 2024a), South Korea is actively developing cost-competitive SMR manufacturing processes, and Japan is innovating with technologies like floating seismic isolation systems for locations with high seismic activity (DOS, 2022). However, the differing regulatory frameworks and their point of focus among the Triad present significant hurdles. Each country's safety standards have evolved from unique historical, institutional, and societal contexts, making alignment complex. These differences can complicate efforts to establish joint projects or mutual recognition of licensing, underscoring the need for deliberate harmonization strategies.

All three countries recognize the necessity and benefits of SMR standardization and pre-licensing frameworks and there is a general openness to using U.S. NRC regulations as a common baseline. Coordination with the IAEA is essential to ensure international alignment and credibility, and it could serve as a foundation for broader multilateral cooperation. However, each country's regulatory body is institutionally independent:

- The U.S. NRC is autonomous, even from the Department of Energy and the State Department.
- South Korea's regulatory framework is stringent and comprehensive.
- Japan lacks readiness in both its regulatory infrastructure and technical priority.

As a result, a full mutual recognition regime is unlikely to be feasible in the short term. A more pragmatic starting point would be indirect cooperation, such as aligning with and helping disseminate U.S. nuclear regulatory reforms wherever possible. For example, South Korea and Japan could incrementally align their national regulatory systems with the U.S.'s streamlined licensing model, followed by a trilateral pilot project and partial mutual recognition over time.

Also, establishing a trilateral working group to align regulatory standards and share best practices could help harmonize approaches. This group could focus on creating a unified set of standardized safety protocols and regulatory processes that meet the requirements of all three countries, streamlining approvals and enhancing cooperation.

Regulatory cooperation is already progressing among countries such as the U.S., Canada, and the U.K., demonstrating that such collaboration is feasible (NRC, 2024). However, it is important to note that even in these cases, a fully integrated cross-border licensing system has not yet been implemented. For example, while the U.S.-Canada agreement includes the possibility of establishing a joint regulatory platform, the current approach still requires each country's regulatory authority to conduct its own review, albeit with the benefit of shared evaluation results.

Additionally, Japan's Nuclear Regulation Authority (NRA) does not yet have an established framework for design certification of specific reactor types, which suggests that institutional reform in this area would likely be a necessary first step before trilateral harmonization can be fully realized. It is also not clear how proactive the NRA is regarding the licensing of SMRs and other advanced reactors. If Japan is serious about promoting the deployment of such technologies, it may be necessary to explicitly define this responsibility for the NRA. For instance, the U.S. has legally mandated the NRC to address the licensing of advanced reactors, providing a clear institutional pathway for innovation.

To address these challenges, the Triad should establish a joint standard and engineering/safety protocol framework for SMRs. This framework would enable project approval in one country to facilitate deployment in the others without necessitating separate full-scale national approvals. Such an initiative would enhance safety by integrating the best practices from each country, ensuring that all SMR designs meet rigorous safety benchmarks. Furthermore, this approach would streamline regulatory processes, reducing redundancy and saving time and resources, thereby making SMRs more attractive to investors.

Design Standardization and Trade-offs

Japan currently lacks a ready-to-export SMR design (although several Japanese private companies have formed JV partnership in some advanced SMR companies), faces strong public opposition to nuclear power since Fukushima Daiichi accident, and its regulatory agencies are not yet adequately prepared. However, Japan can be engaged through the following approaches:

- SMRs have their own benefits over large reactors in achieving carbon neutrality and addressing seismic risk.
- Highlight Japan's global competitiveness in turbine and component manufacturing to create economic incentives.
- Emphasize that the SMRs are approved under U.S. and South Korean safety standards, helping to rebuild domestic trust in nuclear energy.

If the three countries establish joint safety standards, trade-offs may be necessary. Harmonizing existing safety protocols to meet common criteria may involve adjusting safety features that are currently more stringent in one country than another. To maintain consistency with international safety standards, the Triad must standardize its SMR designs in accordance with the safety benchmarks compiled in the IAEA's Advanced Reactors Information System (ARIS). This involves ongoing communication with IAEA and regular updates to safety protocols based on emerging technologies and findings. While establishing joint standards may raise concerns about differing safety cultures, these can be mitigated through continuous dialogue and adaptation of standards. However, even if acceptable safety standards are established, actual application and implementation would remain the responsibility of each individual country, highlighting the challenge of weak enforceability across national regulatory systems.

Such trade-offs will also likely be necessary in areas such as seismic performance requirements. For example, the level of seismic resistance required in Japan would probably be seen as excessive from the perspective of U.S. operators. Even seemingly simple issues such as design standards for commonly available materials like rebar or structural steel can pose challenges. For instance, the U.S. typically expects rebar to conform to ASCE or AISC standards. Ensuring that such materials can be produced and installed across all regions under a unified set of calculations may be difficult. Seismic analysis, too, could yield different results depending on national methodologies, requiring careful reconciliation. One possible approach is to establish common standards in areas where consensus is achievable, while allowing each country to maintain its own standards in others. However, the more country-specific requirements there are, the less benefit there will be in terms of streamlining the regulatory review process.

Proposed steps for implementing this framework include establishing a trilateral working group composed of regulatory bodies, industry representatives, and safety experts from each country. This group could focus on creating a unified set of standardized safety protocols and regulatory processes that meet the requirements of all three countries, streamlining approvals and enhancing cooperation. A phased implementation plan could allow for gradual alignment of standards, starting with the most critical safety protocols. From the outset of developing common standards, it is essential to base them on IAEA safety standards and ensure alignment throughout the process. These standards should undergo IAEA reviews both during the formulation phase and periodically thereafter to confirm continued consistency with international benchmarks and evolving best practices.

Supply Chain Integration and Strategic Cooperation

The benefits of regulatory harmonization extend beyond efficiency. A clear and unified regulatory framework can significantly increase investment in SMR technologies by providing companies with a transparent understanding of the approval process. Moreover, positioning the Triad as leaders in global nuclear energy innovation could enhance diplomatic relationships and foster collaboration with other nations interested in nuclear energy, setting a precedent for international cooperation. China's rapid licensing speed and cost efficiency are critical threats to the global SMR market. South Korea and Japan must streamline their regulatory frameworks in alignment with U.S. NRC standards to remain competitive on time and cost.

A regulatory alliance centered on the U.S., South Korea, and Japan could be expanded into a regional bloc involving countries like Vietnam, the UAE, and Indonesia. This would serve to:

- Counterbalance China's growing influence
- Capture emerging market opportunities enhancing scale merit for the same design
- Facilitate the export of SMRs backed by trusted regulatory frameworks

It is essential to demonstrate the construction cost and timeline of a trilaterally designed SMR. For emerging economies with limited financial resources, cost competitiveness and its control assurance is often the most critical factor in decision-making. These countries, many of which are facing rapidly growing energy demand, are also eager to secure large-scale power sources quickly. While not inherent to SMR design, it is also important for the U.S., South Korea, and Japan to establish a cooperative framework to support recipient countries. This could include human resource development, technical training, and financing mechanisms. In Asia, institutions like the Asian Development Bank (ADB) could play a key role. However, ADB currently excludes nuclear energy from its support portfolio. To change this, coordinated advocacy by the Triad like efforts in Europe around low-carbon energy taxonomy could be effective.

In addition to technical and financial cooperation, the transfer of regulatory know-how and non-proliferation measures which are areas of particular importance to the United States should be prioritized. In this context, it is essential for South Korea, the U.S., and Japan to engage in practical collaboration through the U.S.-led FIRST (Foundational Infrastructure for the Responsible Use of Small Modular Reactor Technology) program. Administered by the U.S. Department of State, FIRST is a capacity-building initiative designed to support countries interested in adopting next-generation nuclear technologies such as SMRs.

The program facilitates know-how transfer by helping countries develop the necessary safety, security, and non-proliferation infrastructure, while also supporting the establishment of responsible nuclear energy programs. Its activities include the creation and operation of capacity-building centers (e.g., the E2 Center), training for SMR operators, guidance on legal and regulatory frameworks, and the facilitation of workshops to share best practices in safety, security, and technical operations. Additionally, FIRST promotes cooperation on SMR supply chain development and operational models, making it a valuable platform for trilateral engagement.

Furthermore, if the Triad adopts joint standards, the integration of supply chains — such as nuclear fuel, module manufacturing, and instrumentation — can be achieved through coordinated procurement strategies and collaborative research and development efforts. Joint standards can facilitate shared procurement strategies, reducing costs and improving efficiency. To further reduce costs and shorten the lead time from groundbreaking to completion, it will be necessary to harmonize component certification processes and simplify export control procedures among the three countries. Since the free movement of products is essential for efficient collaboration, uncertainties such as tariff measures should be minimized as much as possible.

While the benefits of supply chain integration are clear, it is important to acknowledge that new nuclear manufacturing has declined globally over the last several decades. Although the nuclear renaissance in the late 2000s began to rebuild this supply chain, the Fukushima incident significantly reduced demand, stalling progress. Vendors were stood up to support new U.S. modular reactor development, but with Vogtle Unit 4 being the last U.S. reactor to go online, the opportunity to capitalize on scaling production is waning. Rebuilding an experienced supplier base will eventually become a strength for the SMR industry, but it will likely take a decade to fully materialize.

Using U.S. NRC licensing alone can already shorten the approval timeline by 2–3 years and reduce regulatory costs by approximately $250–300 million per project. If mutual recognition or a joint pre-licensing system is established, SMR projects could see significantly improved economic viability and return on investment.

Standardized safety protocols would enable interoperability across key segments of the trilateral supply chain, including nuclear fuel, modules, components, and instrumentation. However, several non-technical barriers must be addressed to achieve this integration:

- Non-proliferation agreements (e.g., U.S.-ROK and U.S.-Japan nuclear cooperation agreements)
- Intellectual property rights disputes
- Export control regulations

Therefore, intergovernmental collaboration and a structured dispute resolution mechanism are essential.

Additionally, material standards currently differ between countries, meaning that test results obtained in one country (e.g., the U.S.) cannot be directly applied in another (e.g., Japan). This forces redundant testing and redesigns, increasing costs and delays. Without harmonizing these fundamental technical standards, achieving true standardization of SMR designs will remain difficult. A joint Design Pre-licensing system could be a transformative step forward. However, the U.S. NRC has historically been slow and risk-averse. Any trilateral solution would likely require a rethinking of 10CFR50. The current COL (Combined License) regulation has driven manufacturing and construction to behave like an operating nuclear facility, which is not conducive to cost efficiency or expedited schedules.

Each country in the trilateral partnership brings distinct and complementary strengths to the global SMR supply chain. The United States excels in advanced reactor technology, a favorable business environment for innovation, and is leading efforts to expand uranium enrichment capacity and produce high-assay low-enriched uranium (HALEU). South Korea is recognized for its strong manufacturing capabilities and project management expertise, having successfully completed four new reactor projects in recent years and continuing to win global tenders. Key Korean manufacturing firms include Doosan Enerbility, Hyundai Engineering & Construction, and Samsung C&T, which play critical roles in reactor component fabrication and construction. Meanwhile, Japan is known for its innovation in safety technologies and international collaboration, with highly reliable manufacturers such as Mitsubishi Heavy Industries, Hitachi, JGC, and IHI, many of which have formed partnerships with leading SMR developers like Hitachi-NuScale. Together, these strengths position the Triad as a powerful force in advancing SMR deployment globally. For pressurized water reactor SMRs, where South Korea has strengths, advantages exist across design, manufacturing, construction, and fuel. For non-pressurized water reactors, similar to other countries, there are no comparative advantages beyond design yet. While Japan has mentioned SMR enriched fuel supply, the U.S. is also aiming to strengthen its domestic enriched fuel supply chain, creating potential conflicts. These overlapping ambitions highlight the need for early coordination to avoid duplication and ensure strategic alignment across the Triad's supply chain development efforts.

Implementation Roadmap and Conclusion

A step-by-step implementation path could include:

- Develop a preliminary safety framework based on U.S. NRC standards
- Strengthen the capabilities of South Korean and Japanese regulatory bodies and align legal frameworks
- Launch a trilateral pilot SMR deployment project
- Register jointly approved designs with the IAEA's ARIS to ensure international standard recognition

To become equal partners with the NRC, South Korea's NSSC and Japan's NRA must significantly enhance their technical and organizational capabilities. This includes increased budgets, staffing, and international cooperation experience. The combination of a jointly certified design, lower accident risk, and shared liability mechanisms can build trust in Southeast Asia and the Middle East. A comprehensive offering including joint certification, shared insurance models, and coordinated emergency response protocols would significantly enhance credibility.

In conclusion, to make trilateral-certified SMR designs attractive to emerging markets, strategies should include competitive pricing, demonstrating reliability and safety, and offering flexible financing options. Building partnerships with local governments and industries can enhance market entry and foster cooperation. Additionally, the Triad should establish a joint standard and engineering/safety protocol framework for SMRs, enabling project approval in one country to facilitate deployment in the others without necessitating separate national approvals. This collaborative approach will not only enhance the economic viability of SMRs but also strengthen international cooperation in advancing nuclear technology for a sustainable energy future.

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