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Commentary

Small Modular Reactors and the Nuclear Non-Proliferation Treaty

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December 18, 2025

Summary

Small Modular Reactors represent both the future of nuclear innovation and a critical test for the resilience of the non-proliferation regime.

Small Modular Reactors (SMRs) are widely heralded as the next major leap in civilian nuclear energy. Promising enhanced safety, modular scalability and carbon-free electricity, they are viewed as a crucial innovation for global decarbonisation and energy security. However, beneath this optimism lies a growing unease within the nuclear policy community relating to the proliferation and safeguards challenges that SMRs pose to the existing global nuclear governance system, notably the Nuclear Non-Proliferation Treaty (NPT).

As the race to commercialise SMRs accelerates,[1] it exposes a regulatory lag between technological innovation and institutional adaptation. Multiple countries are now competing to establish first-mover advantages in export markets, standard-setting and supply chains. The U.S. Nuclear Regulatory Commission's approval of NuScale's SMR design,[2] the United Kingdom's advancement of Rolls-Royce SMR through the Generic Design Assessment process,[3] and Canada's national SMR Action Plan[4] indicate a shift from research-oriented development to commercialisation strategies.

Existing nuclear regulatory frameworks were designed for large, centralised reactors. The International Atomic Energy Agency (IAEA) has highlighted gaps in regulatory readiness, licensing harmonisation and workforce capacity with respect to SMRs.[5] Unless new norms and safeguards are developed, the proliferation of SMRs could further undermine the NPT's credibility and create new avenues for proliferation.

SMRs and the NPT: A Structural Mismatch

SMRs, typically generating between 50 and 300 megawatts of electricity, are designed to be factory-fabricated and easily transported to deployment sites. Their small size and modular construction allow them to serve remote or off-grid regions, making nuclear energy more accessible and potentially more sustainable. Major Powers such as the United States, Russia and China are investing heavily in SMR development, while countries such as India and Canada are exploring indigenous designs.

Yet, these very characteristics like mobility, compactness and commercial flexibility also complicate non-proliferation safeguards. The technology's promise of 'nuclear democratisation' risks creating a world with more nuclear actors, more dispersed facilities and less transparency. The NPT, which was drafted over five decades ago, was not designed for such a landscape. The NPT is built upon three pillars: non-

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[1] J. K. Nøland, M. Hjelmeland, L. B. Tjernberg and C. Hartmann, "**The Race to Realize Small Modular Reactors: Rapid Deployment of Clean Dispatchable Energy Sources**", *IEEE Power and Energy Magazine*, Vol. 22, No. 3, May-June 2024, pp. 90–103.

[2] "**Nuscale Power Module**".

[3] "**Clean, Affordable Energy For All**", Rolls-Royce SMR.

[4] "**Canada's Small Modular Reactor (SMR) Action Plan**".

[5] IAEA Report on "**Capacity Building for Nuclear Safety**", September 2015.

proliferation, disarmament, and the peaceful use of nuclear energy. Articles I and II prohibit the transfer or acquisition of nuclear weapons and related technology, while Article III establishes the IAEA's role in safeguarding nuclear materials used for peaceful purposes.

However, SMRs challenge this framework in fundamental ways. Many advanced SMR designs use High-Assay Low-Enriched Uranium (HALEU). This essentially means fuel enriched to nearly 20 per cent uranium-235. This is significantly higher than the 3–5 per cent typically used in conventional reactors and is close to weapons-grade levels.[6] This blurs the boundary between civilian and military nuclear technology.

Another issue lies in the envisioned deployment model. SMRs are marketed as 'plug-and-play' units that can be delivered, installed and even retrieved by the vendor. This model could lead to situations in which reactors operate in countries with inadequate security infrastructure or limited regulatory capacity, which heighten proliferation risks.[7] Historical evidence suggests that economic benefits are often prioritised over proliferation concerns. The US civil nuclear cooperation with China in the mid-1980s and Chinese nuclear infrastructure-related exports to countries like Pakistan, Syria, Iraq, Iran and North Korea in the 1980s and beyond are pertinent examples in this regard.[8] Moreover, in the post-Second World War, countries with nuclear technologies rushed to gain the benefits of commercialising their newfound nuclear knowledge at a time of heightened proliferation concerns.[9]

Emerging Risks and Vulnerabilities

Proliferation challenges associated with SMRs can be categorised into four broad areas. First, the use of HALEU reduces the technological barrier between civilian enrichment and weapons-grade material production. Secondly, SMRs are attractive to developing countries and small island states with limited grid capacity. These countries are often the same regions where nuclear oversight is weakest. A mobile or offshore SMR deployed in such contexts could be targeted for diversion, sabotage, or theft.[10]

[6] "**High-Assay Low-Enriched Uranium (HALEU)**", World Nuclear Association, 13 December 2023.

[7] Zareen Tahsin Anjum and Md. Shafiqul Islam, "**Deploying Small Modular Reactors in Newcomer Countries: Adapting the IAEA Milestones Approach and the Way Forward**", *Energy Strategy Review*, Vol. 61, 2025.

[8] J.M. Malik, "**China and the Nuclear Non-proliferation Regime**", *Contemporary Southeast Asia*, Vol. 22, No. 3, 2000, pp. 445–478.

[9] J. Sarkar, ***Ploughshares and Swords: India's Nuclear Program in the Global Cold War***, Cornell University Press, Ithaca, 2022.

[10] Nicole Virgili, "**The Impact of Small Modular Reactors on Nuclear Non-Proliferation and IAEA Safeguards**", Vienna Center for Disarmament and Non-Proliferation, 2020.

Thirdly, the compactness and transportability of SMRs also complicate the safeguard mechanism. SMRs' modular nature complicates material accounting and verification. Moving reactors or reactor cores across borders undermines traditional safeguards based on fixed-site inspections. Floating SMRs, such as Russia's *Akademik Lomonosov*, also raise jurisdictional ambiguities, such as who bears responsibility for safeguards when a reactor operates outside a nation's territorial boundaries.

Finally, there exists the issue of commercial secrecy and privatisation. With the increasing involvement of private players such as NuScale Power, TerraPower, X-energy, Oklo Inc., Rolls-Royce SMR and Holtec International in SMR development, profit considerations risk becoming more prominent than non-proliferation concerns, thereby posing an additional proliferation challenge.

Institutional and Regulatory Gaps

The aforementioned challenges indicate that current non-proliferation instruments remain ill-suited to these new realities. The IAEA's safeguards system was built for large, stationary reactors with predictable fuel cycles. It did not account for multiple, dispersed, or mobile reactors that might operate across jurisdictions. Export control frameworks such as the Nuclear Suppliers Group (NSG) also lack specific guidelines for SMRs, particularly for scenarios involving the transfer of modular components or reactor leasing.

Since the NPT was never designed with SMRs or lease-based nuclear arrangements in mind, it is questionable whether the existing safeguards framework can be directly applied to such transfers. In scenarios in which a supplier state leases an SMR to a host country, the treaty provides no clear guidance on which party bears primary responsibility for ensuring compliance with NPT obligations and IAEA safeguards. This ambiguity creates potential loopholes that could be exploited to evade international monitoring. Nevertheless, in the absence of explicit provisions, the NPT's core non-proliferation obligations would still govern such arrangements.[11]

Policy Imperatives for the NPT Regime

To maintain the integrity of the NPT regime in the age of SMRs, several policy interventions are essential. First, the IAEA must develop SMR-specific safeguards that incorporate emerging technologies, including remote sensors, real-time monitoring and satellite-based verification. These should be complemented by

[11] "**Nuclear Small Modular Reactors: Key Considerations for Deployment**", *International Energy Forum,* May 2024.

enhanced data analytics, artificial intelligence, and anomaly detection systems capable of tracking small, distributed reactors. Second, there is an urgent need to centralise HALEU production and supply chains under multilateral control. Establishing international enrichment facilities or expanding the IAEA's LEU Bank model to include HALEU would minimise national stockpiling and prevent fuel diversion.[12]

Third, export control regimes must be modernised to address modular and mobile nuclear technologies. The NSG should draft explicit guidelines for SMR exports that require adherence to the Additional Protocol, physical protection standards and end-use verification clauses.[13] Exports should be restricted to states with proven regulatory capacity and comprehensive safeguards agreements in force. Finally, the increasing role of private companies in SMR development calls for robust public–private oversight. Governments must ensure that non-proliferation compliance is embedded in reactor design, licensing and export approval processes. Establishing an IAEA-endorsed certification framework for private developers could help align commercial activities with international norms.[14]

The spread of SMRs will have far-reaching implications for global nuclear governance. While the technology could democratise access to clean energy, it also risks democratising the proliferation of such energy. Major nuclear powers are already competing for SMR export markets, raising the possibility that technology transfers could become tools of geopolitical influence. Without updated safeguards and accountability mechanisms, this new phase of nuclear expansion may erode the NPT's credibility and widen the trust deficit between nuclear and non-nuclear weapon states.[15]

Conclusion

Small Modular Reactors represent both the future of nuclear innovation and a critical test for the resilience of the non-proliferation regime. Their compact, mobile and commercially attractive nature makes them ideal for expanding energy access—but also for challenging existing norms of control, transparency and accountability. The NPT must evolve to address this dual-use dilemma before SMRs become a proliferation loophole.

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[12] "**HALEU: Potential Safeguards and Non-Proliferation Implications**", Vienna Centre for Disarmament and Non-Proliferation, 12 September 2024.

[13] "**Assessing the Nuclear Weapons Proliferation Risks in Nuclear Energy Newcomer Countries: The Case for Small Modular Reactors**", *Nuclear Engineering and Technology*, Vol. 56, No. 8, pp. 3155–3166.

[14] "**Safeguarding the Nuclear Future: Small Modular Reactors**", International Atomic Energy Agency, 23 September 2021.

[15] "**Safeguard a Nuclear Energy 'Boom'**", Nuclear Threat Initiative, 2 June 2025.

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