328

Projecting Spent Nuclear Fuel Inventories from Energy System Pathways: Implications for Geological Repository Capacity

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Extended Abstract

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Abstract Summary

This paper develops a framework linking scenario-based energy system pathways with projections of spent nuclear fuel (SNF) inventories to assess implications for geological repository capacity. While energy system models are widely used to analyze decarbonization pathways and the future role of nuclear energy, the back-end of the fuel cycle, particularly long-term SNF management and repository adequacy, remains insufficiently integrated into scenario analysis. Existing approaches typically rely on generalized discharge factors, introducing structural uncertainty into SNF projections.

The framework combines a harmonized baseline of SNF inventories with scenario-based projections of nuclear electricity generation. A key contribution is an empirical benchmarking approach that derives reactor-specific discharge coefficients based on observed operational data. Reactor-level data from German nuclear power plants are linked to lifetime electricity generation, accounting for actual load factors and complemented with data from the IAEA Power Reactor Information System. This ex post analysis enables the estimation of discharge coefficients that reflect differences across reactor types and operational conditions, moving beyond commonly applied reference ranges. These coefficients are applied in an ex ante projection of future SNF inventories across five energy system scenarios, capturing both phase-out and expansion pathways.

Preliminary results reveal systematic differences in discharge behavior across reactor types, with boiling water reactors exhibiting higher discharge rates than pressurized water reactors. This indicates that generalized discharge assumptions are not sufficiently granular for scenario-based projections. Scenario results show that, while SNF inventories in countries with established programs remain dominated by historical accumulation, expansion pathways can lead to significant additional waste generation. Expected results

suggest systematic underestimation of SNF volumes in such scenarios when relying on generalized discharge factors.

Overall, the study highlights the importance of integrating energy system modeling with nuclear waste considerations and provides a methodological basis for assessing repository adequacy under alternative nuclear pathways.

Presenting Author Biography

Mahdi Awawda is a scientific researcher at the Federal Office for the Safety of Nuclear Waste Management (BASE) in Berlin and an external doctoral candidate at TU Berlin. His research focuses on the back-end of the nuclear fuel cycle, with an emphasis on scenario-based and stochastic modeling of spent nuclear fuel inventories and repository capacity. He holds a Master of Science in Information Systems Management from TU Berlin. His work integrates energy system modeling with nuclear waste management to assess long-term system implications.