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Supplement of

Concretisation of host-rock-dependent canister concepts through the development of a consistent but variable multi-barrier system for the future engineered barrier system

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Interdisziplinäres Forschungssymposium
für die Sicherheit der nuklearen Entsorgung

Institut für Werkstoffkunde
Prof. Dr.-Ing. Hans Jürgen Maier

Concretisation of host-rock-dependent canister concepts through the development of a consistent but variable multi-barrier system for the future engineered barrier systems

Dr.-Ing. Thomas Hassel

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Present situation in the site selection process

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THOMAUSKE, B. (2023). Ist das Standortauswahlverfahren gescheitert? Auswahl von Endlagerstandorten für hochradioaktive wärmeentwickelnde Abfälle? *Atw. International Journal of Nuclear Power*, vol. 68/*3 pp. 7-22*.

The site selection process in Germany failed because the design of the process and the safety of the process cannot be reconciled. As part of an amendment, Thomauske suggests carrying out a cross-host rock comparison before evaluating sub-areas.

2031 shifted to 2046-2068

Source:
BGE GmbH: Zeitliche Betrachtung des Standortauswahlverfahrens, Stand 28.10.2022, www.endlagersuche-infoplattform.de

RÖHLIG, K.J.. (2023). Zum Zeitplan des Standortauswahlverfahrens für die Endlagerung hoch radioaktiver Abfälle in Deutschland. *Atw. International Journal of Nuclear Power*, vol. 68/4 *pp. 52-61*.

Too tight a time limit as well as long extensions in the process pose the risk of non-safety-oriented decision-making behavior. There is little potential for acceleration until a procedural change is made, but the change in the law must begin quickly.

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Initial situation and initial question

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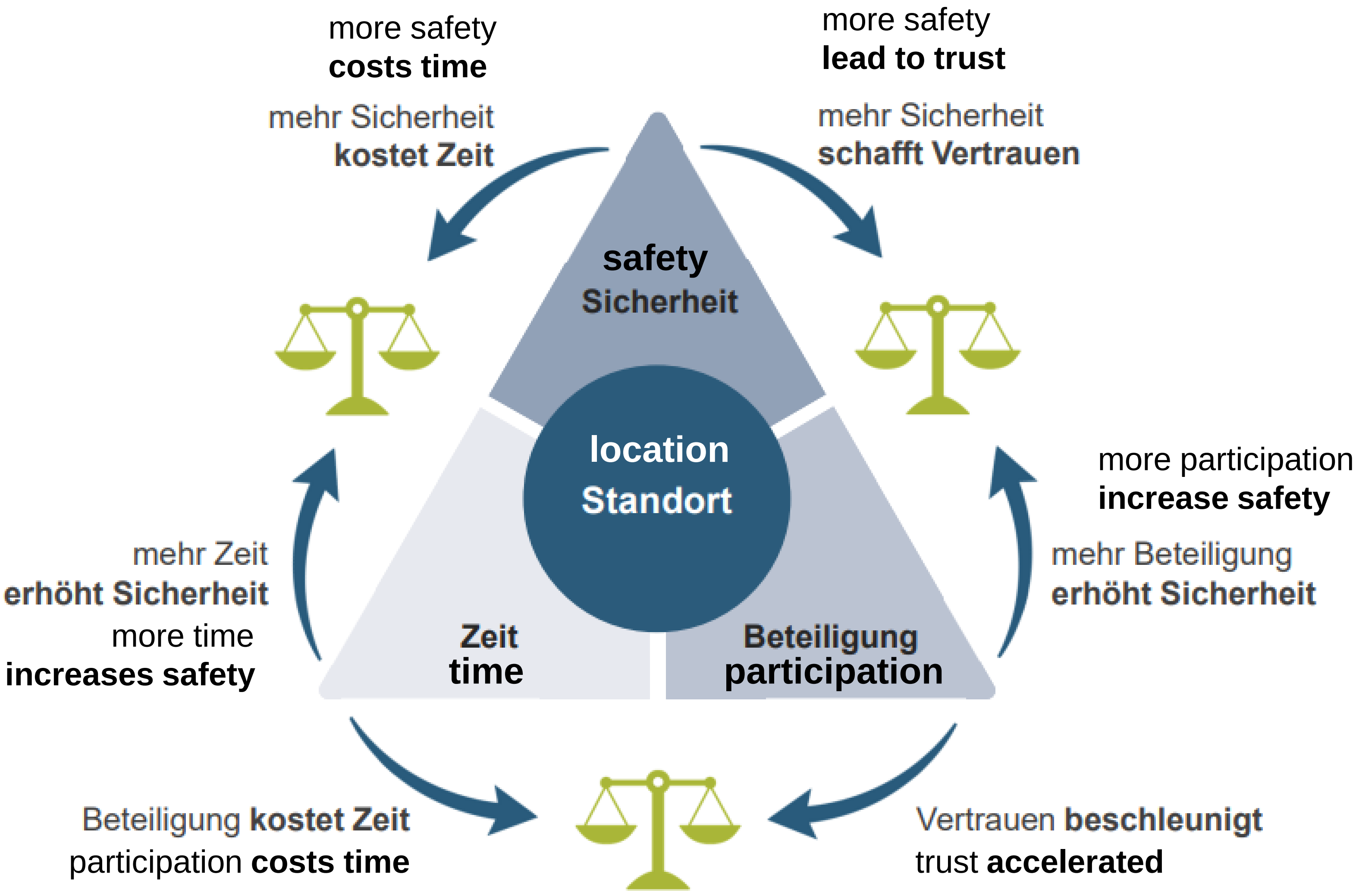
What measures can be taken to counteract a further delay in the final disposal of highly radioactive waste?

Are there tasks that can be decoupled from the host rock issue and can therefore be addressed before this decision is made?



Source: BGE GmbH Workshop des Planungsteams Forum Endlagerplanung; Vorstellung des Rahmenterminplans bis zum Vorschlag für Standortregionen Online-Veranstaltung, 13.01.2023, Translation added by the author!

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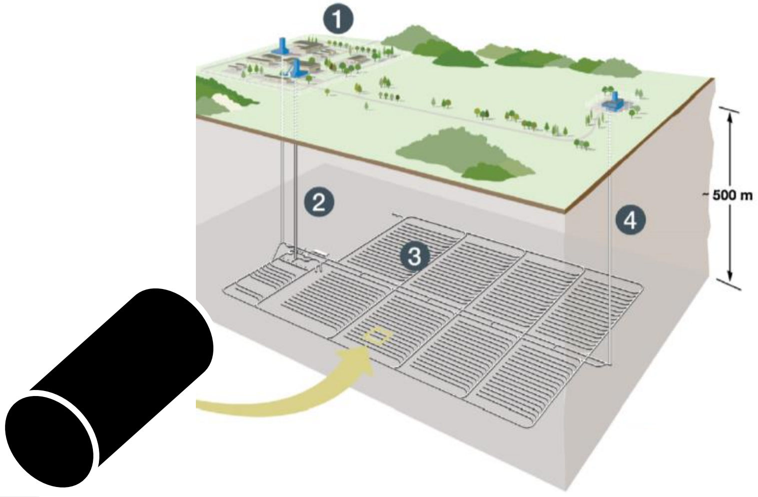
Appointment to the final storage container

Interim storage:
Licenced for 40 years as of first packaging / storage of cask, e.g.1994 in Gorleben

- Condition of the fuel elements
- Expiring permits
- Long-term interim storage
- Transportability
- Conditionability

Wicked things



- Three host rock options
- Various geotechnical barrier systems
- Retrievability
- Recoverability
- Conditionability

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Different reference systems and perspectives

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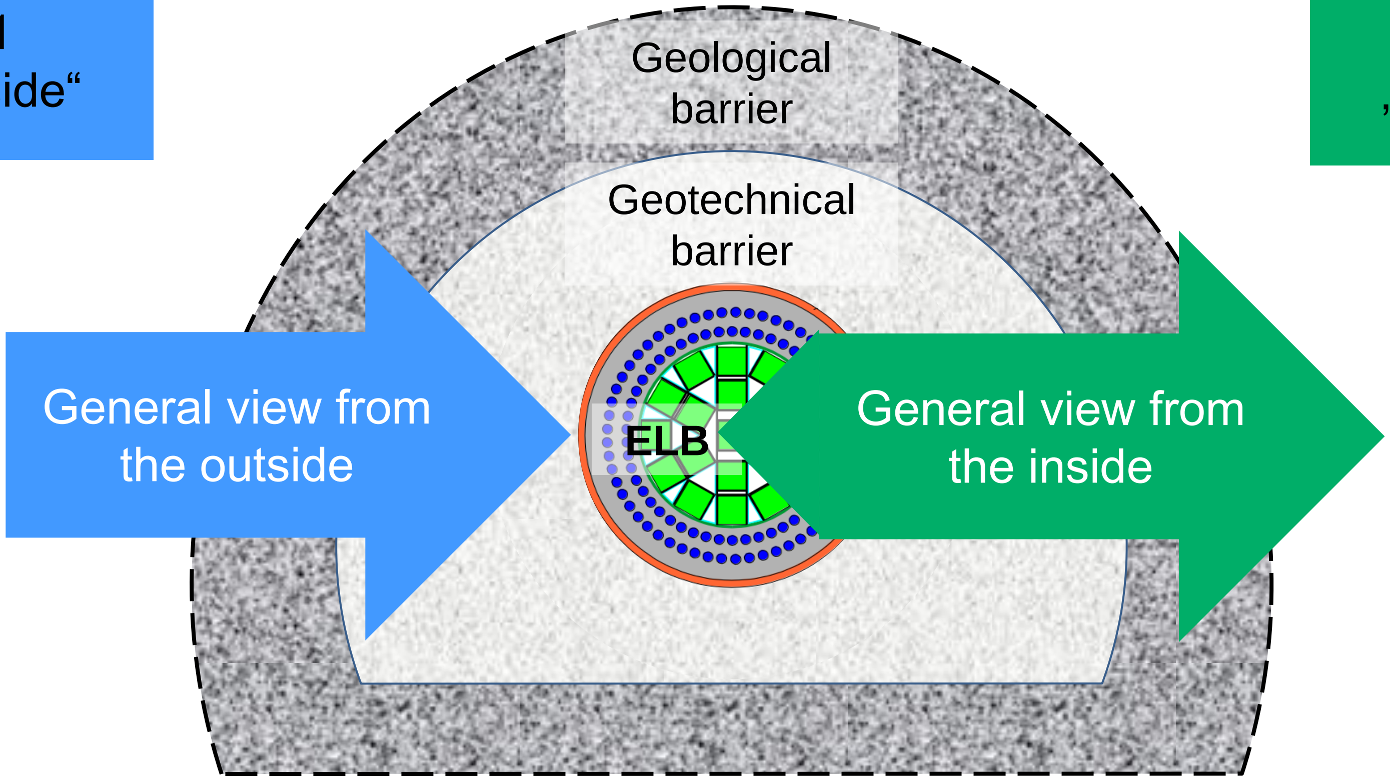
Host rock: salt rock, clay rock or crystalline rock

approach 1
„outside to inside“

- Rock Mechanics
- Far field
- Near field
- Corrosion
- Materials
- Mine
- Scenarios



approach 2
„inside to outside“

- Inventory
- Radiology
- Heat generation
- Criticality
- Nuclide flows
- Conditioning
- Storage technology
- Retrieval strategy

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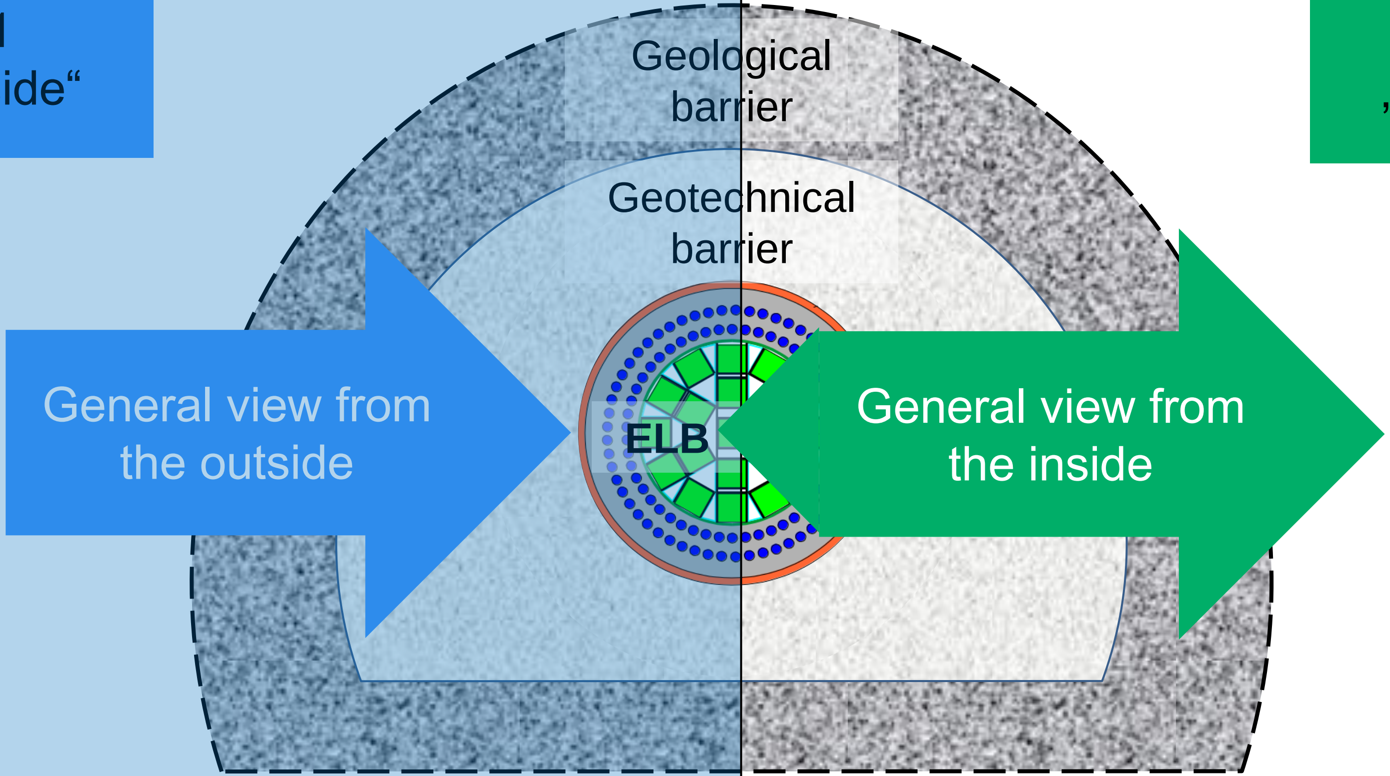
Host rock: salt rock, clay rock or crystalline rock

First Aproach

approach 1
„outside to inside“

- Rock Mechanics
- Far field
- Near field
- Corrosion
- Materials
- Mine
- Scenarios



approach 2
„inside to outside“

- Inventory
- Radiology
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Consequence approach 1

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- Container development will only take place after the location and thus the host rock have been decided ➔ **Danger of delay?**
- From now on, three equivalent complete container systems will be designed, planned, constructed and implemented in parallel ➔ **Costs and resources?**
- Defined requirements for the container must be defined, although one cannot know whether these actually exist at the future location ➔ **Depth, water, etc.?**
- A change of direction in a late phase of site selection is no longer easily possible when the host rock changes ➔ **see change of direction in Switzerland!**
- Production capacities can only be built up after the location decision has been made ➔ **Pre-programmed bottleneck for 10.000 to 20.000 containers?**
- Number of containers can be optimally designed ➔ **Storage space required!**

Different reference systems and perspectives

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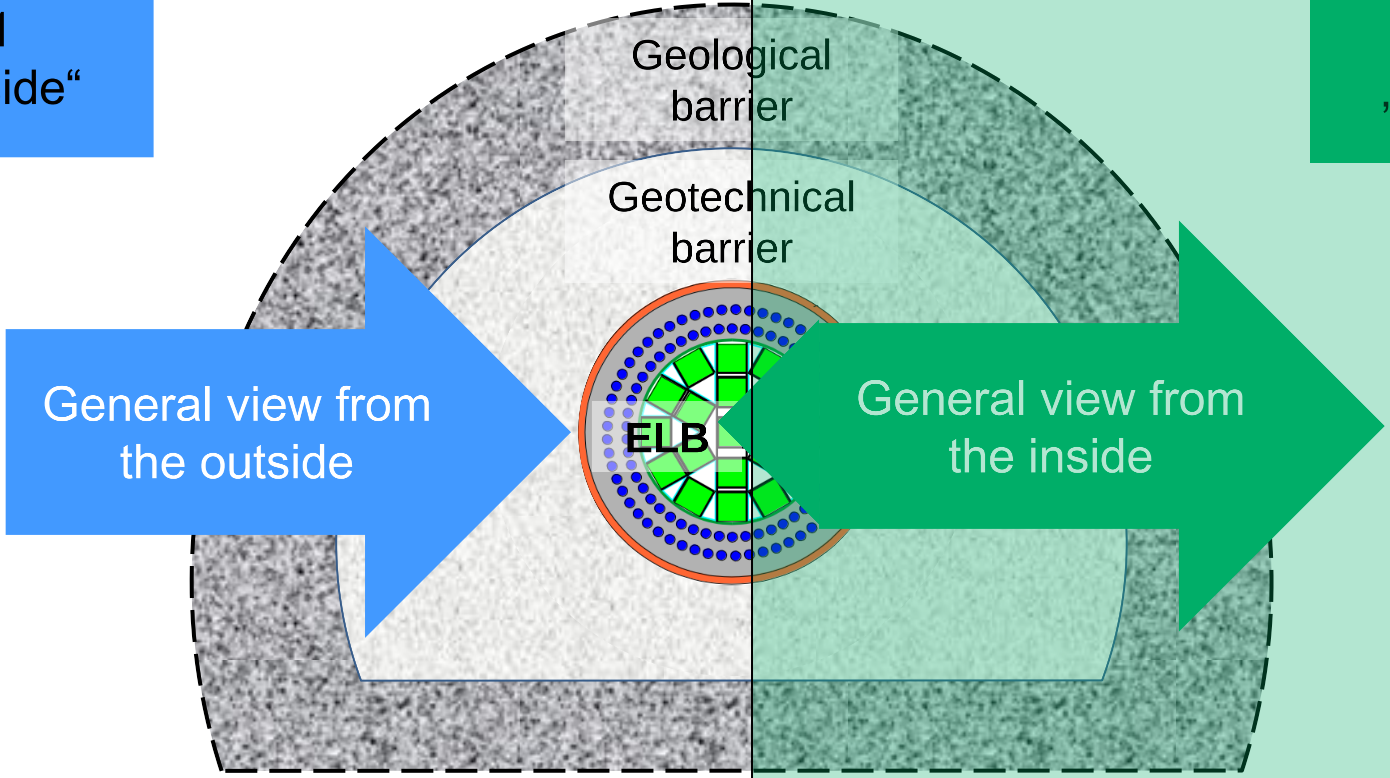
Host rock: salt rock, clay rock or crystalline rock

approach 1
„outside to inside“

- Rock Mechanics
- Far field
- Near field
- Corrosion
- Materials
- Mine
- Scenarios



Second Approach

approach 2
„inside to outside“

- Inventory
- Radiology
- Heat generation
- Criticality
- Nuclide release
- Conditioning
- Storage technology
- Retrieval strategy

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Consequence approach 2

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- The highly radioactive inventory is known ➔ **Burnup and heat generation!**
- The quantity of the waste is known ➔ **Design requires definition of criteria!**
- Shape and dimensions as construction data are available ➔ **BE, special fuels and vitrified molds!**
- Radiological requirements are already defined ➔ **Dose rate on the surface!**
- Material decisions can be made using the international state of the art ➔ **SKB/ POSIVA/ NAGRA!**
- Partial approval procedures can start early ➔ **Process flow!**
- Production capacities available quickly ➔ **No production bottlenecks!**
- Larger number of containers for target host rock ➔ **Safety surcharges!**
- The long-term stability part can be handeld after the decision has been made ➔ **time, costs!**

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Methodical approach of design thinking:

Basic idea:

Design thinking is about designing innovations and creative solutions to complex problems.

Possibilities:

There are no limits to the range of applications of design thinking. It can be applied to products and services as well as to the development of concepts for entrepreneurial or social issues.

Functional scope:

Design thinking is as much a collection of methods as it is a way of thinking and can be defined differently depending on the application. Techniques and tools enable a systematic approach.

Acceptability:

Openness to results, allowing for mistakes, the courage to fail and the willingness to learn from failure form the necessary inner attitude and fit exactly into the StandAG's objectives.

The classic design thinking process is divided into two main phases:

Analysis und Synthesis.

The two main phases can be divided into six further sections:

1. **Understand**
2. **Observe**
3. **Define point of view**
4. **Find ideas**
5. **Develop prototype**
6. **Testing**

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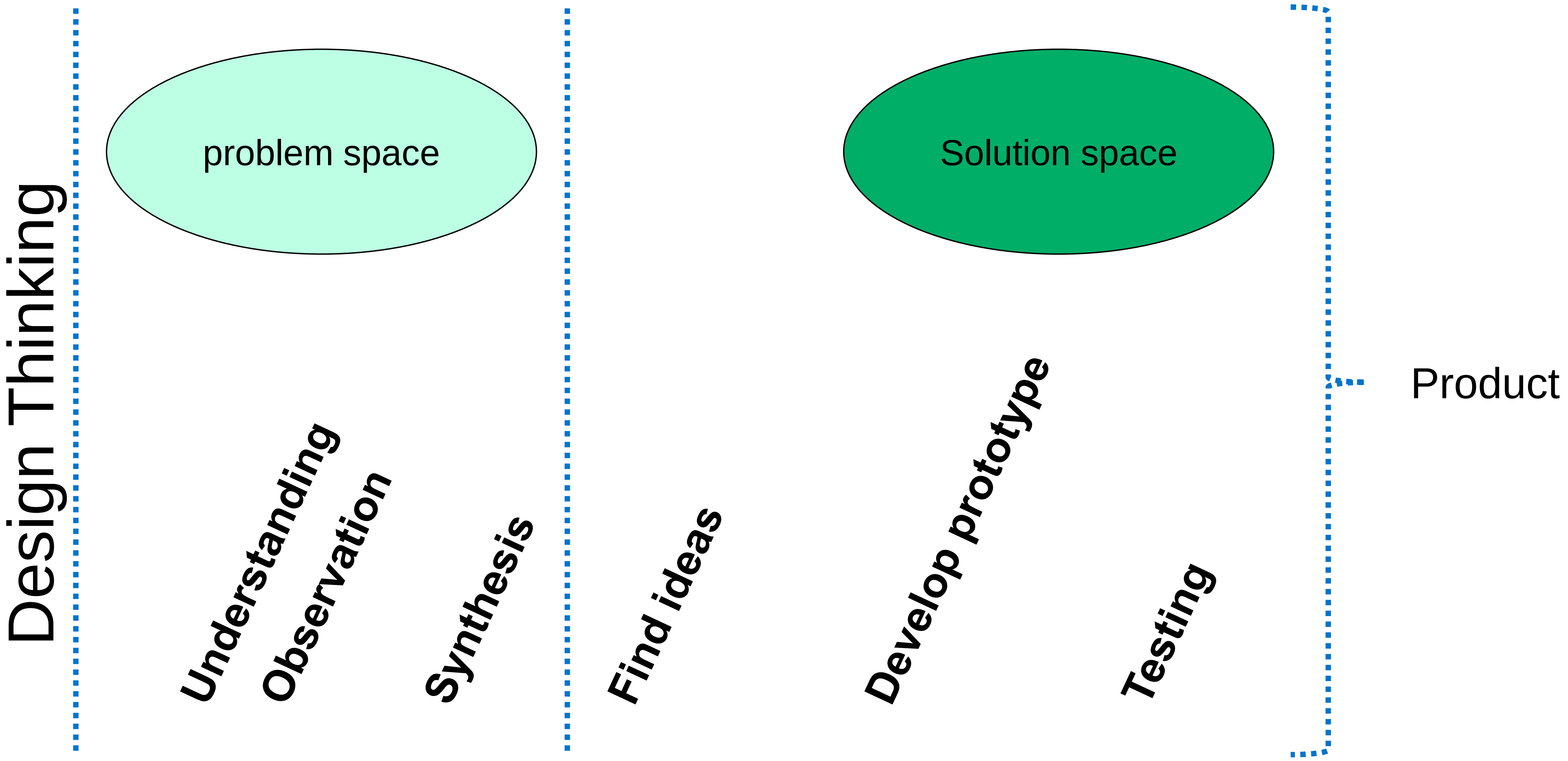
Example of application



Example of application

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Design Thinking

State of the art
problem space

approach 2
inside to
outside
solution space 1

after decision
host rock
solution space 2

Recherche
Understanding
Observation
Identification
Synthesis

Generalisation
Find ideas
Modeling
Prototyp deveopment
Testing

Analysis
Individualisation
Front End Engineering Design
Basic Design Report
Prototype
Testing

Example of application

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approach 2
inside to outside
solution space 1

Generalisation
Find ideas
Modeling
Prototyp deveopment
Testing

after decision
host rock
solution space 2

Analysieren
Individualisieren
Front End Engineering Design
Basic Design Report
Prototyp
Testen

Container
result

- **salt rock**
- **clay rock**

or

- **crystalline rock**

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What to consider?

This approach is not fully optimized to a host rock, so all design criteria must be based on conservative boundary conditions:

- allowable heat generation as a general boundary condition
- permissible dose rate at the surface of the vessel
- permissible mechanical load worst case oriented
- self-shielding or overpack?
- Line storage or vertical in boreholes?
- ...

The procedure must be designed as a transparent learning process to bring society along and achieve acceptability.

However, the number of containers to be stored can thus be determined at a very early stage so that, for example, production capacities can be created in the market.

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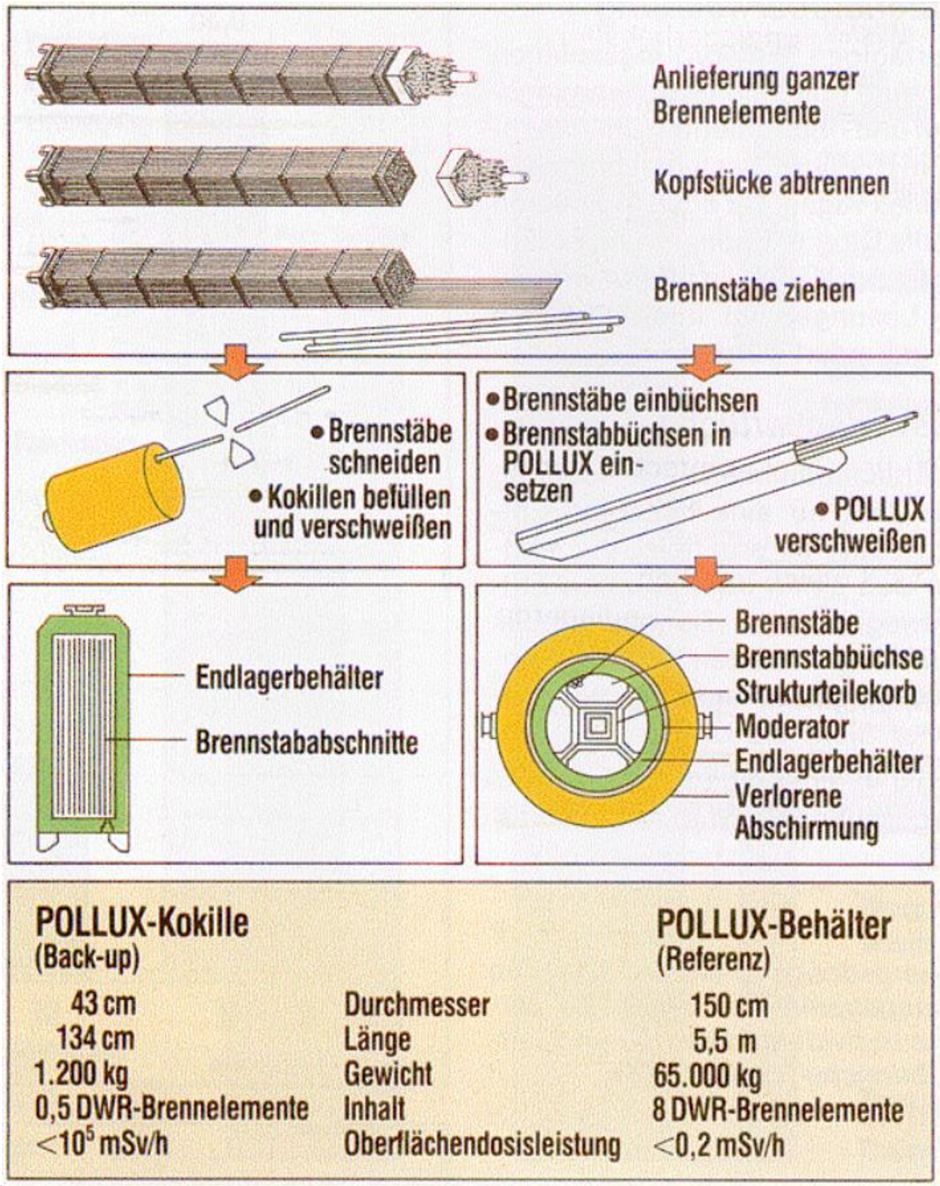
Interpretation of the POLLUX Approach



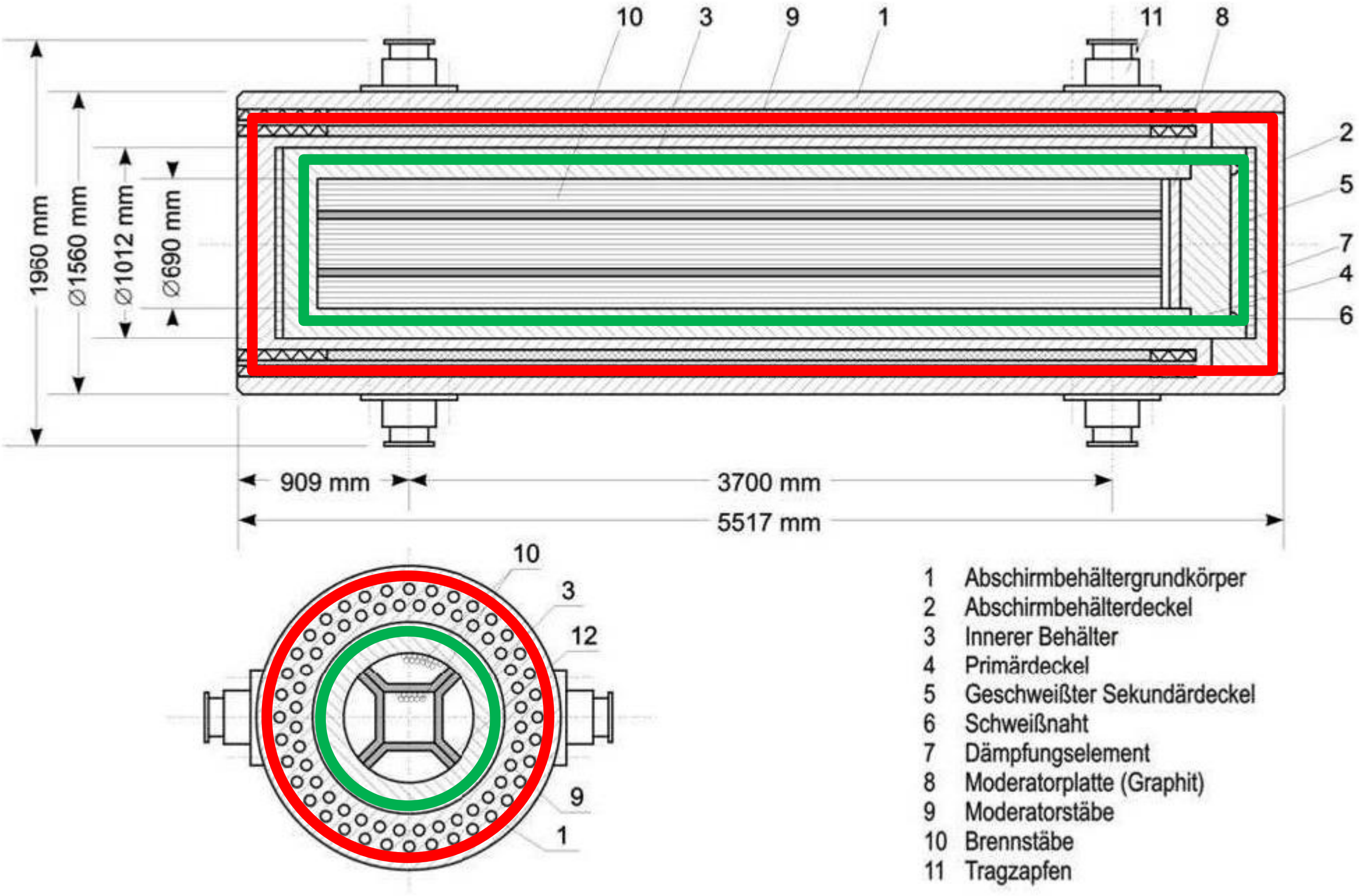
Pollux - family as historical german canister system

1. Pollux 3: Fuel rods (WG clay rock)
2. Pollux 9: Ingot molds (WG salt rock)
3. Pollux 10: Fuel rods (WG salt rock)

Pollux-Prototype-Container
(Source: "Direkte Endlagerung", Kernforschungszentrum, Karlsruhe 1990)

Storage device for Pollux prototype container
(Quelle: Besuch BGE Peine 2023)

Interpretation of the POLLUX Approach



1 Abschirmbehältergrundkörper
2 Abschirmbehälterdeckel
3 Innerer Behälter
4 Primärdeckel
5 Geschweißter Sekundärdeckel
6 Schweißnaht
7 Dämpfungselement
8 Moderatorplatte (Graphit)
9 Moderatorstäbe
10 Brennstäbe
11 Tragzapfen

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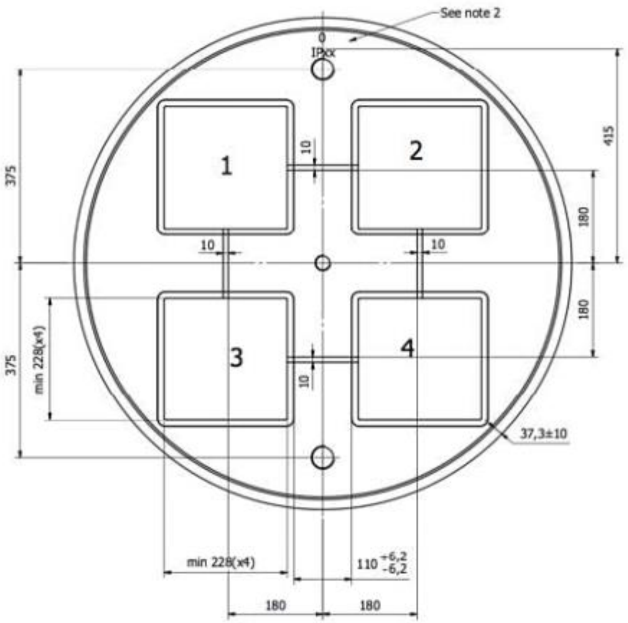
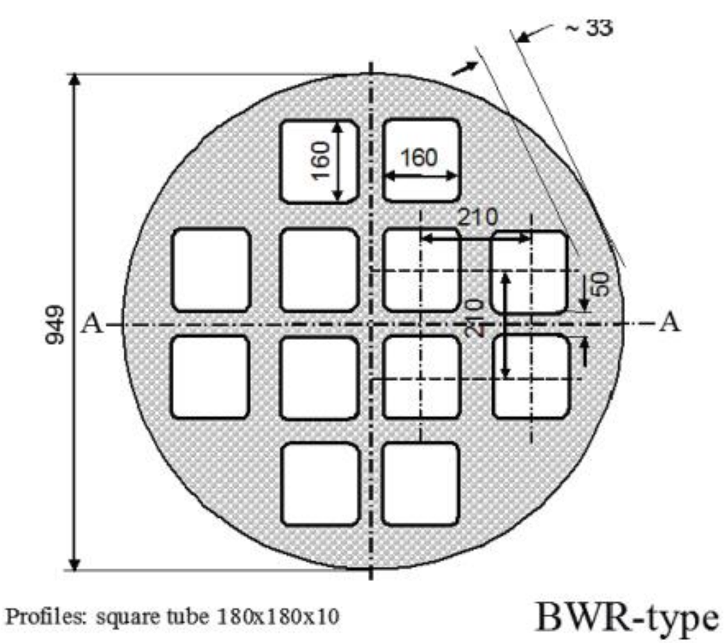
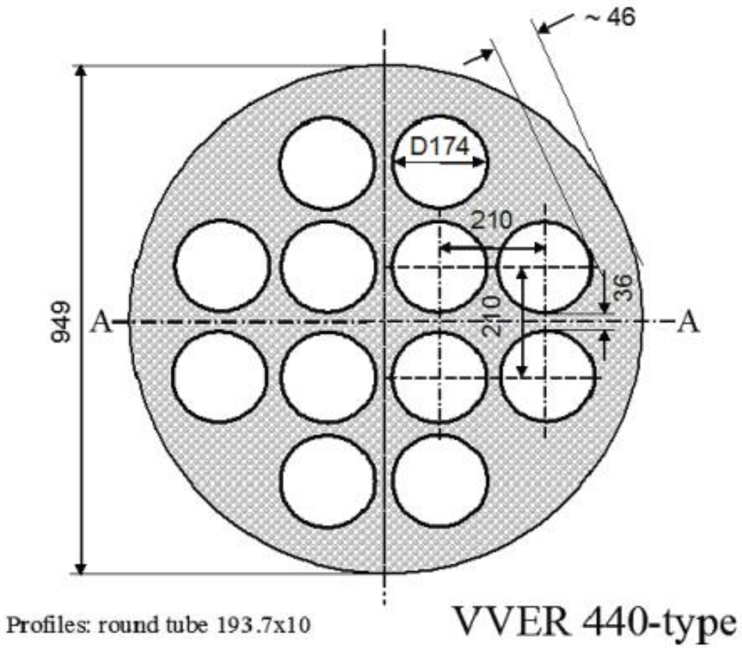
Example: Sweden (SKB)/Finland (POSIVA)

PWR-type





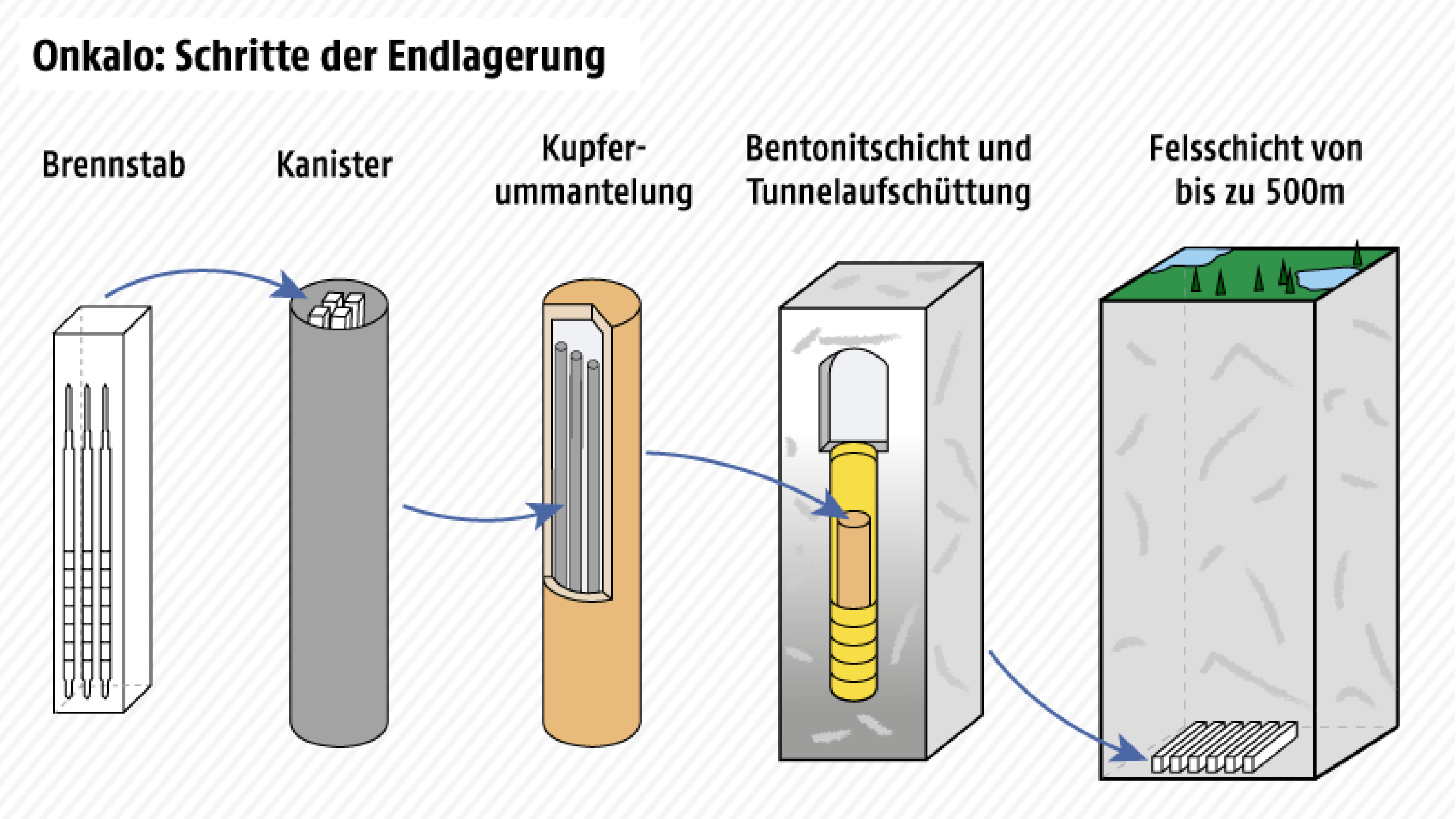


1. Molded tubes made of unalloyed steel to accommodate the fuel elements
2. Casting of these tubes with cast iron (GGG40)
3. Inner steel cover screwed
4. Enclosing of the inlet with a copper cladding
5. Seal welding of Cu cladding and Cu cover

Source: Raiko, H., Sandström, R., Ryden, H., and Johansson, M. 2010. Design analysis report for the canister. Technical Report TR-10-28. Swedish Nuclear Fuel and Waste Management Co.

Example: Sweden (SKB)/Finland (POSIVA)

Finland - only licensed repository in the world - crystalline rock



Conclusions

- Extending the site selection phase carries:
  - the risk of overburdening future generations.
  - the risk of losing the safety-oriented approach by extending the interim storage phase.
  - overall, the risk of failure due to loss of acceptance.
- The application of modern methods enables:
  - the advancement of development steps in cask development without having to develop a complete cask system for each host rock.
  - to quickly complete and manufacture the repository cask after the host rock decision has been made.
  - to use the phase of the repository construction consequently for the cask production and to work ahead.

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