NUCLEAR DATA NEEDS FOR DISPOSAL CANISTER AND STRUCTURAL ELEMENTS

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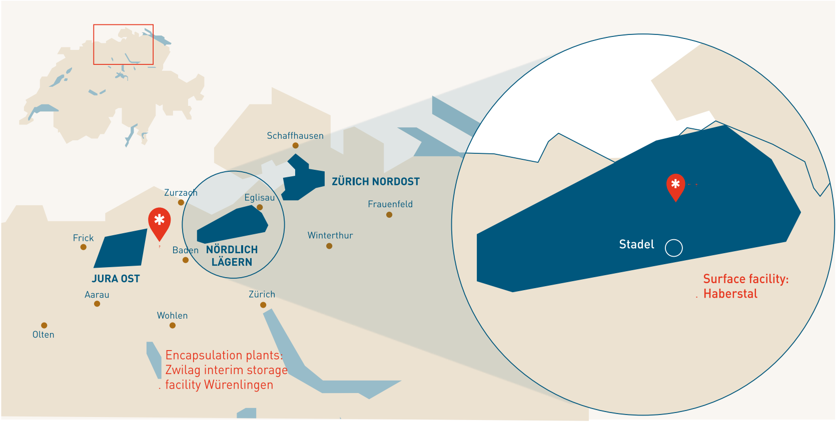
nagra

A SHORT INTRODUCTION TO NAGRA

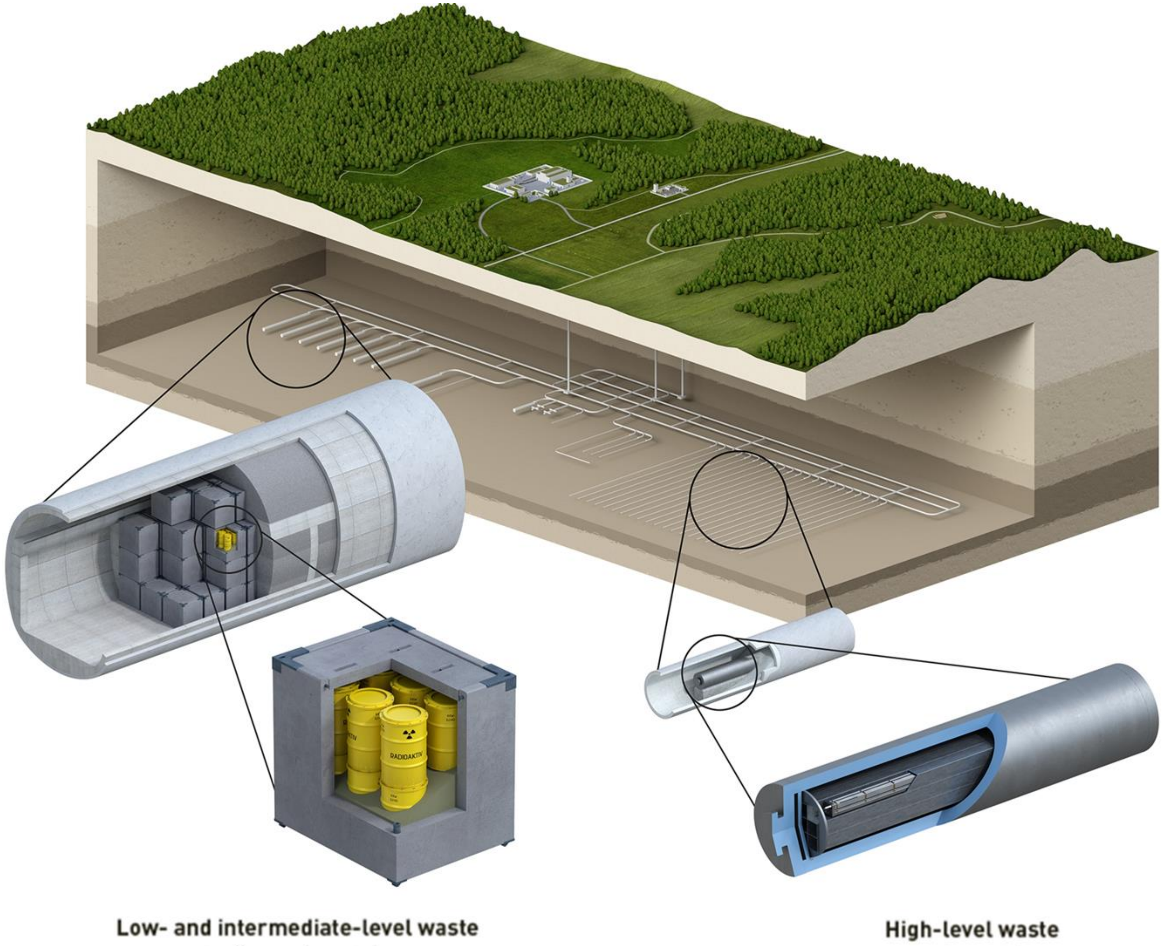
- 1972: Nagra (National Cooperative for the Disposal of Radioactive Waste in Switzerland) is created
  - Funded by the waste producers: Nuclear powerplant operators and Swiss confederation (Federal Government – waste from MIR applications)
  - Development and implementation of safe and sustainable long-term solution for all Swiss radioactive waste (nuclear energy industry and MIR origin)
- Nuclear Energy Act (2003)
  - Waste producers are responsible for the safe management of their radioactive waste
  - Individual steps necessary on the way to geological disposal are set out
- Nagra's mandate:
  - Plan and construct the deep geological repository (2060 ?)

RADIOACTIVE WASTE DISPOSAL – CONCEPT

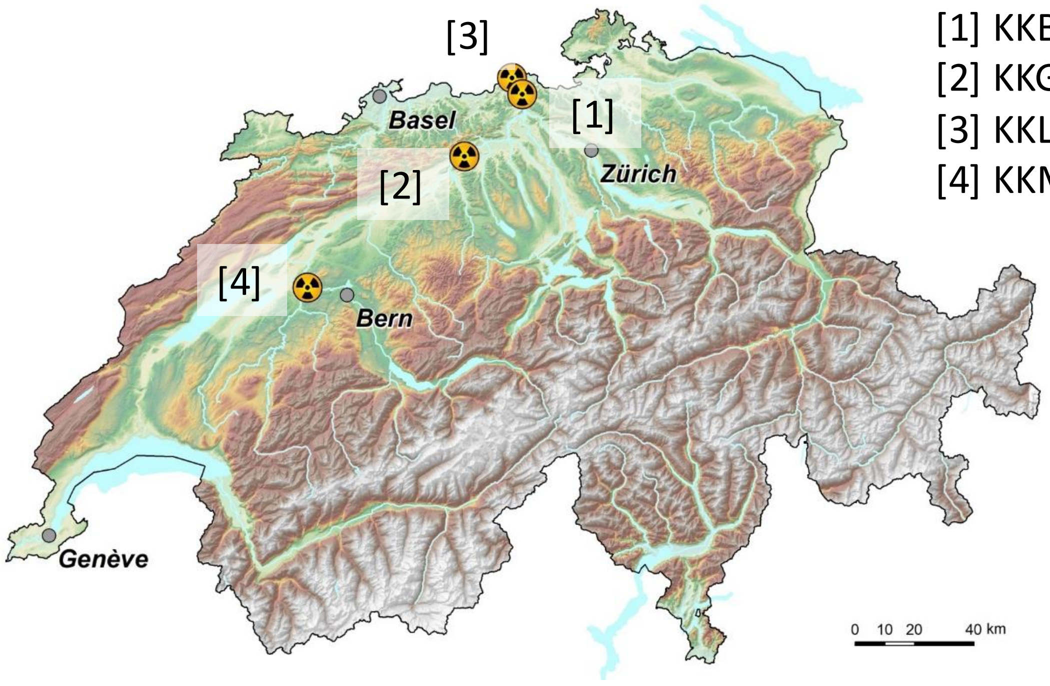
- Opalinus Clay, sufficient depth, large area, fault-free zones → Nördlich Lägern
- Deep geological repository (DGR) for HLW and LLW



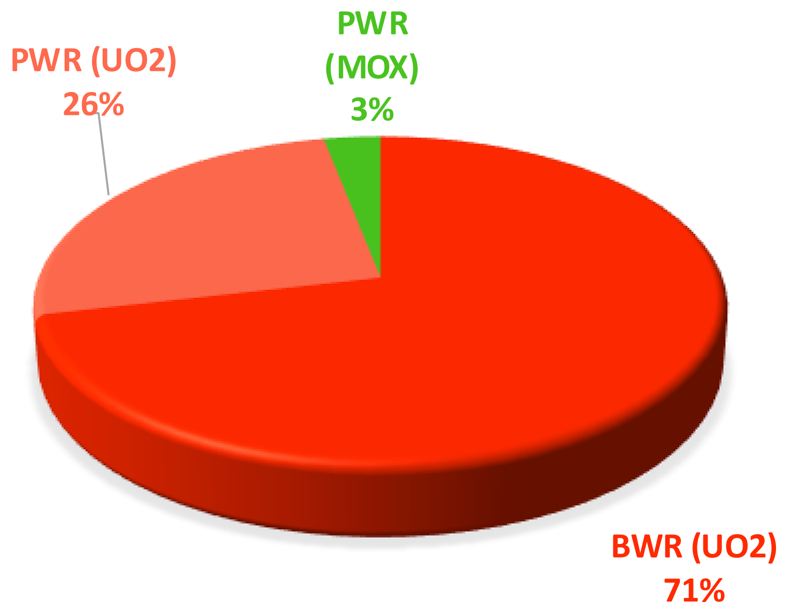
[Nagra's siting proposal additional info]



EXPECTED HIGH-LEVEL WASTE INVENTORY



Legend:
[1] KKB Beznau I & II: PWR (UO_2 & MOX)
[2] KKG Gösgen: PWR (UO_2 & MOX)
[3] KKL Leibstadt: BWR (UO_2)
[4] KKM Mühleberg: BWR (UO_2) – in decommissioning

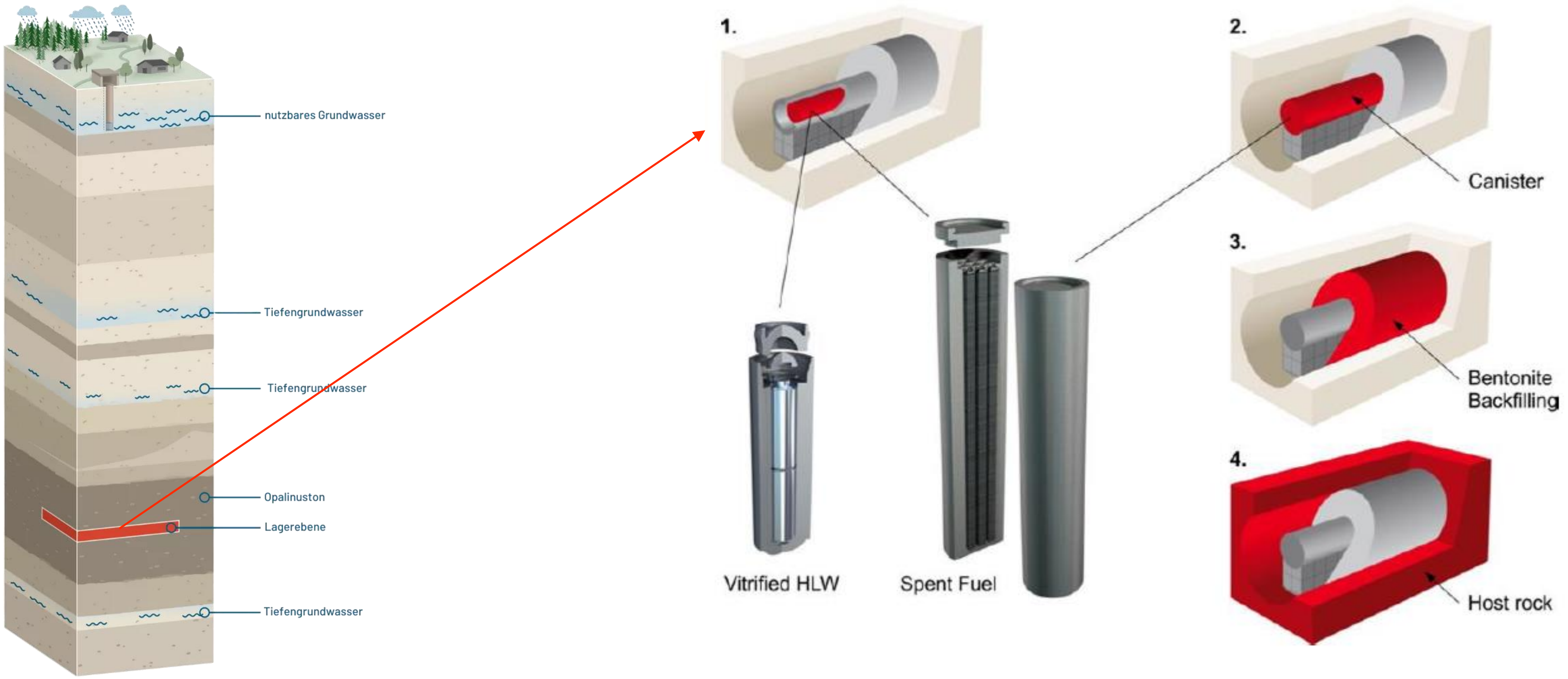


Considering an NPP operation time of 60 years:

- ca. 1’200 reprocessed waste packages
- ca. 12’400 spent fuel assemblies (SFA)

SWISS CONCEPT FOR HIGH-LEVEL WASTE FINAL DISPOSAL

- Multi-barrier system in a stable environment

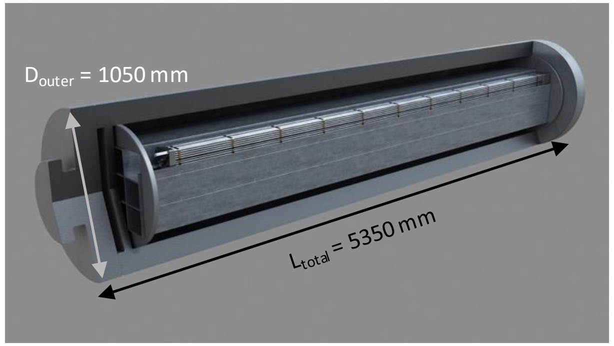


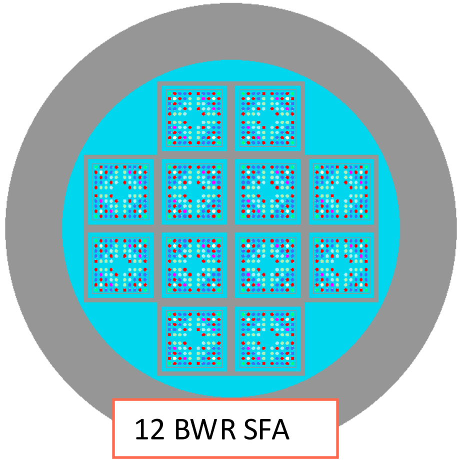
CRITICALITY SAFETY

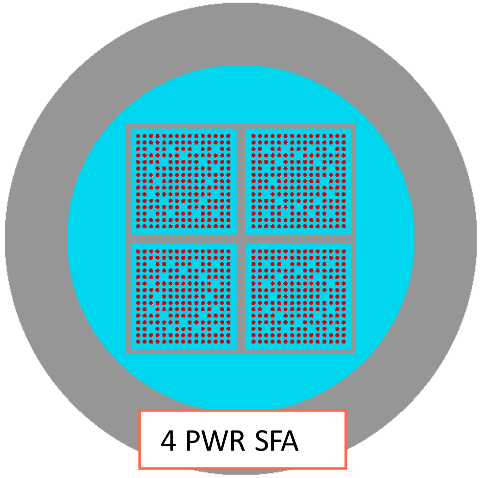
- Swiss regulatory guideline - ENSI G03:

  "Appropriate measures have to be taken to ensure that nuclear criticality cannot occur either during the operational phase or after closure of a deep geological repository."

- **Criticality safety of a deep geological repository can be ensured through:**
  - **Technical measures** – e.g. the design of the final disposal waste package for high-level waste





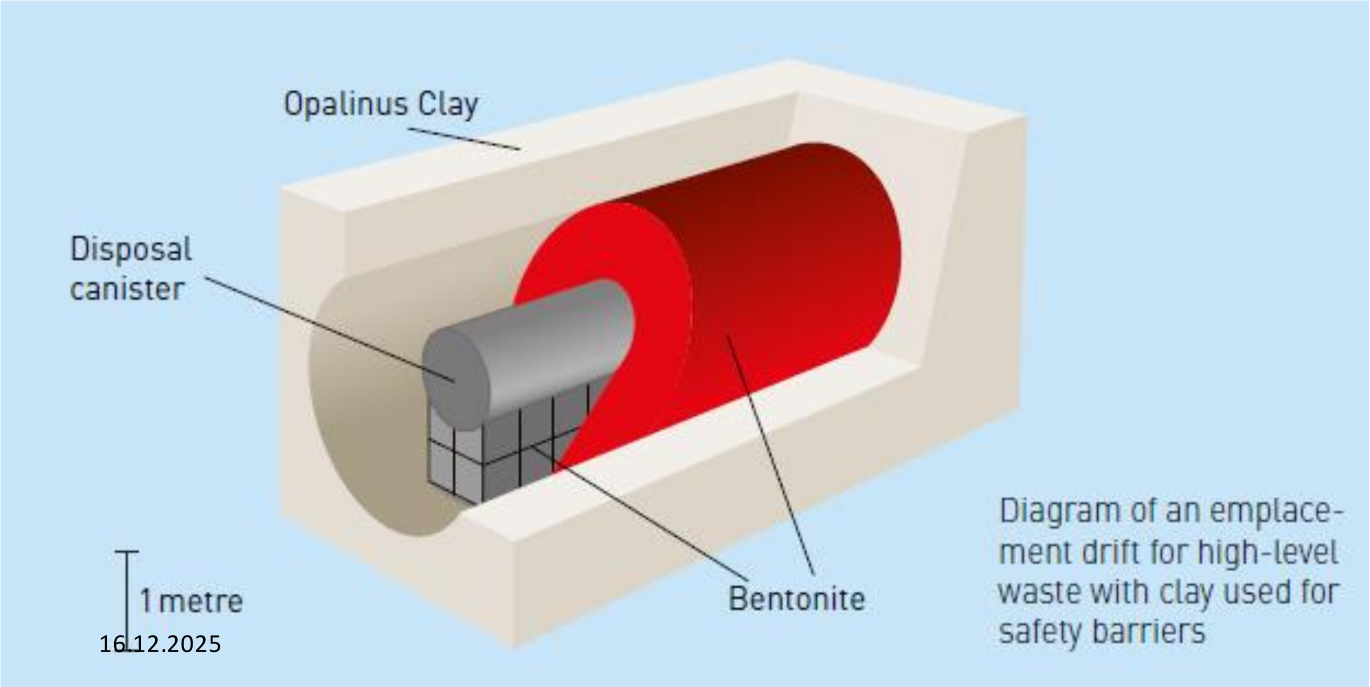


  - **Administrative measures** - e.g. identify optimal limit for fissile material per waste package & configuration

CRITICALITY SAFETY

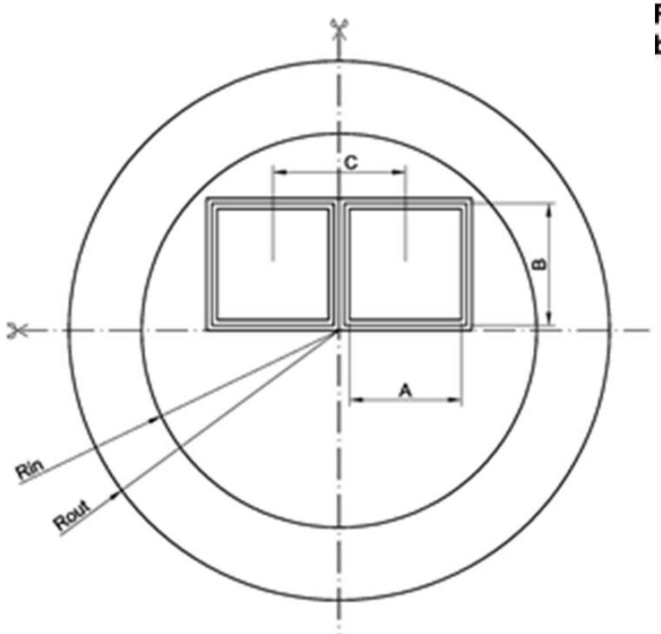
Ongoing work:

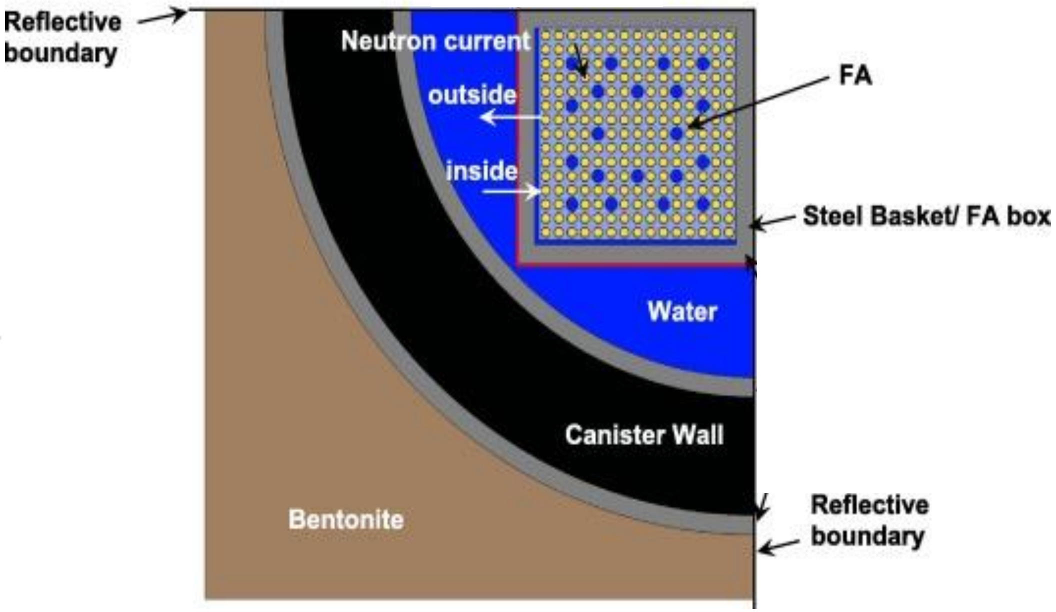
- Exploring solutions for container design optimisation that could contribute to ensuring criticality safety;
- Investigating criticality safety for long-term repository evolution scenarios (including postulated canister degradation);

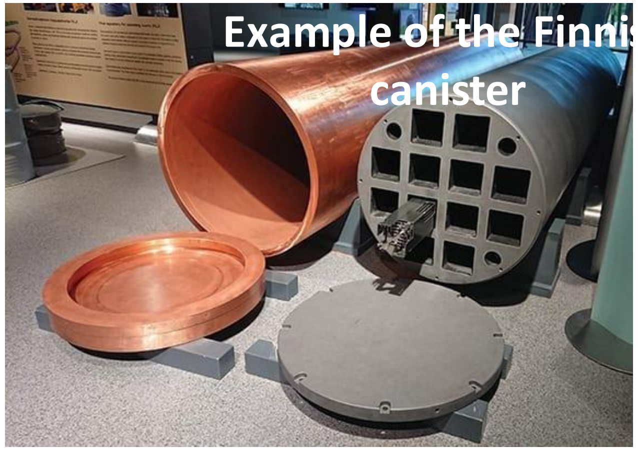


EXAMPLES FOR A PWR CANISTER

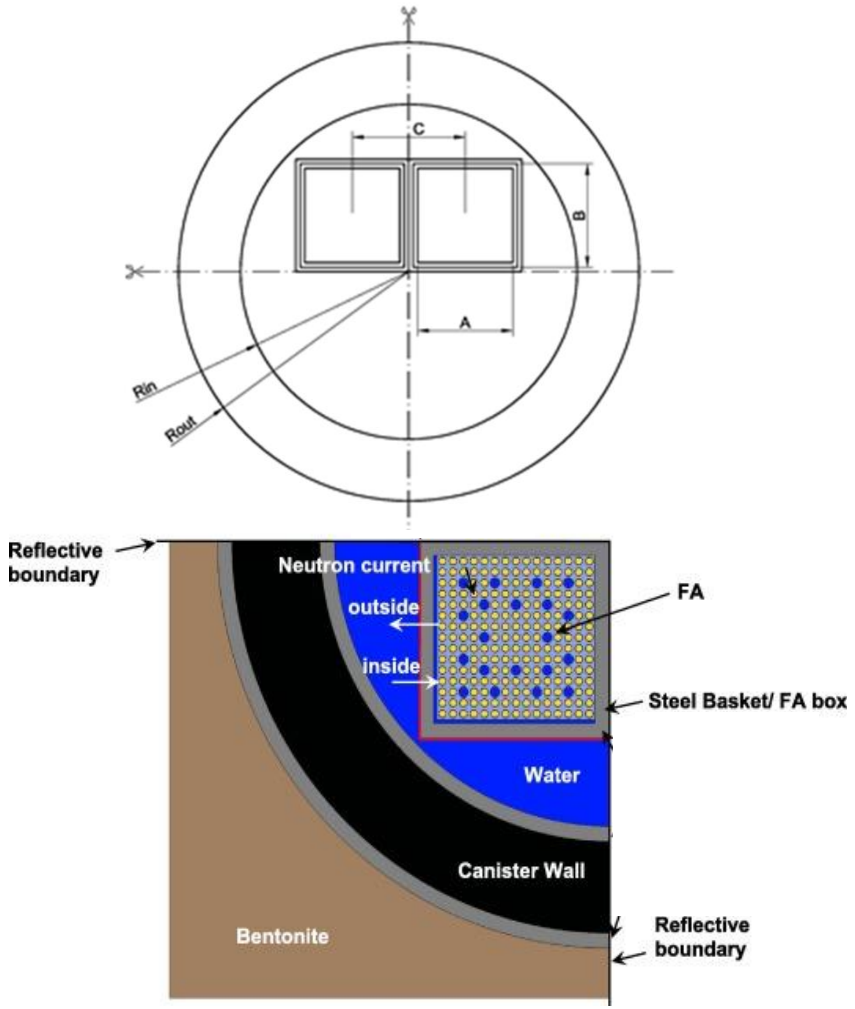
- Canister with 4 PWR SNF,
- Flooded, pure water, (likely to be salty and at about 50˚C)
- Concepts vary between countries

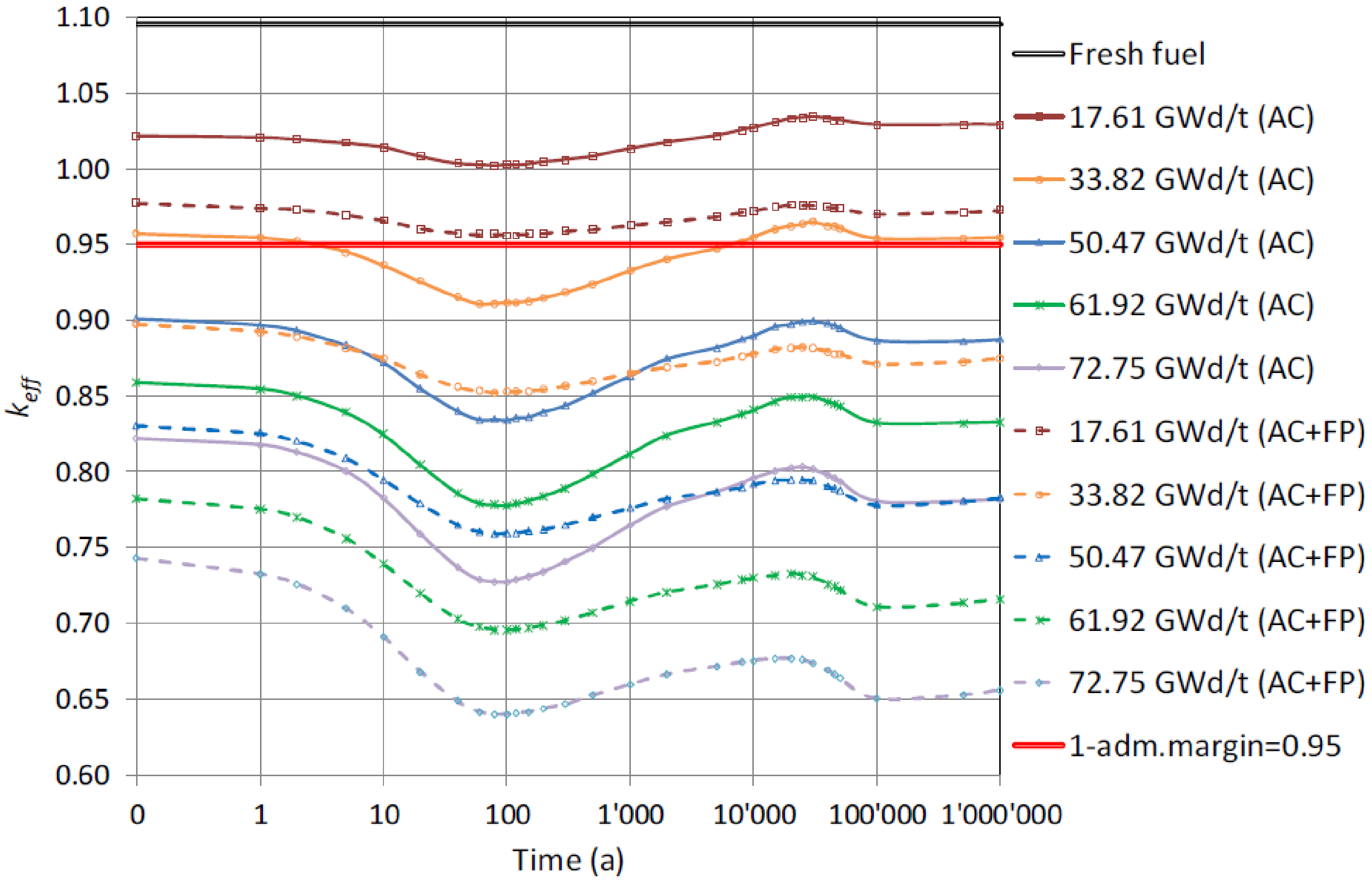






EXAMPLE FOR A PWR CANISTER

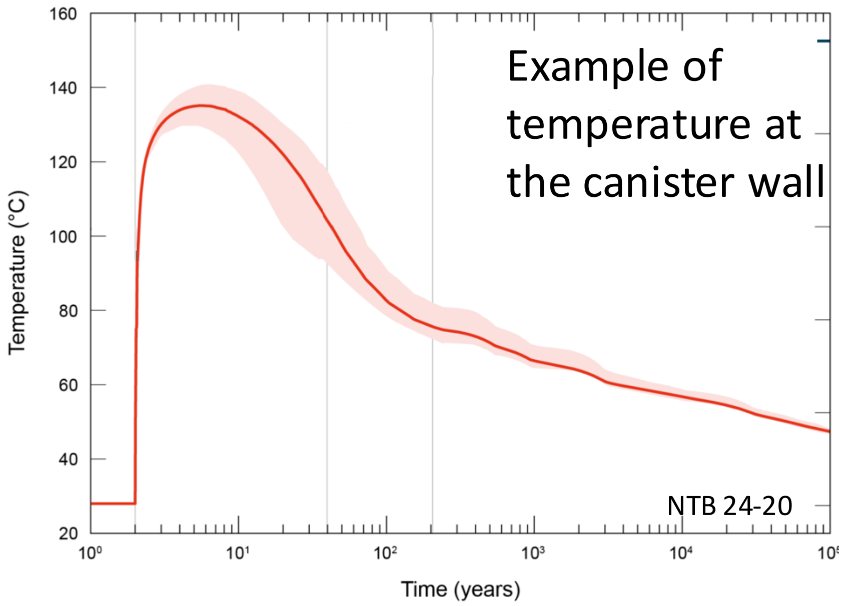




https://www.mdpi.com/1996-1944/12/3/494

EXAMPLE FOR A PWR CANISTER

- Burnup credit is a possibility, implying:
  - Assessment of uncertainties (e.g. from nuclear data)
    - Structural materials
    - Actinides
    - Fission products
  - Validation of calculations
    - Relevant crit-saf. benchmarks (possibly shielding)
    - Other experimental data for burnup validation
  - Adapt the canister design



EXAMPLE FOR A PWR CANISTER

- Examples of materials to be considered:
  - Structural materials: cladding (Cr, Fe, Zr), stainless steel (Mn, Cr, Ni, Fe), copper (and impurities)
  - Surrounding materials (e.g. bentonite): Si
  - Water (with or without salt)
  - Actinides & fission products: UO_2 fuel
    - Fresh ($^{234,235,236,238}U$, ^{16}O)
    - Burned

Actinide and fission product nuclides important to burnup credit criticality analyses

^{234}U	^{235}U	^{236}U	^{238}U	^{237}Np	^{238}Pu
^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu	^{241}Am	^{243}Am
^{95}Mo	^{99}Tc	^{101}Ru	^{103}Rh	^{109}Ag	^{133}Cs
^{143}Nd	^{145}Nd	^{147}Sm	^{149}Sm	^{150}Sm	^{151}Sm
^{152}Sm	^{151}Eu	^{153}Eu	^{155}Gd	–	–

EXAMPLE FOR A PWR CANISTER

- Examples of relevant criticality safety benchmarks:
  - Thermal spectrum
  - Low enriched or mixed (LCT or MCT)
  - Containing structural materials
  - Have a «high» correlation with canister models

- With Copper: LCT9 (reflector), 12, 13, 16, 42, 44, 74, 110. MCM1, MCT14
- With Si: ø
- With Fe: LCT43 (reflector), LCT88, … MCT16
- With Ni: LCT88 (reflector)
- With Zr: LCT16 (reflector)
- With Sm: LCT50
- With Gd: LCT5, LCT52

EXAMPLE FOR A PWR CANISTER

- ENDF-6 Processing for MCNP6.3:
  - ACE files provided by MCNP (tests with ENDF/B-VII.1)
  - perturbed ACE files: NJOY-2016.78 (for covariances) and FRENDY 2.05 (for perturbation)

- Isotopes for perturbation:
  - ^{1}H, ^{12}C, ^{16}O, ^{28}Si, ^{63,65}Cu, ^{56}Fe, ^{90}Zr, ^{235,238}U, ^{239}Pu covariances from ENDF/B-VII.1
  - ^{63,65}Cu no covariances in ENDF/B-VII.1, use JEFF-3.3
    - ^{63,65}Cu JEFF-4.0 instead have processing issues with NJOY
    - ^{63,65}Cu ENDF/B-VIII.1 (INDEN) has no MF33

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*** Parity problem ***
    Group and channel #     1     1
    Spin, L, Chspin =    -1.0    0     1.0
*** Parity problem ***
    Group and channel #     2     1
    Spin, L, Chspin =    -2.0    0     1.0
*** Parity problem ***
    Group and channel #     4     1
    Spin, L, Chspin =     1.0    1     1.0
*** Parity problem ***
    Group and channel #     4     2
    Spin, L, Chspin =     1.0    1     0.0
*** Parity problem ***
    Group and channel #     5     1
    Spin, L, Chspin =     2.0    1     1.0
*** Parity problem ***
    Group and channel #     5     2
    Spin, L, Chspin =     2.0    1     0.0
*** Parity problem ***
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***error in gridd***mt 41 referenced in derivation formula
                     for range  1 does not appear in mfcov
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EXAMPLE FOR A PWR CANISTER

- (Preliminary) results for the nuclear data uncertainties
- Benchmarks at room temperature

k_{eff} uncertainties	Actinides/U5/U8/Pu9 (pcm)	Others /Fe56/O16 (pcm)	Total (pcm)
Canister Fresh fuel	794 / 760 / 305 / 0	483 / 326 / 100	940
Canister Burned fuel	392 / 273 / 230 / 60	331 / 200 / 88	540
Benchmark mct9-1	570 / 40 / 405 / 520	250 / 10 / 85	660
Benchmark lct9-1	800 / 750 / 320 / 0	620 / 25 / 180	1080

- Effect of burnup (decreasing uncertainty, but increase of fission products)
- Combination of benchmarks will be necessary

CONCLUSION

- Nuclear data needs for canister for criticality calculations:
  - Uncertainties & processable files
  - Low bias
  - Structural materials: cladding (Cr, Fe, Zr), canister material (stainless steel Mn, Cr, Ni, Fe & Cu), bentonite (Si)

- Relevant criticality benchmarks:
  - Thermal spectrum, low enriched, mixed (possibly shielding)
  - Corresponding materials (structure and fission products) & geometry
  - Corresponding temperature(s)

- Other benchmarks (e.g. shielding) ?

THANK YOU FOR YOUR ATTENTION – QUESTIONS?

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