Waste Management of Small Modular Nuclear Reactors in Finland – Results from KYT 2022 Project SMRWaMa

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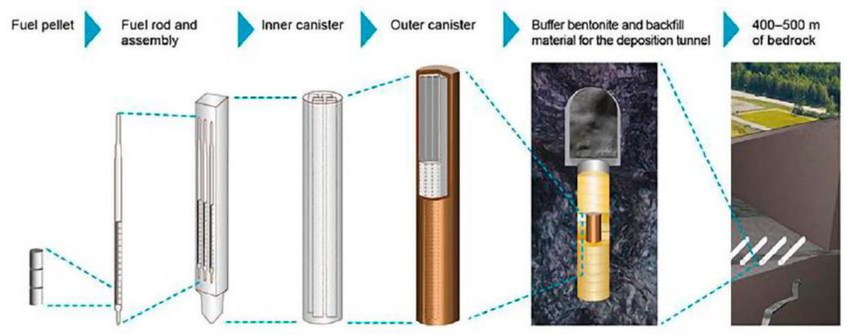
Introduction

Small modular reactors (SMRs) are being considered as future low carbon energy solutions for both electricity and heat production. SMRs are typically nuclear power plants (NPPs) with electrical and thermal outputs less than 300 MWe and 1000 MWth respectively. In Finland, SMRs could be used for, e.g., district heating applications replacing coal and peat power plants.

Planning for the safe management of spent nuclear fuel (SNF) and low and intermediate level waste (LILW) is an essential part of the development, financing and licensing of an SMR plant in Finland and the rest of Europe (EU-taxonomy). Currently, the responsibility for the management of the SNF and LILW and its costs in Finland lies with the operator of the plant (TEM 2022). SNF in Finland from currently operating NPPs will be disposed in the deep geological repository ONKALO® by Posiva Oy. This repository is based on the KBS-3V concept and Posiva Oy submitted an application for operation of the encapsulation and final disposal facility in 2021 (Posiva 2021).



Multibarrier principle in the KBS-3V repository concept. Illustration courtesy of Posiva Oy.

The SMRWaMa project started in 2021 as part of the Finnish research programme on nuclear waste management KYT2022 (Keto et al. 2022).

Objectives of the SMRWaMa project

- Determine the characteristics, waste forms and amounts of SNF and LILW generated in an SMR plant. Compare to the waste streams originating from NPPs currently operating in Finland.
- Asses management methods and strategies.
- Identify the most critical waste management related topics for further studies in 2022 and beyond for safe implementation of SMR's in Finland.

Methods

Effects of reactor and spent fuel characteristics were assessed with 2D Serpent code in two different liquid water reactor–SMR example cases to see how spent fuel and waste characteristics are effected.

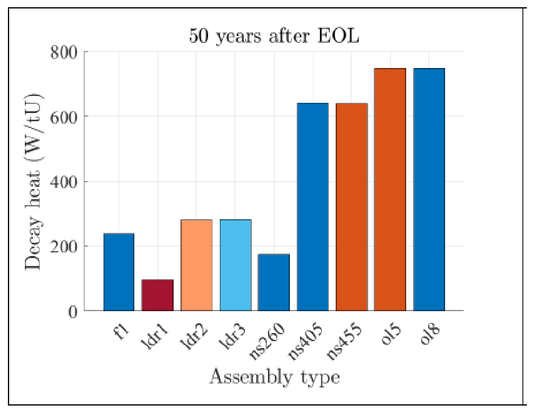
Literature review was performed to study the applicability of the current management methods used/planned in Finland for disposal of SNF and LILW for two example case of SMRs (NuScale Power Module™ and LDR-50-LW-SMR) and for identifying management options and strategies.

Results concerning SNF characteristics

- Spent fuel characteristics with comparable burnups are rather similar.
- Concentrations of mobile nuclides in SMR spent fuel are lower
- The generally lower discharge burnups in SMRs result in lower decay heat and ionizing radiation at an assembly level which may allow for more effective disposal.
- Further studies and 3D calculations needed to dose rates around fuel assemblies and to ensure the fuel sub-criticality in all post-irradiation storage configurations.

ID	Assembly type	Reference discharge burnup (GWd/MTU)
f1	EPR 1.9 % U-235, no Gd	15
ol5	EPR 4.5 % U-235, 16 Gd rods	45
ol8	EPR 4.0 % U-235, no Gd	45
ns260	NuScale 2.60 % U-235, no Gd	12
ns405	NuScale 4.05 % U-235, no Gd	40
ns455	NuScale 4.55 % U-235, 16 Gd rods	40
ldr1	LDR-50 1.5 % U-235, 8 Gd rods with 6 % Gd	7
ldr2	LDR-50 2.4 % U-235, 8 Gd rods with 5 % Gd	20
ldr3	LDR-50 2.4 % U-235, 8 Gd rods with 9 % Gd	20

Decay heating power of all studied assemblies at 50 years after the discharge (Keto et al. 2022). IDs 'f1', 'ol5' and 'ol8' refer to assumed fuel types in EPR (practically Olkiluoto-3). ID 'ns' refers to NuScale Power Module™ and ID 'ldr' to LDR-50.



Results concerning waste management

- The KBS-3V disposal concept is applicable for spent fuel produced in an SMR based on light-water reactor (LWR) technology. Adaptation needed e.g. considering encapsulation, other EBS components and thermal dimensioning of the repository.
- Considering non-LWR technology, there is typically a need for pre-disposal management for separating fuel from the matrix.
- SMRs possibly generate more spent fuel per unit of energy produced considering once-through nuclear cycles (Brown et al. 2017).
- Three different waste management strategies were identified including centralised, decentralised and hybrid management models. The choice will likely be influenced by deployment, ownership structure and plant size.
- Repositories:
  - SNF shall be disposed in a deep geological disposal facility, either KBS-3V type or alternatively borehole disposal.
  - LILW shall be disposed in an intermediate depth repository.
  - VLLW may be disposed in a near surface disposal facility.
- Public and stakeholder acceptability plays a key-role in Finland both considering SMR plant siting and repository siting.

Key conclusions

- **KBS-3V disposal concept can be applied for disposal of spent fuel from LWR-SMRs**
- **Further analysis needed for SNF characteristics**
- **Applicability of the management methods for non-LWR SMRs require further development**

References

- Brown, N., Worrall, A. & Todosow, M. 2017. Impact of thermal spectrum small modular reactors on performance of once-through nuclear fuel cycles with low enriched uranium. Annals of Nuclear Energy, 101 (2), 166-173.
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