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Update on the Status of Deep Borehole Disposal (DBD) of High-Level Radioactive Waste in Germany

GRS

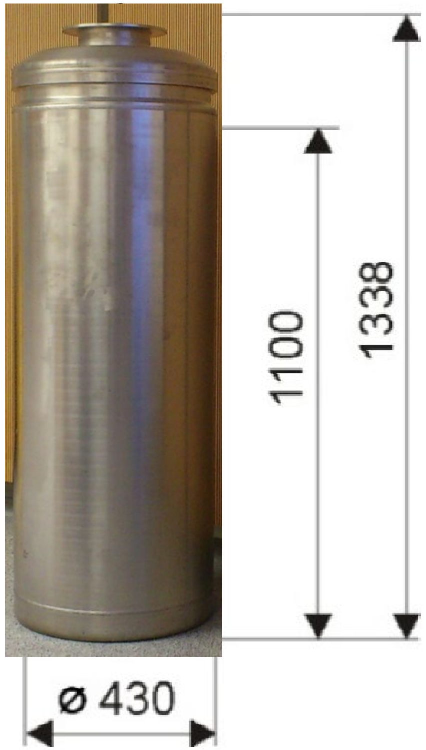
EUROSAFE 2019

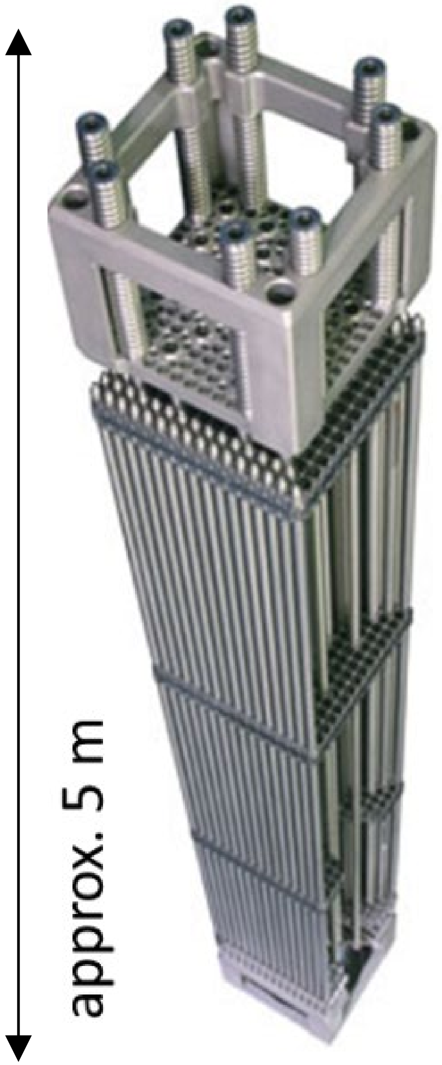
Content

- Inventory of HLRW
- Site Selection Act (Containment Providing Rock Zone, Requirements)
- Geology
- Drilling Technology, Container
- DBD Disposal concepts
- Cost estimate
- Discussion
- Conclusions / Outlook

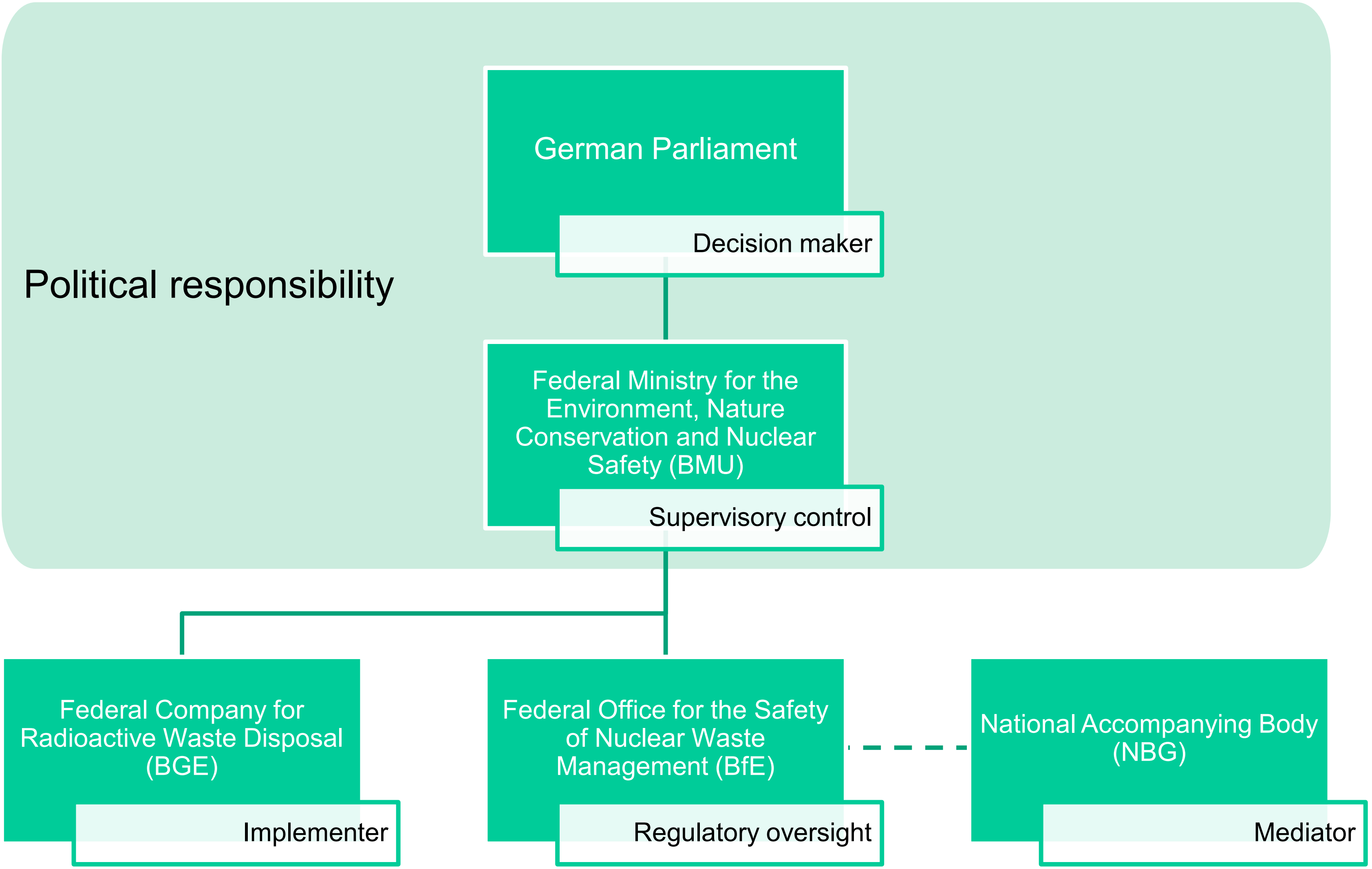
High-level radioactive waste in Germany

- Spent fuel elements (35000 pieces, 10500 Mg - 7600 m^3 as fuel rods)
- Vitrified waste (8000 pieces, 2000 m^3)
- Spent fuel pebbles (2000 m^3)

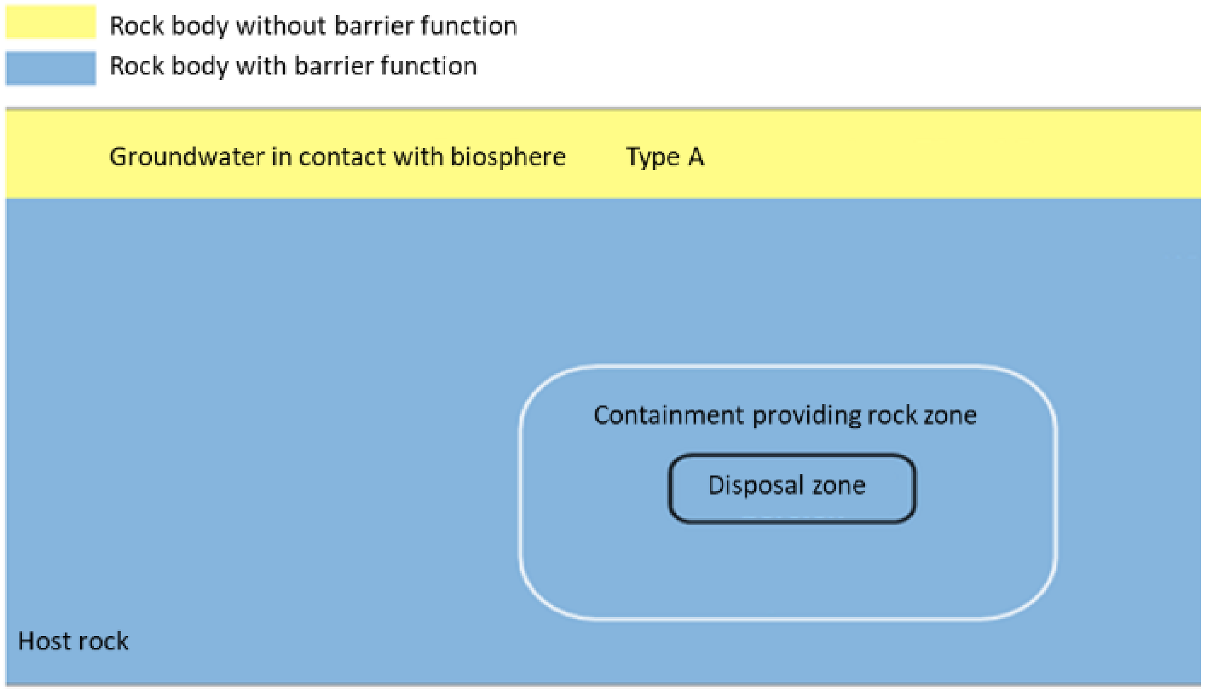


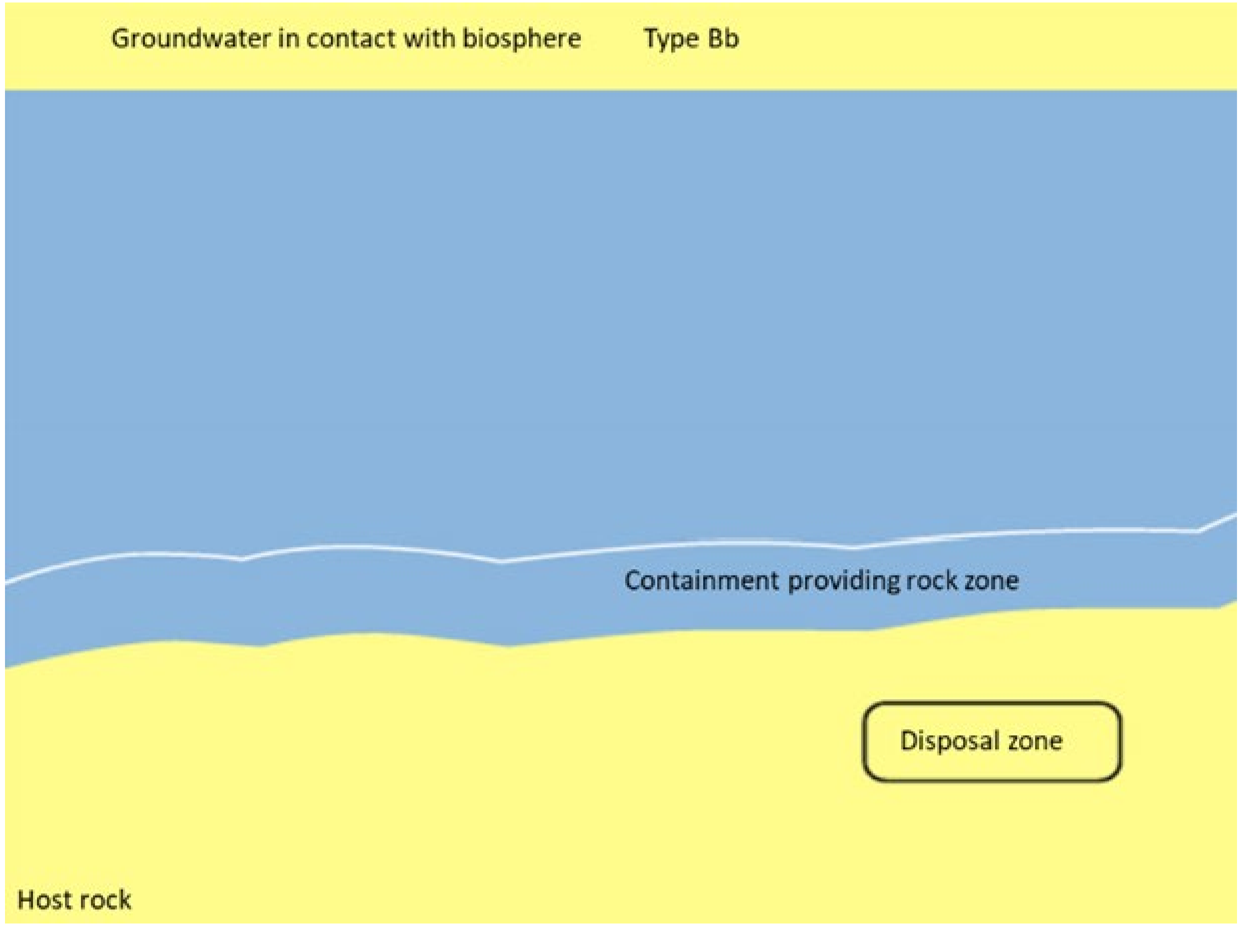


Site selection act (2017)



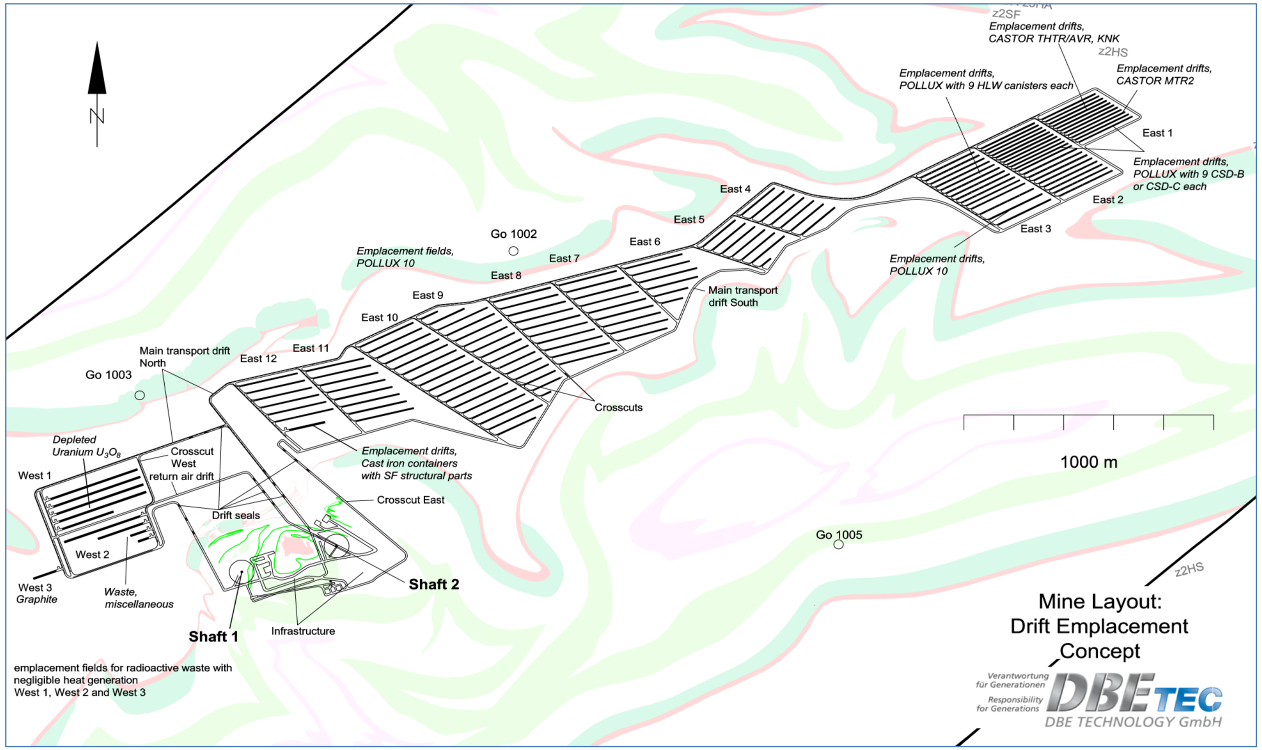
Containment providing rock zone

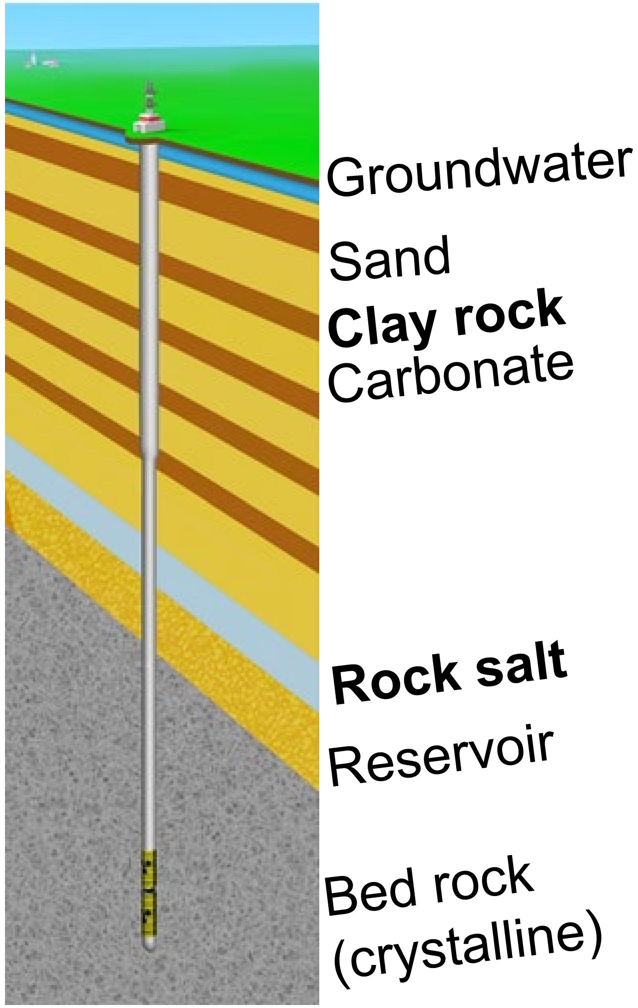




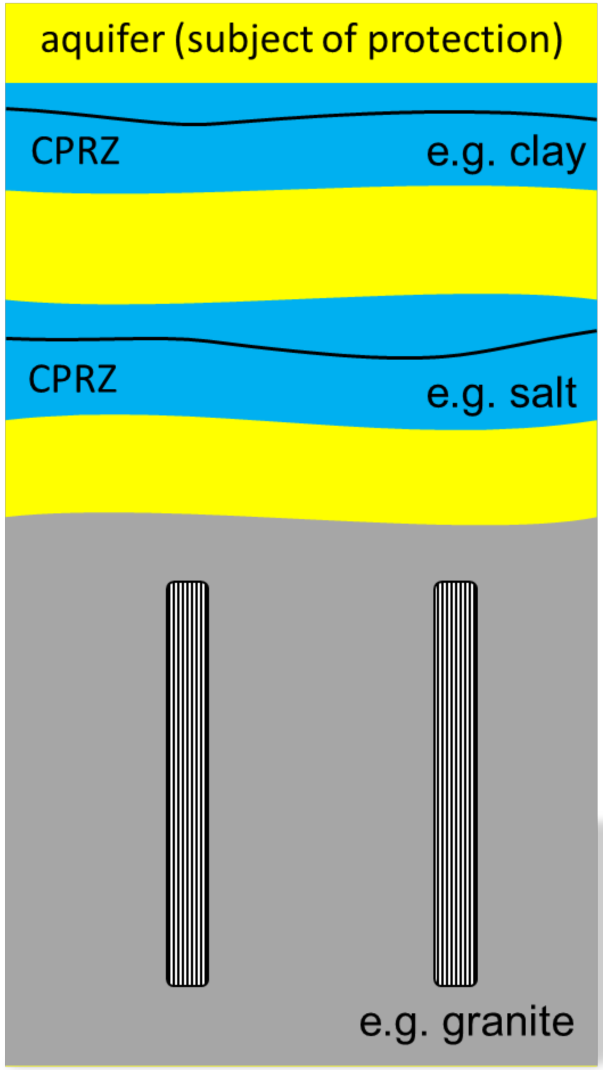
Geology and concepts

- Rock salt, clay rock, crystalline rock
- Disposal in mine versus DBD





Containment providing rock zone

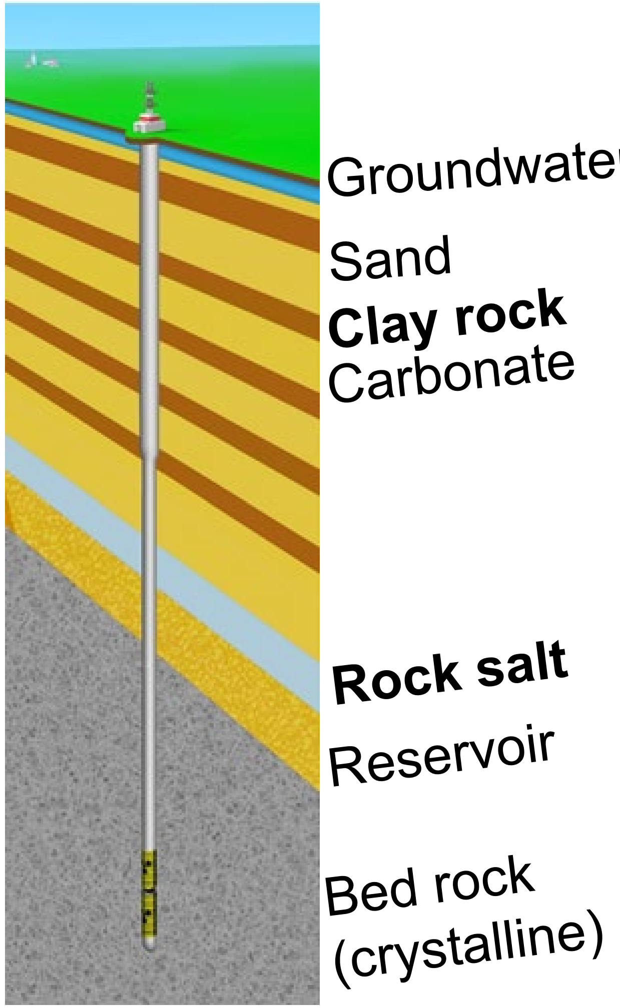


Rock without barrier functions

Rock with barrier functions (clay, salt)

Limit of containment providing rock zones (CPRZ)

Waste disposal zone (crystalline)



Requirements for quality and robustness of containment (StandAG)

	Requirement (§ 24 Abs. 3)	Comment regarding DBD
1.	Transport with groundwater in the CPRZ	achievable
2.	Favorable configuration of rock body, host rock and CPRZ	achievable
3.	Good spatial characterization	Tools to characterize host rock properties are available for greater depths but may pose a larger effort compared to lower depth. However the volume of rock to be characterized for a CPRZ for DBD may be smaller than for a conventional mined disposal site.
4.	Good predictability of the long-term stability of favorable conditions	achievable

Requirements for validation of containment (StandAG)

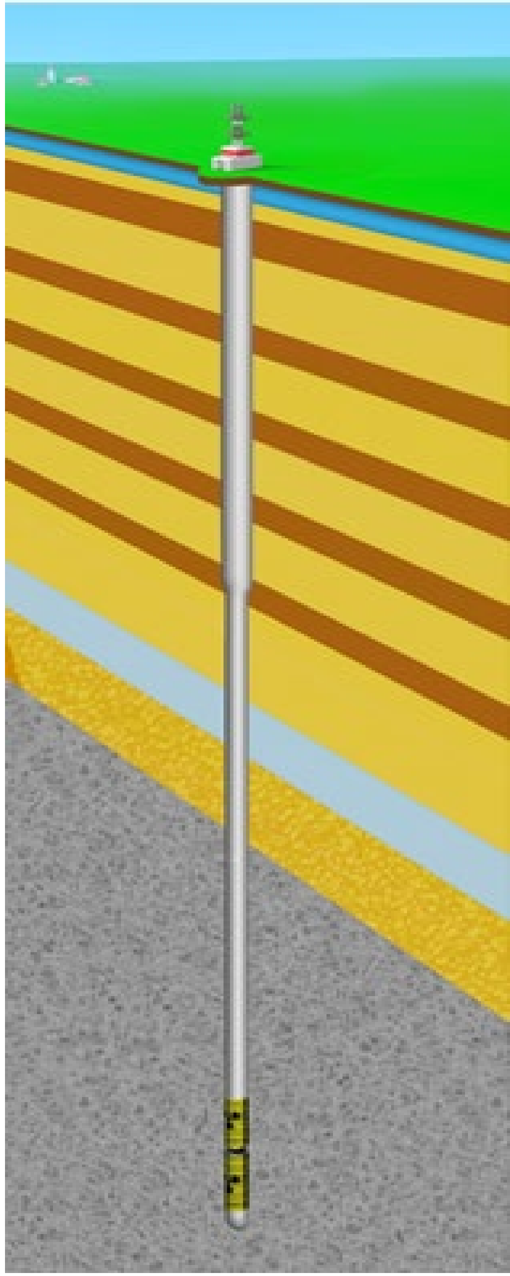
	Requirement (§ 24 Abs. 4)	Comment regarding DBD
5.	Favorable rock mechanics	achievable
6.	Low tendency to generate groundwater flows in host rock and CPRZ	achievable

Requirements for additional safety relevant features (StandAG)

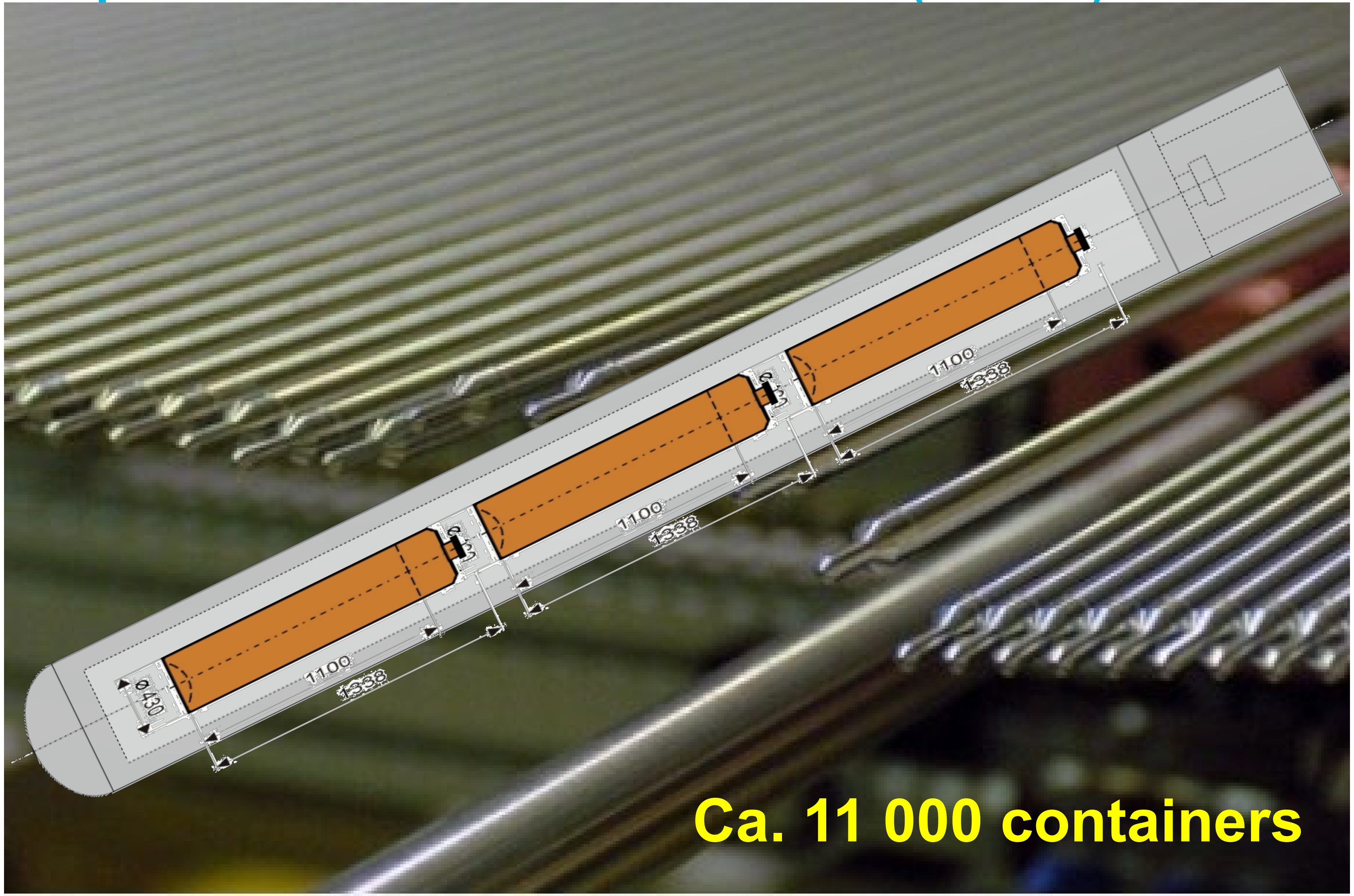
	Requirement (§ 24 Abs. 5)	Comments regarding DBD
7.	Low gas generation	Steel container and casing will inevitably lead to gas generation. A concept may minimize the use of steel or provide gas traps. However, gas generation cannot be completely avoided.
8.	Good temperature compatibility	achievable However, the temperature in the disposal zone will be higher than 100 °C due to the depth (§27 Abs. 4). The safety analyses assess the temperatures and its compatibility.
9.	Radionuclide retention in the CPRZ	achievable
10.	Favourable hydrochemistry	achievable
11.	Protection of CPRZ by overlying rock	achievable

Some questions

- Diameter of borehole ?
- Container ?
- Availability of sites in Germany ?
- „containment providing rock zone“ ?
- Reversibility ?
- …



Deep Borehole Container – Retrieval (DBC-R)



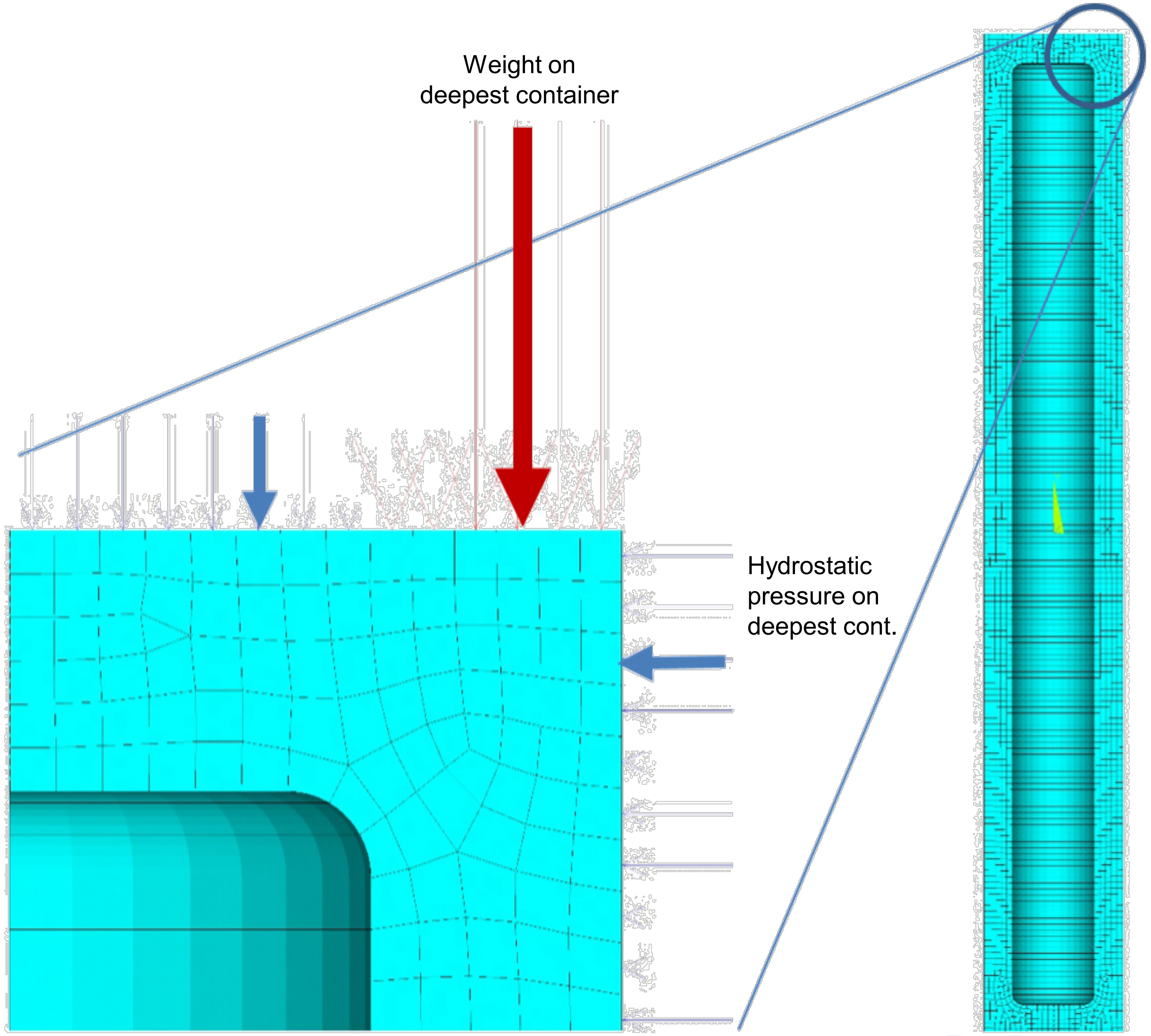
Net volume:
~ 0,72 m^3

Net mass container:
6,6 – 12 Mg

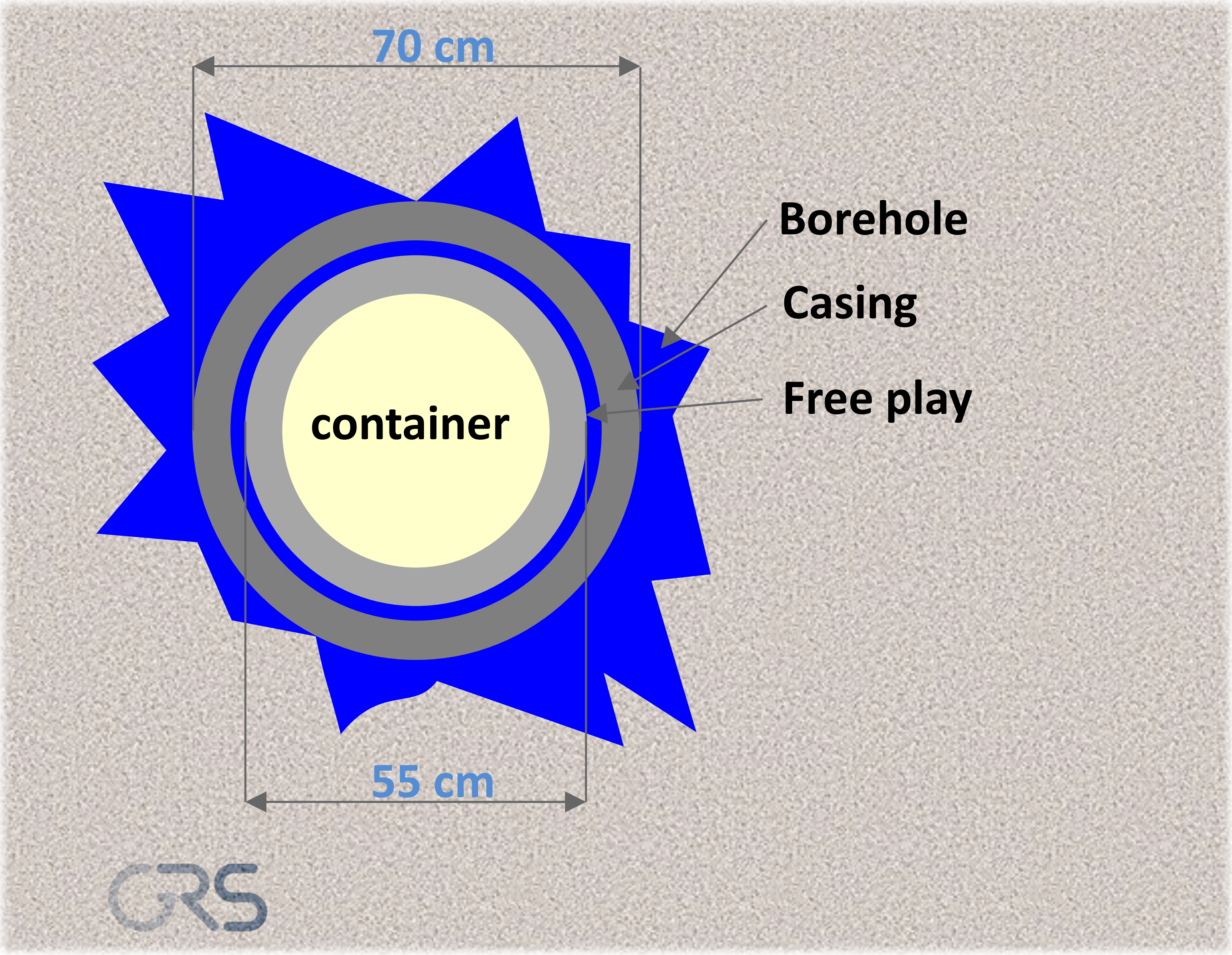
Gross mass DBC-R:
9,5 - 15,7 Mg

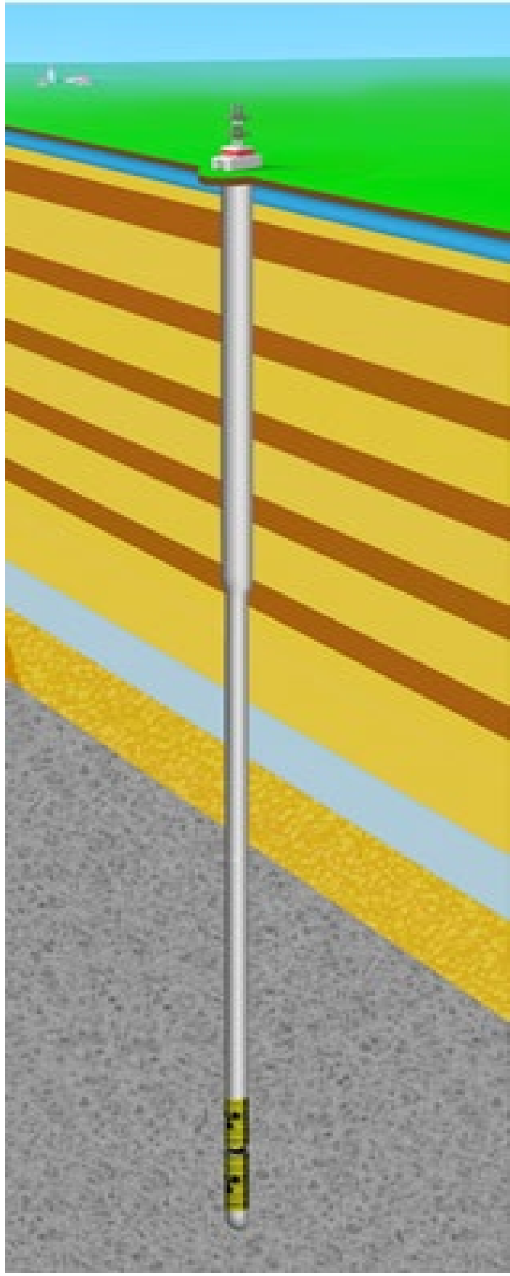
Requirements for container (wall thickness)

- Stacking
- Temperature / pressure
- Corrosion
- Tightness
- Retrievability / recoverability
- …

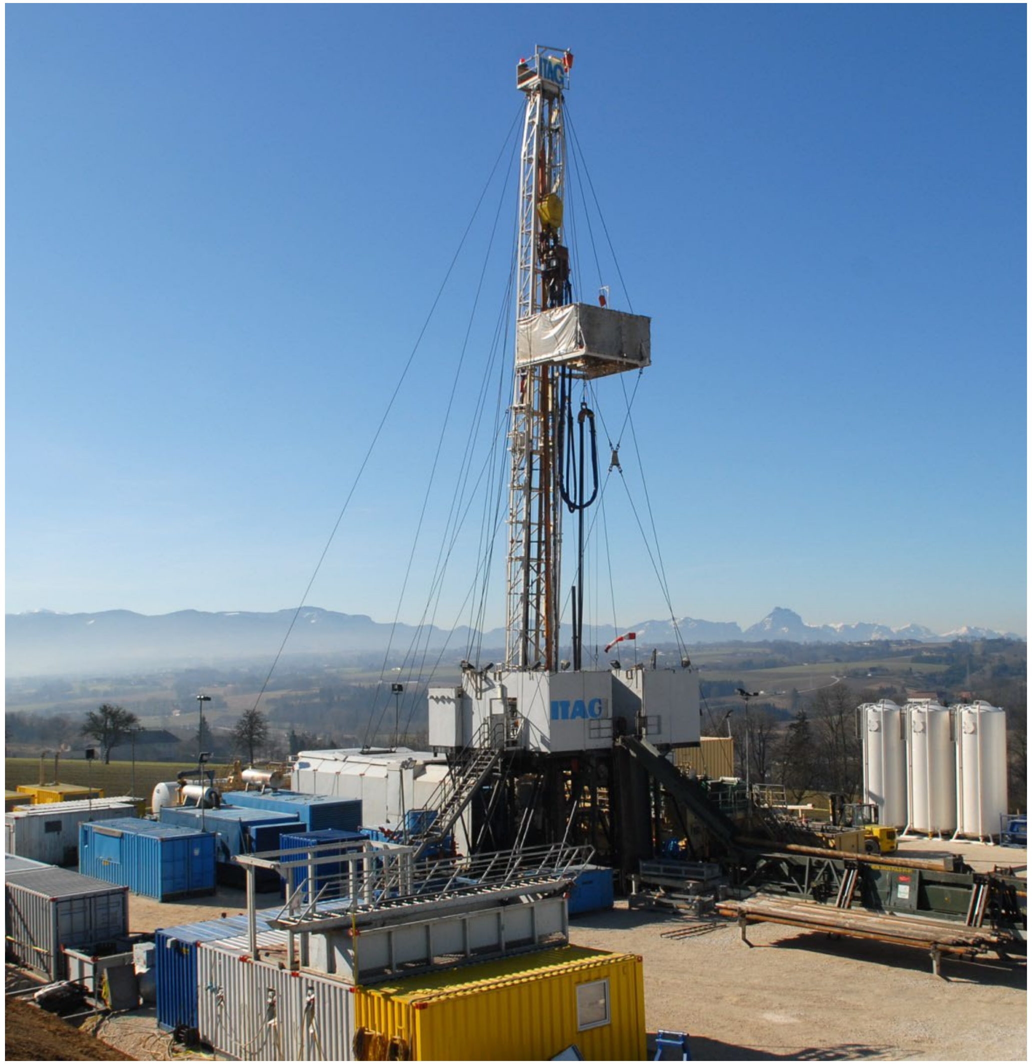


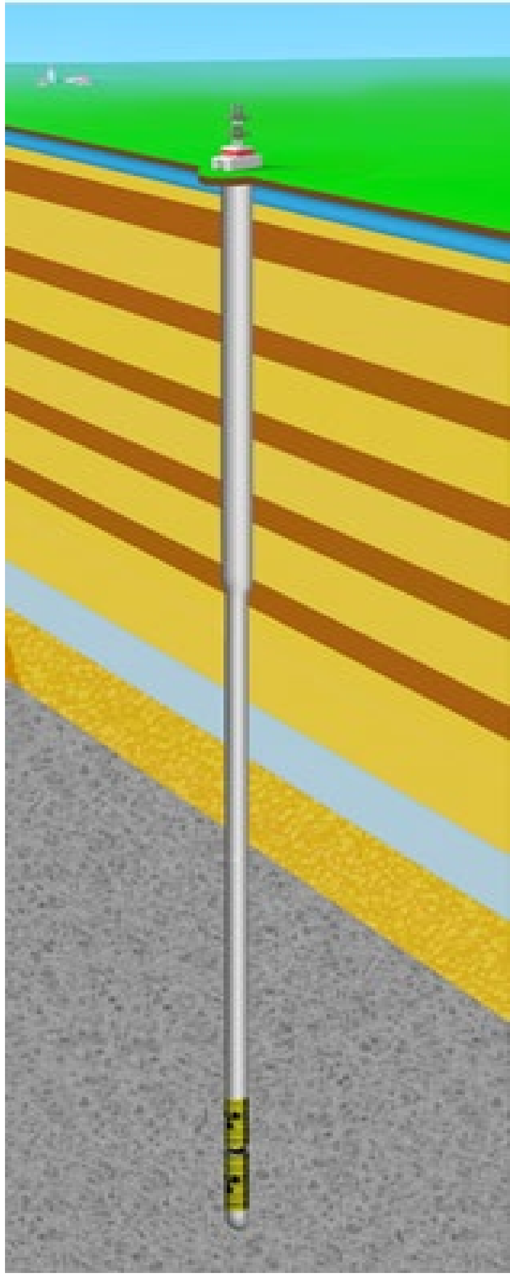
Casing / container





Drilling technology



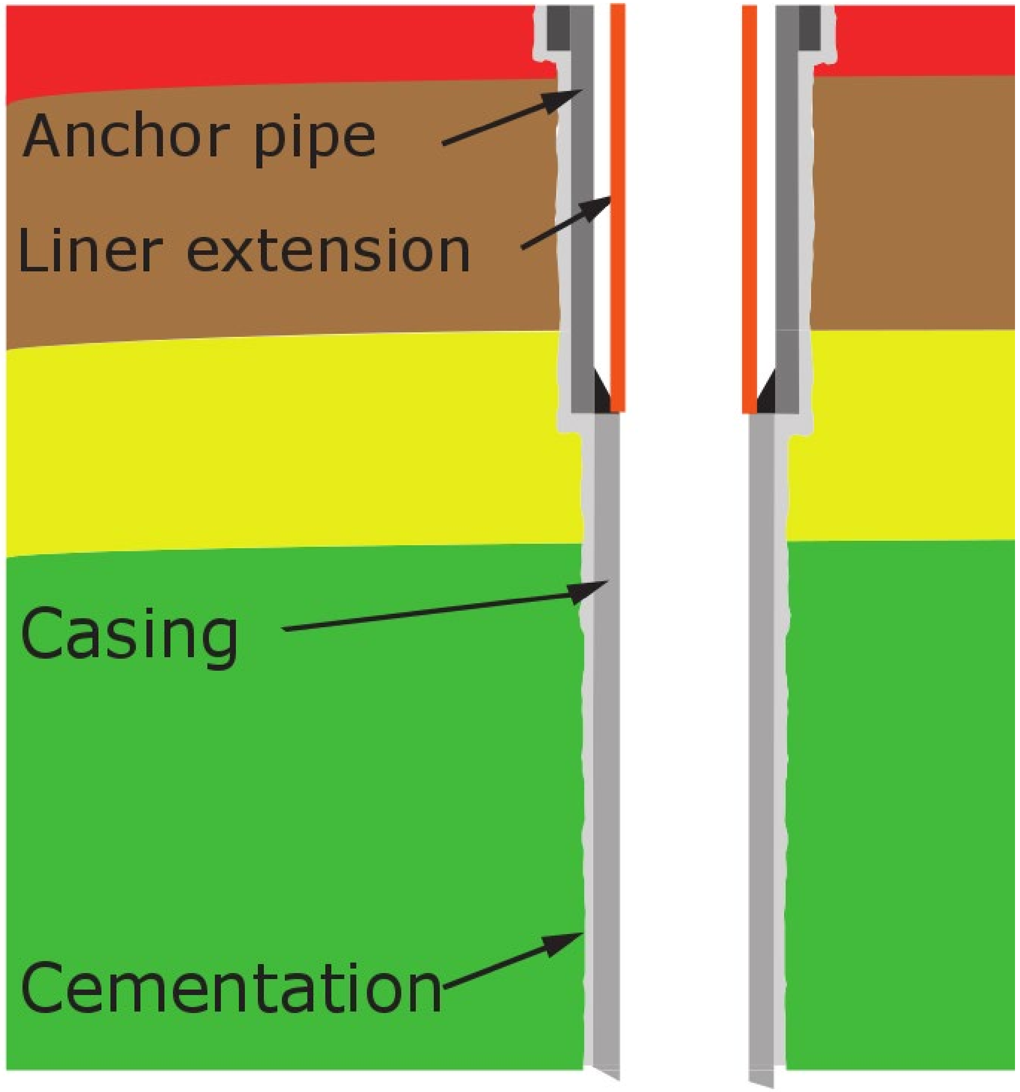


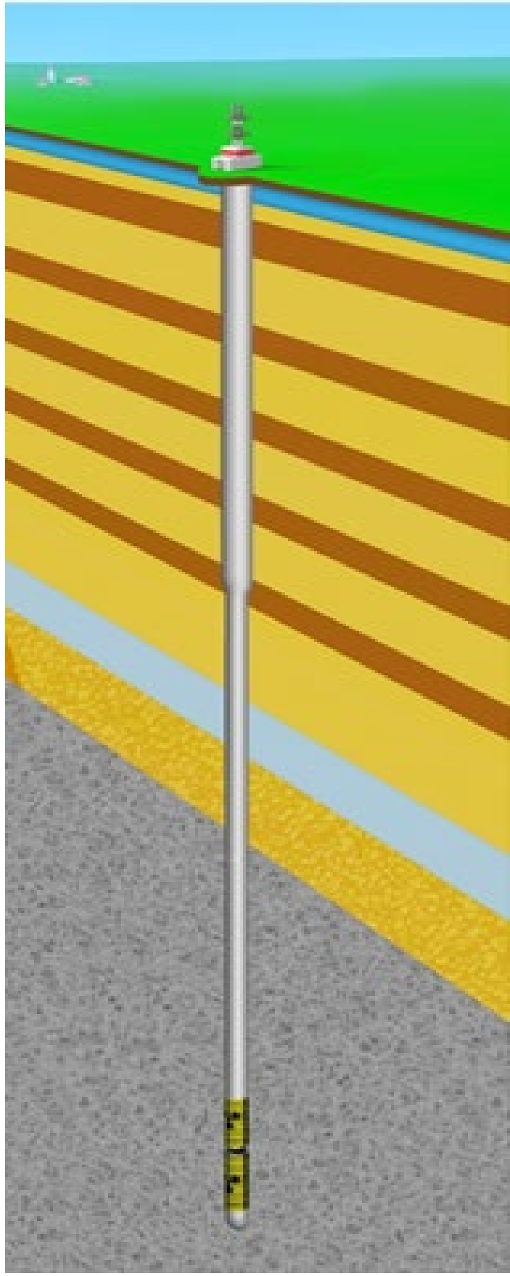
Different DBD concepts

Concept #	1* (2018)	2 (2018)	3 (2016)
Reference	Bollingerfehr et al.	Bollingerfehr et al.	Bracke et al.
Diameter of borehole	445 mm	900 mm	750 mm
Maximum depth of borehole	5 000 m	5 000 m	3 500 m
Disposal zone	3 000 – 5 000 m	3 000 – 5 000 m	1 500 – 3 500 m
Space for cementation	44.5 mm	44 mm	25 mm
Outer diameter of casing	356 mm	812 mm	700 mm
Wall thickness of casing	21.6 mm	63.5 mm	62.5 mm
Play between casing and container	24 mm	25 mm	25 mm
Outer diameter of container	265 mm	635 mm	525 mm
Inner diameter of container	175 mm	435 mm	435 mm
Wall thickness of container	45 mm	100 mm	45 mm
Length of container	5.6 m	5.6 m	5.6 m
Number of containers	27 000	11 000	11 000
Number of containers per borehole	180	356	356
Minimum number of boreholes	150	31	31

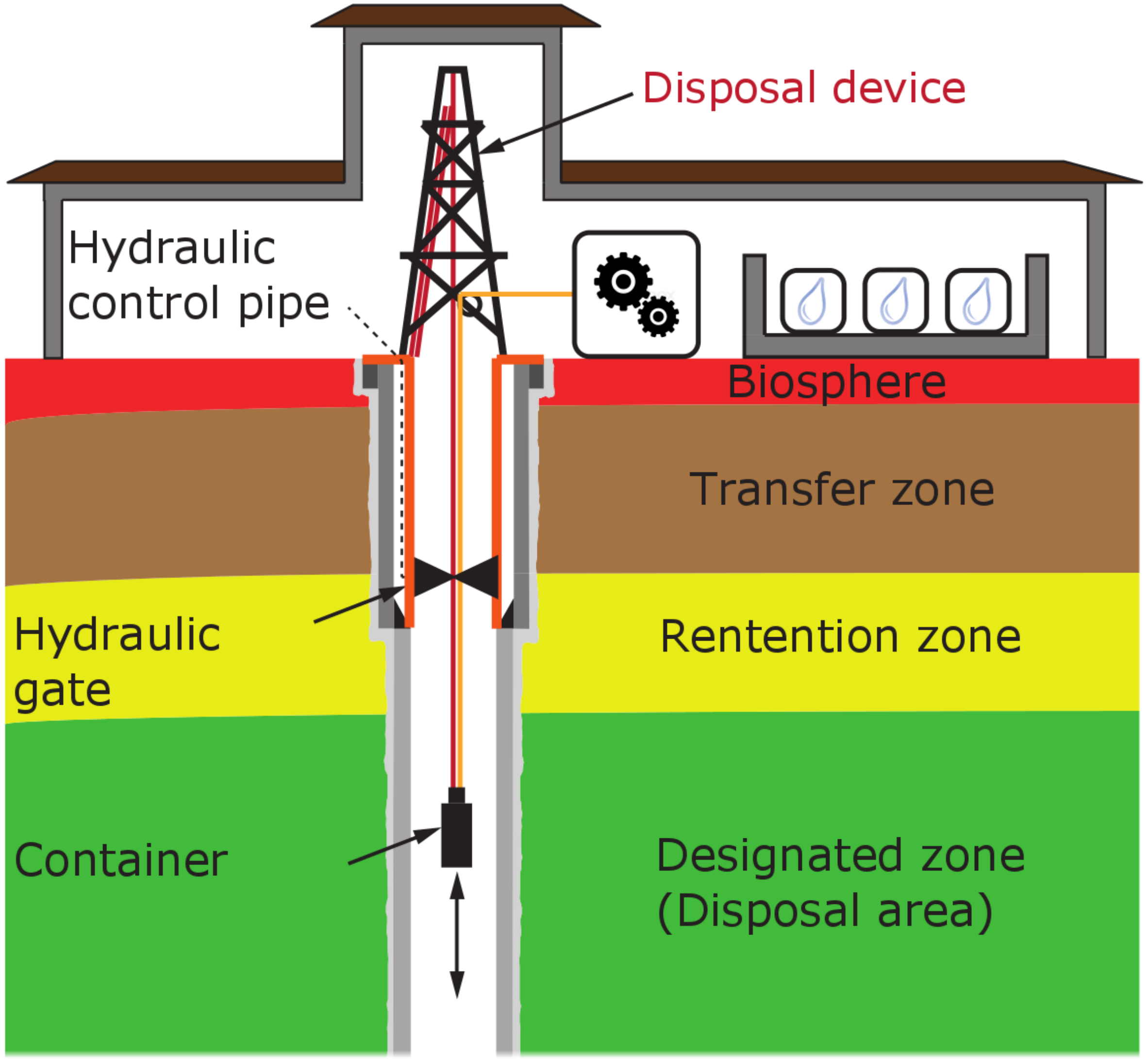
* Spent fuel and pebbles only

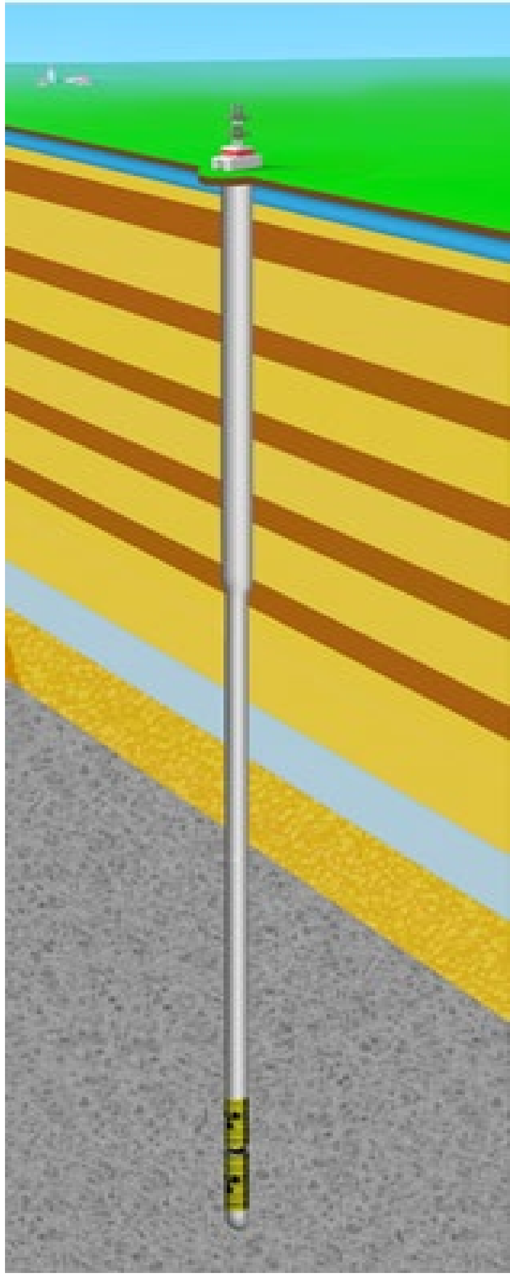
Casing of borehole



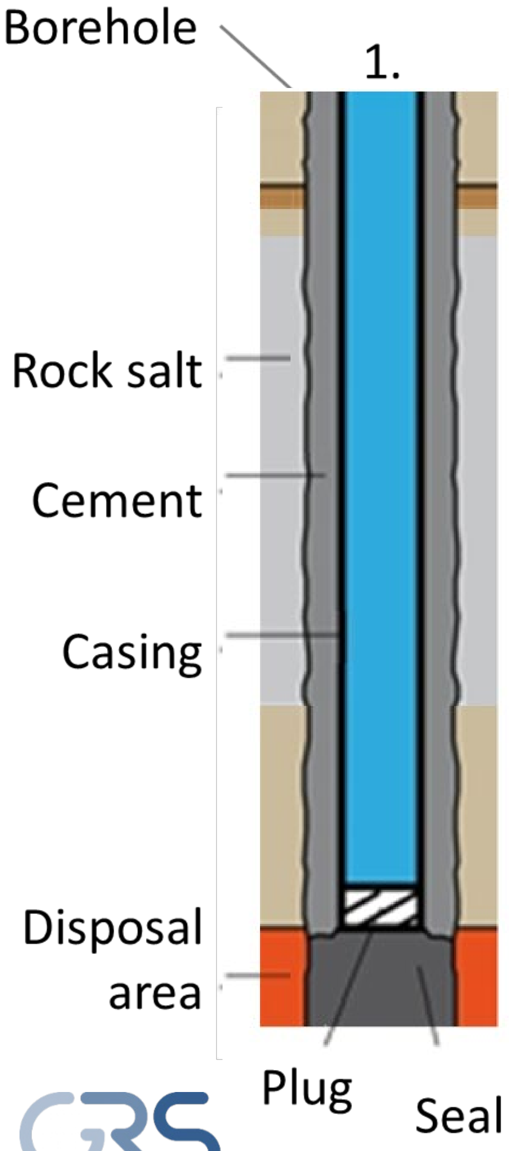


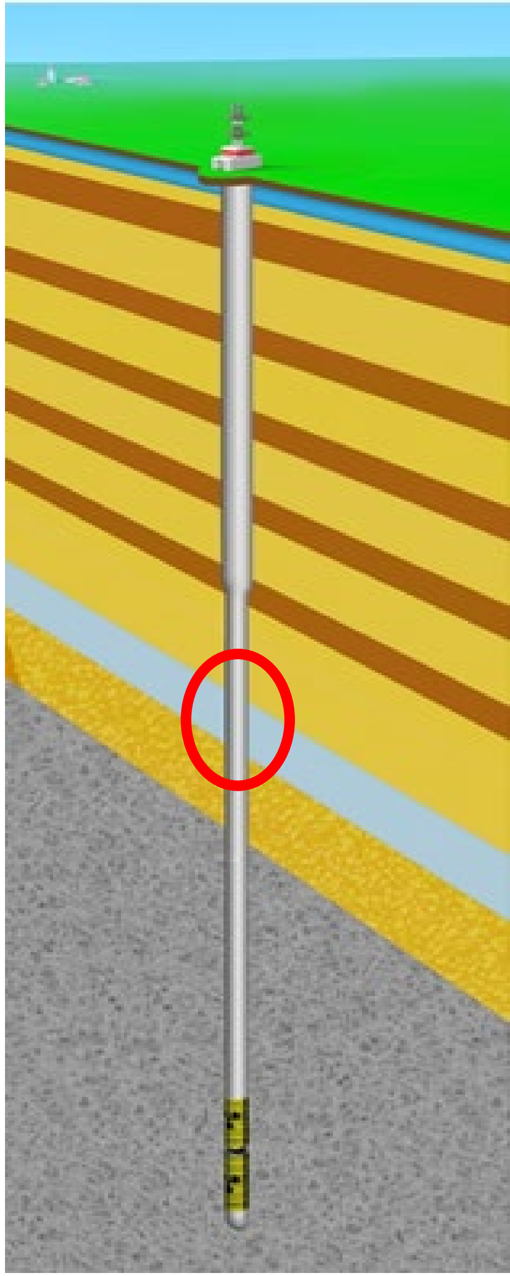
Disposal operation





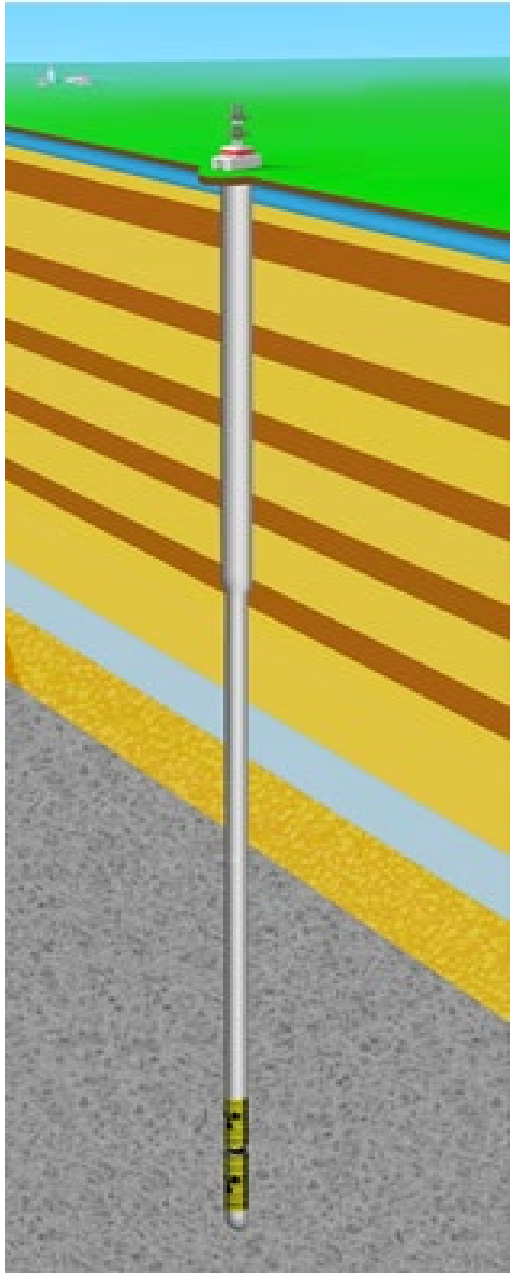
Borehole seals: Example for rock salt





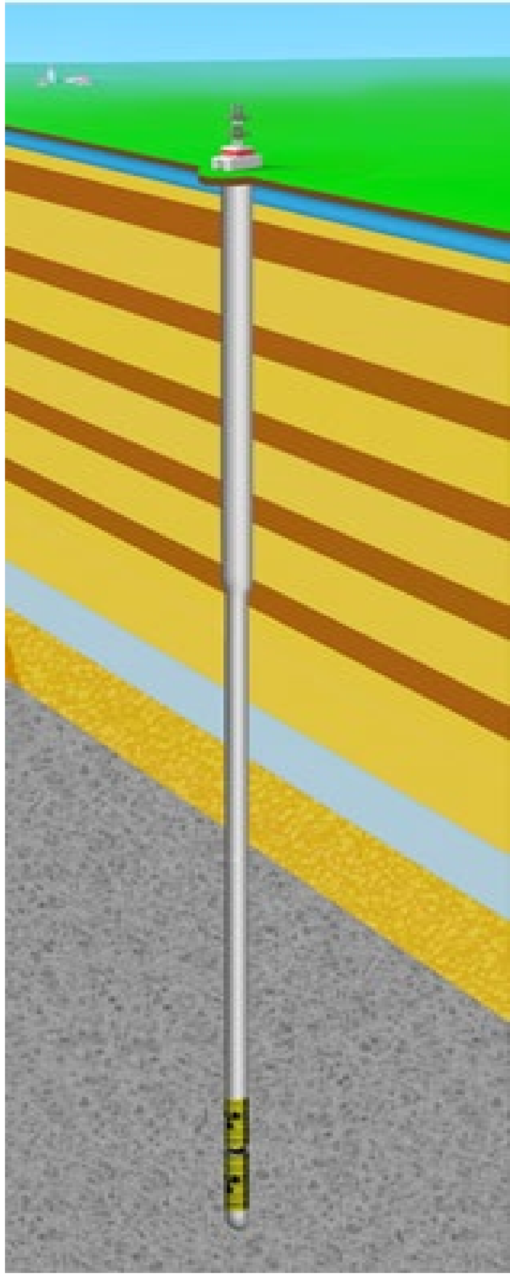
Cost for drilling (Fluid)

Diameter*	Depth	Cost
37,5 cm*	5000 m	~ 30 Mio. €
80 - 90 cm	3500 m	?



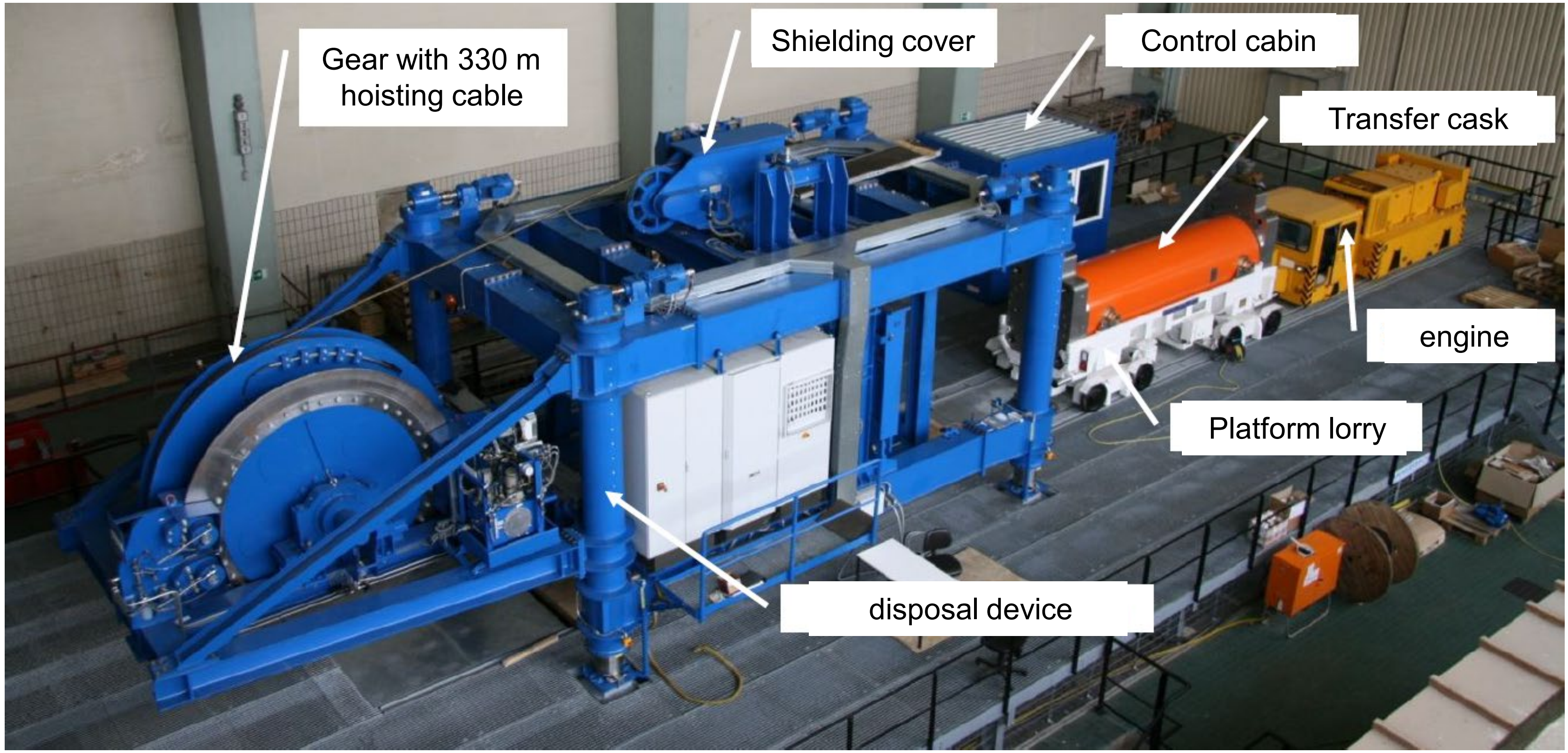
Cost estimate (Germany)

Task	Number	Cost (Mio. €)	Sum (Mio. €)
Feasibility Demonstration	1	500	500
Site Selection and Exploration	5	200	1000
Borehole	35	50	1750
Containers	11 000	0.1	1100
Reconditioning	1	1000	1000
Installation / Operation	35 / 2 years	50 / year	3500
Licensing / safety analyses	35	5	175
Total	-	-	9025



Retrievability / Recovery

- … but will container last for 500 years ?
- and recovery ?

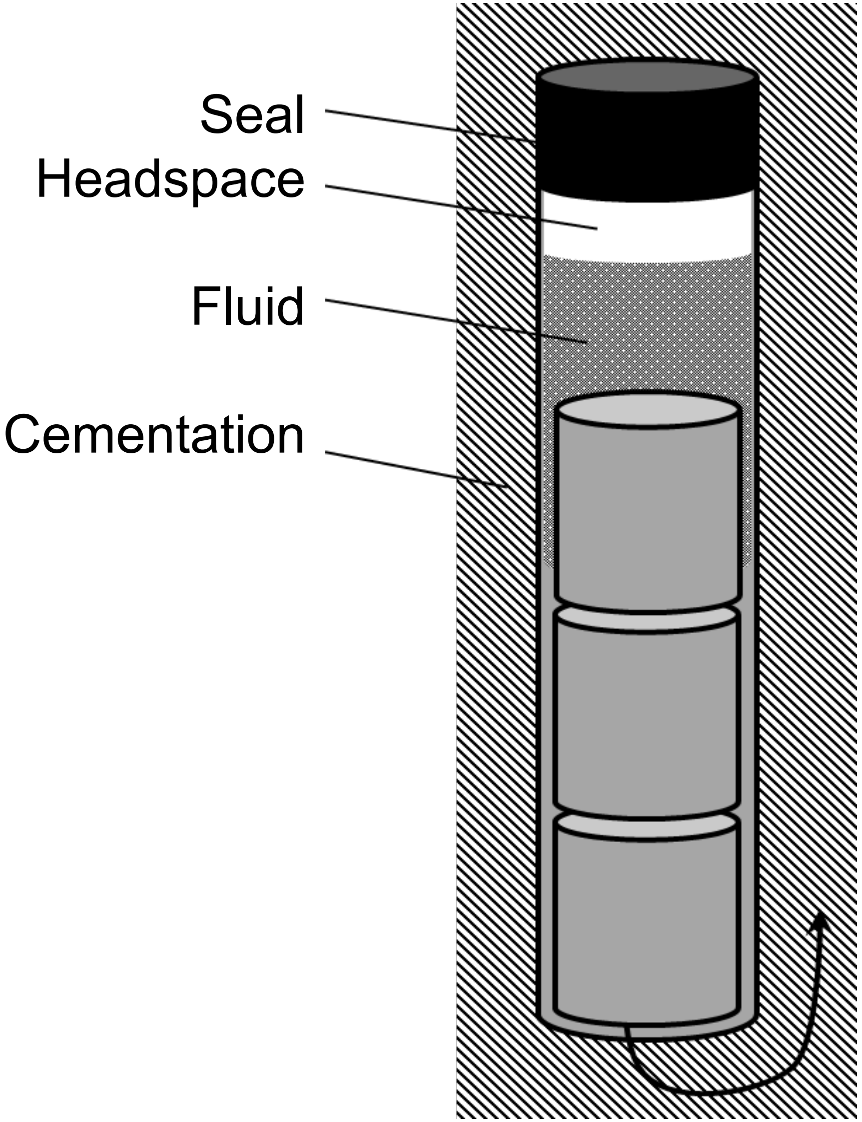


Long-term safety / Radionuclide transport

- Casing / borehole
- Outside casing, disturbed zone around borehole
- Fractures in surrounding host rock

Extremely low release*.

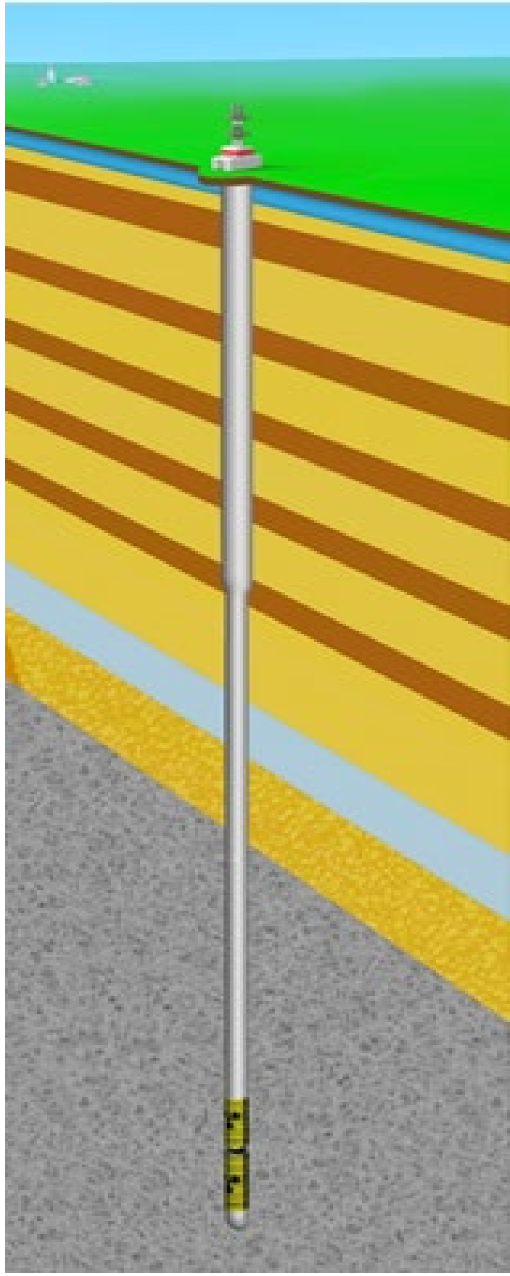
However, to be shown for CPRZ.



*Brady et al. (2011) Deep borehole disposal of high-level radioactive waste. SAND2009-4401, 75 pp, DOI 10.2172/985495.

Research and Development

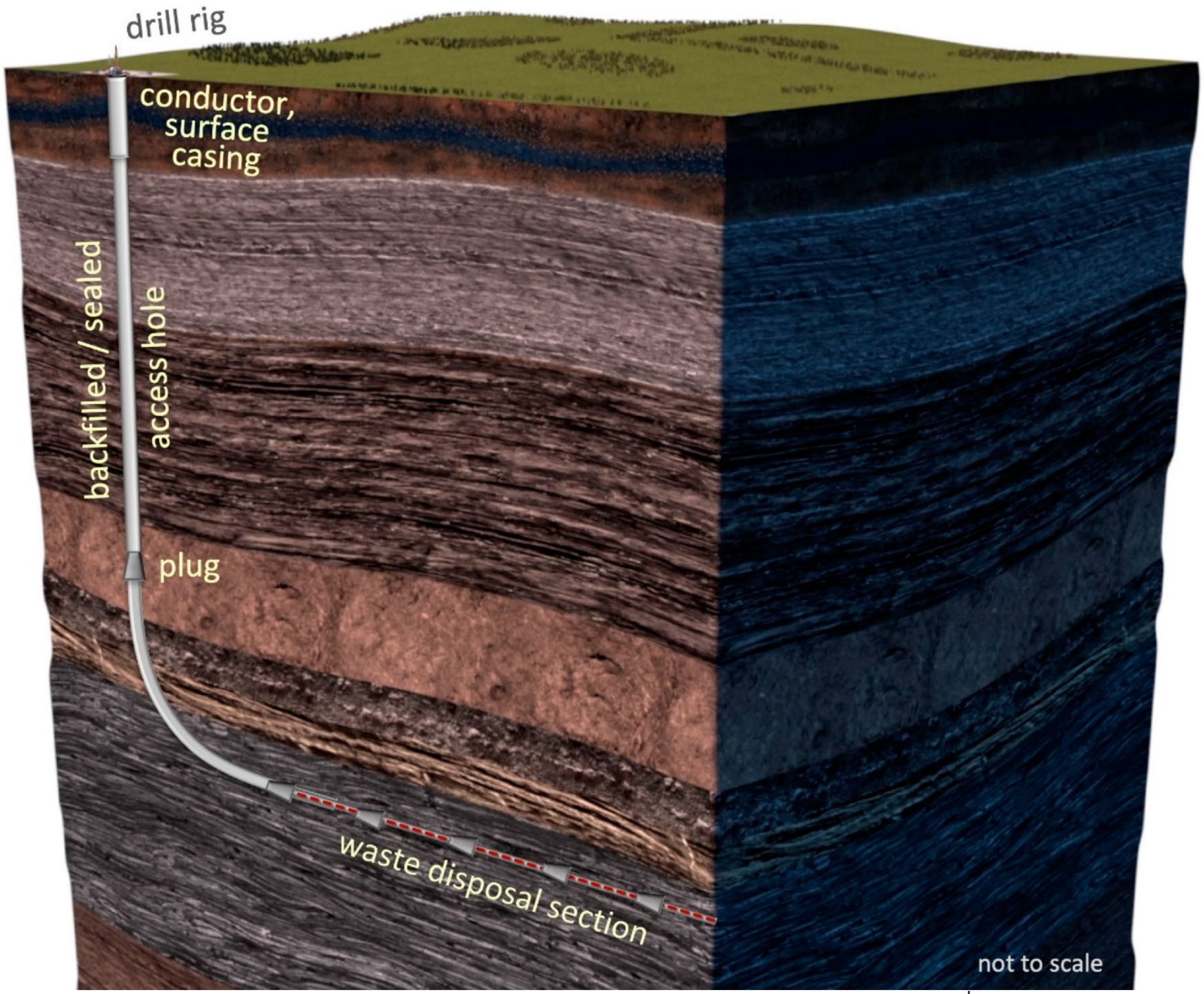
- Borehole diameter of 750 mm beyond today´s standard shelf technology
- Considered feasible for 3 500 m depth
- Concept to be detailed (e. g. container, monitoring, technology)
- Operational and long-term safety analyses
- Feasibility demonstration (drilling, disposal and retrievability)
- Development of containers for recovery for 500 years ?



Other recent work on DBD

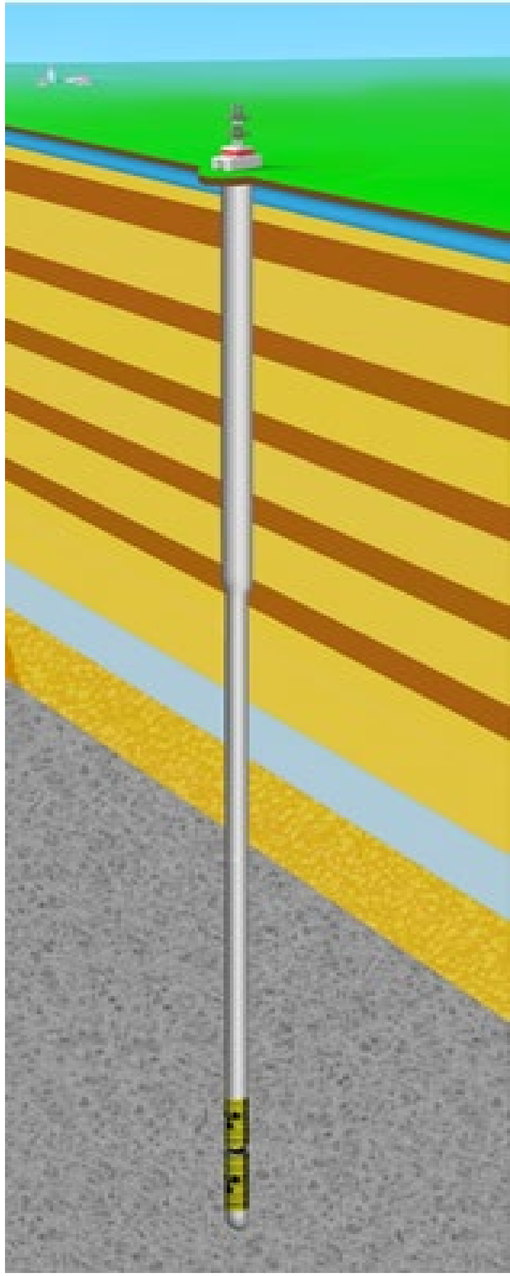
- www.deepisolation.com
  - Directional drilling
  - Smaller diameter

- Very active, single person promoting DBHD. However, not very sound contribution (my personal assessment)



Summary

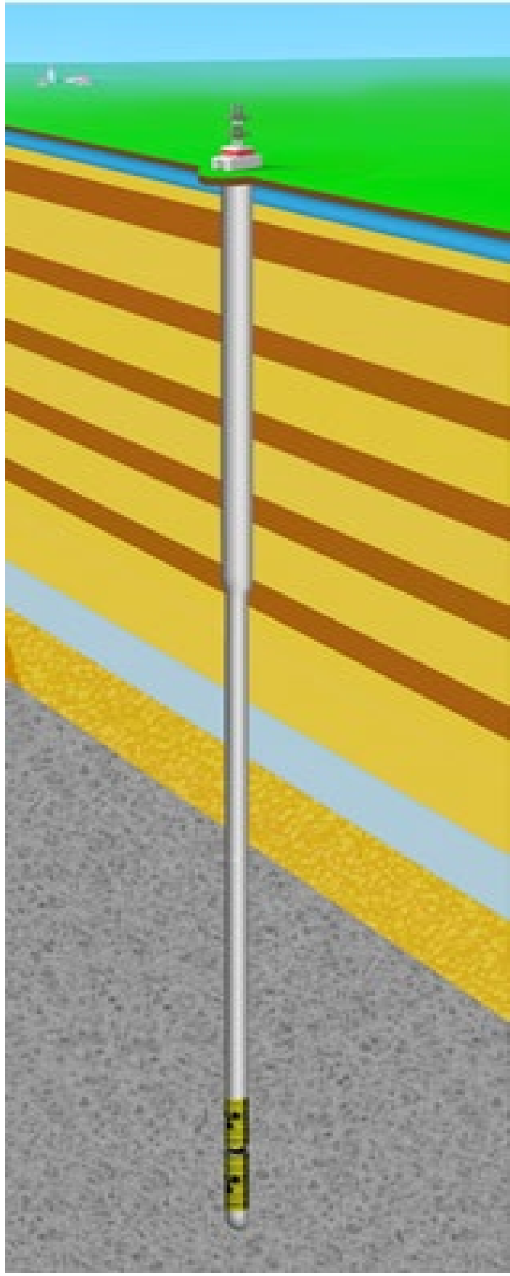
- Several concepts possible
- Container
- Disposal operation
- Geoscientific requirements and criteria
- Sites available (in Germany)
- Safety analysis
- Research and development



Some advantages ⇔ and disadvantages

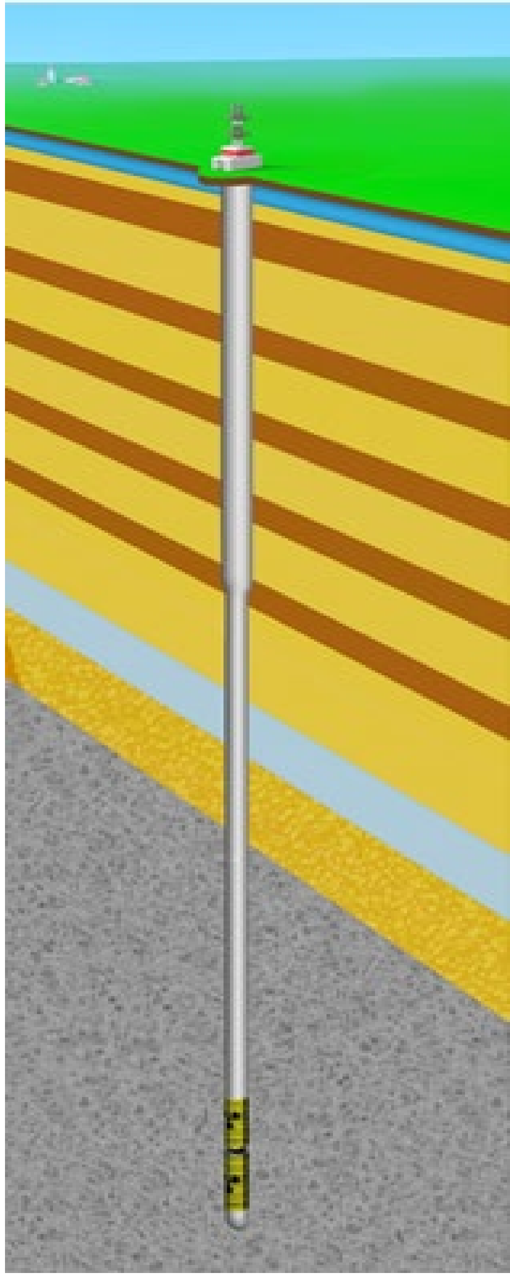
- Multiple barrier system (great depth)
- Manless disposal
- Several sites possible
- Proliferation extremely unlikely
- Less costs and faster implementation
- …

- Research and development
- Exploration for every drilling site
- Corrosion of containers
- Recovery
- …



Conclusions

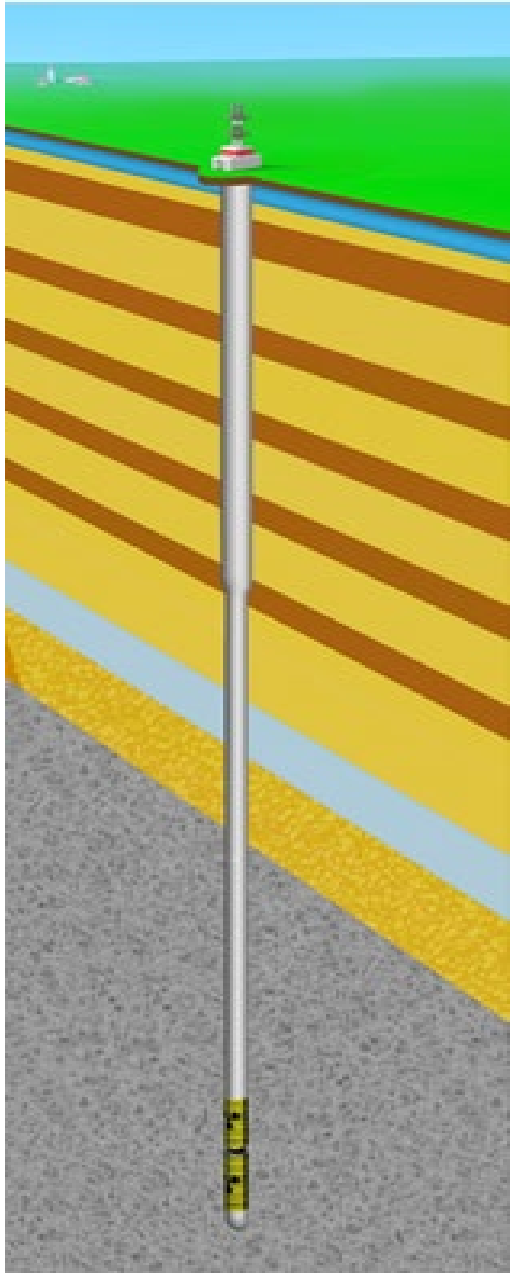
- DBD is a feasible and alternative technical option for deep geological disposal of HLRW for Germany.
- Needs active support of research and development (technology, temperature limit)
- The requirement of a possible recovery for 500 years should be reconsidered



Thank you for your attention

- Any questions ?

(However, do not drill too deep!)



References

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- Bollingerfehr, W., Dieterichs, C., Herold, M., Kudla, W., Reich, M., Rosenzweig, T.: Untersuchungen zu Chancen und Risiken der Endlagerung wärmeentwickelnder radioaktiver Abfälle und ausgedienter Brennelemente in Tiefen Bohrlöchern (CREATIEF), Abschlussbericht.Technische Universität Bergakademie Freiberg (TUBAF), BGE TECHNOLOGY GmbH (BGE TEC), 182 p.: Freiberg / Peine, 31 July 2018.
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- Busch T., Goebel V.: Advancements in the design of Nuclear Waste Repositories, Deep Big Hole Disposal, An Example From Germany. Canadian Consulting Engineer, 59 (7), 20–21, 2018.