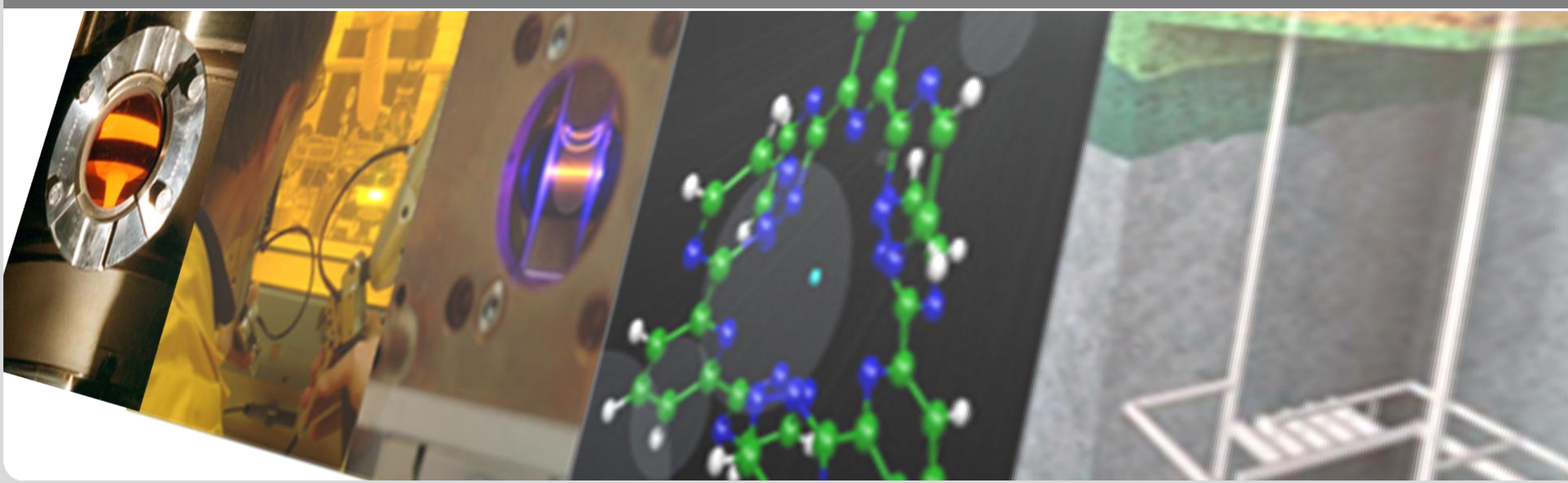
H. Geckeis, V. Metz

Robustness vs. Flexibility and Monitorability in Nuclear Waste Disposal

Workshop “Technological Monitoring and Long-Term Governance”, Karlsruhe, 18. + 19.10.2016

INSTITUT FÜR NUKLEARE ENTSORGUNG (INE)



- Introduction
- Robustness in deep geological disposal of radioactive waste
- Flexibility in deep geological disposal of radioactive waste
- The time scale
- Some final remarks

Disposal of High-level radioactive waste

„The safe handling of radioactive waste belongs to the grand challenges of our present age“

➔ Requirement of a „sustainable“ solution (i.e. a solution which considers the needs of the present generations without endangering the possibilities of future generations, to satisfy their needs appropriately)

➔Provide the best possible option for the disposal of radioactive waste under the primacy of safety

German commission for the storage of high-level radioactive waste, final report, 2016

Disposal of High-level radioactive waste

1st period: 1950‘s to 1970‘s

- Technical problem to be solved for limited waste volumes („closed fuel cycle“)

- Numerous options discussed (extraterrestrial disposal, subseabed, artic glaciers, Partitioning&Transmutation …)

- Deep geological disposal concept remained

➔Development of a „defense-in-depth“, „multi-barrier“, „passive safety“ approach

Disposal of High-level radioactive waste

2nd period: 1980‘s to now

- Controversial discussions on nuclear energy use

    - Concerns about severe accidents

    - heavy doubts related to the safe disposal of highly radiotoxic waste for hundred thousands of years in principle

- political-societal conflicts: increasing mistrust in administration, government, scientists

Status of HLW repository programs worldwide
(acc. to D. Metlay, Cologne, 2016)

Technical suitability \ Social acceptability	Passed	Failed to pass
Passed	4 complete 5 intermediate state	1
Disrupted		11
Failed to pass	1	1

U.S. Nuclear Waste Technical Review Board, Survey of National Programs for Managing High-Level Radioactive Waste and Spent Nuclear Fuel: Update; February 2016

Disposal of High-level radioactive waste

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  - Concerns about severe accidents
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➔ Introduction of new procedural and governance concepts

➔ Introduction of reversibility and monitoring concepts

Aims of radioactive waste disposal

- Containment of the waste*

- Isolation from the accessible biosphere incl. the reduction of the likelihood and the consequences of human intrusion

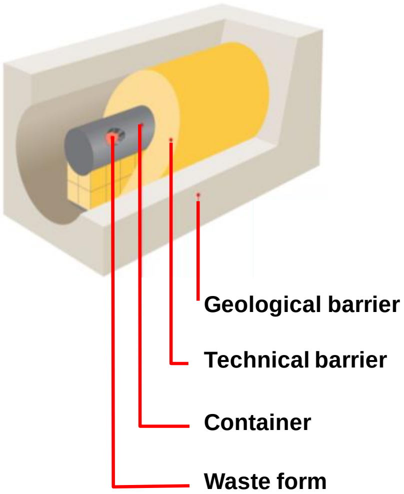
- Inhibition, Reduction and delay of radionuclide migration towards the biosphere

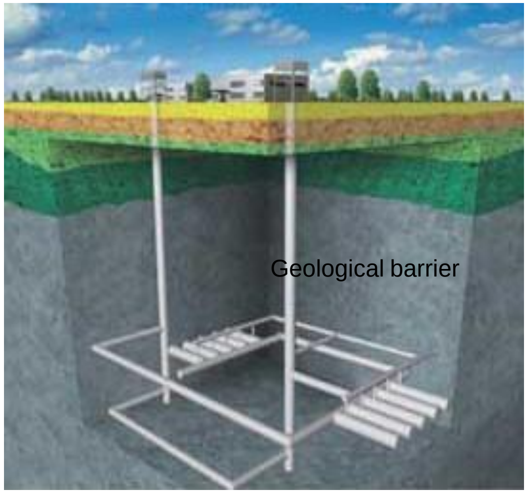
- Ensure that possible radiological consequences to the biosphere are acceptably low at any time

*Disposal facilities are not expected to provide complete containment and isolation of waste over all time. This is neither practicable nor necessitated by the hazard associatied with waste, which declines with time.

IAEA Specific Safety Requirements, No. SSR-5: „Disposal of Radioactive Waste“, 2011

A robust system as a means for getting confidence into a „passively safe“ repository concept





Engineered robustness:
e.g.
- Conditioning in a stable waste matrix
- Use of several long-lasting barriers

Intrinsic robustness:
e.g.
- Host rock with self-sealing properties
- Positioning of the repository deep down
- Host rock with uneventful history, characterized by suitable (buffered) geochemical conditions

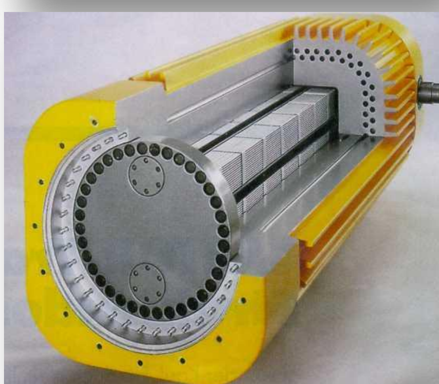
Performance assessment is used to test robustness across a range of „envelope scenarios“

Robustness can be improved by increasing safety margins

Select a site so that uncertainties (related to detrimental consequences) are avoided.

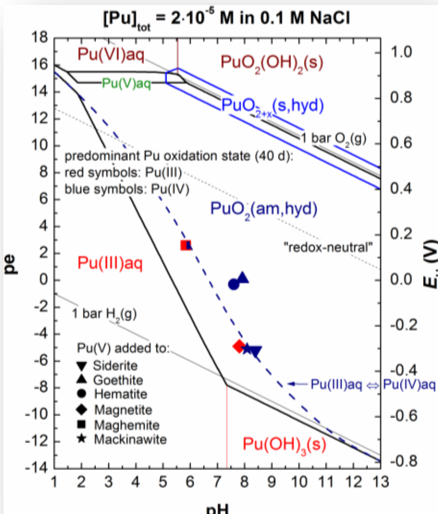
IAEA Specific Safety Requirements, No. SSR-5: „Disposal of Radioactive Waste“, 2011

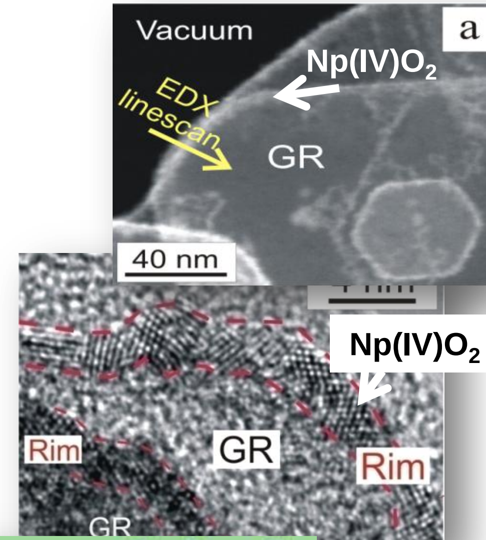
The corroding steel container as a chemical barrier:

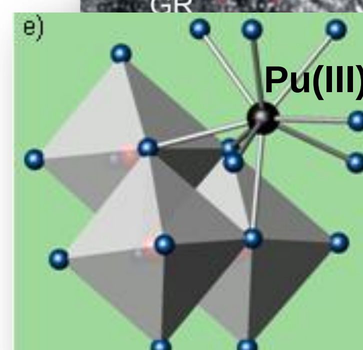


Slow anaerobic steel corrosion

- Hydrogen development inhibits radiolytic spent fuel corrosion
- Radionuclide immobilization (U, Pu, Np, Tc, Se) by redox reactions
- Retention at iron corrosion products (e.g. U, Pu, Np, Se …)

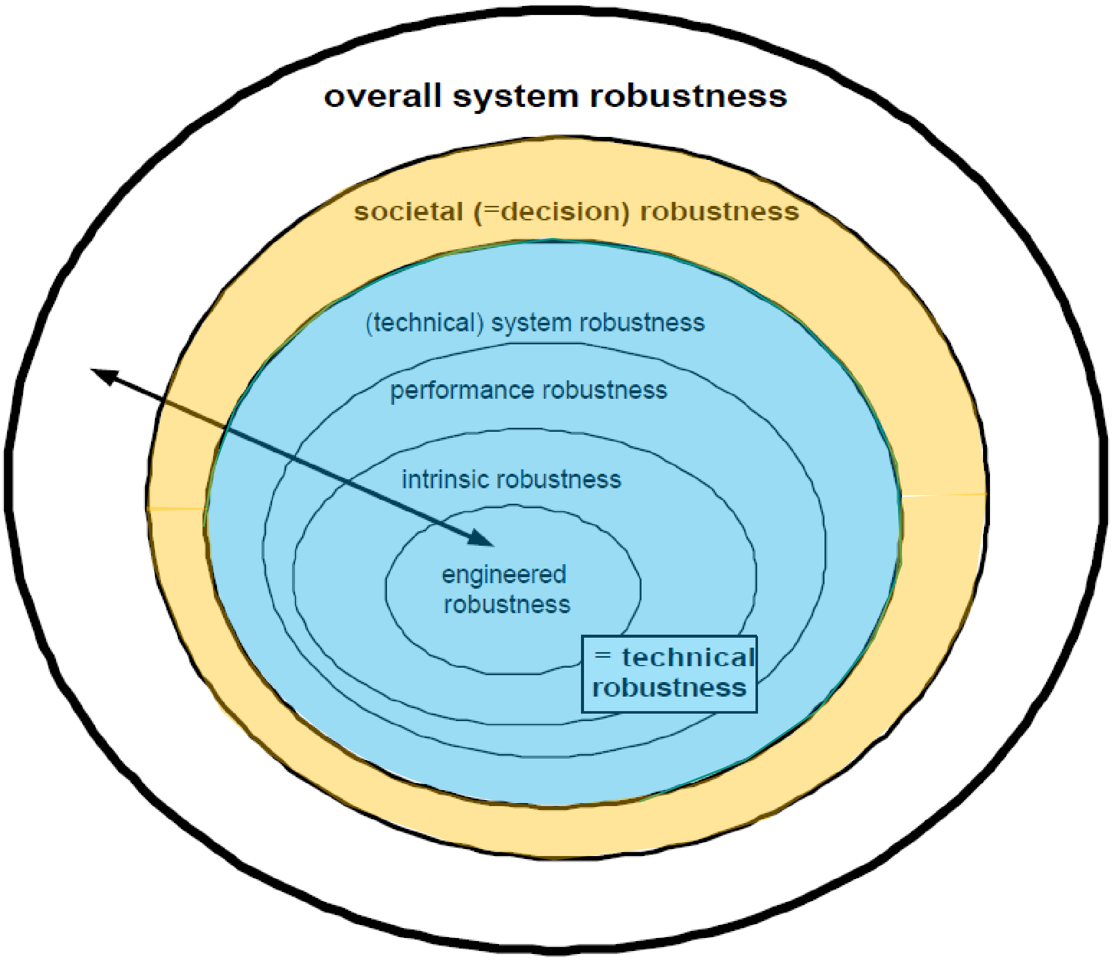




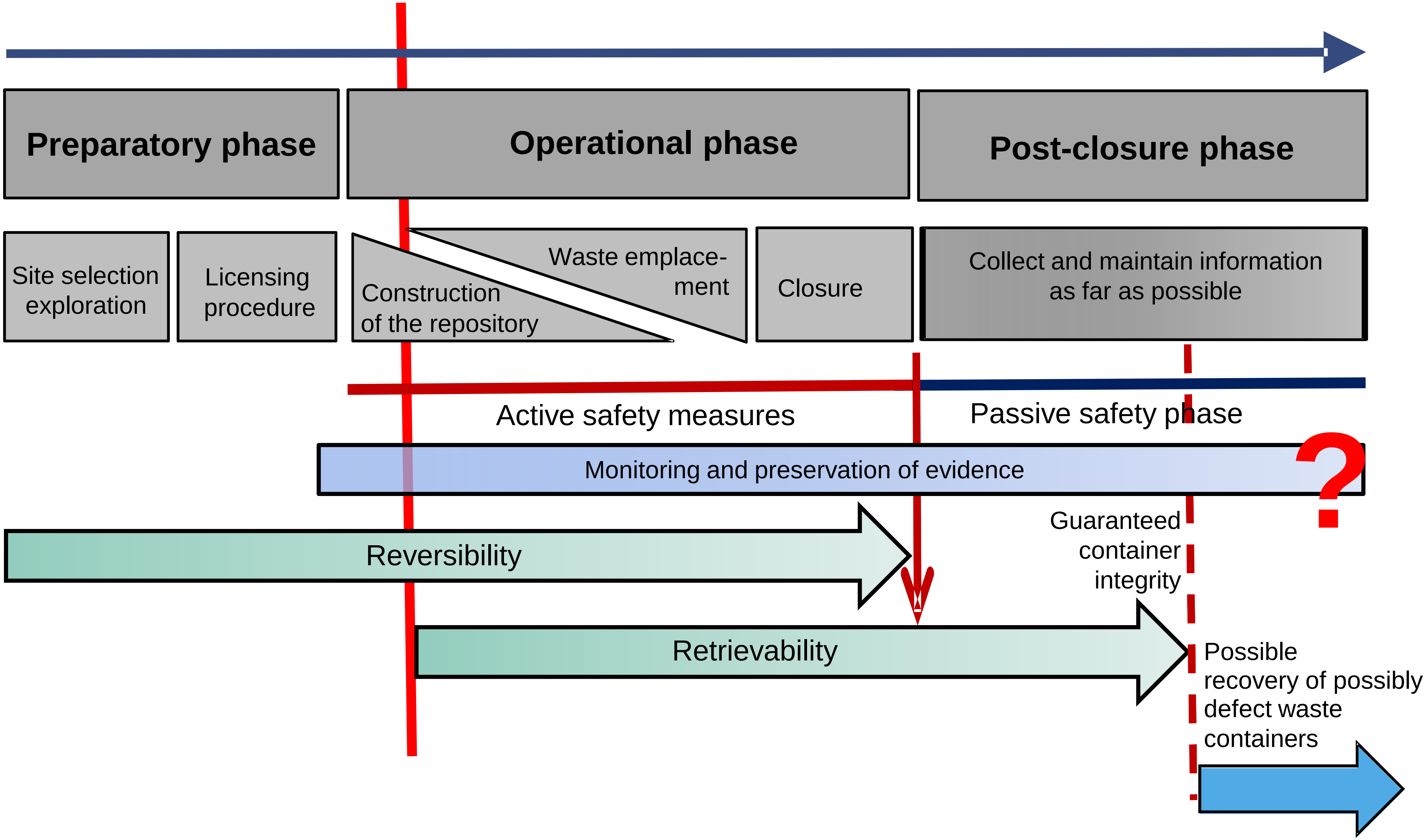


B. Christiansen et al. GCA (2011)
D. Bach et al., Micr. Microanalys. (2010)
R. Kirsch et al., ES&T, (2011)

Extended concept of „robustness“ in radioactive waste management:
A contribution to decision-making in complex socio-technical systems



Flüeler, 2006, Series Environment & Policy (Vol. 42)



Modified acc. to ESK, 2011; D. Appel, J. Kreusch, W. Neumann, Darstellung von Entsorgungsoptionen, ENTRIA, 2015

Repository stages

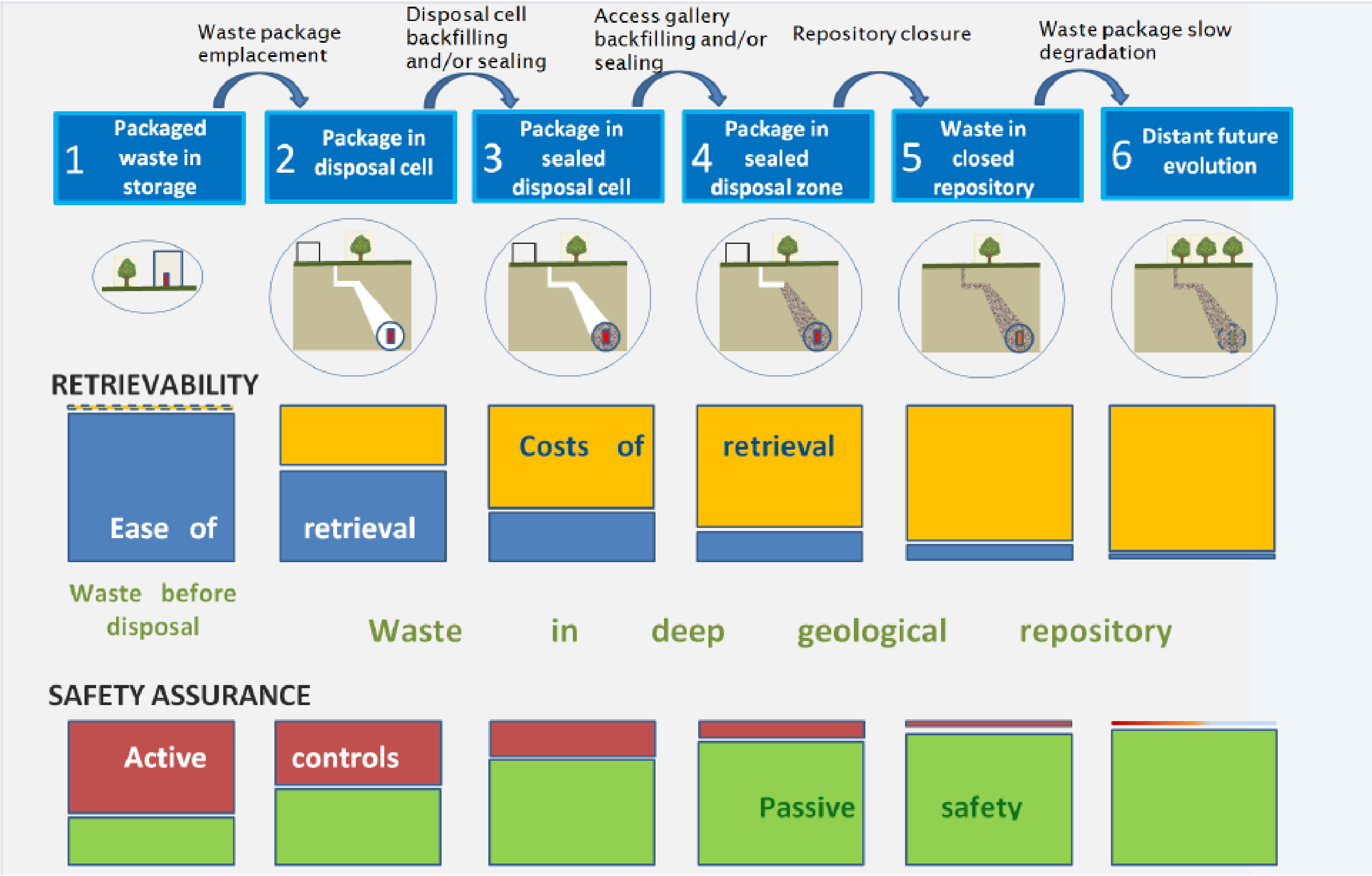


Fig.4: Lifecycle stages of the waste, illustrating changing degree of retrievability, passive safety and active controls in a deep geological repository (actual size of boxes may vary depending on the repository design)

(http://www.nea.fr/rwm/rr)

Monitoring issues:

Surveillance of safety relevant elements of the repository systems and ongoing processes. Demonstration/Control of repository evolution acc. to forecasted conditions and processes.

Questions:

What should be monitored?

How monitoring should be realized (which parameters, how representative)?

What are the consequences of monitoring results (problem: false negative/false positive results)?

Who will take decisions based on monitoring data?

EKRA 2000, 2002; D. Appel, J. Kreusch, W. Neumann, Darstellung von Entsorgungsoptionen, ENTRIA, 2015

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Monitoring levels and aims

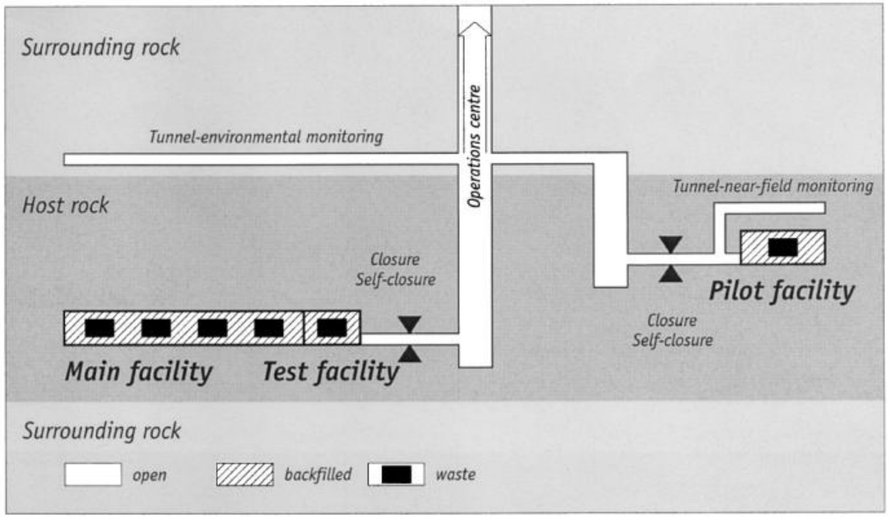
- Environmental monitoring (baseline – operation – post closure) mostly from above ground
- Safeguard (fissile material); observation via satellite; visits etc.
- Enhance our understanding of repository behaviour
- Confirm assumptions and models
- Provide information on repository system for decision making (reversibility, retrievability etc.)
- Supports public confidence building/instrument to check system (main reason)
- social monitoring

Requirements:

- technical monitoring should be „minimally invasive“ (avoid enhanced radiation doses for personnel, no impact on barrier functions etc.)
- time scale beyond closure has to be defined (limited lifetimes of instrumentation?)
- Consequences of monitoring results have to be defined
- Criteria for actions to be taken

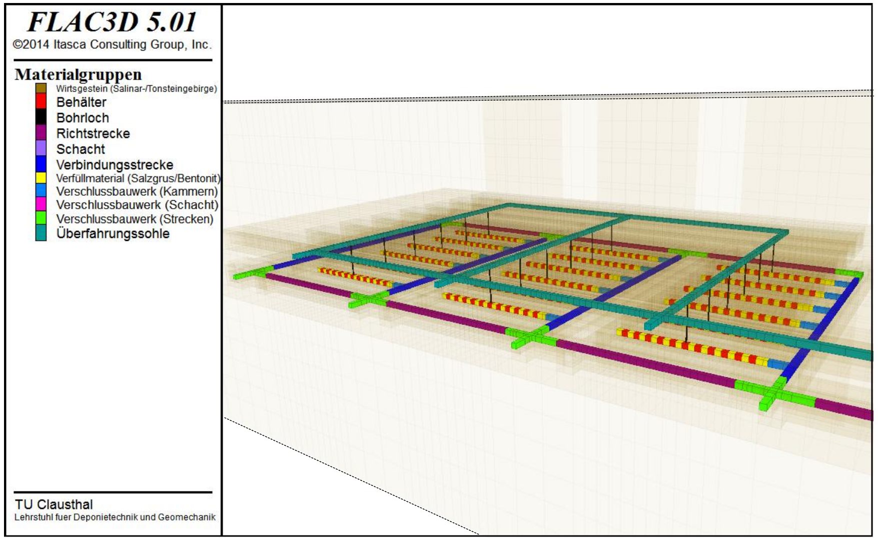
IAEA, 2001; EKRA, 2000, 2002; Appel et al., 2015; Kuppler, Hocke, TATUP 21, 2012, 43;
A. Bergmans, M. Elam, P. Simmons, G. Sundqvist, TATUP 21, 2012, 22

„Monitoring“ concepts



EKRA 2000

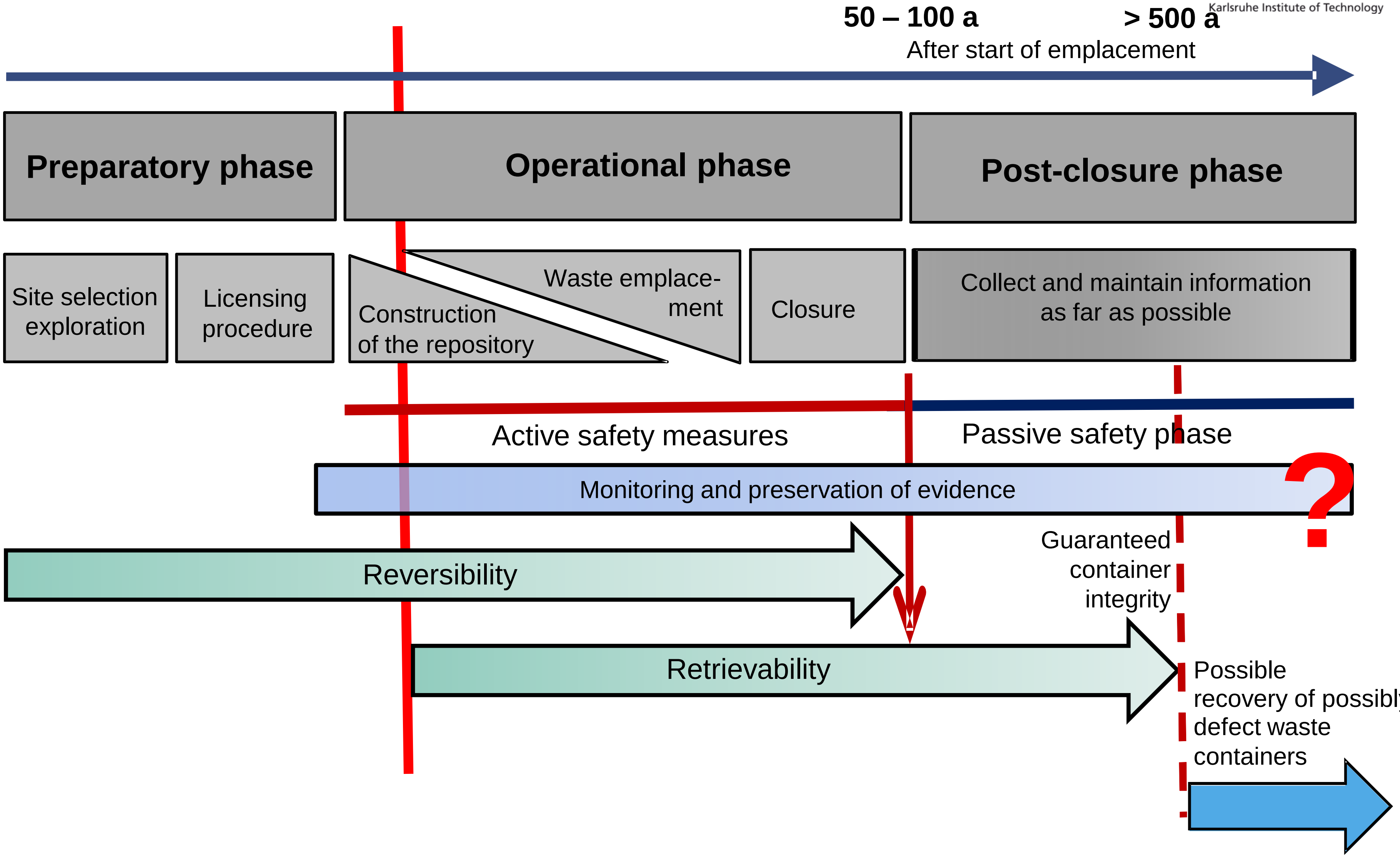
Pilot facility



R. Wolters, K.H. Lux, 2016

„Direct“monitoring
(Monitoring Drift)

The time scale



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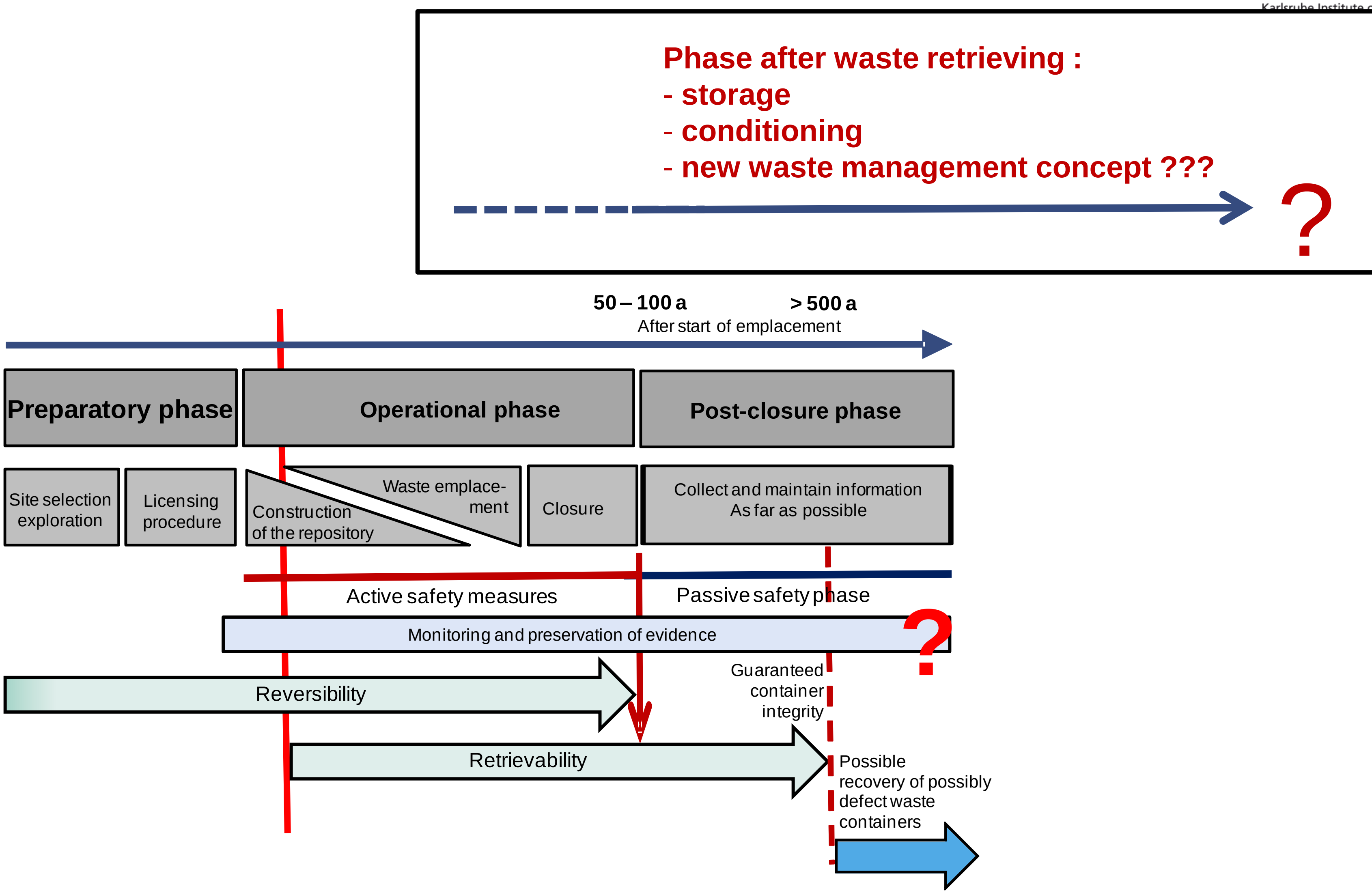
The time scale



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Chances and risks of monitoring/flexibility/reversibility measures in nuclear waste disposal concepts

Chances:

- Helps to decrease uncertainties
- Enhances opportunities for error correction
- Involvement of the public and stakeholders into a transparent fact-based decision process
- Strengthens confidence in long-term safety
- Evolution of new technologies
- Evolution of improved concepts

Risks (increasing with time):

- enhanced radiological exposures to employees and possibly as well to the population due to retrievability option
- technical uncertainties (repositories left partially open for quite some time)
- competencies in nuclear waste management issues get lost
- economic risks
- societal changes
- security issues (unauthorized misuse of radioactive material)

European economic crisis reaches boiling point

Terrorism!

Relative risks for a radiological exposure of the population at different evolutions of a repository system

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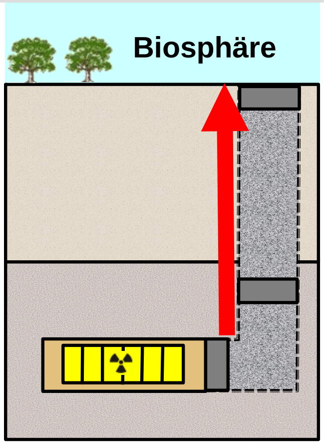
Evolution / Option	Positive	Impairment of barrier functions
1) DGR w/o retrievability option	„expected“	Water access/ RN migration through geosphere
2) DGR with retrievability option	„expected“	Water access/ RN migration through geosphere/ unauthorized access
3) Long-term interim storage	„expected“ (**But:** temporally limited :~ x 100 a; then consider option 1) or 2))	Water access/ RN release into bio-sphere directly/ unauthorized access in case maintenance is abandonned! Time scale?
4) „Doing nothing“ Waste remains in interim storage facility	„expected“ (**but:** temporally limited: ~ x 10 a; to be connected with 1), 2) or 3))	Water access/ RN release into bio-sphere directly unauthorized access in case maintenance is abandonned! Time scale?

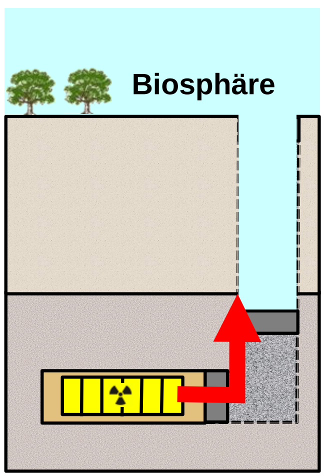
No or negligible RN release

radiological exposure to population increases

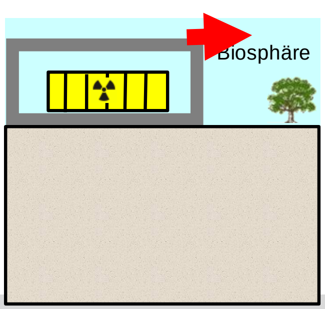
The time scale



Repository w/o retrievability option



Repository with monitoring/retrievability option



Long term Intermediate storage

Flexibility decreases (from a today‘s perspective)

Robustness decreases on the time scale (decades/ centuries); Risks increase

?

Inconsistent issues

- Concepts for flexibility of nuclear waste repository projects rely on present-day ideas …. projected for decades/centuries into the future

- Implementing more flexibility does not *per se* mean more safety (on the long-term)

- Uncertainties increase, the longer a repository is prevented from reaching the „passive safety“ status (compatible with the ideas of sustainability and robustness?)

- even reduction of flexibility can be the consequence over time

What to do?

All life is problem solving ….

➔ Continue intense interaction with public/politicians; clear communication of what things mean and where problems lie, e.g.:

- inconsistencies in perceptions and expectations
- the pros and cons of long lasting procedures

➔ Invest in planning for long-term **(centuries!)** institutions to foster the basis for the economic, organisational development and research continuously pursuing the safe solution of the nuclear waste disposal challenge