BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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CONTAINER REQUIREMENTS FOR HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL IN ROCK SALT, CLAYSTONE, AND CRYSTALLINE ROCK – OUTCOMES OF THE RESEARCH PROJECT KOBRA

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Outline

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1. Introduction

- Suitable containers for receiving the high-level radioactive waste are a key elements of every repository system concerning different host rocks like rock salt, claystone and crystalline rock as being considered in Germany
- Disposal container design is decisive regarding
  - boundary conditions for the transport and emplacement techniques
  - operational and long-term safety assessment

Conclusion

The systematic derivation of the requirements to be placed on disposal containers forms the basis for a *targeted, comprehensible and transparent* development of containers that meet the requirements.

R&D project **KoBrA**

Requirements and Concepts for Containers for the Final Disposal of Heat-generating Radioactive Waste and Spent Fuel Assemblies in Rock Salt, Claystone and Crystalline Rock

by

BAM und BGE TECHNOLOGY GmbH

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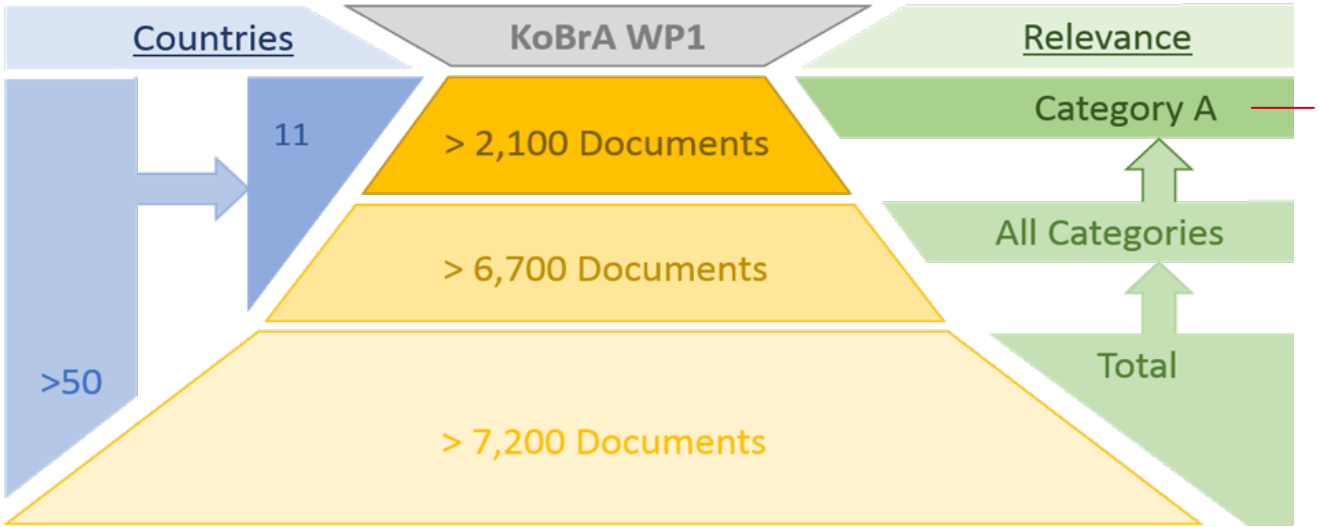
BGE TECHNOLOGY GmbH

Bundesministerium für Wirtschaft und Energie

2. International container concepts for final disposal of high-level radioactive waste (HLW)

As part of a comprehensive literature review, the national and international status of container requirements and concepts for high-level radioactive waste in various host rocks was recorded, evaluated and compiled in a document collection.

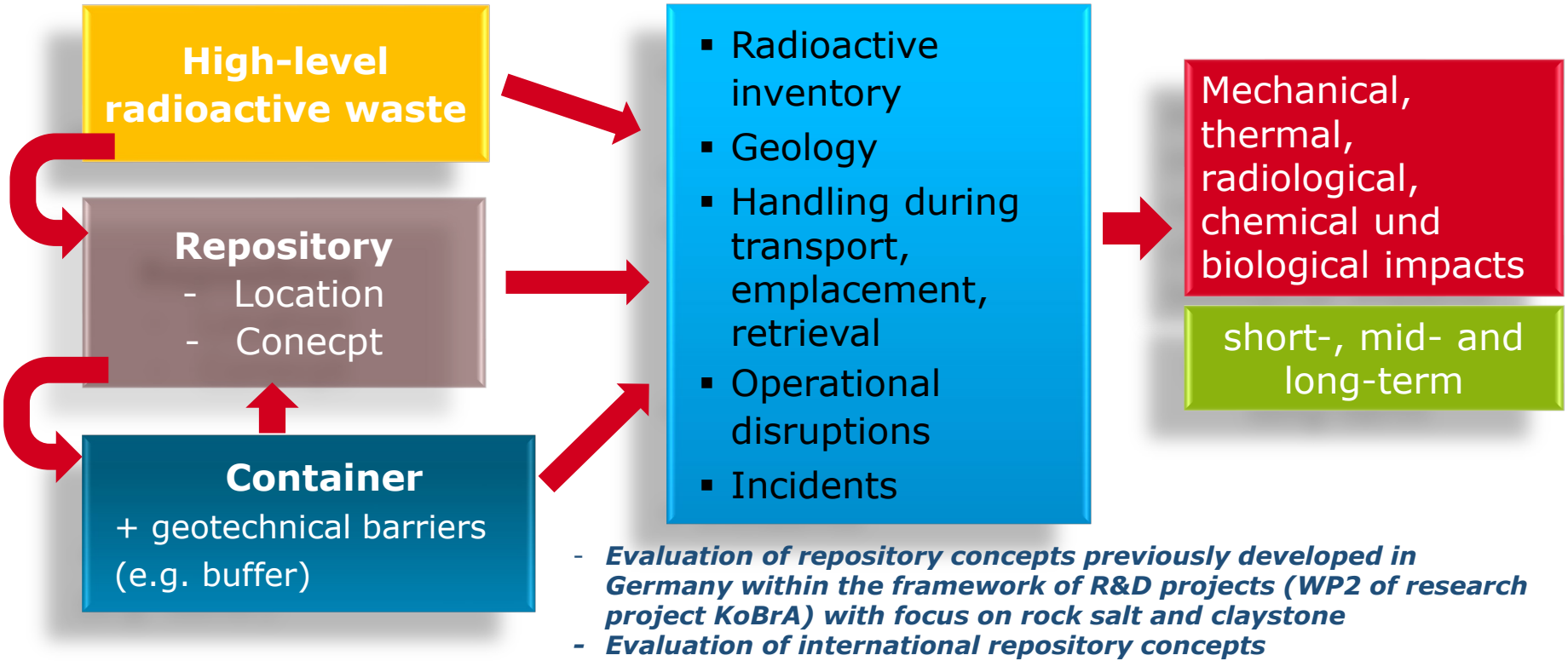


2. International container concepts for final disposal of high-level radioactive waste (HLW)

Relevant international repository programs

- Most advanced programs for crystalline rock in Finland and Sweden, for claystone in France and Switzerland.
- Open siting processes in Germany, UK, US (besides Yucca Mountain)
- Internationally largely the same protection goal definitions
- The majority of the internationally considered concepts include robust containers that are not adequately shielded for handling and transport, so that additional overpacks are required.
- Requested container service lifes
  - crystalline rock up to 100.000 years (Germany up to 1 million years)
  - claystone some thousand years
  - Rock salt about 500 years (Germany)

3. Container specific impacts and boundary conditions



- ***Evaluation of repository concepts previously developed in Germany within the framework of R&D projects (WP2 of research project KoBrA) with focus on rock salt and claystone***
- ***Evaluation of international repository concepts***

Overview of the static mechanical loads (pressures) acting on the repository packages in the repository concepts considered.

Host rock	Country	Depth [m]	Pressure [MPa]			
			litho-static	hydro-static	swelling pressure	glacial load
Crystalline rock	Sweden	500	--	5	≤ 15	≤ 25
	Finland	420		4,1		
	Rep. Korea	500		5	10	
	Czech Rep.				15	
	Canada			6	≤ 11,5	≤ 30
Claystone	Belgium	240	4,5	2,2	5…6	
	France	525	12	-- (5,3)	≤ 7	
	Switzerland	450…850	15…22	4,5…8,5	2..4	≤ 5
Rock salt (VSG)	Germany	870	18,8	--	--	≤ 15

Overview of the thermal and radiological boundary conditions to be assumed in the repository concepts considered.

Host rock	Country	Depth [m]	Rock temperature [°C]	Dose rate on the package surface [Gy/h]
Crystalline rock	Sweden	500	10,5	≤ 0,055 [C]
	Finland	420	10…12	≤ 0,22 [C]
	Rep. Korea	500	35[B]	≤ 0,1 [C]
	Czech Rep.		10	
	Canada		11	≤ 0,135 [C,D,*]
Claystone	Belgium	240	16	< 25 [C]
	France	525	23	< 30
	Switzerland	450…850	30…45	< 0,035[C]
Rock salt (VSG)	Germany	870	38	(POLLUX®) < 0,01 [A,*]
				(BSK-3) ≤ 100 [C,*]

A - according to design
C - calculated
D - distance of 20 cm from the surface of the "buffer box" after 10 years decay time
** - values calculated in Sv/h (equivalent dose rate).*

4. Derivation of requirements for HLW disposal containers

Basic regulatory requirements (in Germany)

- Atomic law
- Radiation protection law and related ordinances
- Site selection law (Standortauswahlgesetz – **StandAG)**
- **Endlagersicherheitsanforderungsverordnung - EndlSiAnfV** (06. Okt. 2020)
  (Disposal Safety Requirement Ordinance)
  Former safety requirements of the BMU (Sept. 30, 2010) for the disposal of heat-generating radioactive waste
- Guidelines and recommendations of the Nuclear Waste Management Commission (ESK),
  e.g. RECOMMENDATION of the ESK - *Requirements for packages for the disposal of heat generating radioactive waste* (20.01.2017)

4. Derivation of requirements for HLW disposal containers

Endlagersicherheitsanforderungsverordnung – EndlSiAnfV
(Disposal Safety Requirement Ordinance)

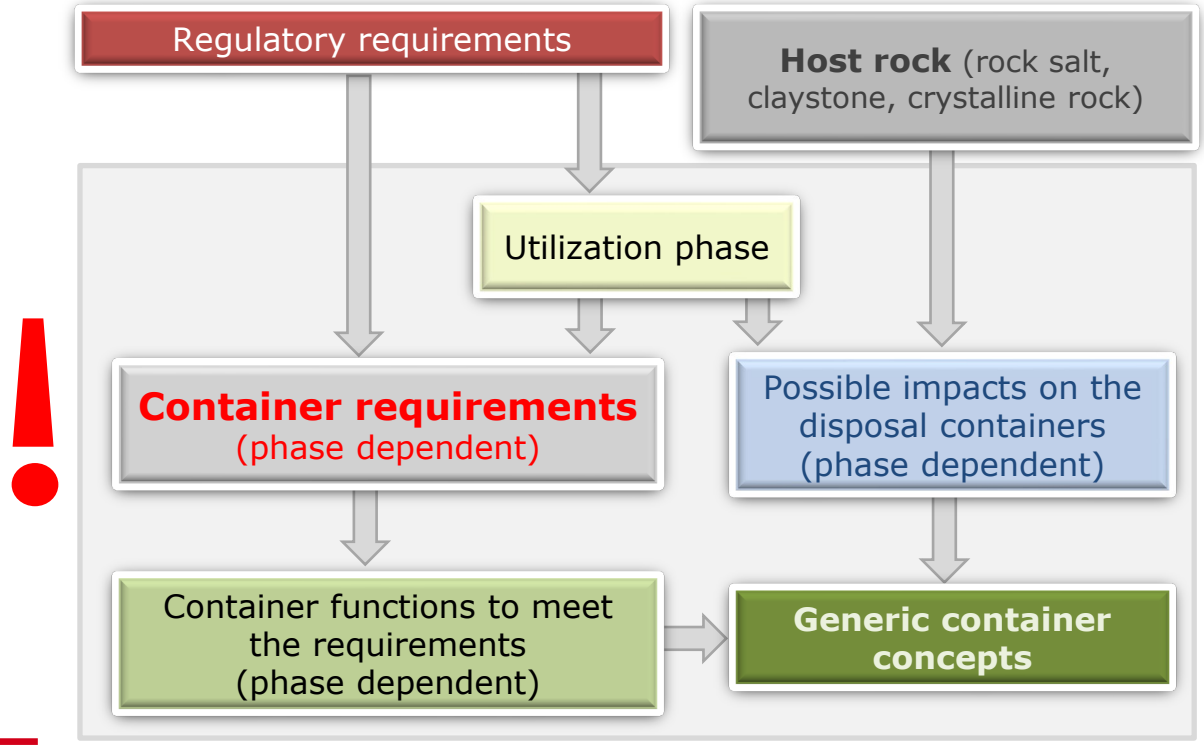
Utilization phases			
Emplacement phase	**Retrievability phase**	**Recovery phase**	**Later post-operational phase**
Provision of the container for emplacement until emplacement is completed	Completion of emplacement of the container until start of decommissioning of the repository	Start of decommissioning of the repository until 500 years after closure of the repository	500 years after closure of the repository until the end of the verification period

4. Derivation of requirements for HLW disposal containers

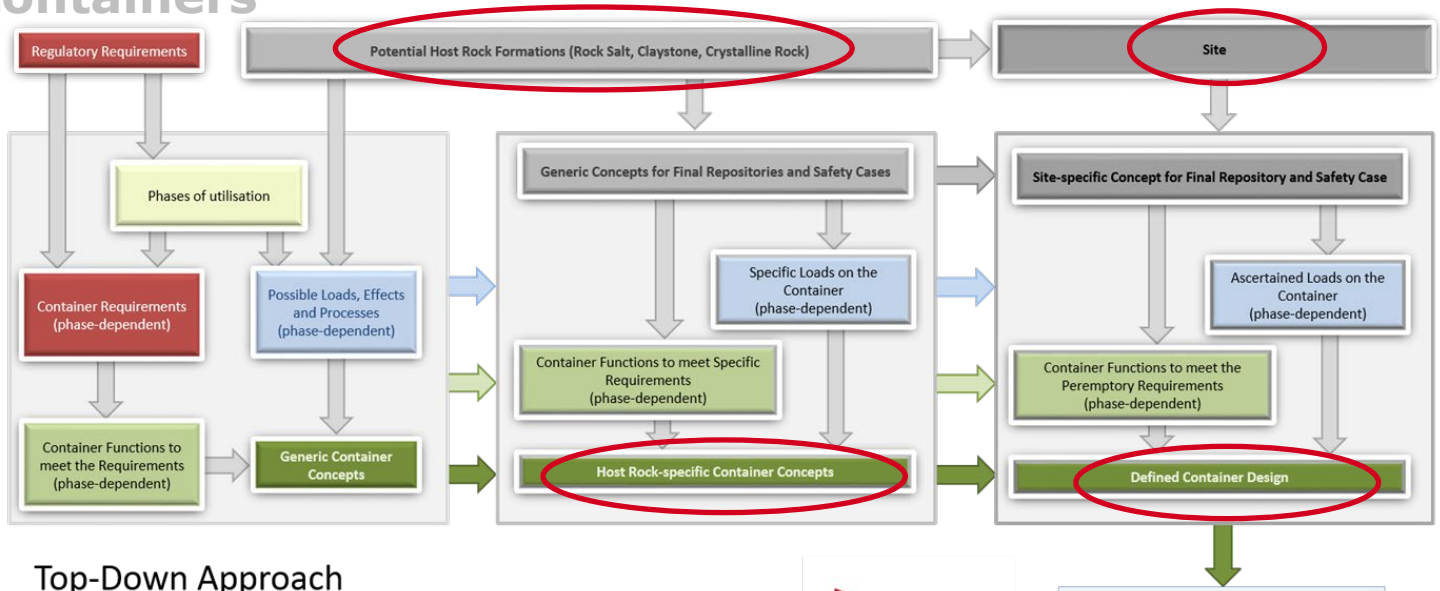
Time dependency of the basic container requirements

Basic requirements on disposal containers (independent from host rock type)	**Utilization phase**			
	Emplacement	**Retrievability**	**Recoverability**	**Later post-operation**
Confinement of the radioactive inventory	To be ensured completely			Depending on the safety and verification concept
Radiation shielding	To be ensured sufficiently *Protection of personnel, population and the biosphere; possibly in conjunction with a transfer container*			
		To be ensured sufficiently *Avoidance of safety-relevant radiolytic or radiolytically promoted damage to the barriers*		
Preclusion of criticality	To be ensured completely *for the most reactive arrangement of nuclear fuel*			
Temperature limitation	To be ensured sufficiently *Safe handling, possibly in conjunction with a transfer container*			
		To be ensured sufficiently *Avoiding safety-relevant thermal damage to the barriers, the host rock and the container inventory*		
Limitation of corrosion and gas-production		To be ensured sufficiently *Prevention of damaging barriers due to high gas pressures and the formation of safety endangering gas transport paths*		
Handling (emplacement, retrieval, recovery)	To be ensured sufficiently			

Approach for the development of generic container concepts



4. Derivation of requirements for HLW disposal containers



Top-Down Approach
for the Development of Final Disposal Containers, meeting all Requirements for the Final Disposal of High-Activity Wastes

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Safety Case (container-specific)

Confirmation and verification of fulfilling the relevant container functions and of meeting all requirements, considering all relevant loads, effects and processes over the entire time span defined by the safety case for the final repository

Results of the R&D project KoBrA
BMWi funding IDs 02E11527 and 02E11537

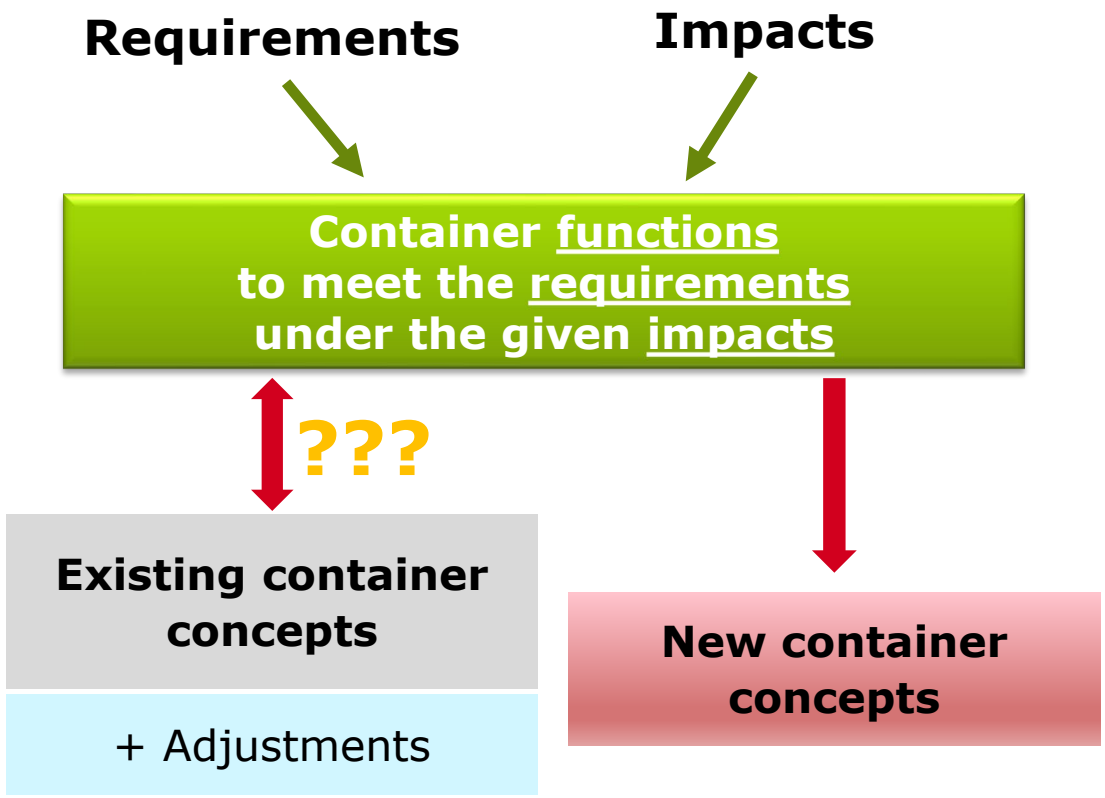
5. Considerations regarding potential container concepts

Top-down-approach

Generic

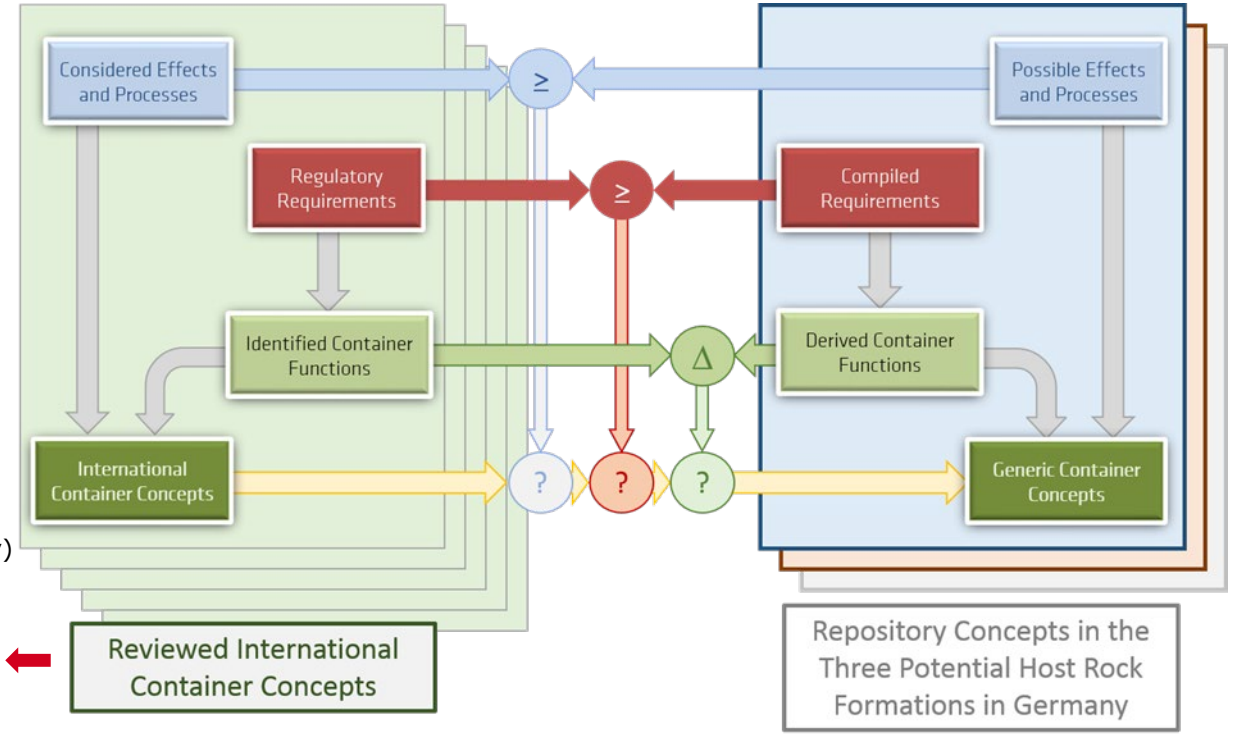
Host rock type/ repository region

Site location



5.1 Transferability of existing container concepts

Method for examining existing container concepts with regard to transferability to repository concepts in Germany



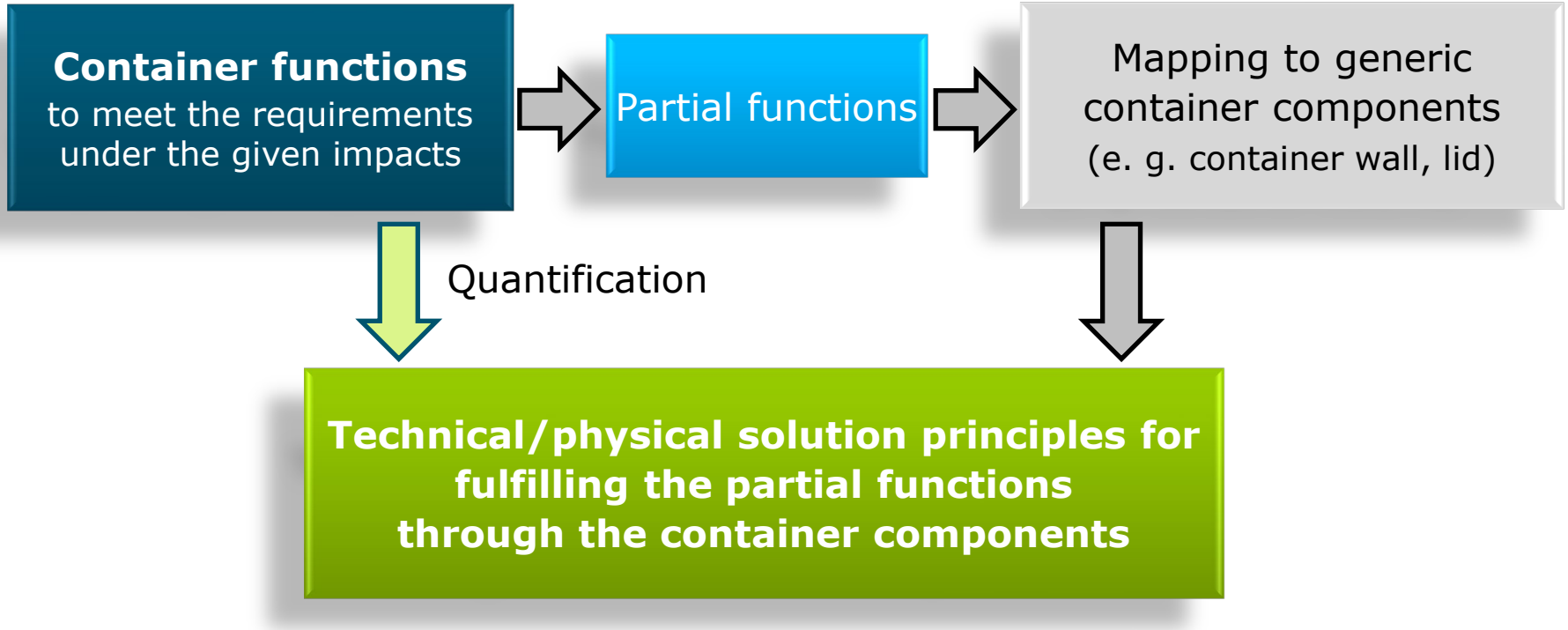
e.g.

- KBS-3 (SKB/Posiva Oy)
- Category-C-Container (Andra)
- BSK-3 (GNS)
- POLLUX®-10 (GNS)

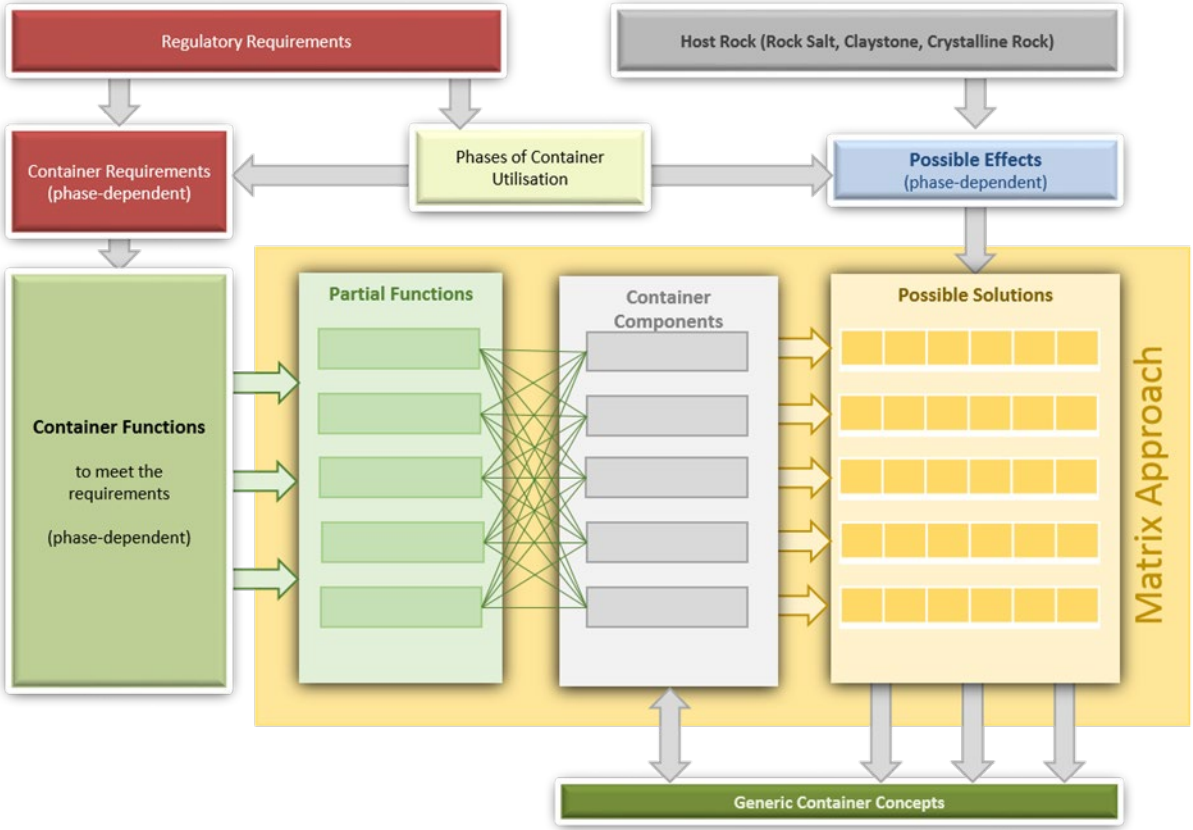
Conclusions regarding existing container concepts

- To date, mainly generic container concepts have been developed.
- So far, qualitative statements based on hypotheses and argumentative considerations have prevailed.
- Quantitative statements on requirements and impacts are only available to a limited extent.
- There are significant gaps in knowledge regarding the quantitative effects on disposal containers (depending on the site location) → need for further R&D.
- For transport and storage containers (TLB) there is a considerable additional need for evidence; important here is their long-term stability.
- The requirement for recoverability exists exclusively in Germany and has not yet been considered for any container concept.

5.2 Development of generic container concepts



Solution matrix for the development of generic container concepts



Conclusions regarding generic container concepts

- By fulfilling all partial functions through the components, the container concept as the sum of the components also fulfills the sum of the partial functions.
- Not every free combination of solution principles offers an equally good qualitative or quantitative fulfillment of all requirements.
- Interactions must be taken into account.
- The optimization process includes weighting of the partial functions and availability of materials and (manufacturing) technologies → this includes trial and test programs.
- The systematic and comprehensible optimization and narrowing down of suitable container concepts is of crucial importance; this requires a systematic derivation and presentation of weighting factors and optimization processes.

6. Main conclusions from the KoBrA - project

- The developed top-down approach enables a systematic derivation of suitable container concepts as part of the site selection process for all three potential host rocks in Germany.

  Basis therefore are:

  - Clearly defined **requirements** for the disposal containers, taking into account retrievability and recoverability (regulations),
  - **Site-specific impacts** on disposal containers (geological data-base, possibly covering data),
  - Specification of the **operational impacts** on the disposal container in conjunction with the development of suitable repository concepts (possibly covering impacts),
  - Derivation of a methodology for determining selection and decision-making criteria for suitable disposal container concepts, taking into account the requirements for transparency and the time frame of the site selection process.

6. Main conclusions from the KoBrA- project

- First assessment of the suitability of container concepts that have already been developed
  - nationally (e. g. POLLUX®),
  - internationally,
  - transport and storage containers

  → in all cases, significant adjustments and further evidence are required.
- The current general temperature limit of 100°C leads to a considerable adjustment effort for the majority of the container concepts considered in Germany so far.
- The demand for recoverability is associated with open questions for all container concepts, which in terms of long-term durability are likely to determine the design in part.
- The solution approach developed for new container concepts opens up a huge variety of concepts, the step-by-step optimization and narrowing of which must be comprehensible and transparent.

6. Main conclusions from the KoBrA- project

General recommendation:

Against the background of the tight timeframe of the site selection process, preference should be given to robust container concepts based on materials and (manufacturing) technologies that have already been developed and tested, and which can be manufactured reliably, with the required quality and on time in the large quantities required.

Recent developments:

- BGE is now responsible for the development of HLW disposal containers in Germany.
- BGE has already awarded a project for the development of a disposal container concept for crystalline rock, further projects for claystone and rock salt are planned for the near future.

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Final report of the KoBrA - project (only in German)
https://www.tib.eu/de → Link

Thank you for your attention

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Any questions ?