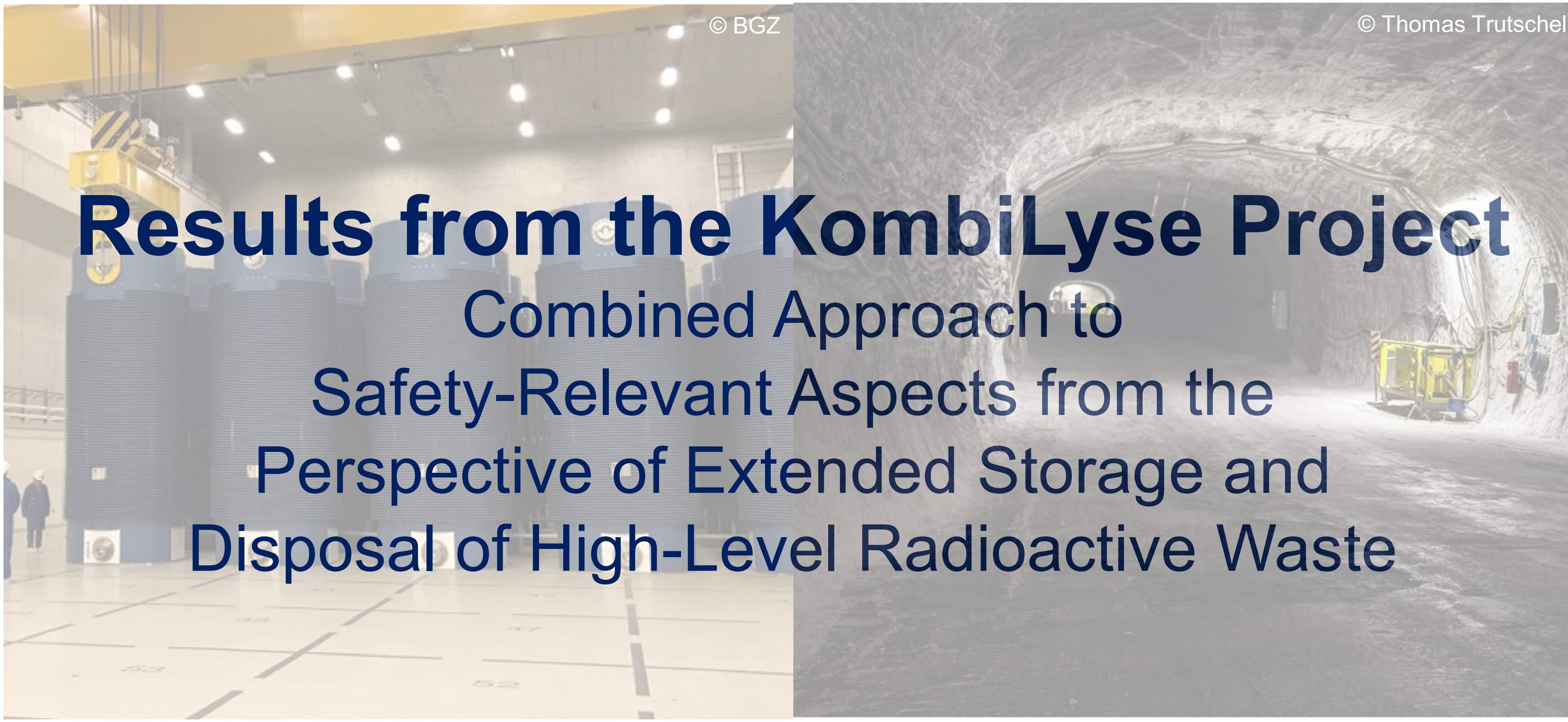


# Results from the KombiLyse Project

## Combined Approach to Safety-Relevant Aspects from the Perspective of Extended Storage and Disposal of High-Level Radioactive Waste

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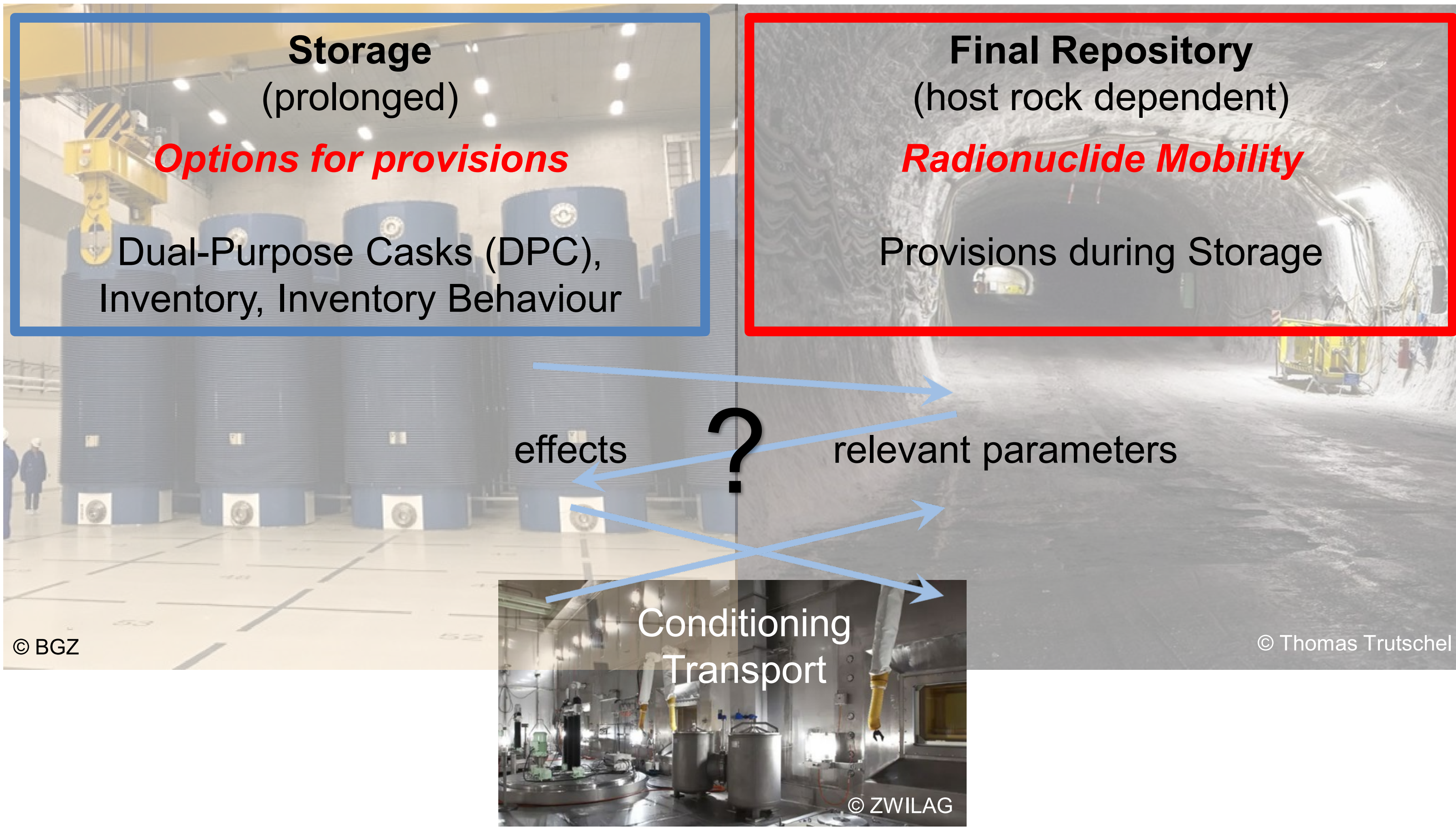
Federal Office for the Safety of Nuclear Waste Management

Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
Decommissioning and Storage Department

safeND, Berlin, 14.09.2023

# Content

# KombiLyse: Project Scope and Structure



# Inventory

**SF from LWR:**
PWR, BWR, WWER

**Chemical composition:**
$UO_2$, $(U,Pu)O_2$

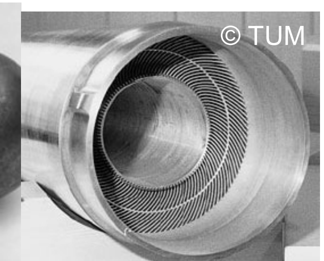
**Vitrified waste:**
- CSD-V
- UK-HAW
- VEK-mold

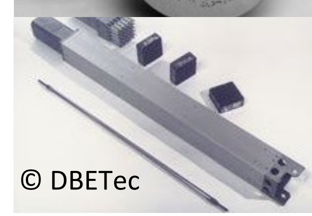
**Chemical composition:**
Borosilicate glass

**Research and Test Reactors:**
HTR, TRIGA, MTR, WWR, FBR

**Chemical composition:**
$UC_2$, $ThC_2$, $UO_2$, $ThO_2$, UCO, $UZrH_x$, $U_2Si_3$-Al, $UO_2$-Mg, Al, $(U,Pu)O_2$



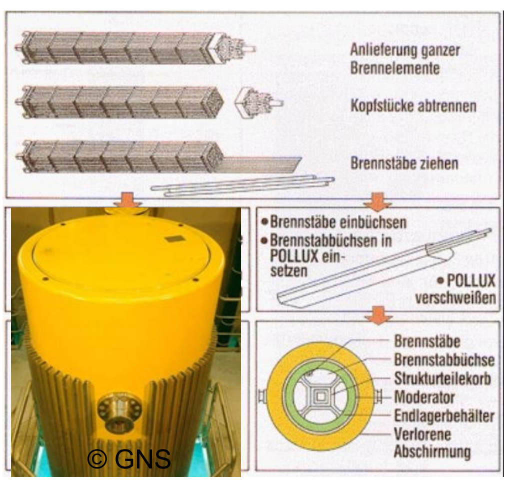




# Reference Final Disposal Concepts

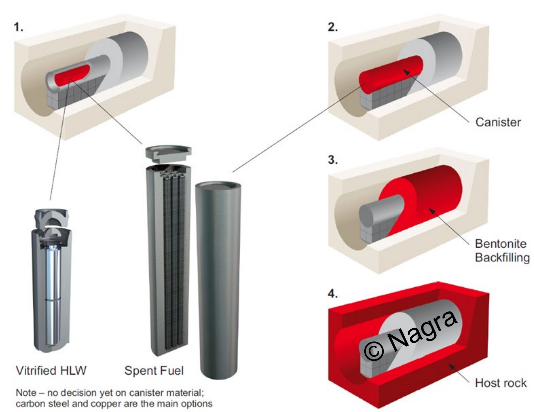
## **Salt** (Former German)


- POLLUX® cask
- $T_{0,cask}$ = 200 °C



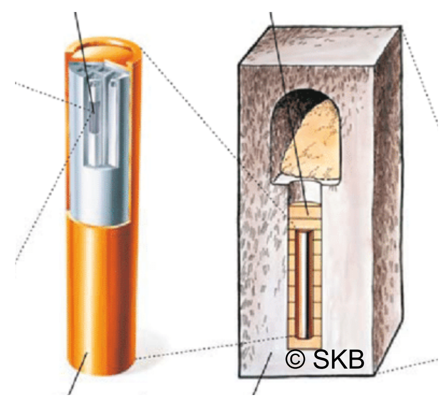

## **Clay** (Swiss)


- Steel cask
- Bentonite (Mx-80)
- $T_{0,cask}$ = 150 °C




## **Crystalline** (Swedish)


- KBS-3
  (iron and copper cask)
- Bentonite (Mx-80)
- $T_{0,cask}$ = 100 °C



# Concept of Storage Analysis

**Selection of specific loadings of DPC**

- Grouping of inventories
- Choice of representative loadings
  - Burn-up
  - Decay
  - Activity
  - Thermal output
  - Temperature
- Identification of problematic cases in terms of mobilisation

**Considerations on inventory behaviour**

- Representation of relevant effects including causes and consequences
- Time resolution of inventory behaviour concerning barrier effectiveness
- From operation over storage to disposal

**Options of various mitigation measures**

- Focus:
  - Handling
  - Conditioning
  - Radionuclide mobility
- Timeline for action required
- Identification of possible measures
- Impacts on storage safety

**Thermal analyses**

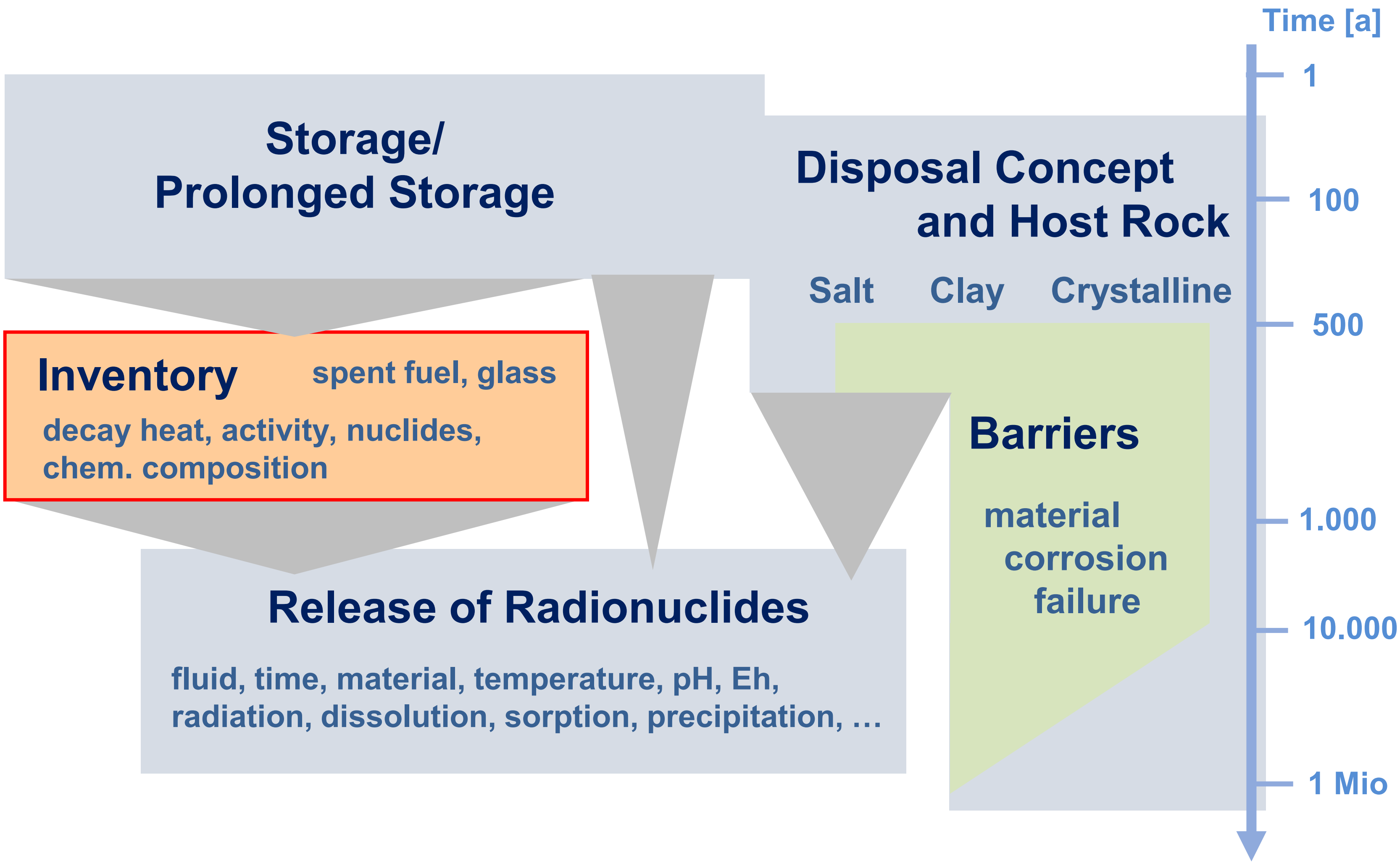
**Radionuclide mobility**

**Disposal safety**

# Results of Storage Analysis

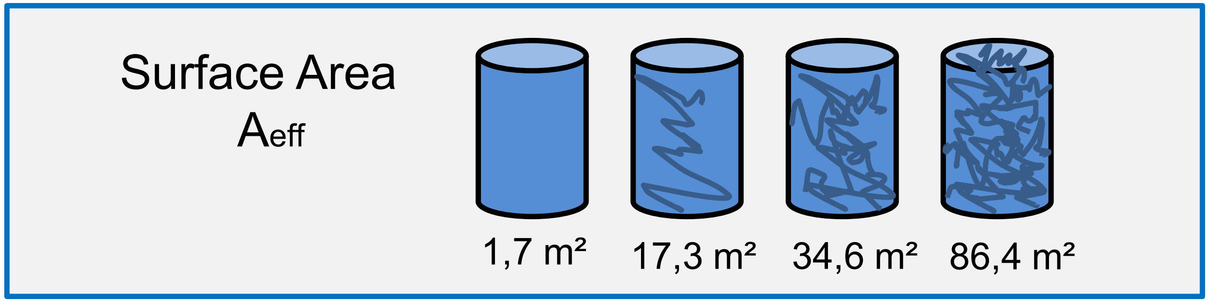
- **Currently, no evidence of systematic failure during prolonged storage** of cladding, enclosures, or barriers of the inventories considered if the casks continue to meet their safety functions.
  - **thermal analyses** indicate temperature levels that are not expected to produce any unacceptable temperature-driven effects and thus **no significant negative effects on material behavior** during prolonged storage
  - **radiation-induced effects** on the fuel/glass matrix and the surrounding material **are to be regarded as low**
- Consideration of **hypothetical scenarios** in which temperature, radiation and effects of radioactive decay can lead to impairment of the integrity of the enclosure (basis for derivation of options/measures)
  - temperature-induced effects addressable by measures during storage or early-transport/conditioning before effect occurs
  - effects caused by radioactive decay addressable by early-transport/conditioning before effect occurs
- Identified knowledge gaps should be addressed by R&D (e.g. on material properties)

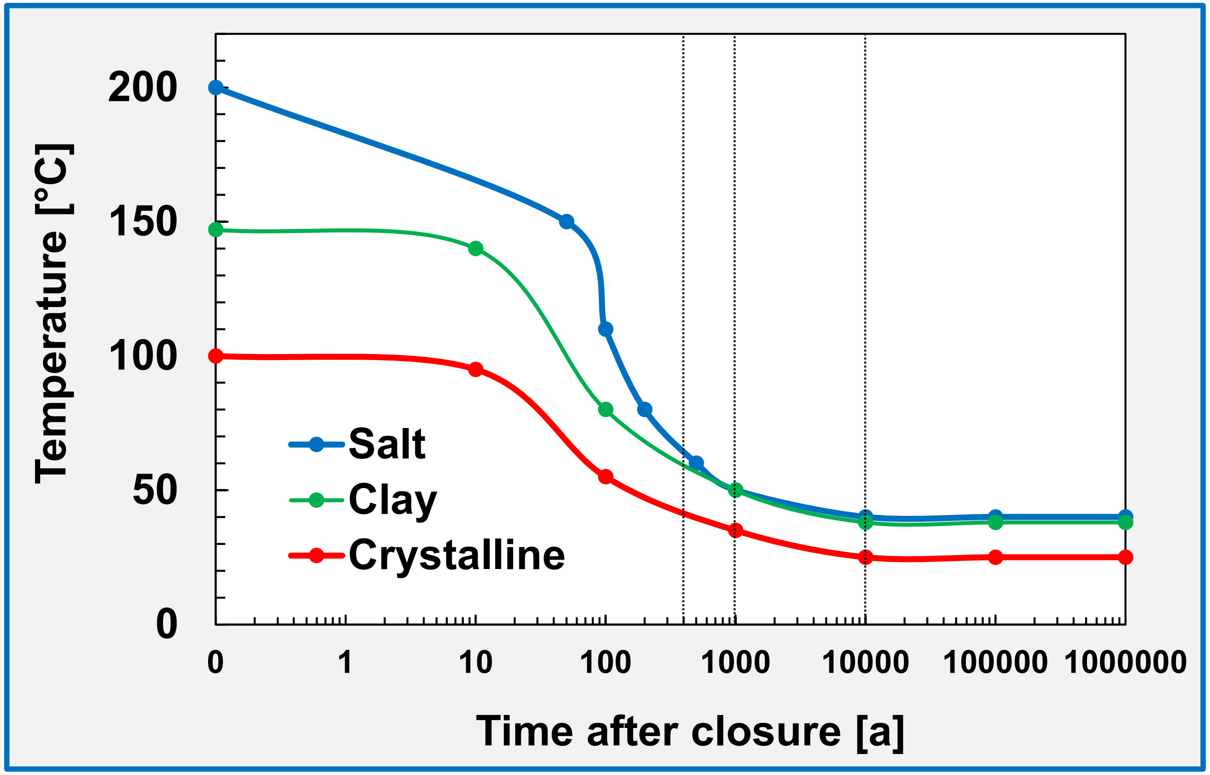
# Repository and Radionuclide (RN) Mobility Analysis



# Corrosion Models: Parameter Studies - HAW-Glass

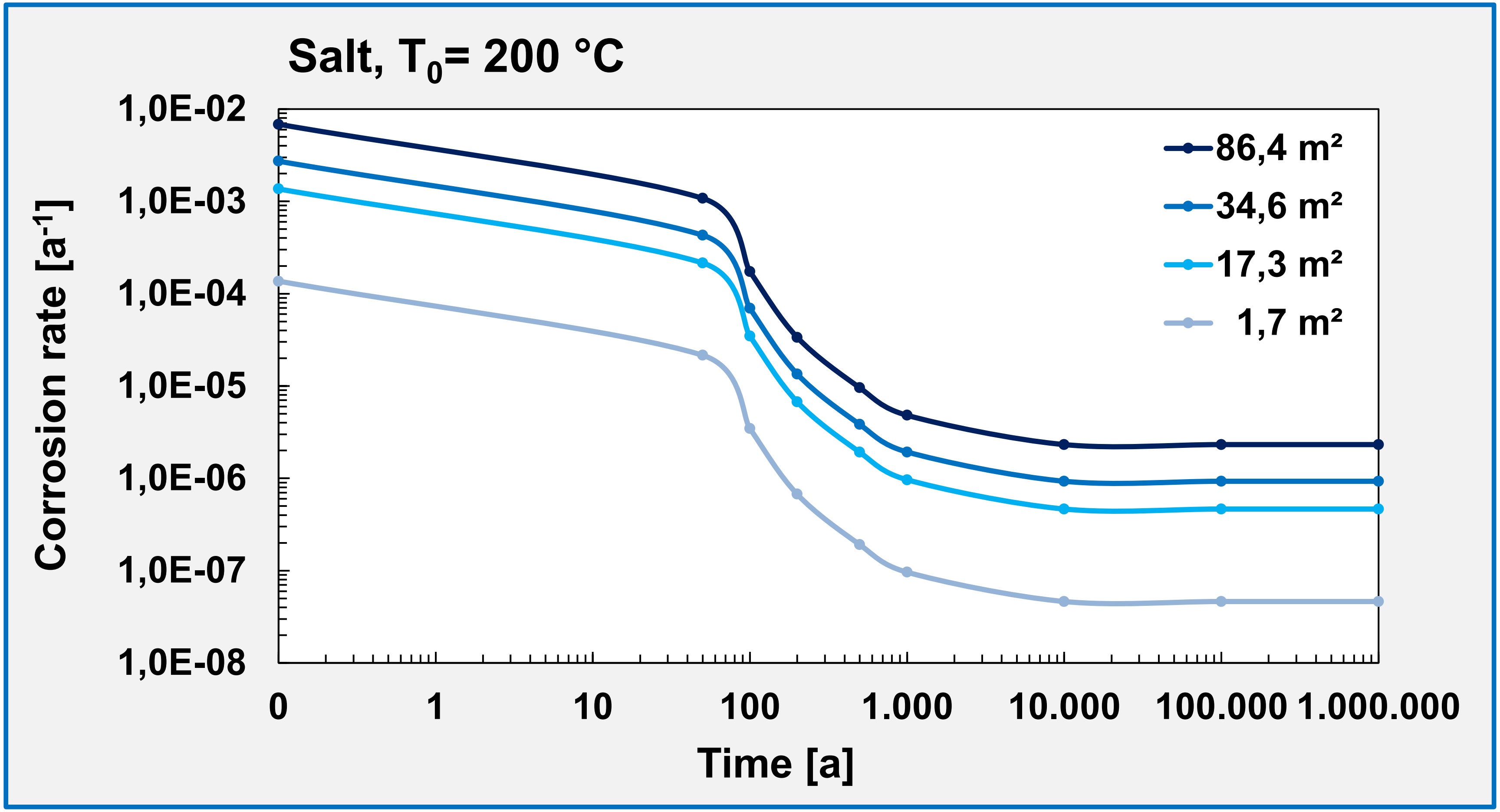
- **Water flux**
  - Conservatively assumed unlimited,
  - No consumption
- **Glass surface**
  - 1,7 m² („ideal“/geometric surface)
  - 3 diff. values assumed
- **Temperature [°C]**
  - $T_0$= 200, 150, 100
- **Barriers failure [a]**
  - 500, 1000, 10000



# Corrosion Models: HAW-Glass – Results

- Time dependency of corrosion rates for vitrified waste based on available surface – parameter study – unlimited fluid availability



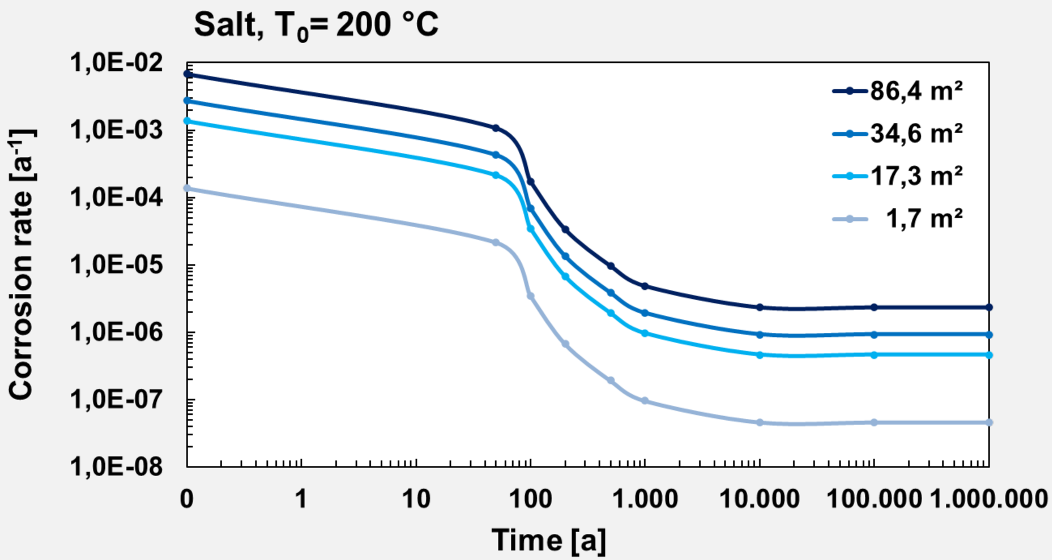
## Corrosion Models – Parameter Studies Summary

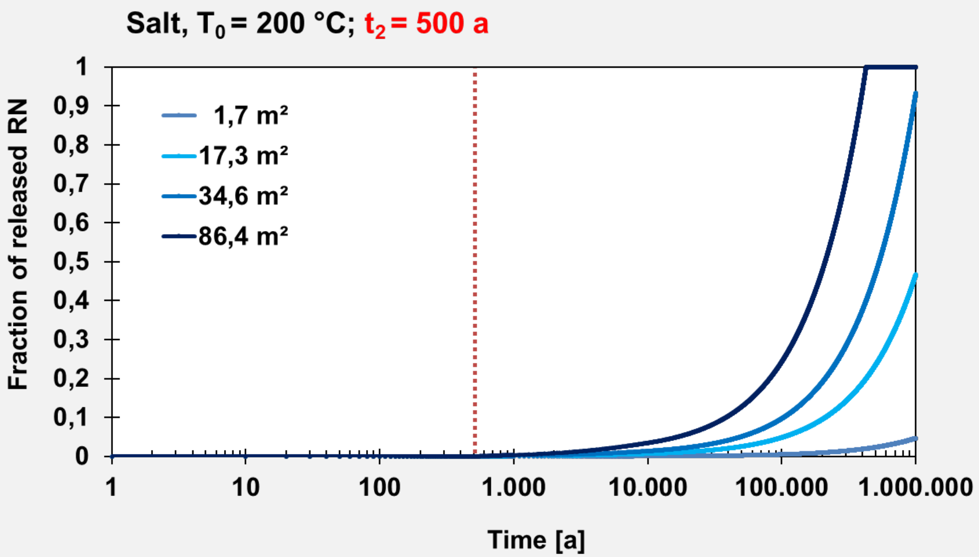
**Results**

- Inventory corrodes, contact time with fluid determines start, inventory/activity at the given time is used
- Model for vitrified waste depends on temperature and surface area

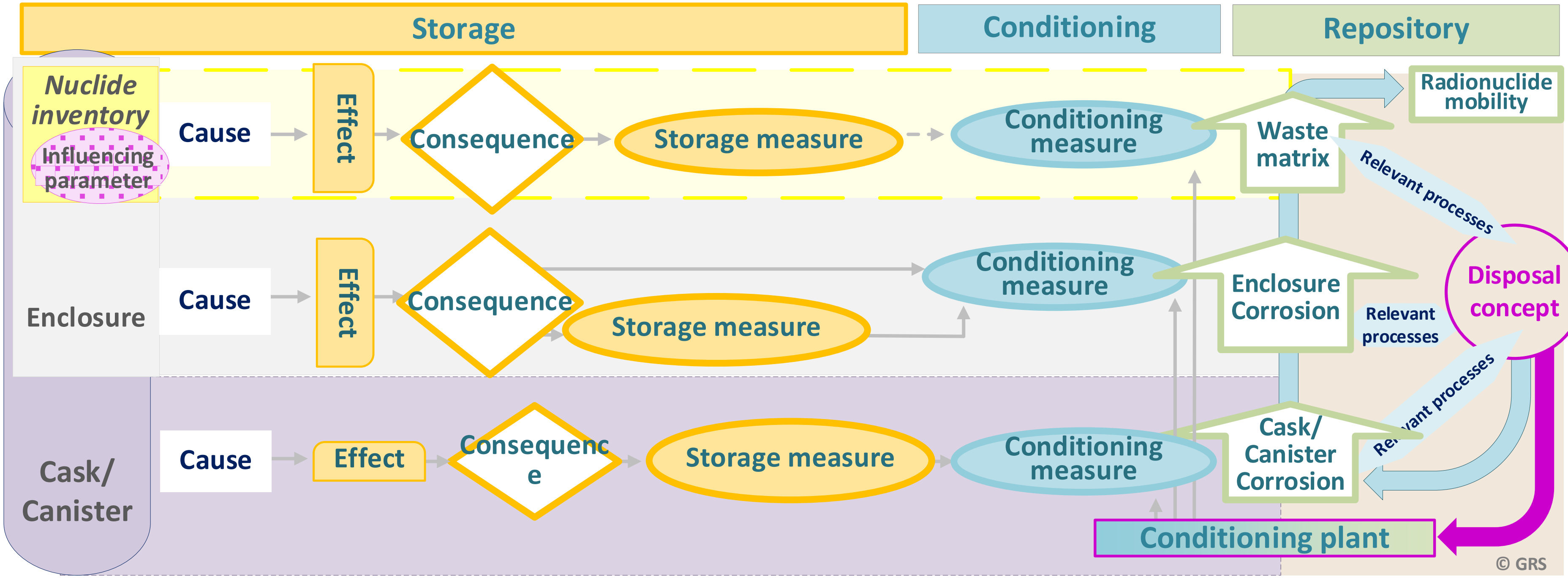
$$\vec{r} = A_{eff}^{Glas} \cdot \frac{1}{m^{Glas}} \cdot F \cdot e^{\left(-E_a/_{RT(t)}\right)}$$

- Model for LWR depends on radiation chemical yield (alpha activity), surface of fuel
- Release fractions from fuel/glass matrix (consideration of the near field only)



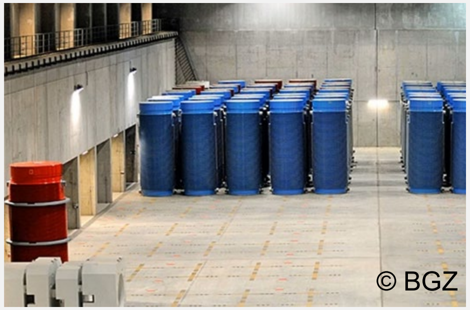



## Generic Flow Chart of Effects, Consequences and Possible Actions




**Compilation of possible actions for:**

- Vitrified high active waste
- LWR fuel assemblies
- WWER fuel assemblies
- AVR/THTR fuel assemblies
- Research reactor fuel assemblies




Storage


Conditioning

## Example: Vitrified Radioactive Waste

**Measures**

I. Thermal Treatment

II. Early-Transport

Storage

I. Early-Transport/Conditioning

II. Overpack

III. Thermal Treatment

Conditioning


## Vitrified Radioactive Waste

### Measures

**I. Thermal Treatment**


*In comparison to the reference case:*

- *Radionuclide mobility*
- *Radiation protection*
- *Handling*
- *Storage*

Effect: – Degradation of the glass matrix

Cause: – Alpha-decay, decay gas

Consequence: – Increase of the inner surface due to glass defects

**Goal:** – **Reduction of the inner glass surface**
**→ direct influence on corrosion rate in the modell (RN Mobility Analysis)**

Technical feasibility has to be evaluated!

## Vitrified Radioactive Waste


**Measures**

I. Thermal Treatment

**II. Early-Transport**

*In comparison to the reference case:*

- ○ *Radionuclide mobility*
- ● *Radiation protection*
- ○ *Handling*
- ○ *Storage*

Effect: – Gas accumulation in the stainless steel canister

Cause: – Release of helium from the glass matrix

Consequence: – Pressure build up and potential loss of integrity of the stainless steel canister and helium release in the cask

**Goal:** – **Early-transport to conditioning plant to prevent loss of integrity**

## Vitrified Radioactive Waste

**Measures**

**I. Early-Transport/Conditioning**


*In comparison to the reference case:*

- ○ *Radionuclide mobility*
- ● *Radiation protection*
- ○ *Handling*

| | | |
|---|---|---|
| Effect: | – | Gas accumulation in the stainless steel canister |
| Cause: | – | Release of helium (from alpha decay) from the glass matrix |
| Consequence: | – | Pressure build up and potential loss of integrity of the stainless steel canister and helium release in the cask |
| **Goal:** | – | **Early-transport to conditioning plant to prevent loss of integrity** |

## Vitrified Radioactive Waste


**Measures**

III. Early-Transport/Conditioning

**IV. Overpack**

*In comparison to the reference case:*

- ○ *Radionuclide mobility*
- ● *Radiation protection*
- ○ *Handling*

Effect: – Gas accumulation in the stainless steel canister

Cause: – Release of helium (from Alpha decay) from the glass matrix

Consequence: – Pressure build up and potential loss of integrity of the stainless steel canister and helium release in the cask

**Goal: – (Re-)establishment resp. preservation of the barrier**

# V. Results: Course of Actions

## Vitrified Radioactive Waste


**Measures**

III. Early-Transport/Conditioning

IV. Overpack

**V. Thermal Treatment**

*In comparison to the reference case:*

- *Radionuclide mobility*
- *Radiation protection*
- *Handling*

Effect: – Degradation of the glas matrix

Cause: – Alpha-Decay, Decay Gas

Consequence: – Increase of the inner surface due to glas defects

**Goal: – Reduction of the inner glass surface**
**→ direct influence on corrosion rate in the modell (RN Mobility Analysis)**

## Overview of possible measures

| | Measure | RNM | HAN | Inventory type |
|---|---|---|---|---|
| Storage | Thermal Treatment | X | | Vitrified Radioactive Waste |
| | Early-Transport | | X | Vitrified Radioactive Waste, LWR, WWER |
| | Heating | | X | LWR |
| | Gentler procedure | | X | LWR |
| Conditioning | Early-Transport/Conditioning | | X | Vitrified Radioactive Waste, LWR, WWER |
| | Overpack | | X | Vitrified Radioactive Waste |
| | Re-packing/Overpack for Stainless Steel Canister | | X | AVR/THTR |
| | Thermal Treatment | X | | Vitrified Radioactive Waste |
| | Encapsulation of Fuel Assemblies | | X | LWR, WWER, FR-BE |
| | Heating/Quenching | | X | LWR |
| | DPC used as Disposal Canister | | X | LWR, FR-BE |
| | Welding of Canisters | | X | AVR/THTR |

RNM = Radionuclide Mobility, HAN = Handling

## Conclusion

- KombiLyse project systematically examined the interactions between storage and final disposal with regard to **storage safety** and **radionuclide mobility** (safety of disposal) within the final repository (causes – effects – consequences).
- Resulting course of actions rely on **hypothetical scenarios** developed during storage analysis.
- Summary table reflects only **direct influence** on RN mobility according to the model used for the repository analysis and the **reference case** ("doing nothing", no (unforeseen further) effects during storage, transport to conditioning and transfer to final disposal canister), neglecting possible positive (or detrimental) effects
- Repository site and disposal concept are a prerequisite for the conditioning of the inventories
  - ➡ without specified acceptance criteria the presented course of actions cannot be finally evaluated concerning plausibility and feasibility
- Resulting mitigation measures and actions described aim to
  - **maintain or restore** the handling properties of HAW-glass/fuel elements
  - and/or to **delay** RN mobility within the near field of the final repository

# Thank you for your attention!

*The research project "Combined analysis of safety-relevant aspects from the perspectives of storage and disposal of high-radioactive waste taking into account longer periods of storage (KombiLyse)" has been commissioned by BASE under the project number 4719F10701. Project start: 01.08.2020, term: ~ 3 years*

*This presentation reflects the view and opinion of the contractor and does not have to agree with the opinion of the client.*

Federal Office
for the Safety of
Nuclear Waste Management