ERDO

Association for Multinational Radioactive Waste Solutions

Borehole disposal
Lessons learned from an ERDO project

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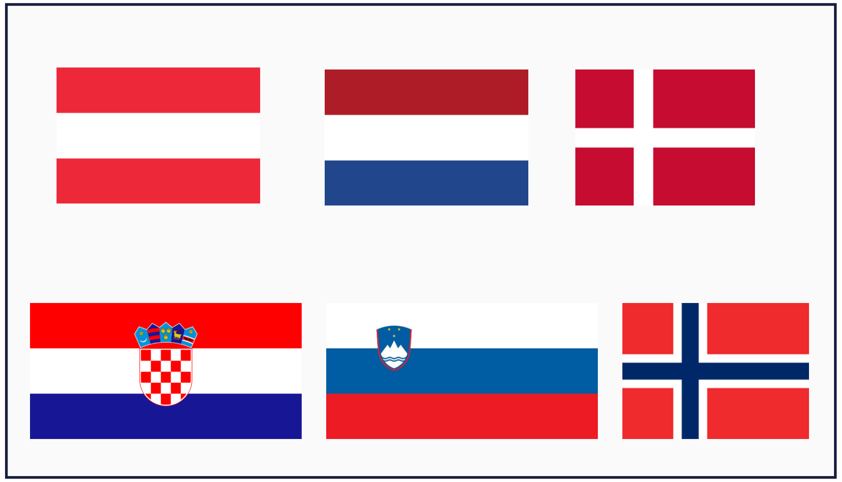
Borehole disposal project

Outputs:

- Generic borehole disposal concepts
- Waste inventory compatibility with borehole disposal
- Strategic implications of borehole disposal
- Maturity of safety case
- Costs
- Time of implementation
- RD&D-needs



Duration: January 2020 to June 2022

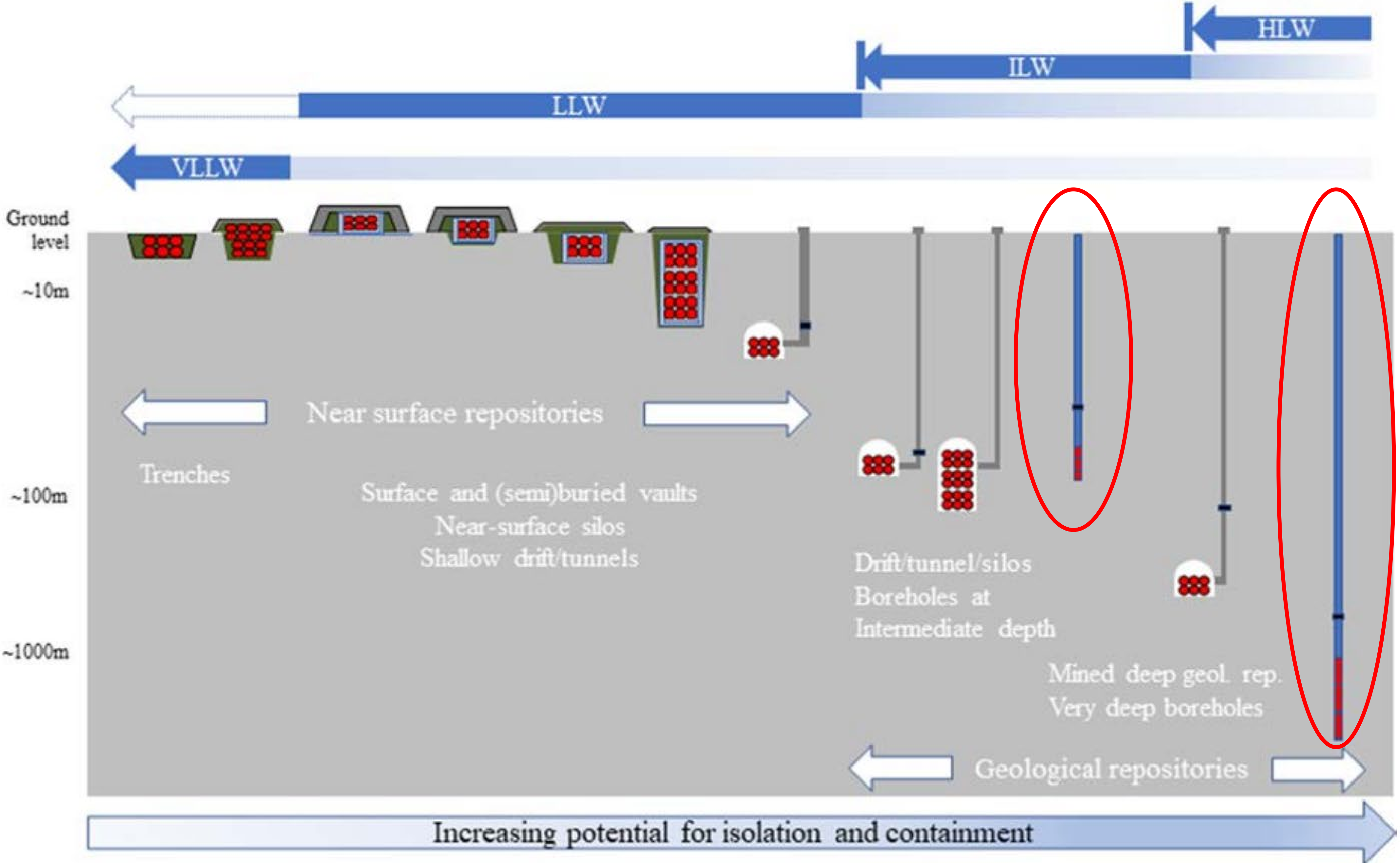


Image: IAEA, Status and Trends in Spent Fuel and Radioactive Waste Management, 2022

Deep borehole disposal is feasible

- Deep borehole disposal has been studied since at least 1976
- Studies commissioned by NND during 2020-2021:
    - University of Stavanger and University of Waterloo
    - BGE-TEC
    - Halliburton
- Several ongoing or recent initiatives:
    - IAEA Coordinated resesarch project
    - Private companies like Deep Isolation
    - Sandia NL
    - CSIRO

Halliburton:

«We have a rig that is available, when do you need it?»

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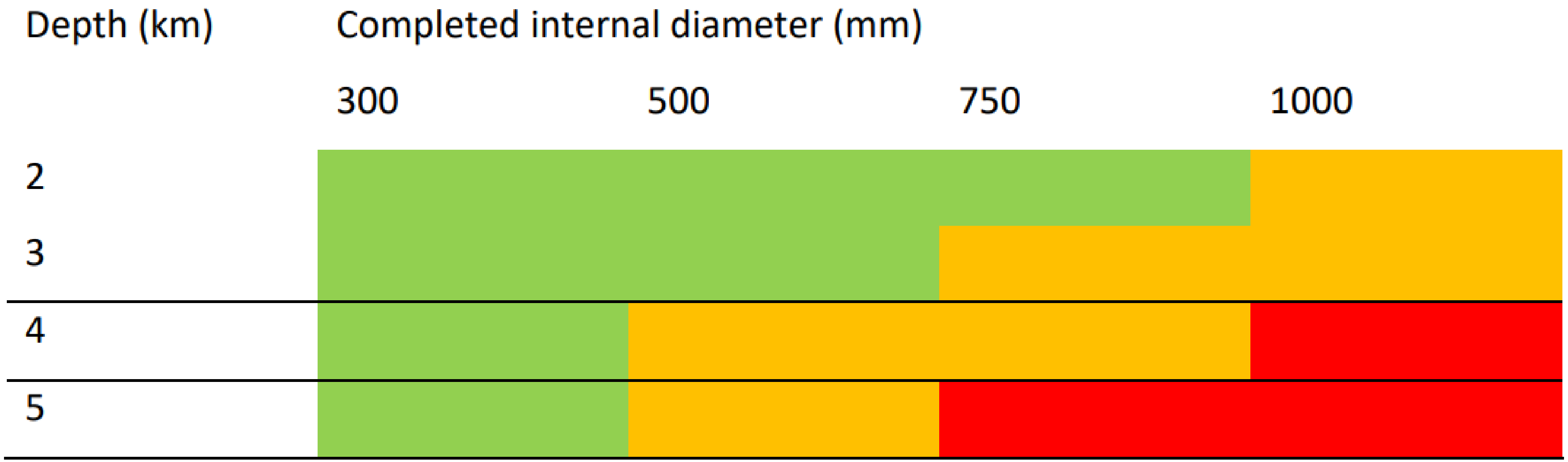
Deep borehole disposal is feasible

Table 2-1: Feasibility of drilled diameter for different borehole depths (Beswick, 2008)



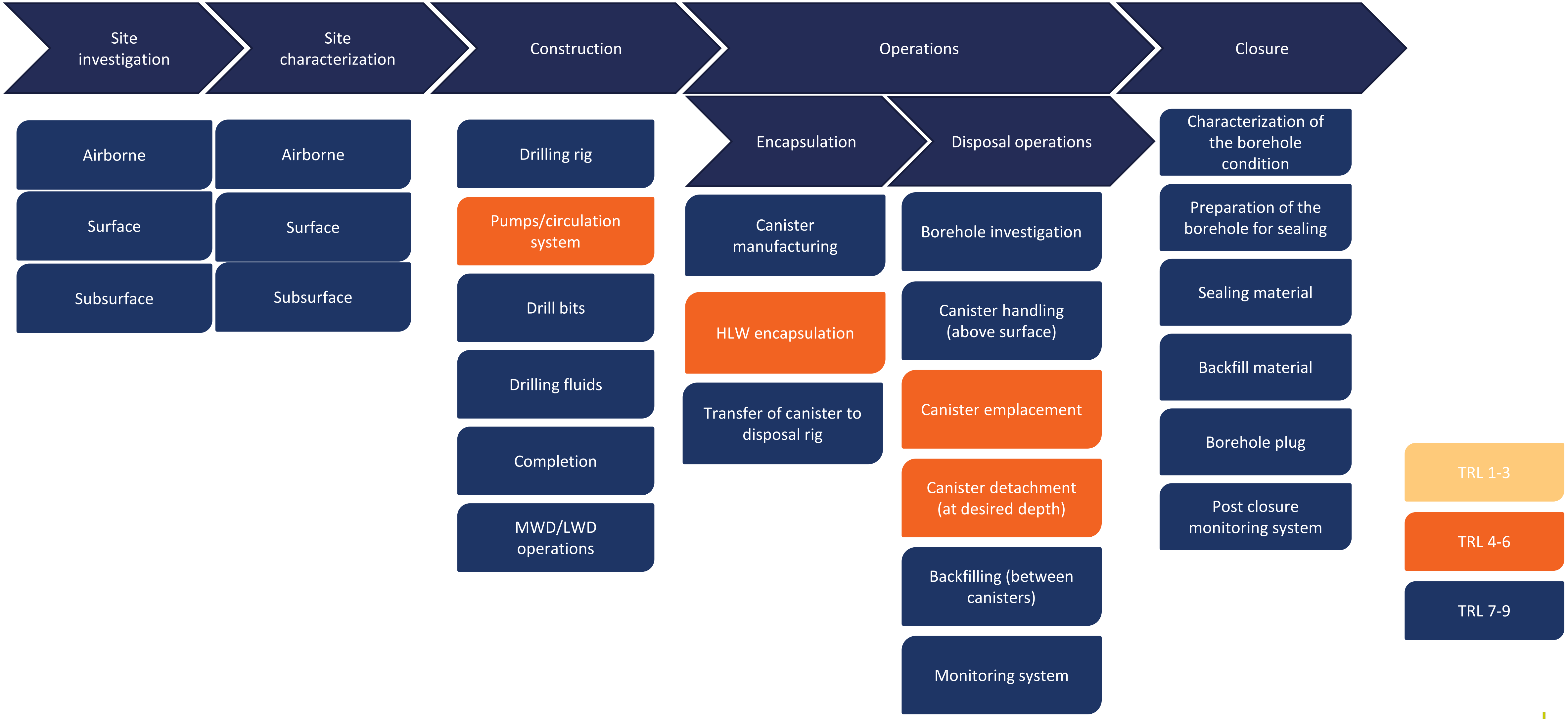
Key: **Green** = feasible with current technology and favorable geological conditions

Orange = may be achievable with tool and process development

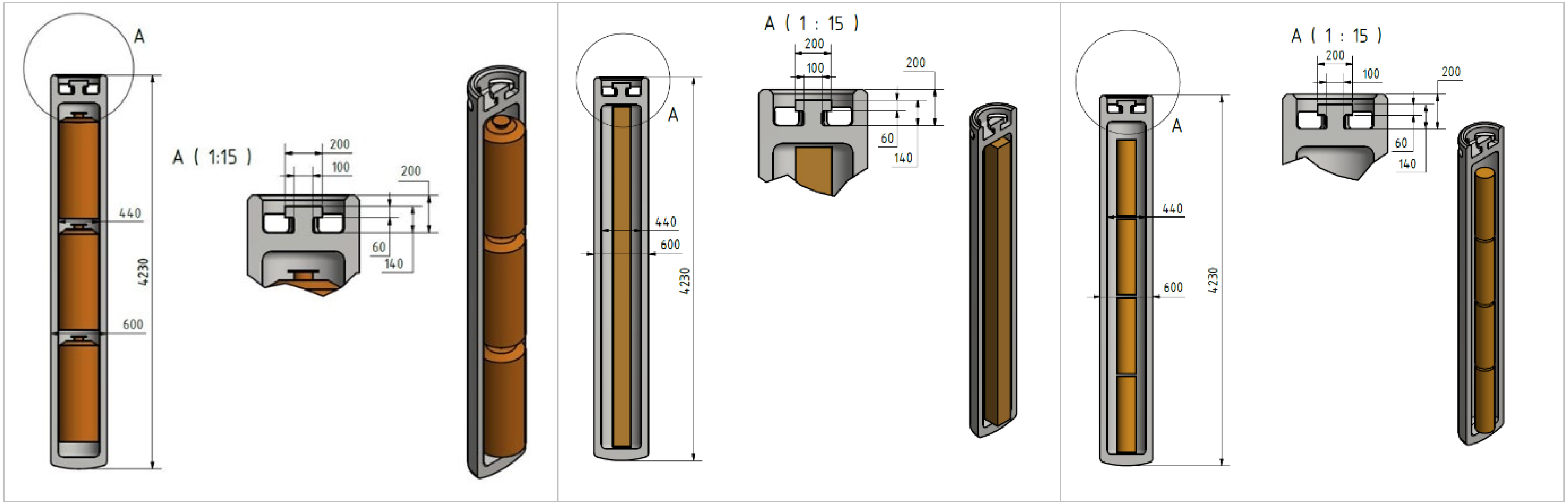
Red = considered impractical in the foreseeable future

Aadnøy & Dusseault (2020), https://www.norskdekommisjonering.no/wp-content/uploads/2020/10/Deep-Borehole-Placement-of-Radioactive-Wastes-A-Feasibility-Study-1.pdf

Overview of Technical Readiness Level for Deep Borehole Disposal



A generic canister design that suits several national inventories



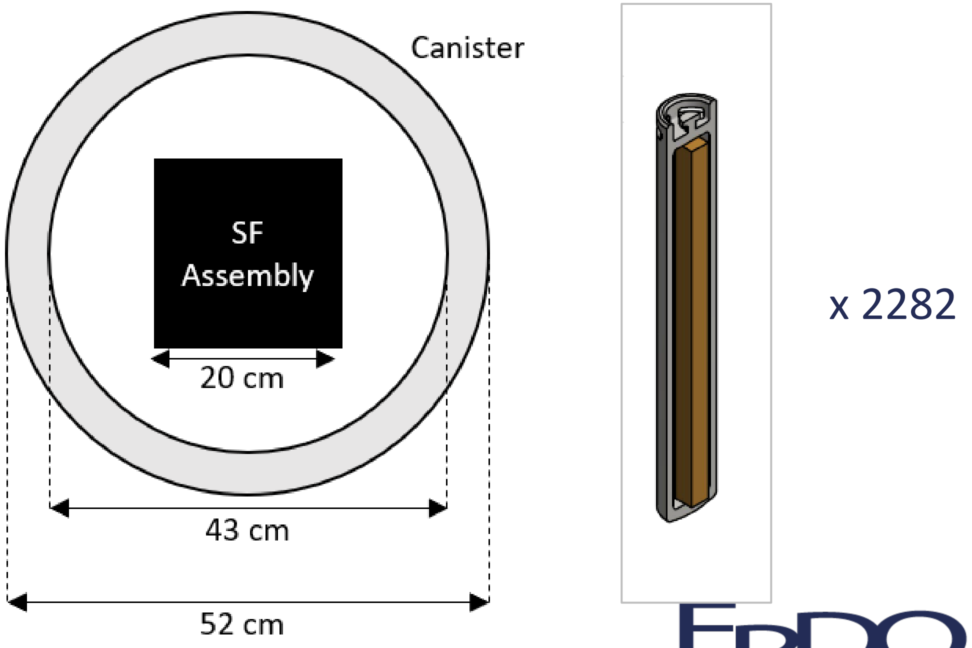
Borehole canister with reprocessing waste (left), SF (NPP Krško, middle), and Danish waste (right)

Croatia and Slovenia

- Share ownership and responsibility for the nuclear powerplant in Krško
- 2282 assemblies (926 tons) of spent fuel expected by final shut down
- Slovenia will also need to manage approximately 0.2 tons spent fuel from a Triga research reactor, which is expected to remain in operation until 2043. For simplicity, the Triga fuel is not included in the following analysis
- 1 fuel assembly per borehole canister gives 2282 canisters
- Narrower canisters (lower cost for the same borehole length) or wider canisters (>1 assembly per canister) should be considered

Decommissioning and operation of an encapsulation facility for spent fuel is expected to generate 409 m^3 HLW, packed in HI-SAFE-containers (diameter = 2.5 m, too large for boreholes)

Photo: Slovenia Times



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Denmark

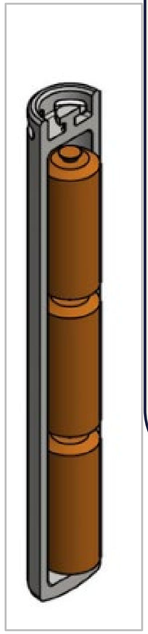
- Denmark has had three research reactors in operation. All have been shut down.
- The fuel has been returned to the country of origin, but 233 kg of residues from post-irradiation experiments remain. This is classified as high-level waste (but it is not heat generating)
- The 233 kg are held in 33 stainless steel cylinders, 5 of which could fit in each borehole canisters. Therefore, Denmark would need 7 borehole canisters.

7 x

The Netherlands

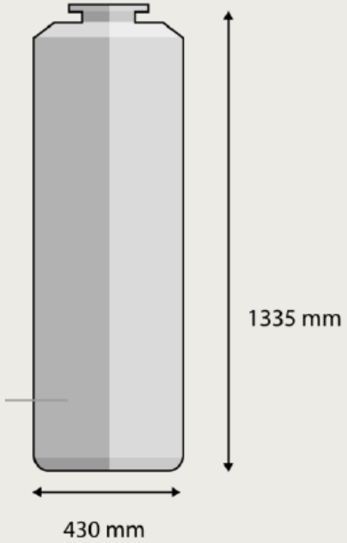
- Nuclear power plants:
  - Borsele (1973-)
  - Dodewaard (1969-1997)
- Research reactors:
  - High-flux reactor (1961-)
  - Low-flux reactor (1960-2010)
  - Hoger Onderwijs Reactor (1963-)
- The Dutch strategy is to accumulate and store waste until 2130, while investigating permanent solutions

Waste from reprocessing would require 359 canisters

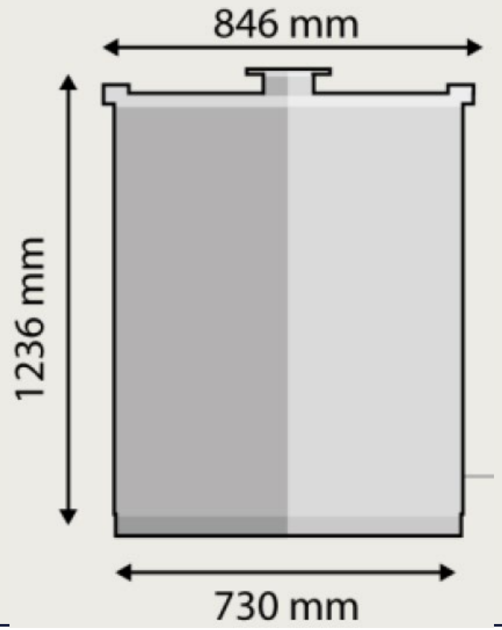


Expected inventory in 2130

1078 canisters of reprocessing waste (CSD-V and CSD-C). These could fit in 359 borehole canisters



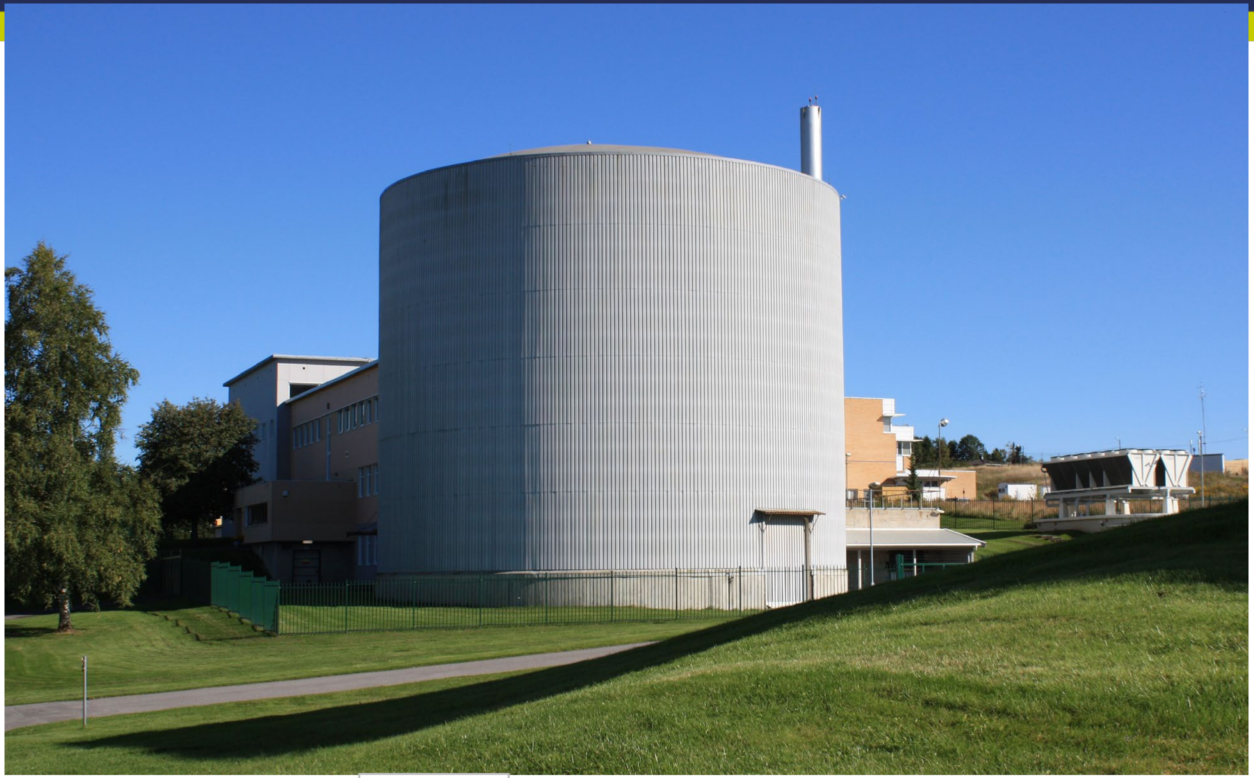
350 ECN-containers of spent research reactor fuel and other HLW. ECN-containers are too wide for the reference borehole



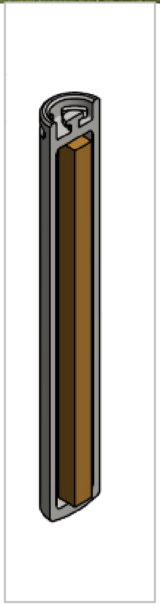
Figures: COVRA

Norway

- Norway has had four research reactors in operation. All are now shut down.
  - Joint Establishment Experimental Pile I (JEEP I)
  - Norwegian 0-energy Reactor Assembly (N0RA)
  - JEEP II
  - Halden Boiling Water Reactor
- 16.5 tons of spent fuel of various types require a long-term solution. It could all fit in 69 borehole canisters.

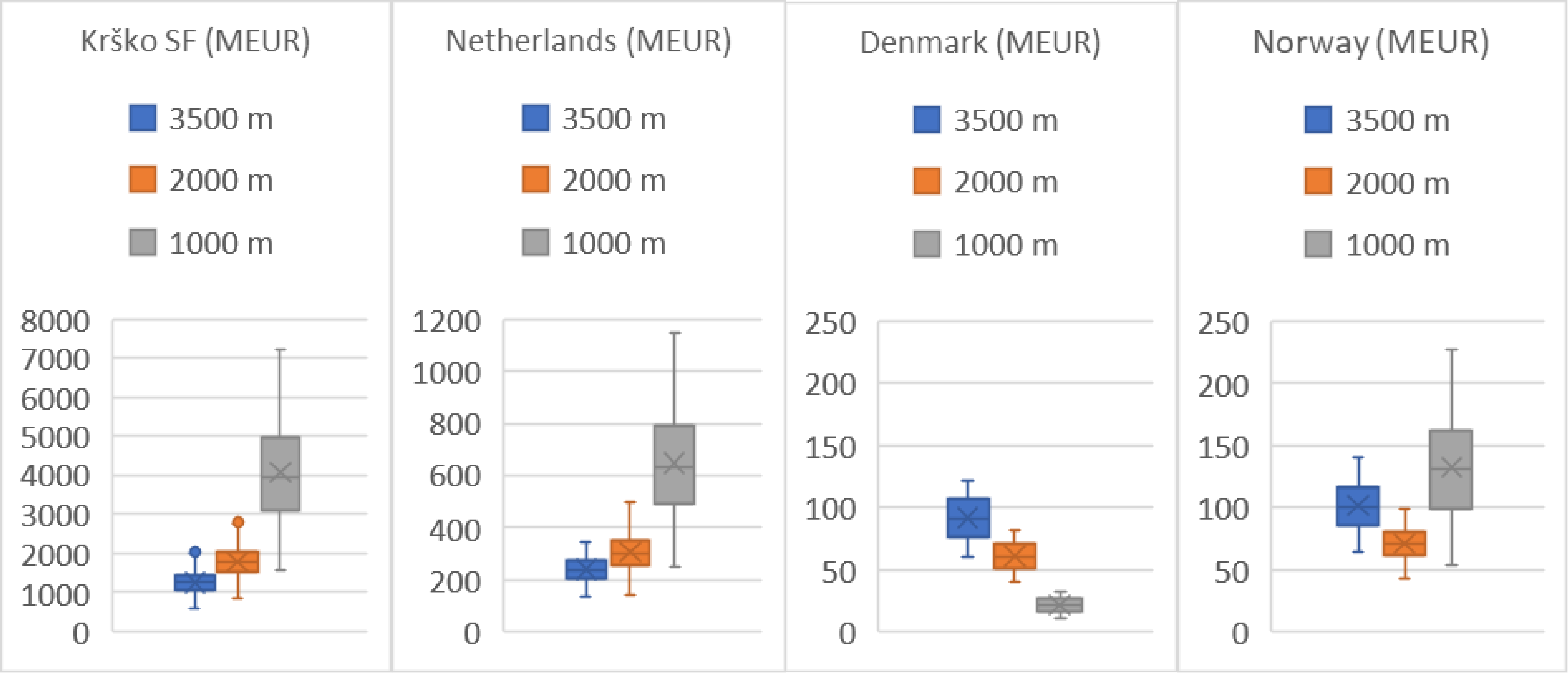


JEEP II (Photo: IFE)

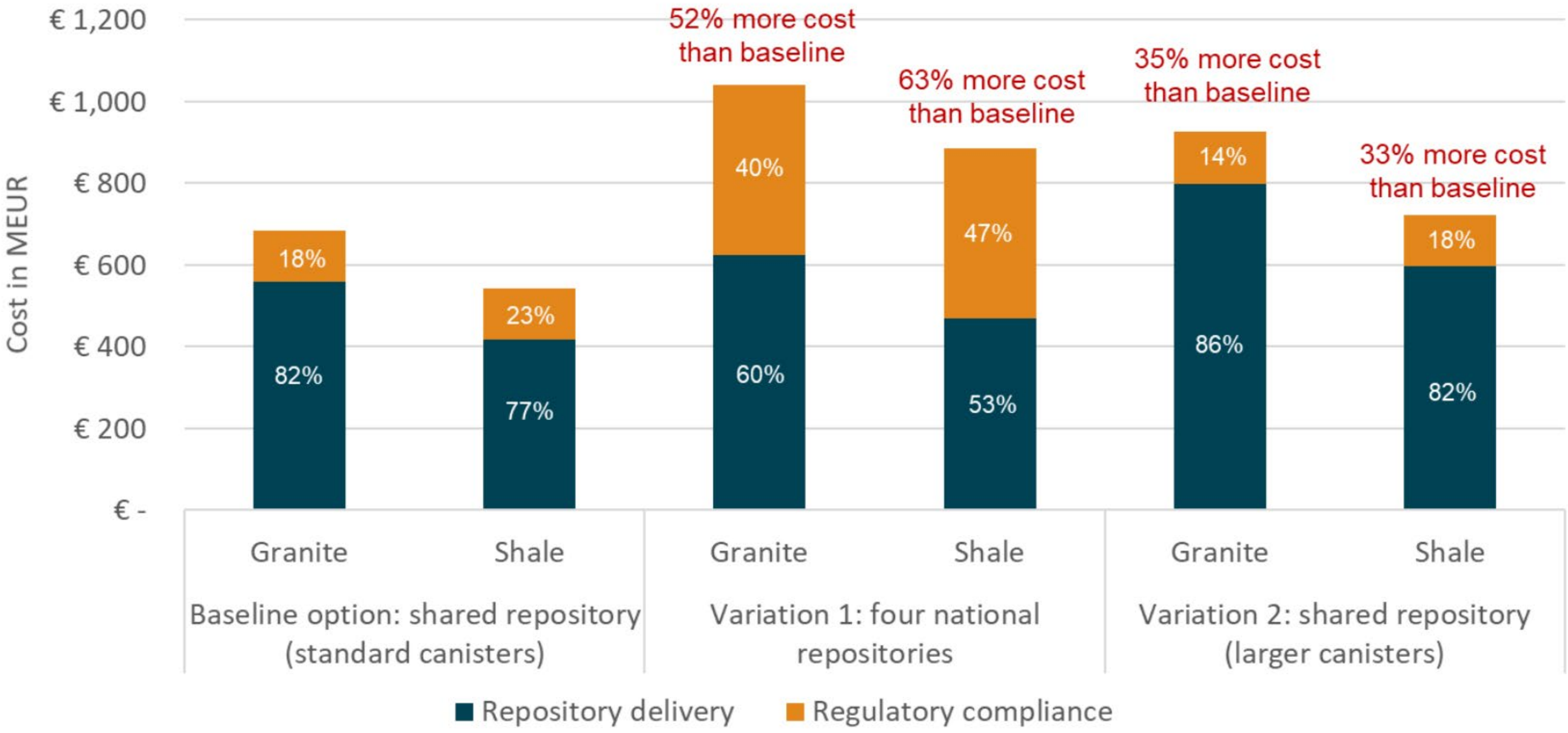


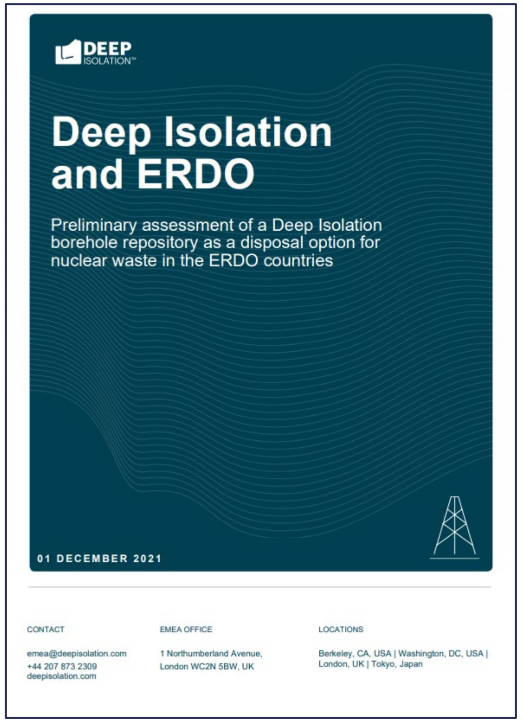
x 69

Cost estimates for disposing of the respective national inventories in boreholes of different depth.



A multinational repository is beneficial also if you use borehole disposal





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Austria

- One TRIGA research reactor
- Fuel-return agreement
- Storage and treatment of LILW at Nuclear Engineering Seibersdorf (NES)
- 60 m3 of long-lived LILW

Images: NES

Borehole disposal could be an option for small volumes of long-lived LILW

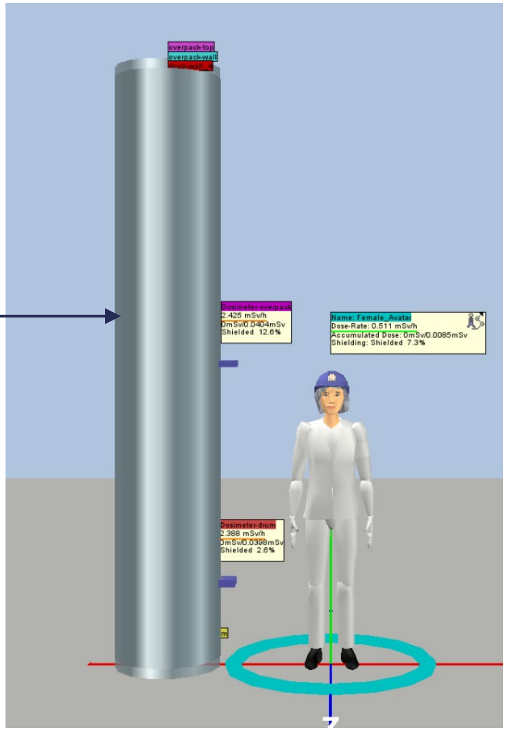
Example: Austria

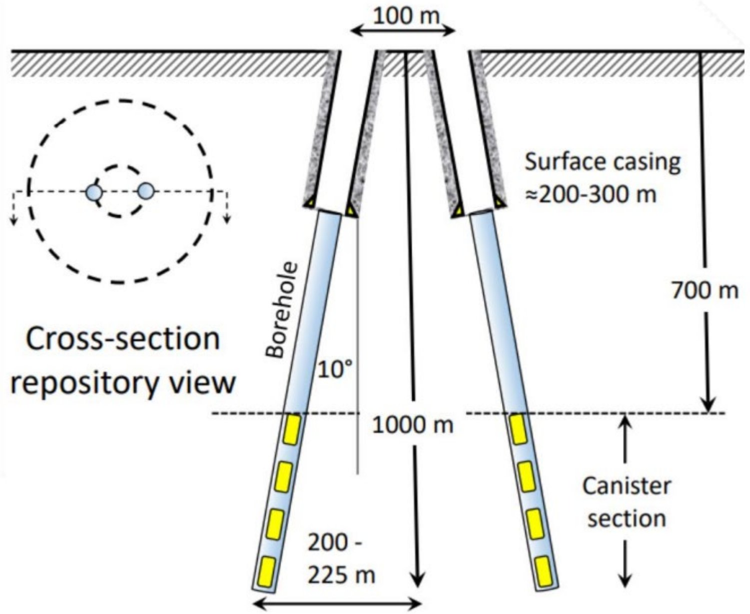
60 m3 LL-LILW

≈ 300 drums (200 liter)

= 75 overpacks

1 to 3 boreholes, costing < 10 MEUR





Conclusions

- Deep borehole disposal is feasible
- Deep borehole disposal could be a solution for ERDO countries
- Potential gains from collaborating on:
  - Technical development, safety assessment
  - Licensing
  - Supply-chain development and procurement
- A shared repository is beneficial also for borehole disposal
- Borehole disposal is also an option for small volumes of long-lived LILW

Thank you for your attention

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