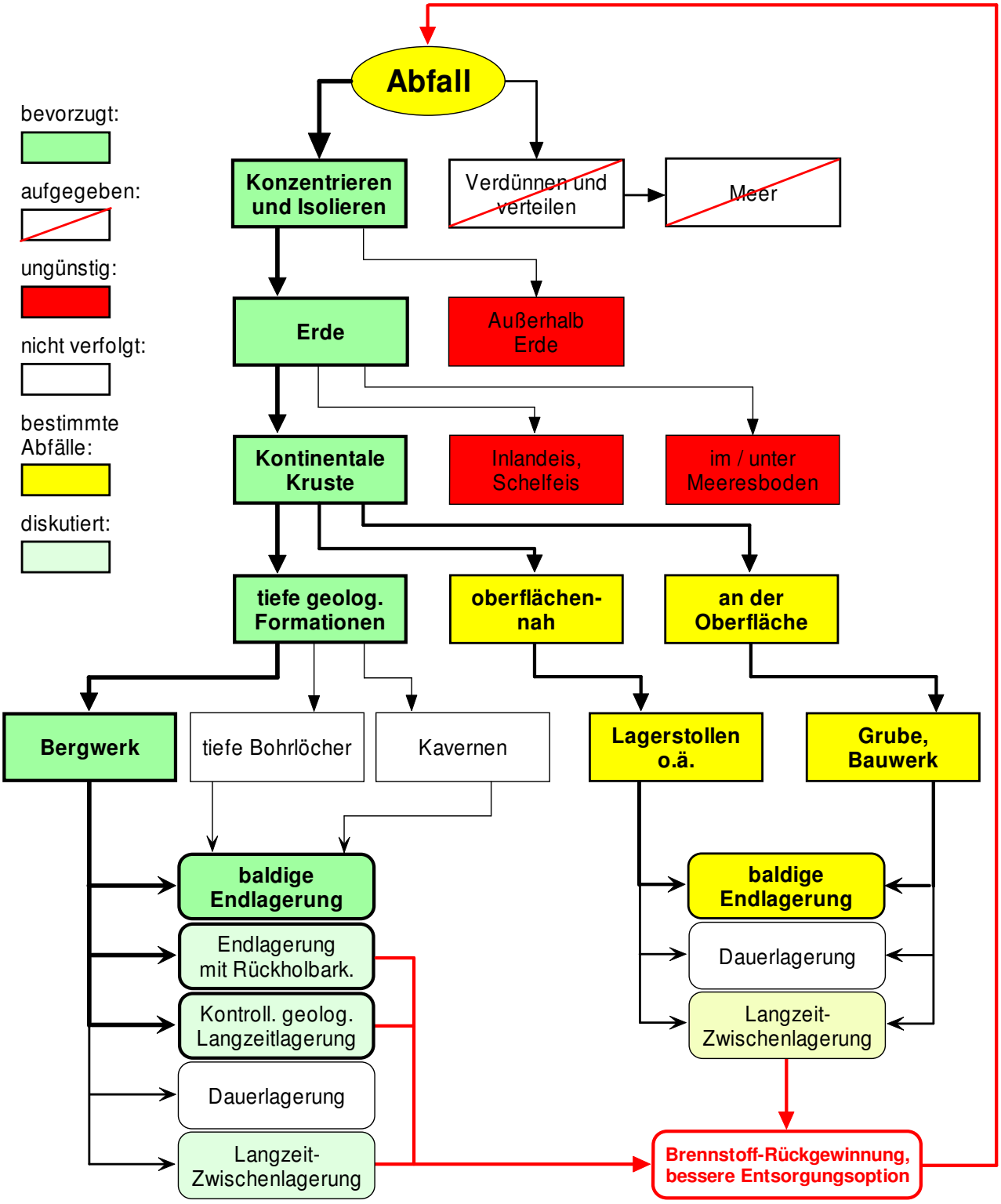
Detlef Appel
PanGeo – Geowissenschaftliches Büro, Hanover

The future of radioactive wastes - possibilities and risks of various waste management options

- Review of the discussion about waste management
- Different waste management strategies for different types of waste
- Final disposal in deep geological formations of the earth crust - preferred option for long-lived wastes (including SF)
  - Why other options?
  - Which other options?
- Partitioning & Transmutation (P & T) - an option to reduce the risk immanent to wastes?
- Final disposal and/or storage - options to reduce risks related to exposure?
  - Characteristics
  - Comparative evaluation
- Summary

Waste management options

Entsorgungsoptionen für radioaktive Abfälle



Actual management strategies for different waste types

LLW + ILW (short-lived radionuclides)

- Final disposal on surface (construction, pit)
- Final disposal near to surface (gallery / tunnel, mine)
- Final disposal in deep geological formations (gallery / tunnel, mine)
  - may include retrievability of waste
  - may include test- / demonstration emplacement
- Controlled geological long-term storage / Geological deep disposal (gallery / mine)
- Long-term interim storage, on surface / ? below surface (construction, gallery / mine)

Particularly HLW / SF + ILW (long-lived radionuclides)

- Final disposal in deep geological formations (mine)
  - may include retrievability of waste
  - may include test- / demonstration emplacement
- Controlled geological long-term storage / Geological deep disposal (mine)
- Long-term interim storage, on surface / ? below surface (construction, gallery / tunnel, mine)

Key characteristics of final disposal in deep geological formations?

Advantages

- waste outside biosphere, large transport distances for waste constituents
- retention capacity of geotechnical and geological barriers against groundwater transport of radionuclides (and other contaminants)
- no need for post-closure maintenance of safety carrying elements (geotechnical + geological barriers) → passive system
- status of passive safety is reached soon after closure
- function and stability of geological barrier to be derived from nature observation

→ early decision for final disposal

Key characteristics of final disposal in deep geological formations?

Disadvantages of final disposal

- wrong decision on repository site cannot be corrected ("irreversible")
- no chance to react on unexpected behaviour of disposal system
- long-term behaviour cannot totally be described and evaluated
- correctness of the demonstration of long-term safety cannot be proven in a natural-scientific sense, predictions about function of barriers with uncertainty
- monitoring with major restriction only, no long-term monitoring
- repair not possible

→ **discussion about alternatives**

Discussed waste management alternatives

→ Reducing the immanent danger of radioactive wastes

- Partitioning & Transmutation **P & T**

→ Reducing risks related to possible exposure

- final disposal in deep geological formations **EL**
- final disposal in deep geological formations, including possible retrievability of waste/SF **ELR**
- controlled geological long-term storage (geological deep disposal) **KGL**
- long-term interim storage (on surface / ? below surface) **LZL**
- permanent storage [guidance] (on surface / ? below surface) **DL**

Partitioning & Transmutation (P & T)

! Separation of long-lived radiotoxic radionuclides from waste / spent fuel and their transmutation to short-lived radionuclide or inactive nuclides !

Arguments presented for P & T

- reducing the radio-toxicity of waste
- reducing the needed isolation period
- reducing problems of system prediction with regard to demonstration of long-term safety
- reducing the amount of waste do be disposed
- reducing the heat production in the repository
- reducing the risk of proliferation by destroying fissionable U and Pu isotopes

Partitioning & Transmutation (P & T)

Evaluation

Radio-toxicity / isolation period / long-term safety

- dose depends on long-lived fission products, but
  - Transmutation of long-lived fission products not intended so far
  - feasibility open

Amount of wastes

- P & T of HAW / spent fuel only
  - larger amounts of LLW and ILW not affected
- additional secondary waste

Proliferation

- P & T requires additional interim storage and handling of separated materials prior transmutation
  - possible access to fissionable materials more simple as for spent fuel, particularly in a closed repository

Partitioning & Transmutation (P & T)

Evaluation (ctd.)

Status of development

- P & T needs large-scale technical facilities, the operation of which is connected with risks
- it is open, if and when P & T is ready for application, but
- no application within the next decades

Summary P & T

- no short-term solution for waste management problem
- based on permanent large-scale nuclear industry
- repository needed anyway (not treated wastes / secondary waste)

⇒ **Achievement of P & T objectives just a hope**

Arguments presented for storage options (HLW/SF + ILW$_{(long-lived)}$)

Safety (general)

- Waiting for less dangerous management strategy (P & T) **ELR, LZL**
- confidence in measures **>** in functioning of geological barrier **DL**

Long-term safety of repository, proof of long-term safety

- repository site turns out to be not suitable after start of operation **ELR**
- reaction to unexpected events **ELR, KGL**
- improvement of system understanding and quality of the safety demonstration by in-situ investigations and observations **ELR, KGL**

Fairness → today's generation

- democratic participation in decision about waste management **ELR, LZL**

Fairness → future generations, sustainability

- democratic participation in decision about waste management **ELR, KGL**
- maintaining the room for manoeuvre of future generations **ELR, LZL**
- facilitating later recovery of fissionable material **ELR, LZL**
- put into action the "polluter pays principle", avoiding burdens **EL, KGL**

Acceptance **ELR, LZL**

motives?

Characteristics of storage options (HLW/SF + ILW$_{(long-lived)}$)

Definitive options

- **Final disposal** — **EL**
  (may include test / demonstration emplacement)
  place: deep geological formations (mine) — **geosphere**
  safety: geotechnical + geological barriers — **passive**
  accessibility of wastes (after definitive emplacement)? — **no**
- **Permanent storage** / guardianship — **DL**
  place: **on surface** / ? below surface (construction, gallery / tunnel, mine) — **biosphere** (geosphere)
  safety: technical barriers, measures (control, maintenance, repair) — **active**
  accessibility of wastes? — **always**

Preliminary options

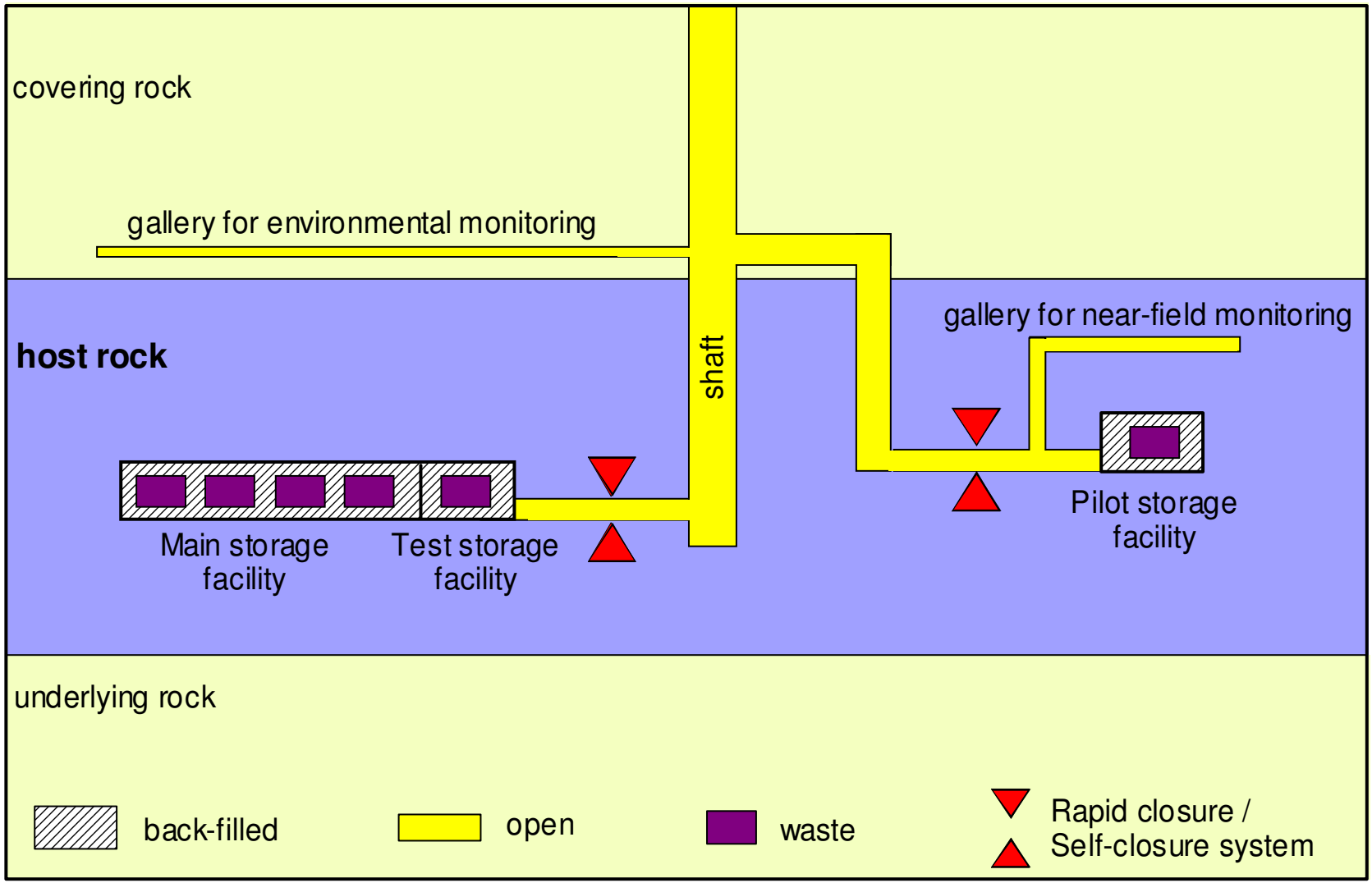
- **Long-term interim storage (on surface** / below surface**)** — **LZL**
  place: on surface / ? below surface (construction, gallery / tunnel, mine) — **biosphere** (geosphere)
  safety: technical barriers, measures (control, maintenance, repair) — **active**
  accessibility of wastes? — **always**

Characteristics of management options (HLW/SF + ILW$_{(long-lived)}$)

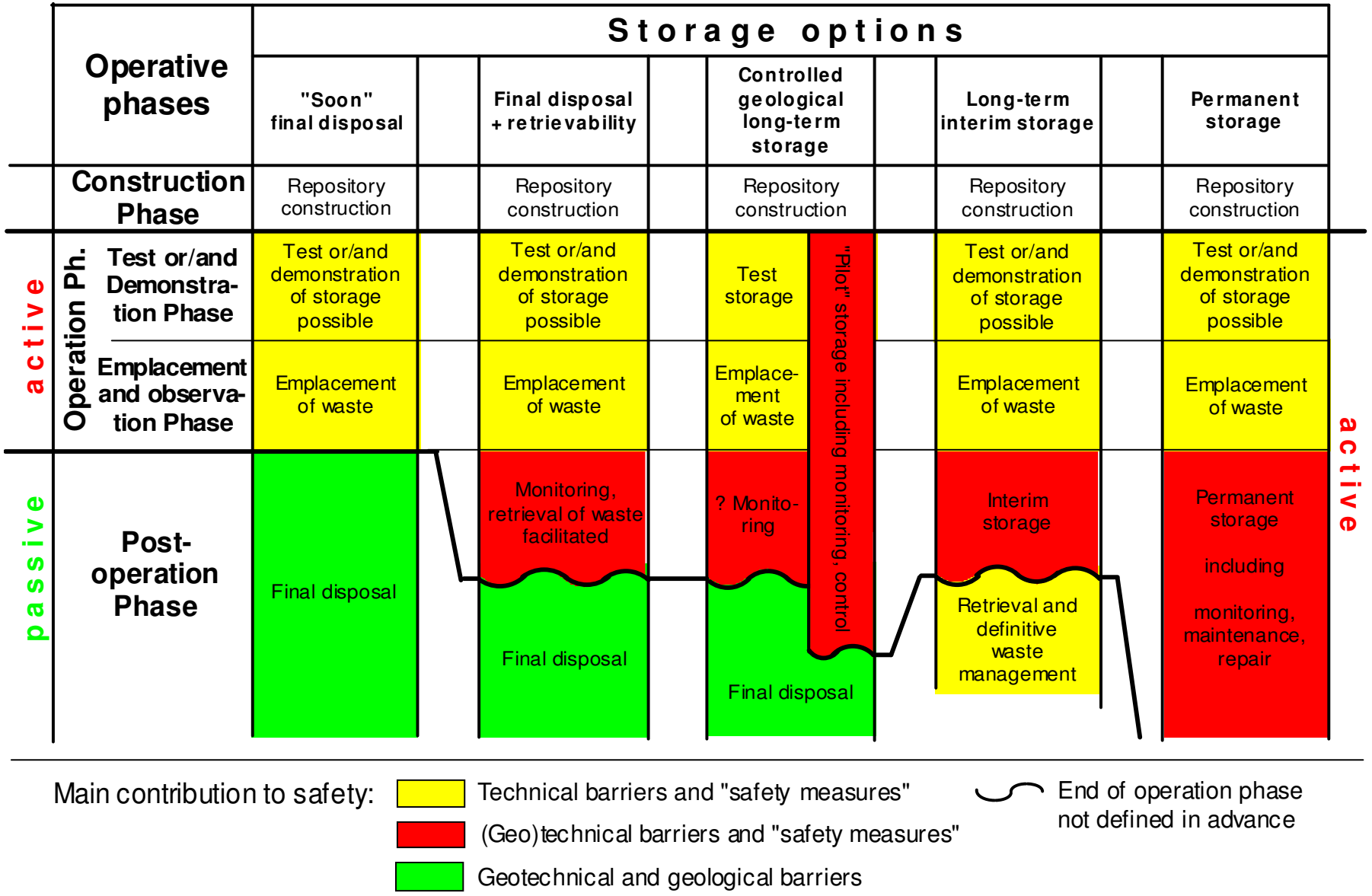
Definitive options with transient phase

- **Final disposal with retrievability of waste** — **ELR**
  (may include test / demonstration emplacement)
  place: deep geological formations (mine) — **geosphere**
  "short-term" safety: technical barriers, measures (control, maintenance, repair) — **active**
  long-term safety: geotechnical + geological barriers — **passive**
  accessibility of wastes? — **restricted period**
- **Controlled geological long-term storage (Geological deep disposal)** — **KGL**
  place: deep geological formations (mine) — **geosphere**
  "short-term" safety: technical barriers, measures — **active**
  long-term safety: geotechnical + geological barriers — **passive**
  accessibility of wastes? — **restricted period**

Elements of a controlled geological long-term storage facility (KGL)



Operative phases of various storage options



Comparative evaluation of storage options

Mains fields of evaluation criteria	waste management options **EL**	**ELR**	**KGL**	**LZL**	**DL**
Long-term safety					
passive (1) or active (2) safety elements (barriers, measures)	***1***	***1 - 2***	***1 - 2***	***2***	***2***
safety reserves in case of unpredicted system behaviour	**1**	**1 - 2**	**1 - 2**	**2** / **3**	**2** / **3**
robustness of the safety system in case of wrong assessment	**1**	**1 - 2**	**1 - 2**	**2** / **3**	**2** / **3**
Demonstration of long-term safety					
predictability of safety providing elements / the overall system	***1***	***1 - 2***	***1 - 2***	***2***	***2***
prediction techniques available	***1***	***1 - 2***	***1 - 2***	***2***	***2***
Fairness, sustainability					
room of manoeuvre for future generations	**3**	**2**	**2**	**1**	**1**
recovery of fissionable material	**3**	**1 - 3**	**1 - 3**	**1**	**1**
polluter pays principle	**1**	**2**	**2**	**3**	**3**

1, 2, 3 threefold scale of evaluation (1 > 2 > 3) ***1, 2*** twofold scale of evaluation (*1* > *2*)

1 - 2, **1 - 2** evaluation depends on length of considered time period (long-term - short-term)

2 / **3** evaluation for underground / surface facilities

Summary

Partitioning & Transmutation

- P & T for next decades just a hope
- repository needed anyway

Storage options

- **long-term safety / demonstration of long-term safety**
  to be preferred: definitive storage options outside biosphere (inside geosphere) providing passive safety → EL > (ELR, KGL)
- **fairness, sustainability**
  evaluation inconsistent

If preliminary waste management option chosen - then

- no safety deficiencies as compared to final disposal
  → permanently operating surveillance system (to be demonstrated!)
- well defined objective of applied option
- defined perspective regarding transition to definitive status
- technique for retrieval already available!
- design of facility to facilitate retrieval "without" risks
- provision of institutional and financial conditions for surveillance and retrieval