Unique Issues in SMR Spent Fuel and Waste Management

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SNETP Forum
TS5: Waste minimization and fuel cycle

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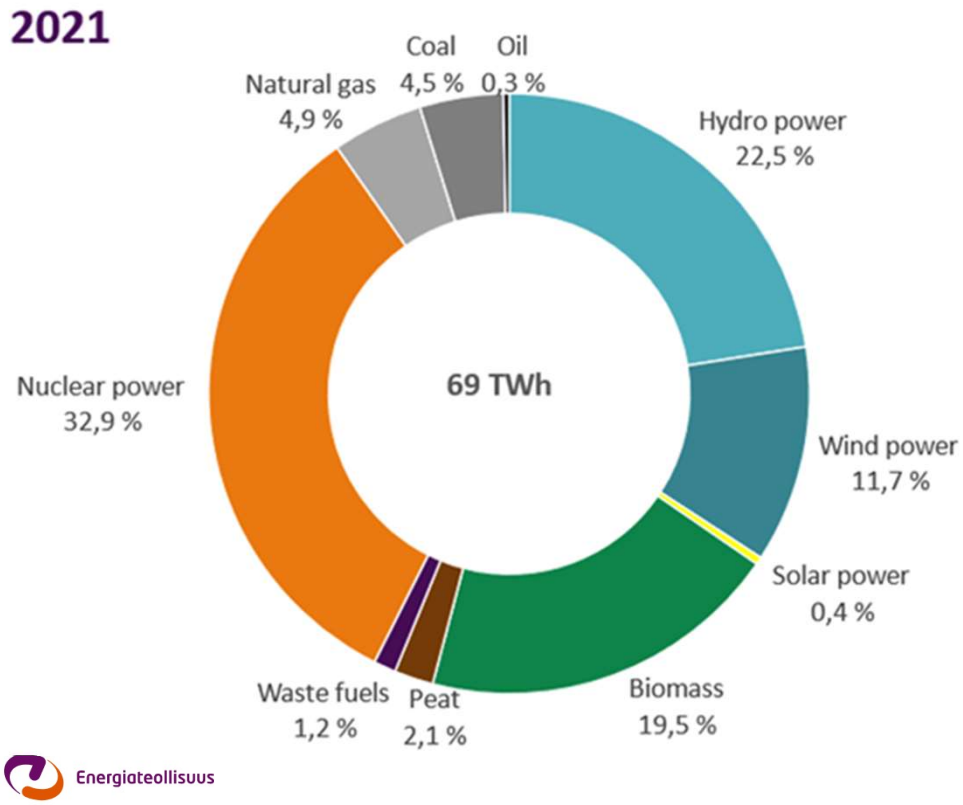
SNETP
Sustainable Nuclear Energy Technology Platform

Unique Issues in SMR Spent Fuel and Waste Management: Finnish Perspective

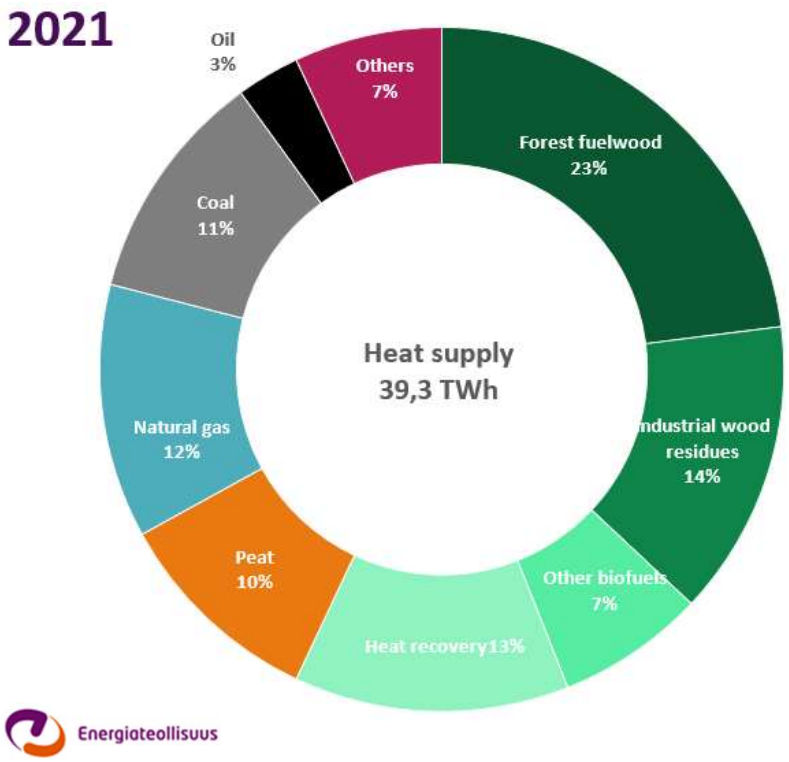
- Heat and electricity production in Finland
  - opportunities for SMRs
- Cases for preliminary studies of spent fuel, waste management and disposal plans
  - small electric grid LWR-type SMR
  - district heating LWR-type SMR
- Outcomes
  - spent fuel characteristics
  - compatibility with current disposal routes in Finland
  - SMR deployment schemes and waste management strategies
  - adjustments to regulatory framework

Electricity Production in Finland



- Nearly 70% of electricity produced in Finland is carbon-free.
- OL3 reactor to be fully operational in September.
- Domestic wind power production is increasing.
- Finland is expected to become fully self-sufficient in electricity production by 2023.
- Nationwide distribution network.

District Heat Production in Finland



- Produced almost entirely through combustion.
- Fossil fuels still used to a significant extent (36%).
- District heating supplies over 50% of demand in Finland.
- Decentralised networks covering local end-user needs (<30 km).

➢ SMRs?

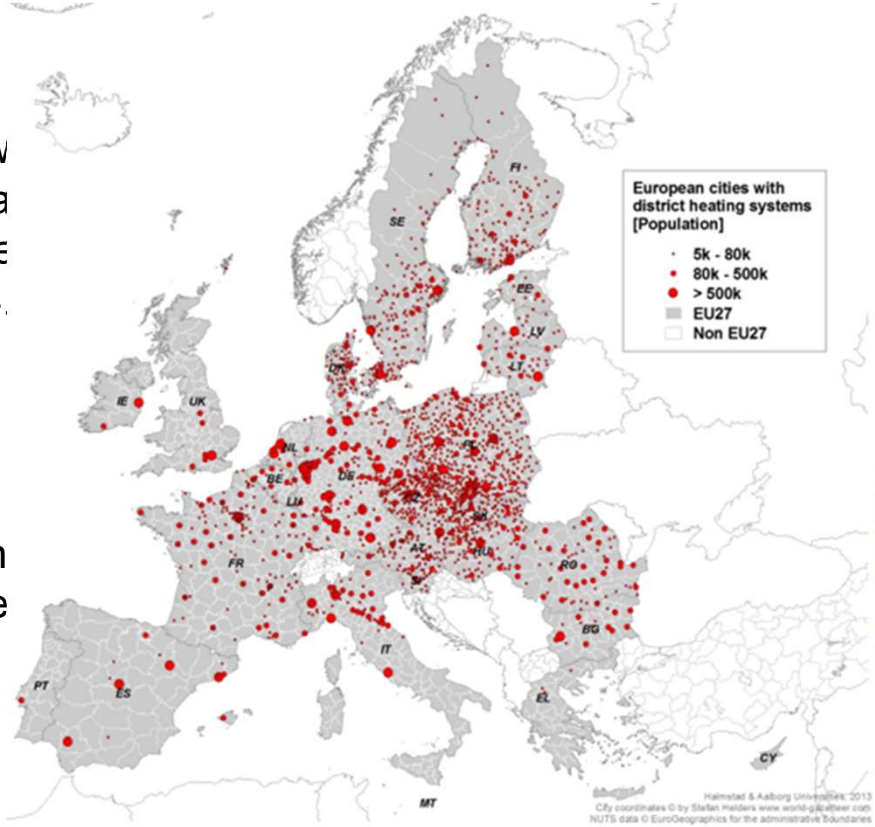
Opportunities for SMRs in Finland and abroad

Political Support

”The Nuclear Energy Act v
next government term, pa
to SMRs” (Finnish Gove
Energy Strategy Draft 14.4.

Industrial Support

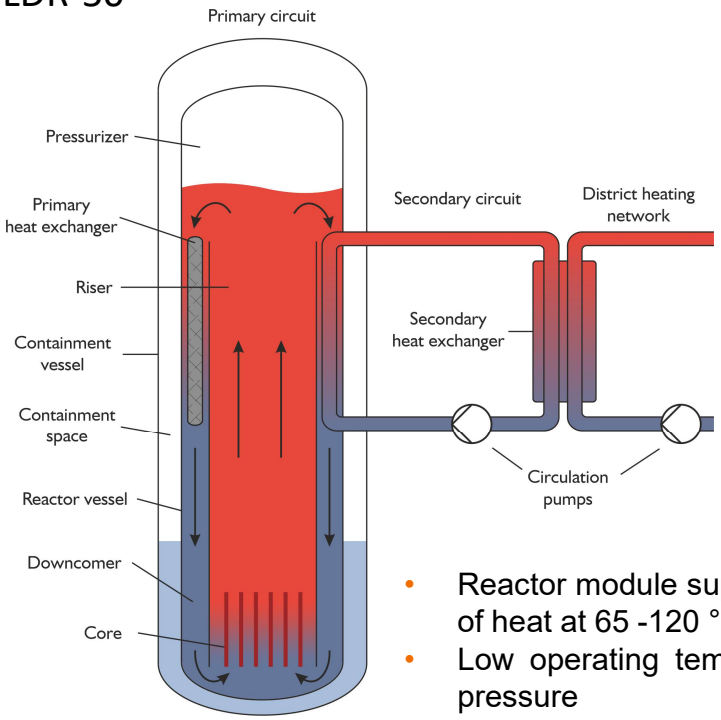
TVO’s strategic planning in
of 10 SMR technologies/de



roduction units in Finland 2018.

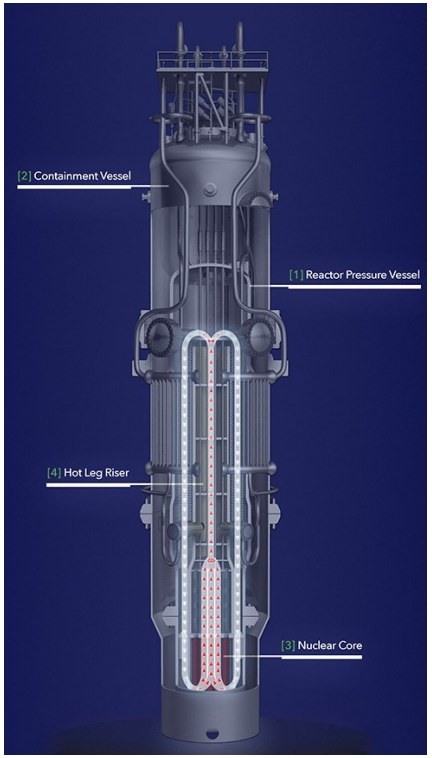
Cases for preliminary studies of spent fuel, waste management and disposal plans

LDR-50



- Reactor module supplies 50 MW of heat at 65 -120 °C
- Low operating temperature and pressure
- No turbine cycle

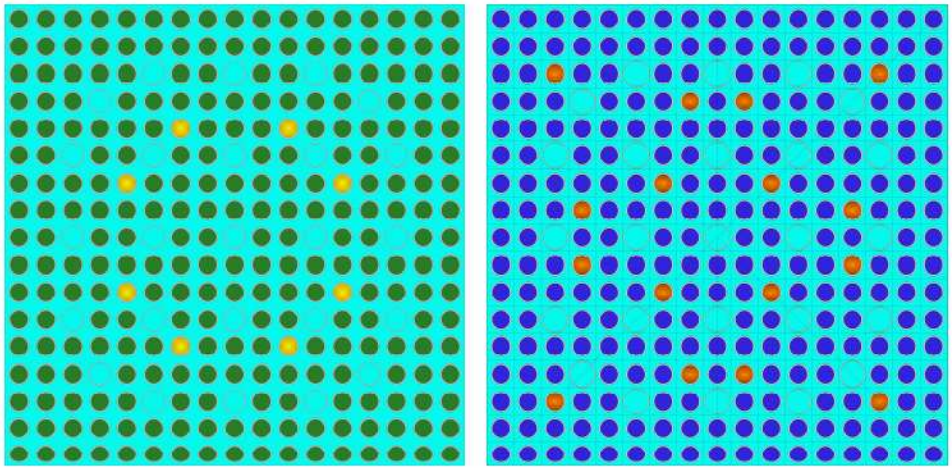
NuScale Power Module™



https://www.nuscalepower.com/technology/design-innovations

- Generates 60 MW of electricity
- Possible cogeneration
- Closest to commercialization

Spent fuel calculations



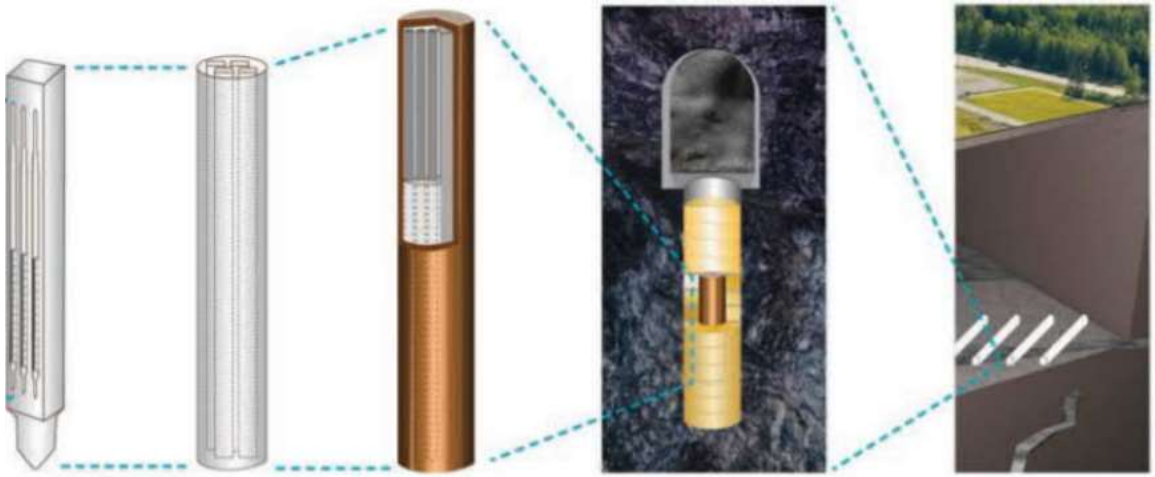
LDR-50 (left) and NuScale (right) model fuel assembly geometries used in Serpent calculations.

- Burnup calculations were performed with various uranium enrichment and burnable absorber contents in infinite 2D geometries for fuel assemblies resembling the NuScale power module and LDR-50 designs.
- Results are compared to those of an EPR due to the highly similar configurations of fuel assemblies for all three:
  - 17 x 17 arrays of fuel rods, control rods and instrument tubes
  - The burnup for multi-cycle assemblies was assumed to be 45 GWd/MTU for the EPR, 40 GWd/MTU for NuScale and 20 GWd/MTU for LDR-50.

Spent fuel characteristics

- 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 will contribute to higher post-irradiation reactivities.
  - Impact on how criticality safety criteria for transportation, storage and disposal are met.
- 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.

Spent fuel disposal



- The fuel assemblies used in the LW-SMRs are based on 17×17 HTP type fuel designs and are quite similar to the fuel assemblies used in OL3, with the exception of height.
- No substantive factors prohibiting the use of the KBS-3V concept for disposal of LW-type SMR spent fuel.
- Differences in fuel assembly dimensions, fuel configuration, fission product inventory, decay heat generation, physical and chemical form and fissionable material content would need to be taken into account in repository design (spent fuel mass per canister, canister spacing, etc.)

Waste Management Strategy

- Centralised waste management strategy where spent fuel and other nuclear waste is transported from different SMR sites from across Finland to a centralised site in the country that features resources for spent fuel and waste handling, treatment, processing, packaging, interim storage, encapsulation and final disposal facilities. These facilities could include a near surface repository for VLLW, an intermediate depth geologic repository for LILW (including decommissioning waste) and a deep geologic repository for HLW (spent fuel).
  - Individual SMR plants produce limited waste volumes.
  - Ownership?
  - The use of a centralized repository would greatly increase the need for cross-country transport of SNF (and possibly other nuclear waste), given the potential for SMRs to be deployed at multiple locations around the country (district heating application).

Alternatives

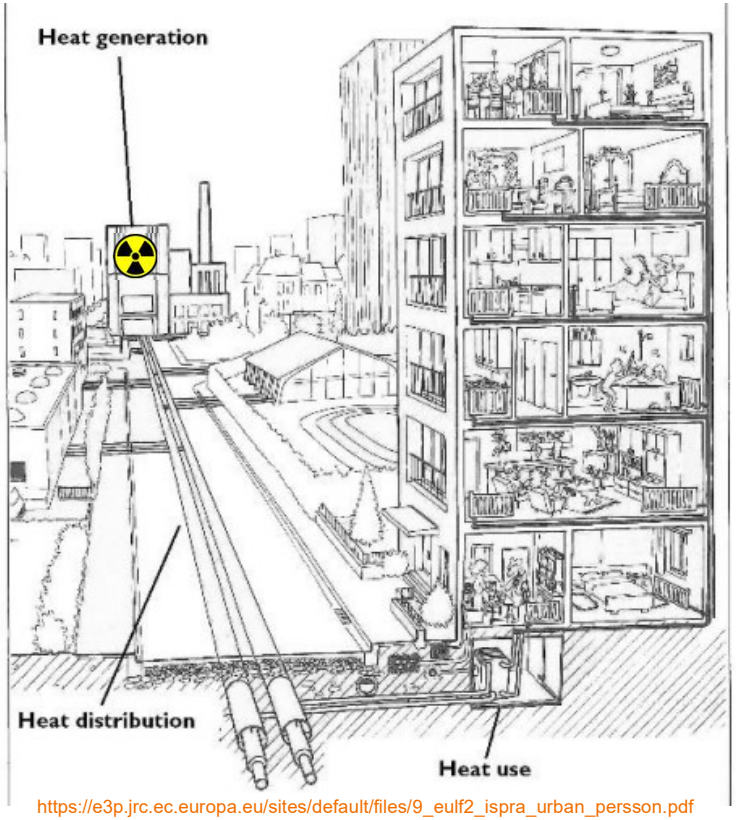
- Decentralised waste management
  - Not technically, economically or socially feasible over the entirety of SMR nuclear waste management.
  - Deep borehole disposal could be an option for decentralized deposition of SMR spent fuel and some LILWs. However, DBD is still relatively unproven technology.

- Hybrid Waste Management
  - Some part of the management could be handled in a centralised manner and some locally. E.g., one centralised facility for SF packaging and disposal another for LILW waste streams (also from decommissioning) and possible VLLW disposal on site. Or some combination thereof.

Restricted Options

- Sending spent fuel (and other radioactive waste) to another country for final disposal, e.g., to a European Multinational Repository.
- Decommissioning of SMR units outside Finland (even considering that the final disposal would still take place in Finland).
  - The dismantling and recycling of components of a decommissioned SMR at a centralized factory is expected to be more efficient and less expensive compared to performing the activity on-site.
- Leasing of the SMR (and fuel) itself with agreements that upon reaching the end of its service lifetime the entire plant facility is decommissioned and returned to its point of origin along with any accumulated wastes.
- Service model where the responsibility is contracted to a third party for handling, storage and/or for final disposal of the spent nuclear fuel (HLW) or other nuclear waste streams. Is carrying the financial responsibility enough to fill requirements?
- Reprocessing of the spent fuel outside Finland to enable final disposal (pertains to non-LWR SMR units).

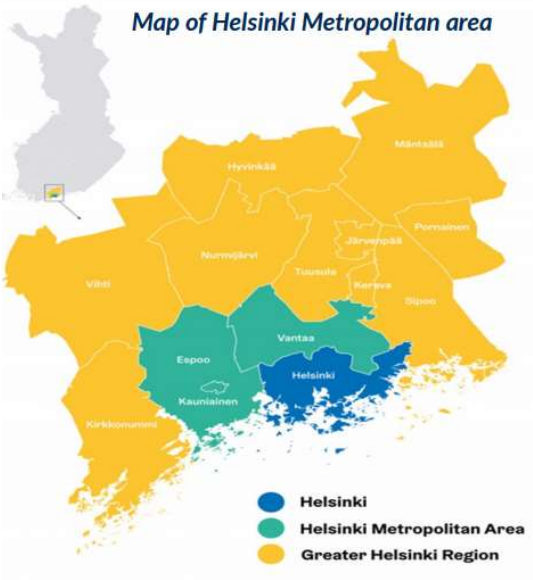
Are we ready for nuclear reactors and waste management in more urban settings?

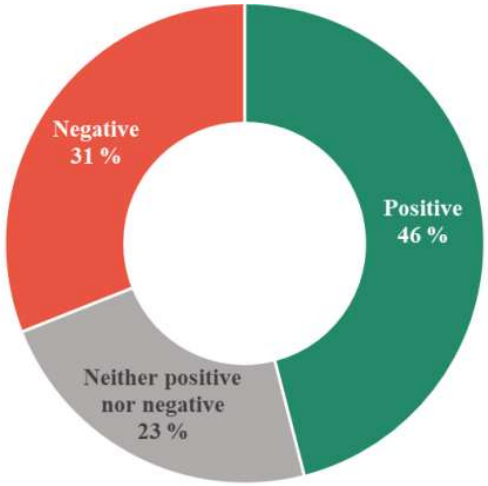


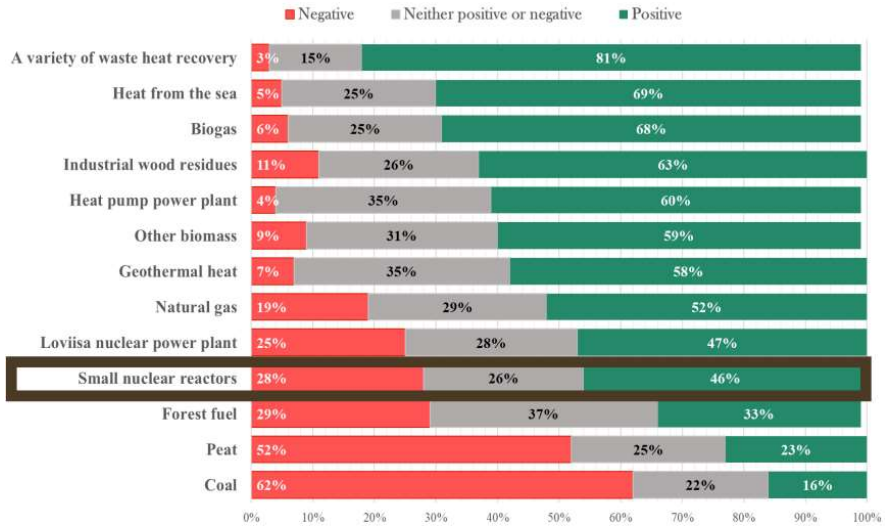
https://e3p.jrc.ec.europa.eu/sites/default/files/9_eulf2_ispra_urban_persson.pdf

Social Acceptance

- What would be your stand on SMRs if one would be located in your residential area (Kojo et al. 2022)?







- The Eurajoki Municipality, where the Olkiluoto SF repository is situated, has already stated some concerns regarding the disposal of additional SNF there in the future.

Thank you!