CET 2024
Estimations of Metallic Long-Lived Intermediate Level Waste and Spent Nuclear Fuel Volumes From Decommissioning of A Light-Water Small Modular Reactor

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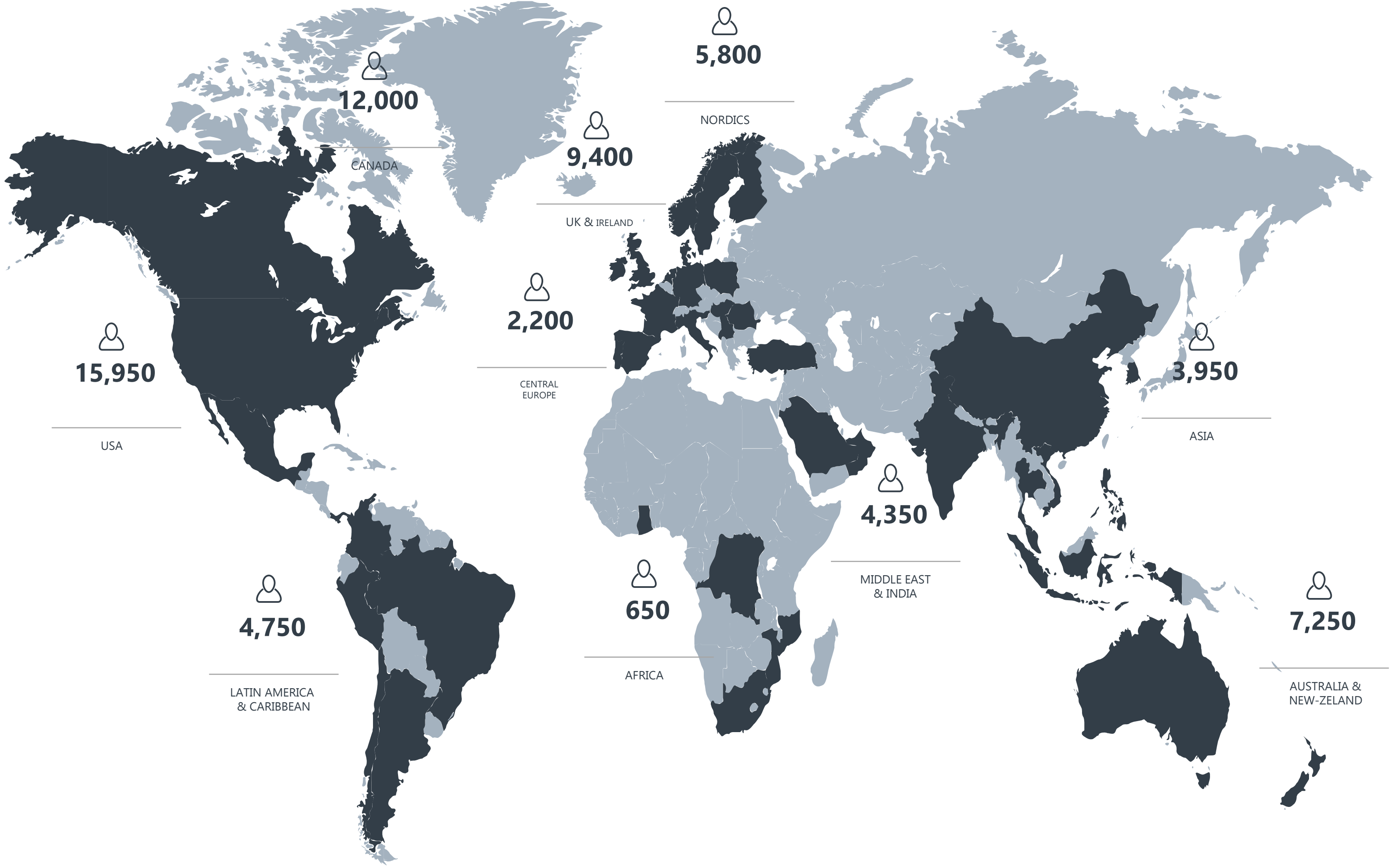
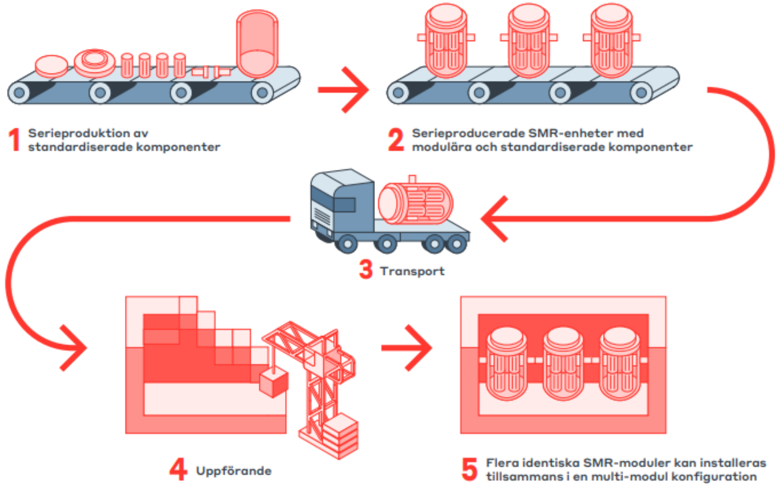
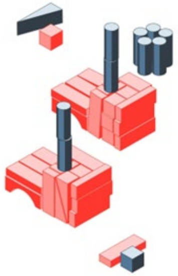
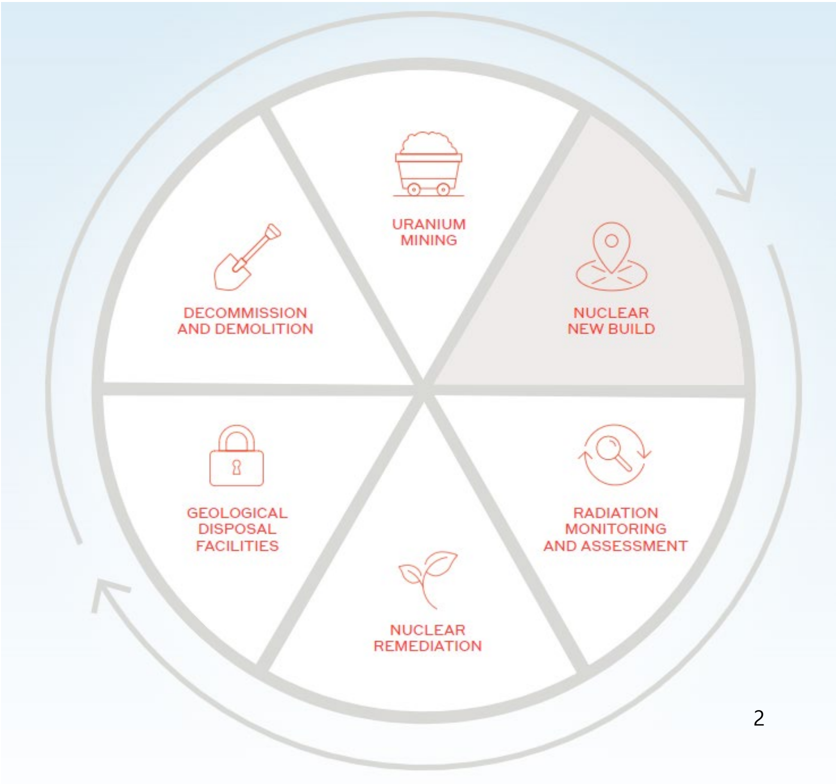






~70 000 people, in ~ 600 offices, across all geographies.



CET2024:

Estimations of long lived intermediate level waste and spent nuclear fuel Volumes from Decommissioning of a light water small modular reactor

Research papers published in Nuclear Engineering and Design (2024) and prepared for IAEA's *International Conference on Small Modular Reactors and their Applications* (2024).

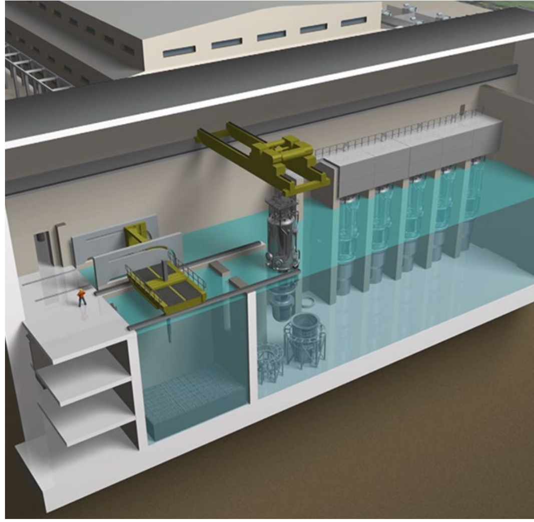
Authors: Tugba Yildirim (WSP), Fredrik Dehlin (KTH), Martin Amft (Sydkraft Nuclear Power AB) and Nils Sandberg

Questions - Motivation

- Decommissioning and waste a natural part in the early stage of the project
- Licensing documentation for new reactors must include preliminary waste management and decommissioning plans.
- Investigate the differences between a large scale and a small modular reactor in the different stages in a nuclear reactor's life cycle.

- How will small modular reactors and large reactors differ regarding their life cycle assessment and environmental footprint?
- **How will small modular reactors and large reactors differ regarding the amount of radioactive waste?**

NuScale™ Power Module (NPM)



- A methodology to do the estimation
- Most of the long-lived radioactive waste from their decommissioning consists of neutron activated metallic components in the core region.
- NPM was selected as a reference design
- Serpent 2, A 3D continuous-energy neutron and photon transport Monte Carlo code.

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Serpent 2.2

A Continuous-energy Monte Carlo Reactor Physics Burnup Calculation Code

 - Version 2.2.0 (May 5, 2022) -- Contact: serpent@vtt.fi

 - Reference: J. Leppanen, et al. "The Serpent Monte Carlo code: Status,
              development and applications in 2013." Ann. Nucl. Energy,
              82 (2015) 142-150.
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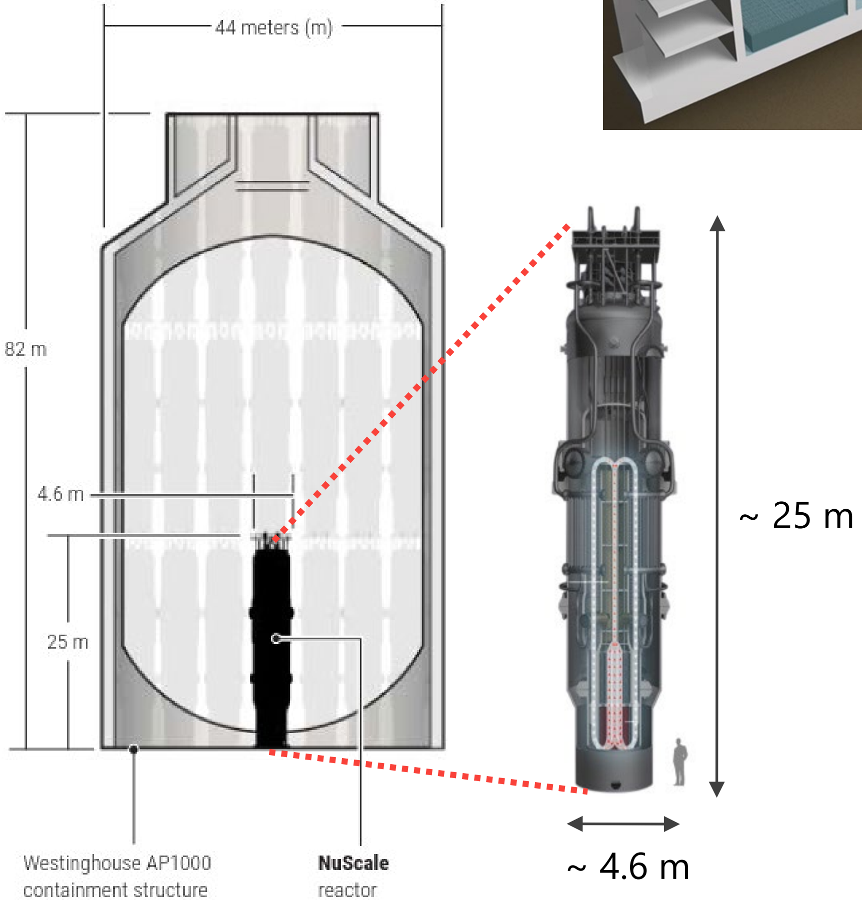
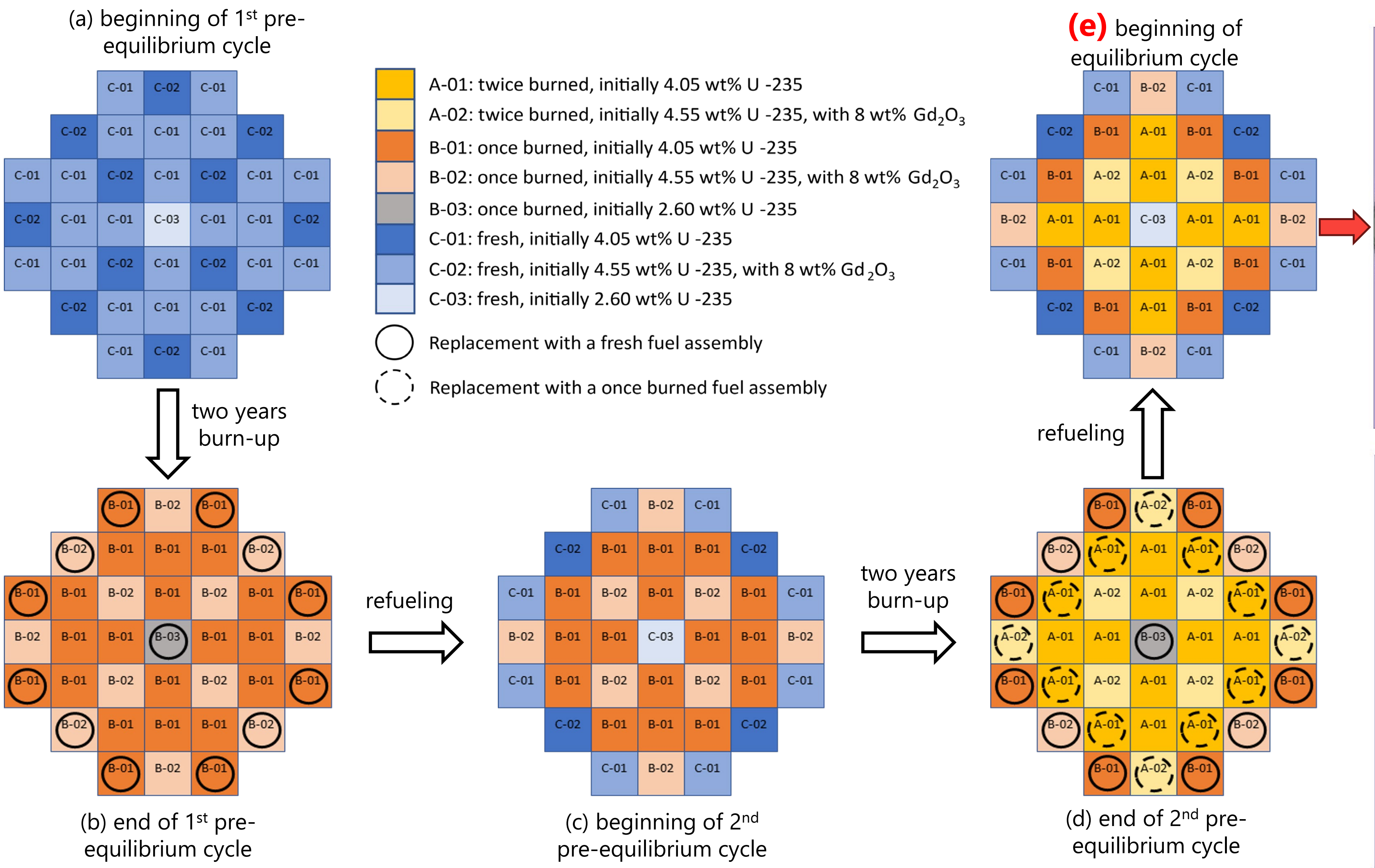
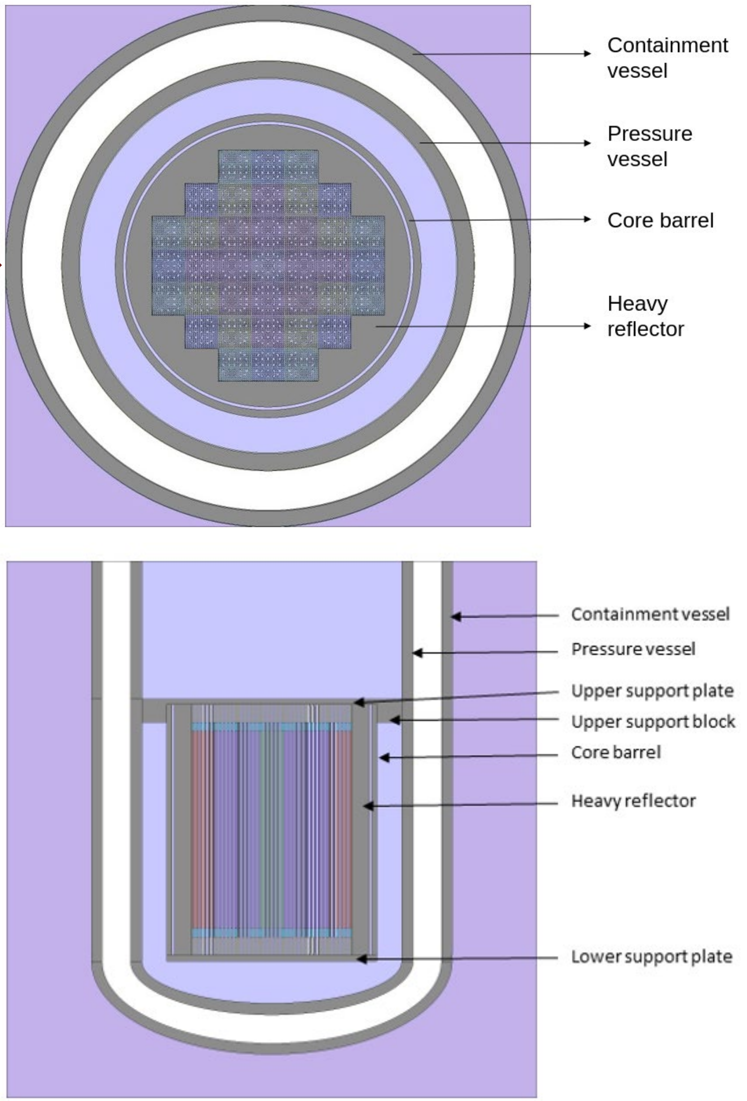


NPM Equilibrium Core Layout





Waste volume estimations was compared with U.S. Waste Classification limits

Neutron-Induced Activity after 60 Years of Operation of the NPM (US Context)

Component	^{14}C (Ci/m³)	^{59}Ni (Ci/m³)	^{94}Nb (Ci/m³)	^{99}Tc (Ci/m³)
Heavy reflector	117.88	232.60	0*	0*
Core barrel	86.48	224.75	0*	0*
Lower support plate	14.87	42.19	0*	0*
Upper support plate[1]	6.14	17.62	0*	0*
RPV core region[2]	0.69	2.51	8.88E-7	3.52E-4
RPV upper part[2]	3.41E-2	0.13	1.70E-9	4.87E-5
RPV calotte[2]	1.23E-2	3.42E-2	1.78E-7	2.85E-5
Containment core region[2]	4.47E-2	0.14	1.94E-7	1.18E-4
Containment upper part[2]	1.30E-2	4.73E-2	1.26E-11	5.42E-5
Containment calotte[2]	7.43E-3	2.10E-2	4.85E-9	1.32E-5
US-NRC Limit	80	220	0.2	3

* The activity results for ^{94}Nb and ^{99}Tc are listed as zero since the precursors of these isotopes are absent in the materials composition used for these stainless steels.

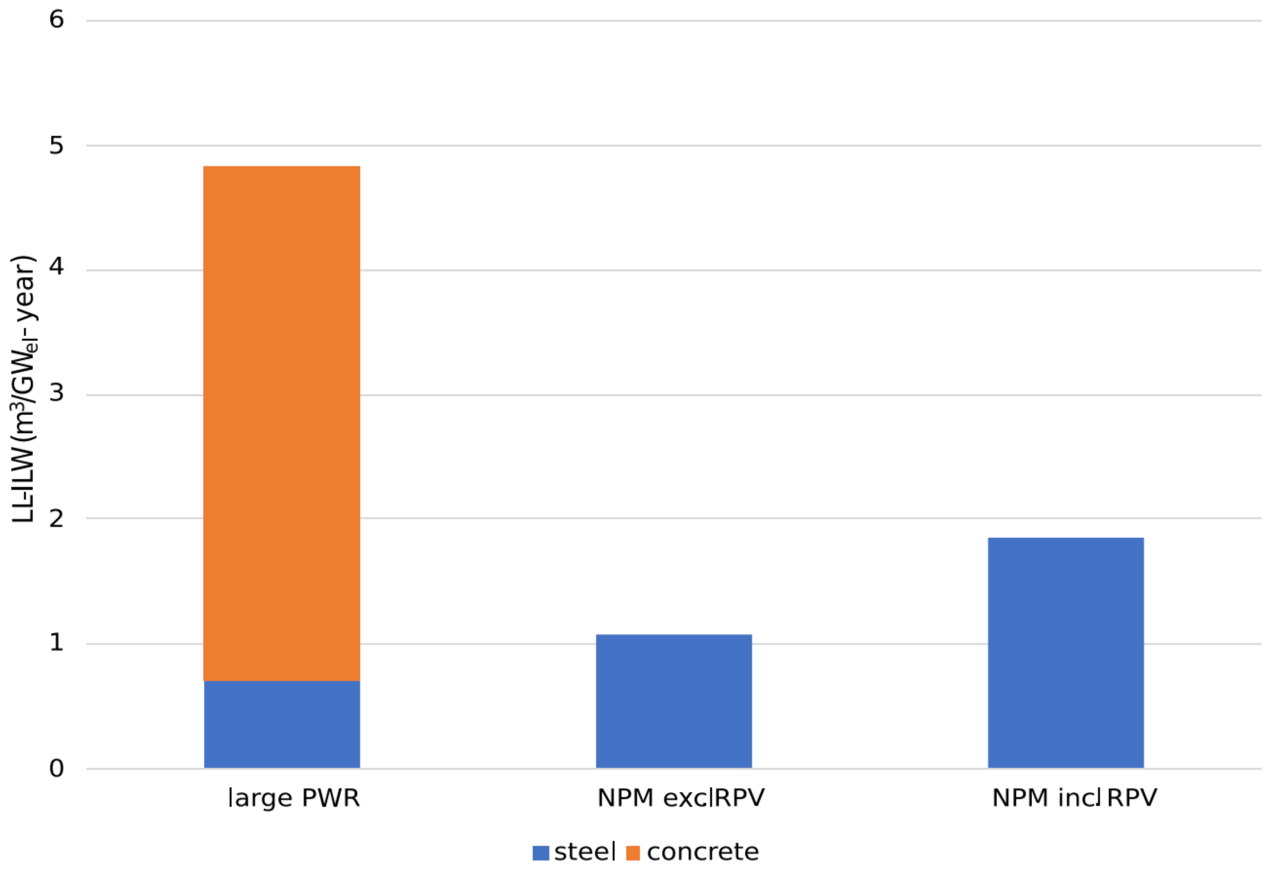
[1] Including the support blocks.

[2] Including the inner and outer cladding layers.

- NPM produces 10 times larger LL-ILW waste volume per energy produced according to NRC waste categorization
- According to the US-NRC §61.55 Waste classification, heavy reflector and core barrel exceed the concentration limits for near-surface disposal.
- The remaining parts are suitable for near surface disposal in the US as expected.

NuScale Power Module - Swedish Context (LL-ILW)

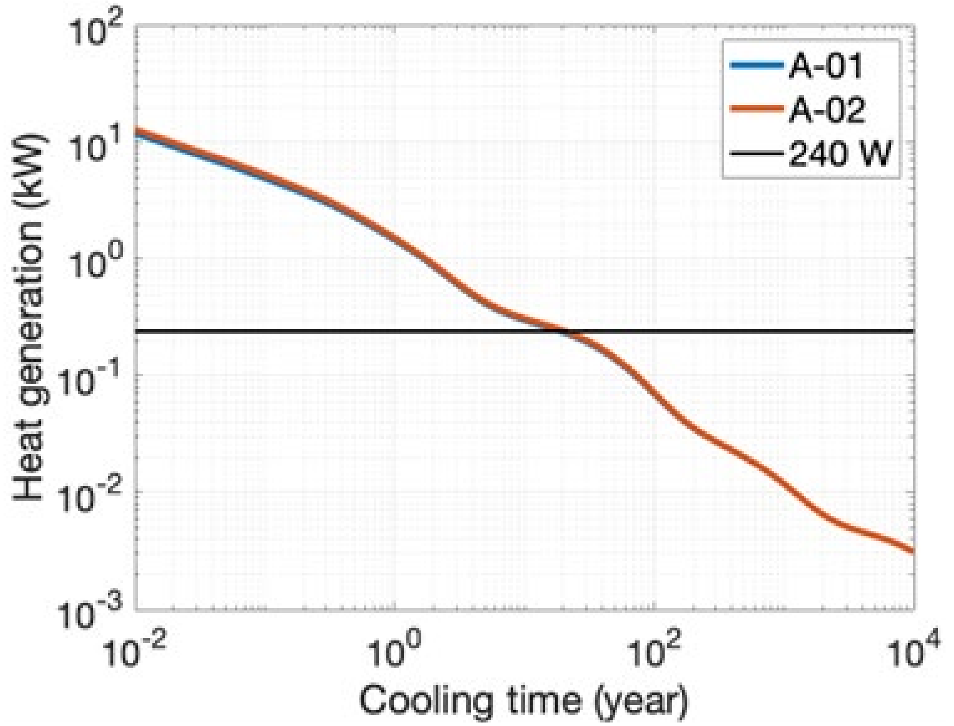
- Different waste classifications comparable to the NRC Regulations
- Waste that is radiologically suitable for SFL
- 1.08 to 2.13 cubic meter per energy-equivalent metallic long lived intermediate level waste
- Somewhat larger than metallic LL-ILW anticipated for the existing large PWRs at Ringhals
- Suitable for the current waste management system



LL-ILW from decommissioning, suitable for the Swedish geological repository SFL, of a large-scale PWR in Sweden and an NPM.

NuScale Power Module - Swedish Context (SNF)

- Serpent 2, was used to model the equilibrium core of the NuScale Power Module to estimate the amount of spent nuclear fuel generated.
- The burnup of and decay heat from the fuel assemblies were calculated
- A total of 96 metric tons of spent nuclear fuel during 60 years of operation
- Fuel assemblies ~ 57 % the length of a conventional PWR fuel assembly



Decay heat emitted from fuel assemblies of type A-01 (4.05% UO2) and A-02 (4.55% UO2), after six years in the NPM core as a function of cooling time.

Conclusions

- This methodology provides solid estimates of waste characterization and volumes expected from the decommissioning of SMR:s.

- In the US context, NPM is estimated to give rise to almost 10 times more volume of metallic long lived intermediate level waste per energy equivalent produced.

- The waste, is suitable for disposal in the SFL.

- The metallic LL-ILW volumes per energy unit produced are estimated to be somewhat larger than those anticipated for the existing large PWRs at Ringhals.

- After around 20 years of decay, the SNF can sufficiently be disposed of according to the so called KBS-3 method.

- Additional studies would be required to define the optimal disposal route for components situated further away from the nuclear core.

- Additional studies would be needed to identify which parts of the NPM become activated less than the established clearance levels, allowing them to be recirculated into the conventional economy.

Thank you!

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