SMR Waste Management and Disposal

EcoSMR dECOmm and SMRSiMa Final seminar
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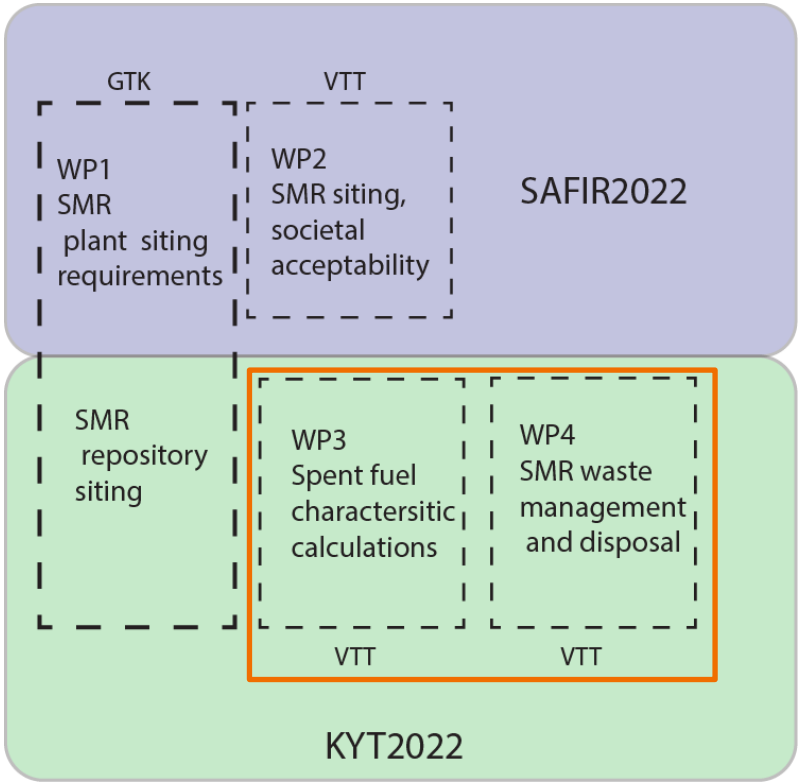
Background

- Small modular nuclear reactors (SMRs) are being considered as part of the solution to producing clean, stable and secure energy. Replacement of fossil fuel-based district heating systems is especially interesting for Finland.
- Safe and efficient management of nuclear waste is a prerequisite for deployment of SMRs (EU-taxonomy approved in July 2022).
- Small national research (KYT2022) project ”SMR Waste Management in Finland” started in 2021 with the aim to begin:
  - studying the differences between spent fuel and LILW produced in SMR modules in comparison to the waste produced in a large NPP,
  - assessing the applicability of the current waste management methods in use, and
  - developing SMR waste management strategies and identifying regulatory framework challenges and opportunities.
- This work has continued in 2022 in cooperation with the Geological Survey of Finland in a follow-up project “SMR Siting and Waste Management”. Focus on LWR-SMRs.
- Reform of Finnish Nuclear Energy Act ongoing (see presentation by Ville Koskinen / STUK).

Project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VTT
WP1
SMR
plant siting
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WP2
SMR siting,
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repository
siting
WP3
Spent fuel
characteristic
calculations
WP4
SMR waste
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and disposal
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Objectives (SMRSiMa WP3 & WP4)

- Study SMR spent nuclear fuel characteristics (KÄRÄHDE & SMRSiMa):
  - Comparison to current NPPs (characteristics, amount)
  - Effect on disposal (decay heat, dose rates, post-irradiation reactivity and criticality safety at disposal)
  - Focus on LWR-SMRs
- Applicability of current management methods (KBS-3V) and identification of the development needs.
- Establish alternatives for organising the management of SMR waste in Finland.
- Regulatory framework in Finland.
- Identify the most critical topics for further studies in order for SMR waste management to progress towards safe implementation.

SMR Waste management and considerations in updating the Nuclear Energy Act (1987/990)

Sections 6a and 6b

- **Section 6a**: “Nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be **handled, stored and permanently disposed of in Finland**.” Exception: Minor quantities for research purposes.
  - SMRs: could handling be possible outside Finland, e.g. encapsulation?
  - ERDO, European shared geological repository.
- **Section 6b**: “Nuclear waste generated in connection or as a result of use of nuclear energy **elsewhere than in Finland**, shall not be handled, stored or permanently disposed in Finland. Exeption: minor quantities for research purposes and nuclear waste of unknown origin.
  - SMRs, handling of foreign waste (e.g. encapsulation)

Waste management obligation

- Waste management obligation (jätehuoltovelvollisuus) includes:
  - Waste management obligation (huolehtimisvelvollisuus)
  - Financial provision obligation (varautumisvelvollisuus).
- Section 9:
  - "The licence holder shall be under an obligation to **ensure the safe use of nuclear energy**. **This obligation may not be delegated to another party**."
  - "A licence holder whose operations generate or have generated nuclear waste (**party with a waste management obligation = jätehuoltovelvollinen**) shall be responsible for all nuclear waste management measures and their appropriate preparation, as well as for their costs (**huolehtimisvelvollisuus**)."

→ Conclusions for SMRs: Section 9 does not limit transfer of waste management obligation to another party.

Transfer of waste management obligation

- Section 30: When a nuclear facility, a mine intended for the production of uranium or thorium, a milling facility, or nuclear waste is transferred to another party, the Ministry of Economic Affairs and Employment may, on request, transfer the management obligation (huolehtimisvelvollisuuden) to the transferee in part or in full if the transfer of the obligation does not endanger the implementation of the nuclear waste management."
- Not preferred options:
  - Section 29: Mandatory waste management cooperation (jätehuoltotoimenpiteet)
  - Section 31: Transfer of nuclear waste to the State, in case of failure.
- Section 35: Financial provision obligation (varautumisvelvollisuus). Responsibility of the producer of the waste.
- Nuclear Energy Decree sections 81-83 gives more information on the transfer of waste management obligation and how financial provision obligation should be organized.
- Section 32: Expiry of waste management obligation

Waste management

Waste management strategy options

- Affecting: Finnish regulations, ownership base, plant size (amount of SNF and other nuclear waste produced and level of expertise / safety culture of the operator),
- Spent nuclear fuel **interim storages:** at site or centralised (transportation spent fuel with little time to cool)
- Spent nuclear fuel disposal: **centralised disposal** or alternatively **local**
- ONKALO is not automatically an option for centralised disposal, as it is licensed only for SNF from current NPPs (OL 1-3, Lo 1-2)
- Borehole disposal discussed as alternative for SNF.
- Low- and intermediate level waste, possibly **hybrid strategy** taking into account:
  - Higher volume of the waste produced in comparison to SNF
  - Economic considerations and transportations to a centralised repository
  - Site (possibly close to urban areas)
  - Underground disposal (intermediate depth level 60-100 m below ground surface).
- Alternatives limited by current legislation (fuel reprocessing, disposal outside Finland)

Effect of SMR spent nuclear fuel characteristics on the final disposal

- Spent nuclear fuel characteristics studied in SMRWaMa project with Serpent 2D numerical modelling for LDR-50 district heating reactor (VTT design) and for older version of the NuScale Power Module™ reactor with following conclusions:
  - The lower discharge burnups in the SMRs lead to lower decay heat and ionizing radiation at the assembly level.
  - Concentrations of mobile nuclides in the SMR spent fuels are lower.
  - The lower average burnups in combination with high enrichment variations may contribute to higher post-irradiation reactivities (criticality safety).
  - Considering similar discharge burnups, the 2D model gives spent nuclear fuel inventories that are very similar to EPR fuel.
- Further SNF characteristics are being studied (3D Serpent-Ants calculations).

Applicability of the currently used management methods

- Waste form / EPR-type spent fuel assemblies should be compatible with current encapsulation methods using shorter canisters.
- Differences in fuel dimensions, configuration, fission product inventory, decay heat generation, physical and chemical characteristics and fissionable material content would need to be taken into account in repository design (spent fuel mass per canister, canister spacing, etc.)
- The KBS-3V concept was designed for UO_2 fuel with specific properties (Johnson et al. 2022); the disposability of (fully characterised) SMR spent fuel will need to be demonstrated.
- Some studies suggest that SMR use may lead to more spent fuel and LILW being generated per GWe-year (Krall et al. 2022, Brown et al. 2015, Glaser et al. 2013) than in large NPPs, but these results need to be verified.
  - The actual waste amount might not be the only metric as there is the radiotoxicity / heat generation aspects that may be less in low discharge burnup fuel even if the disposed mass is more

Non-LWR SMRs

- SMRs based on non-LWR technology (e.g., gas cooled high temperature reactors):
  - Fuel may require different type of handling before encapsulation (for example separation of the fuel kernels from the matrix).
  - Possibly creation of new-type of LILW streams (e.g. graphite)
  - KBS-3V concept design for UO_2 fuel.
  - Fuel characteristics, site requirements and concept open → High need for development.

Low and intermediate level waste streams from LWR-SMRs

- For LWR-SMRs it is highly likely that current management and disposal methdos are applicable.
- Separate project on SMR LILW planned for SAFER2028 by Antti Räty & Anu-Maija Leskinen (VTT)

Continuation of the work in SAFER2028