Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

# Waste Management in Germany

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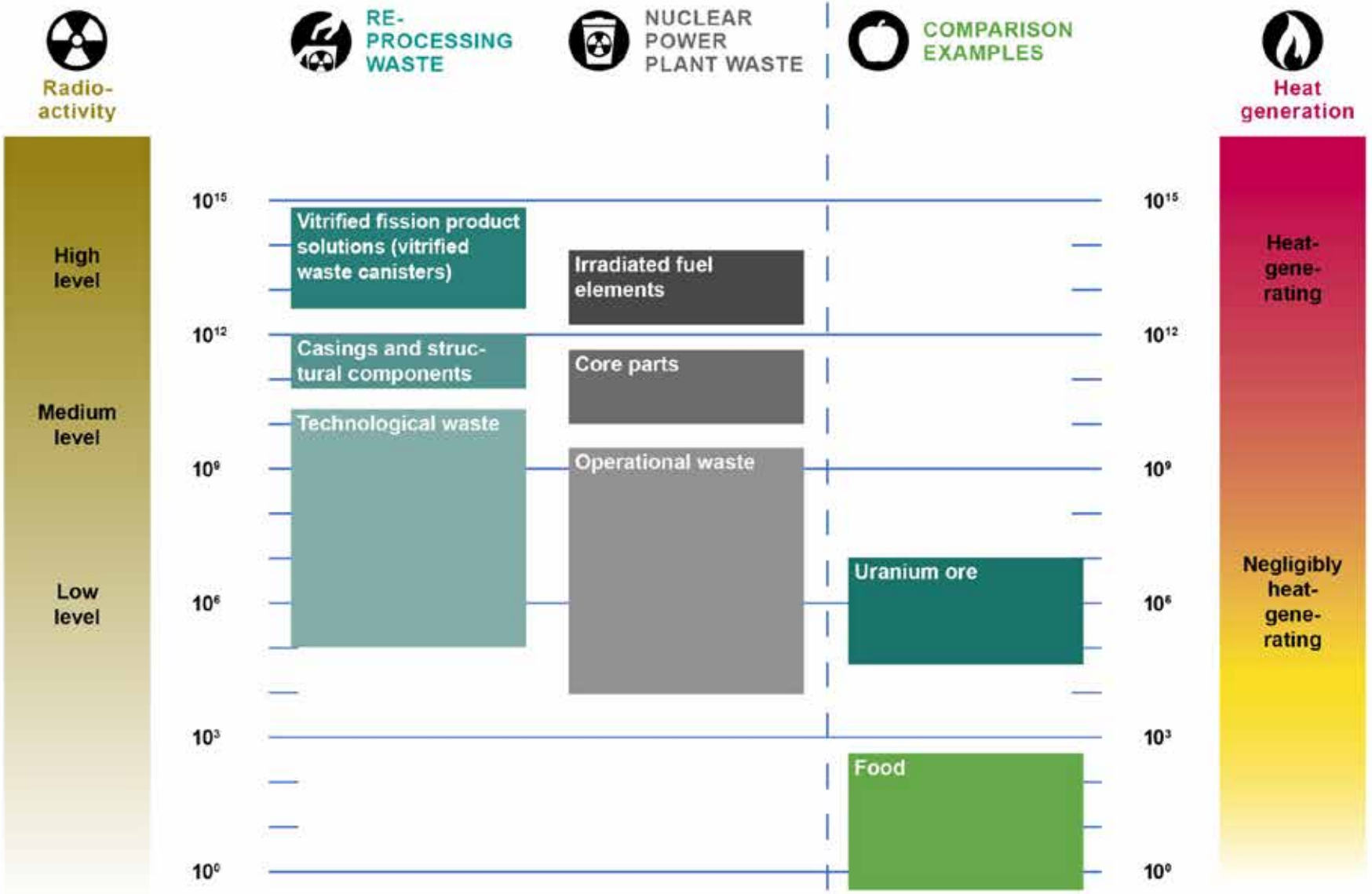
Tokyo, June 2016

# Categories and properties of radioactive waste

## Activity and heat generation at a glance




Radioactivity in becquerels per kilogram or becquerels per litre (Bq/kg oder Bq/L)

# Radiactive Wastes – Amounts

## Amount of spent fuel elements until 2022 (shutdown of last NPP in Germany):

- Approx. 17.200 t HM (17.200 t Uran and Plutonium) in spent fuel elements
  - Of those: 10.500 t as fuel elements
  - 6.700 t were reprocessed

## Amounts from reprocessing:

- approx. 1.400 m³ heat generating wastes

## Total amount of heat generating wastes:

- Approx. 28.100 m³

# Radiactive Wastes – Amounts

## Radioactive wastes with negligible heat generation:

- Amount 2013:
  - Packed and conditioned, at interim storag facilities: 114.000 m³
  - Unconditioned (raw) wastes and preconditioned wastes: approx. 23.000 t

- Total amount until 2080: approx. 300.000 m³
  from NPPs, reprocessing, research, industry …

- [illegible]

- **Which repository?**
  - § ~~Konrad or~~
  - § **Final repository for „mainly highly radioactive wastes“ (StandAG §1)**

## Uran-Tails from fuel enrichment:

- Uran-Tails: approx. 100.000 m³

# Radioactive Wastes - Reprocessing

Reprocessing is no longer seen as a means of desposing of radioactive wastes in Germany

Wastes from reprocessing are to be returned to Germany from France and U.K:

- Highly radioactive fission product solution embeded in glass matrix in stainless steel canister,
- Claddings and structural elements of the fuel assemblies, pressed and packed in stainless steel canisters,
- Waste amount from operation of the reprocessing facility

Part of these wastes will be transported back to germany („Castor-transports“), another part with lower amounts of radioactivity will be subsituted for wastes with higher amounts of radioactivity.

# Radioactive Wastes – current treatment and storage

## Heat generating wastes

- are packed in Castor casks (or comparable) and
- Stored at interim storage facilities:
  - at NPP sites,
  - at central sites (Gorleben, Ahaus, Jülich, Greifswald).

## Wastes with negligible heat generation

- are mostly conditioned, i.e. pressed, dried, burned or cemented …
  → The aim is to achieve a chemically stable product and to reduce volumes,
- are packed and placed in interim storage,
- final disposal shall take place at „Schacht Konrad“ near Salzgitter but will not start before 2022.

Currently, all radioactive wastes arising in Germany are stored in interim storage facilities (sooner or later).

# Current situation with respect to spent fuel elements

**Wet storage in NPP pools**

CASTOR® V Behälterdesign von GNS (Quelle: GNS)

Seit 1992 …..

**Dry cask storage in central interim storage facilities**

**Interim storage + Transport- and storage casks**

**Prohibition of transports and revision of german atomic energy act**

Seit 2002 …..

**Dry cask storage at interim facilities at all NPP sites**

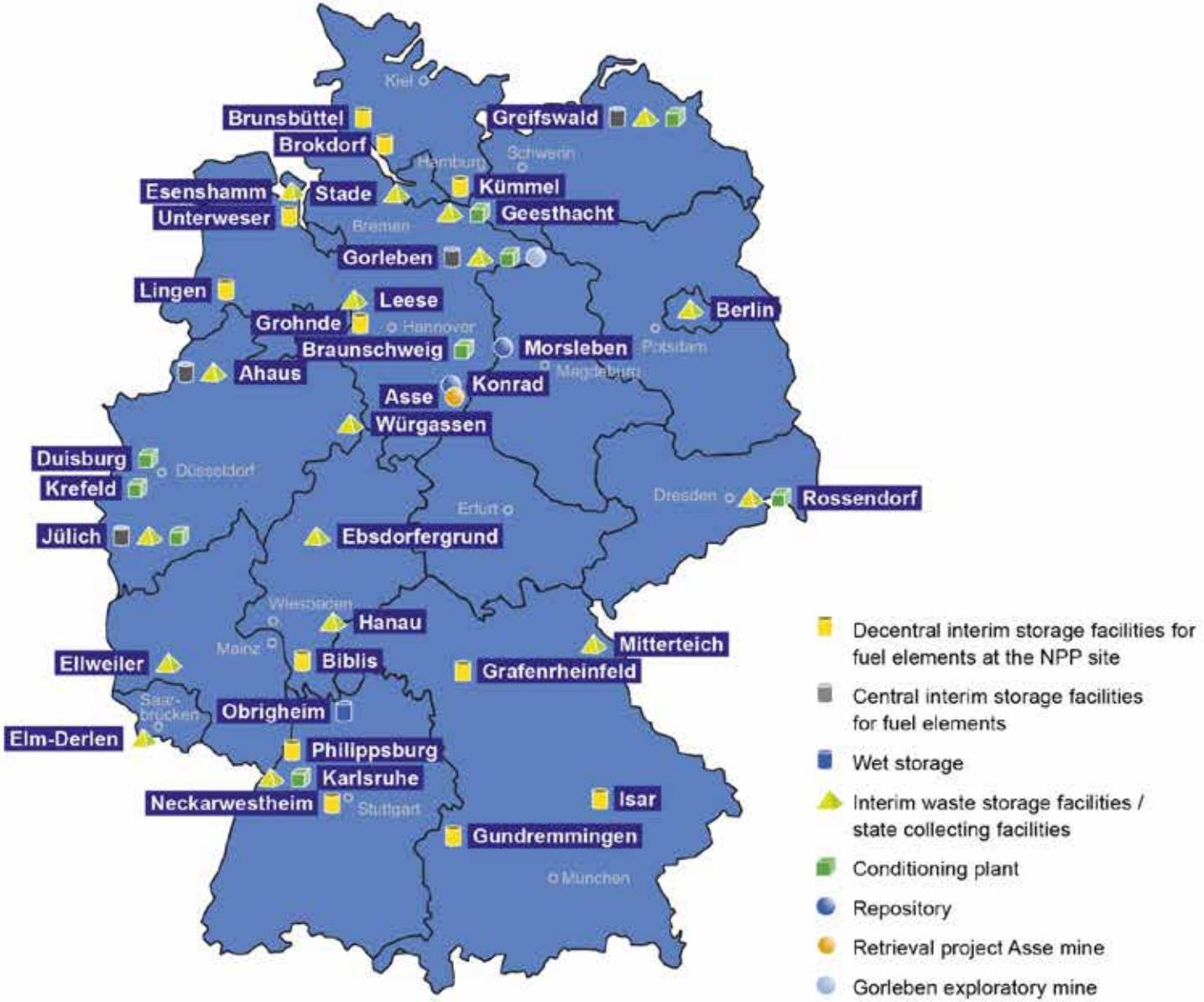
**All licences for interim storage facilities are limited to 40 years of operation.**



Quelle: H. Voelzke, VdTÜV Forum Kerntechnik, Berlin, 17.-18. März 2014

# Radioactive waste management facilities in Germany

## Overview of all sites at which radioactive waste is stored




SOURCE: OEKO-INSTITUT, 2014

# Dry cask interim storage

## For spent fuel and wastes from reprocessing

- Transport- and storage casks
- Thick-walled metal casks
- Two barrier cover with monitoring of seal function
- Passive safety functions by cask (cooling, confinement of radioactivity)
- It is required to ensure that transportation is possible at all times
- There is a qualified concept for repair in case of a malfunction of the cask cover

# Radioactive Wastes – interim storage times

## Licences for interim storage facilities

- for wastes with negligible heat generation usually without time limit
- for heat generating wastes (spent fuel/reprocessing) 40 years
- Important reason for time limit in licences today: ensure that it will not turn into a “final repository”

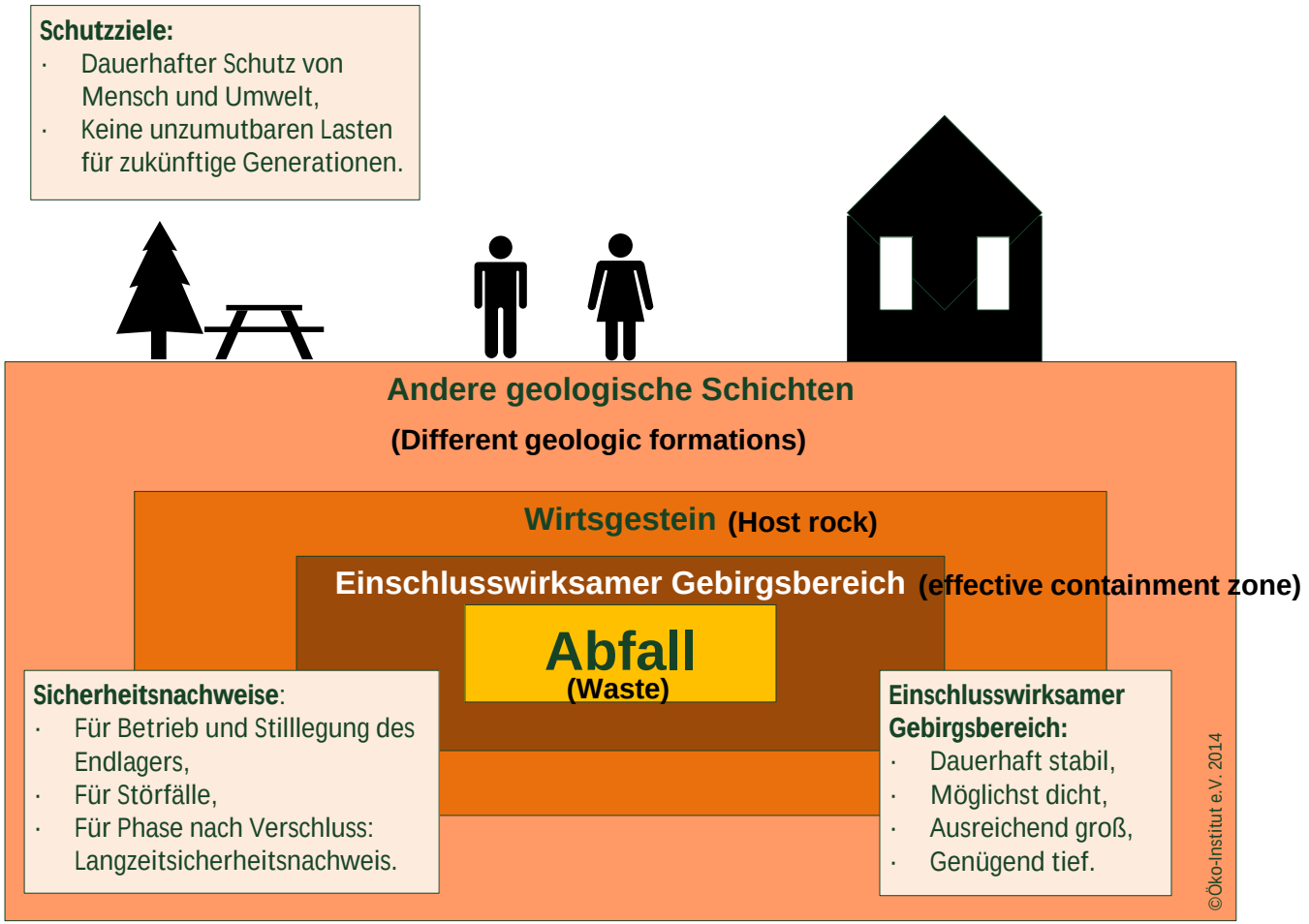
## An interim storage facility is not a final repository and shall not become one factually!

- Not yet clear: How to continue when license time is expiring and no final repository is available (very probable for heat generating wastes)

# Final disposal – concept, risks and long term safety

- Geological layers of certain host rocks shall ensure long term stable conditions to enclose radionuclides (for example some salt domes in germany are more than 50 million years old)
- Safety cases have to show long term enclosure of waste
  Period of proof: 1 million years
- Function of enclosure performed mainly by effective containment zone of the host rock (in german: einschlusswirksamer Gebirgsbereich (EWG)) due to its characteristics (thickness, type of rock, permeability, long-term behavior …)
- Access points to repository (shafts, drifts …) have to be sealed without unduly lowering the quality of enclosure
- Radionuclides nevertheless leaving the repository shall not, even in the long term, lead to doses of the public that are higher than todays legal limits

# Final disposal – concept, risks and long term safety



# Final disposal – concept, risks and long term safety

**Host Rocks in comparison**
modified according to BGR 2007

**Rockproperties**

| Property | Rocksalt | Clay/Claystone | Crystallin rock (z. B. granite) |
|---|---|---|---|
| Conductibility of temperature | high | low | medium |
| permeability | practically impermeable | Very low to low | Permeable to slightly permeable (depending on chasms) |
| stability | medium | Low to medium | high |
| Deformation behavior | viscous | Plastic till elastic | brittle |
| Solubility behavior | high | Very low | Very low |
| Sorption behavior | Very bad | Very good | Medium to bad |
| Temperature resistance | high | low | high |
| Stability of cavities | high | low | High to low (depending on chasms) |

favorable

medium

unfavorable

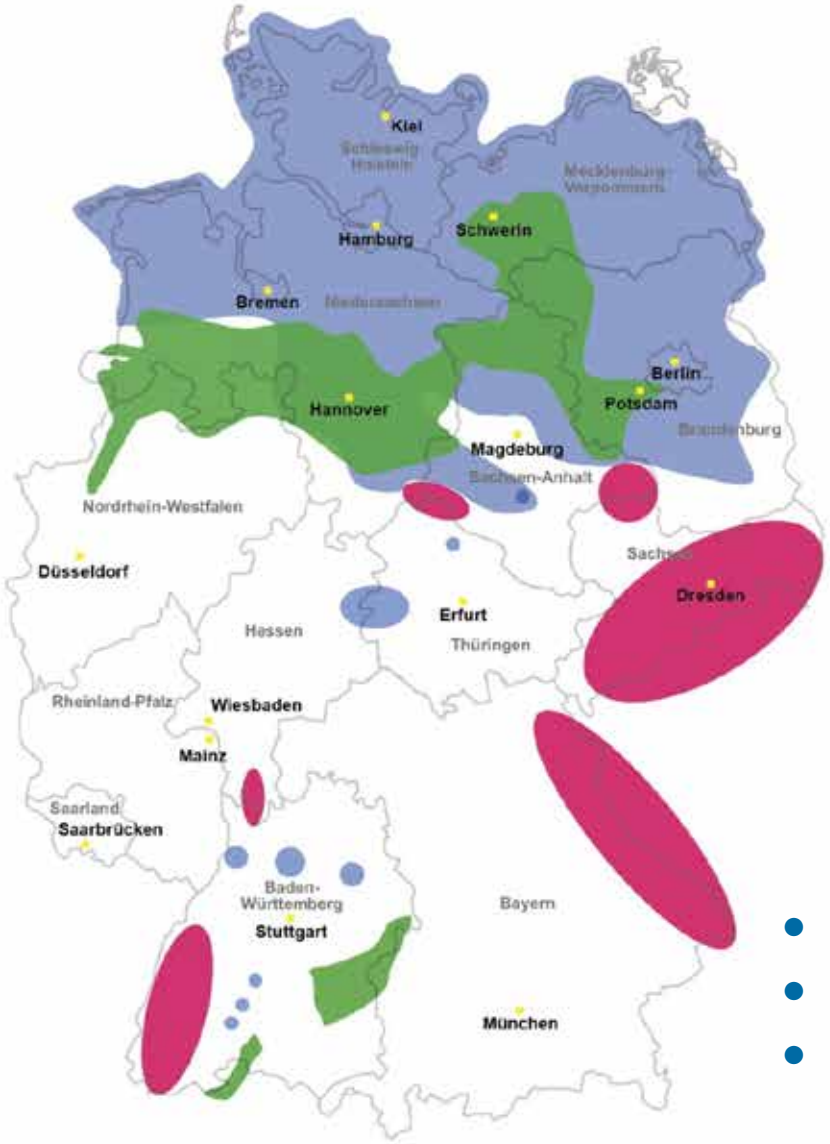

Steinsalz (rocksalt)


Tonstein (claystone)


Granit (granite)

Source: according to BGR

# Vorkommen der Wirtsgesteine Salz, Tonstein und Kristallin in Deutschland




- Clay
- Ganite
- Salt

# Final disposal – concept, risks and long term safety

## Examples of exclusion criteria:

- Large scale vertical movement
- Active fault zones
- Strong seismic activities
- Active volcanism
- Large scale erosion or subrosion of rock
- Young ground water at the depth of the repository
- Natural resources, that might be searched by following generations

# Four german „sites“



Sources: Asse and Konrad: Öko-Institut, Gorleben: Fice (Wikipedia), Morsleben: AxelHH (Wikipedia)

# Asse II

## near the town of Wolfenbüttel


- 1909 - 1964 used as (potash and rock) salt mine
- 1967 - 1978 „test-wise“ emplacement
  - without intention to retrieve the wastes
- Amounts: approx.125.000 barrels with low level wastes and approx. 1.500 barrels with medium level wastes, in total approx. 47.000 m³.
- Research activities with respect to salt as medium for final repository
- Since end of 80s more and more brine intrusion from surrounding rock, currently daily approx. 12.000 l
- Problem with structural integrity: surrounding rock presses to the south part of the mine and leads to deformations of cavities
- Since beginning of 2010: aim is total retrieval of emplaced wastes, additionally stabilisation and water management is undertaken

# ERAM Morsleben

## Community of Ingersleben

- About 1900 – 1970 used as salt mine
- 1971-1991: final repository of GDR for low- and intermediate level wastes
- 1994-1998: continued use by FRG
- In total approx. 37.000 m³ wastes as well as approx. 6.600 sealed sources
- 2001: stop of further emplacement for safety reasons. ERAM has structural integrity problems and brine intrusion, that will be severe in the long term
- 2005: „plan for decommissioning of ERAM"
- 2009: public review process (more than 13.000 objections)
- 2011: public hearing
- Approval decision still not granted.

# Konrad
## Salzgitter

- 1957 – 1976 extraction of iron ore
- 1975 – 1982 Investigation of qualification as potential repository
- 1982 – start of approval process
- 2002 – approval decision, entry into force is delayed due to lawsuits
- 2007 – entry into force after dismissal of final lawsuit
- Since 2008 conversion of shaft installation to final repository for wastes with negligible heat generation
- Approved capacity 303.000 $m^3$
- Originally planned for 2013, commissioning is delayed. Approx. startup in 2022?

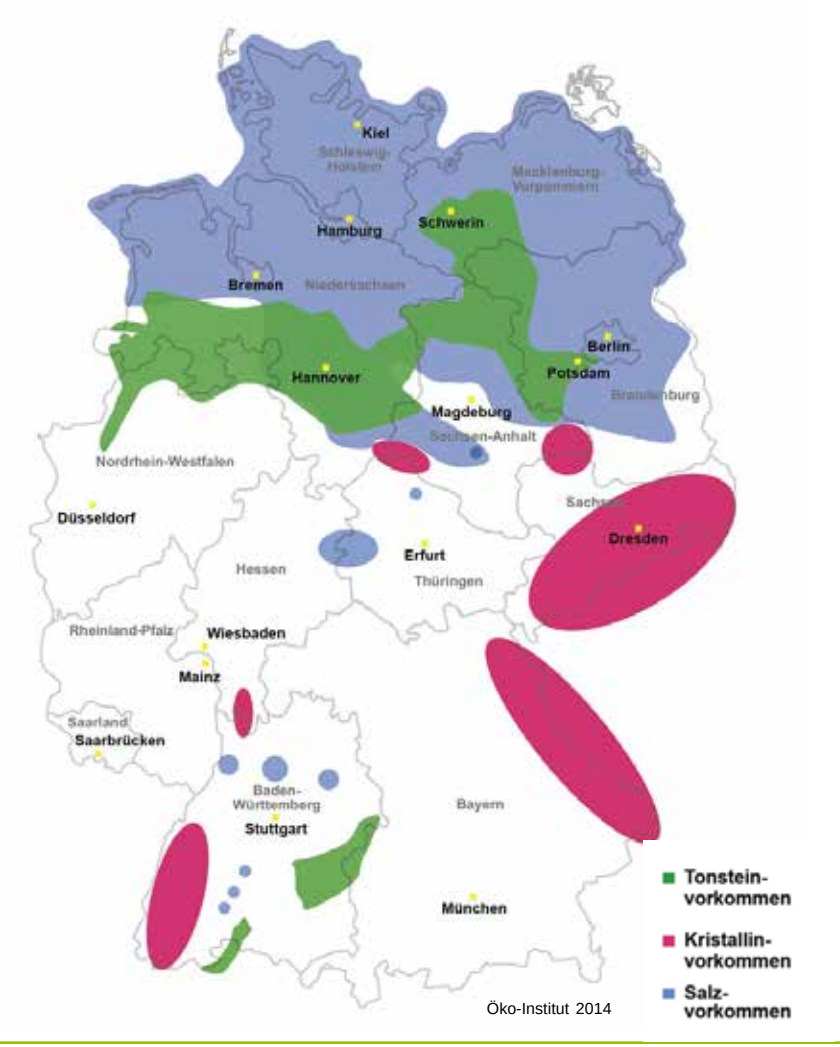
# Gorleben

- 1977 named as site for waste management center: reprocessing, conditioning and final repository on one site.
- 1979 – 1984 exploration from above ground (drilling), but also: cancellation of reprocessing in Lower Saxony.
- 1986 – 1997 underground exploration, start of drifting the exploratory mine,
- 2000 – 2010 Gorleben Moratorium
- 2011: resumption of underground exploration, „preliminary safety analyses“
- 2013: Site selection act §29 decides on status of Gorleben:
  - Gorleben in the procedure, no „special treatment“
  - Preliminary safety analyses stopped
  - No further exploration

# Site selection and the public

- Key points of criticism for choosing the Goleben site:
  - Site selection was neither transparent nor reproducible
  - Development of site selection criteria and process were done without involvement of the general public
- A congressional investigation committee of the german parliament investigated between 2010 and 2013 the site selection – in the end with mixed votes
- Major insight: Search of a repository site does not only incorporate the search for appropriate geological and technical criteria.
  A transparent and comprehensive selection process including appropriate public participation is important.

# Site Selection Act of 2013




## Starting point:

- Political consensus for a stepwise site selection
- „white map “
- Proposals for criteria exist (AkEnd; safety requirements)
- Considerable knowledge from R&D in technological and sociological fields
- Good knowledge with respect to rock salt
- International exchange

# Site Selection Act of 2013

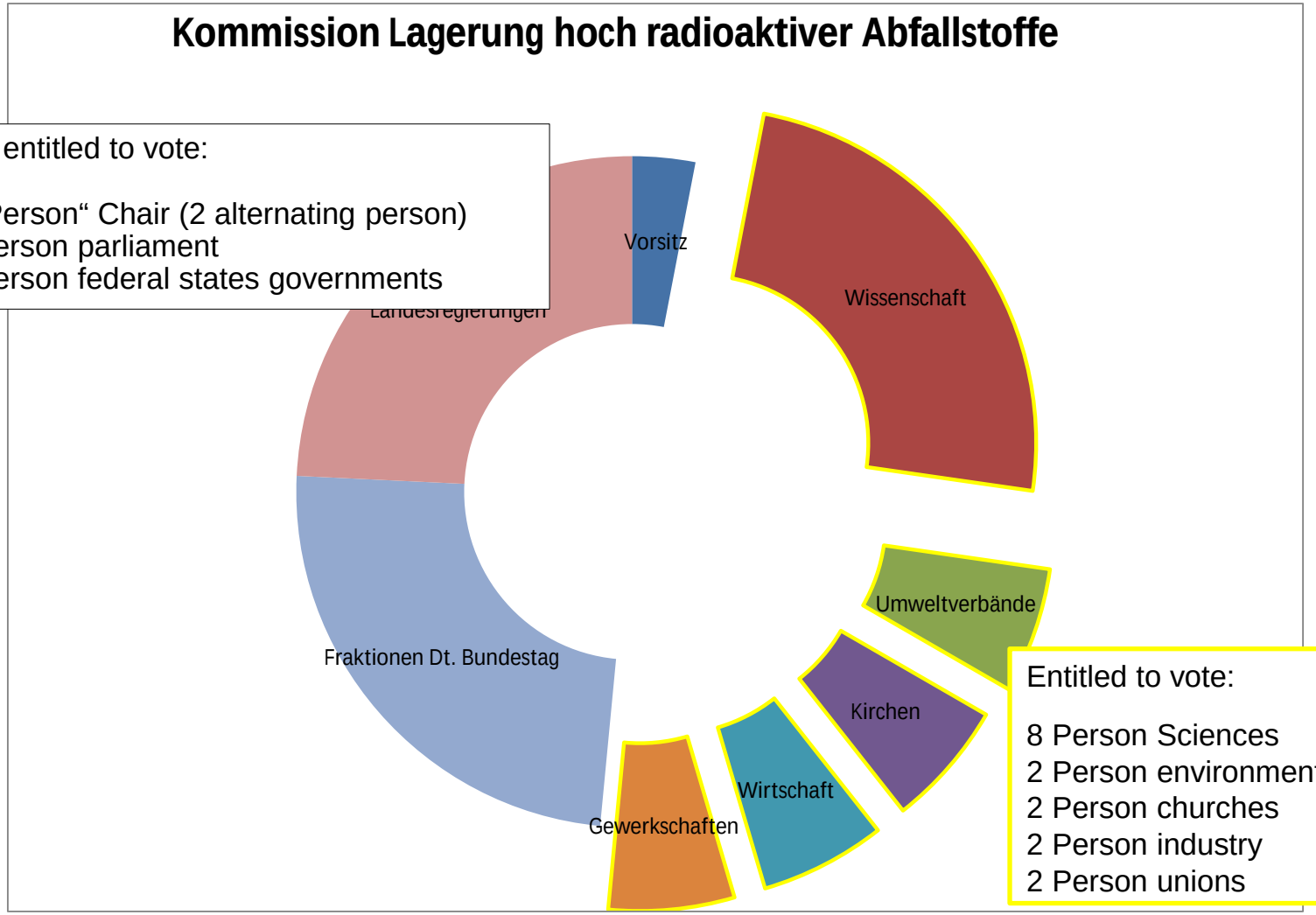
## Timeline

| | | |
|---|---|---|
| 2014 | Commission „Storage of High-Level Waste“ | §3 |
| 2016 | Report of the commission with recommendations, evaluation of site selection act | §4 |
| 2014 | Foundation of Federal Office for the Regulation of Nuclear Waste Management | §7 |
| 2016 | Start of site selection process | §12 |
| 20xx | Decision on sites for exploration from above ground | §14 |
| 2023 | Decision on sites for exploration from below ground | §17 |
| 2031 | Site selection | §20 |

afterwards: licensing, construction, operation, closure of repository

Aim: best suitable site regarding safety

# Site Selection Act of 2013



# Site Selection Act of 2013

## Commission – duties

### Compile a report with recommendations for:

- **Alternatives** to geologic disposal.
- **Decision fundamentals** such as safety requirements, exclusion criteria, minimum requirements, geological criteria, host rock specific criteria for salt, clay, cristallin, host rock independant criteria, social and technical consideration criteria
- Criteria for **fault correction** during site selction, but also for repository conceptional design (retrievability, recoverability, detectablility)
- Requirements with respect to the **selection process** and examination of alternatives
- Requirements concerning **public engagement**, **information** and **transparency**

Report is basis for Evaluation of Site Selection Act by the german parliament.

# Alternatives to geological disposal?

## Alternatives:

- Unlimited „interim storage“
- Deep boreholes
- Delivery to space
- Ocean dumping
- Partitioning and transmutation
- …

## No „better“ option than geological disposal identified

# Site Selection Act of 2013

## Stepwise narrowing until site decision

§§ 18-20 Standortentscheidung
- Untertägige Erkundung der festgelegten Standorte,
- Erstellung umfassender vorläufiger Sicherheitsuntersuchungen,
- Gesetz über Standortentscheidung

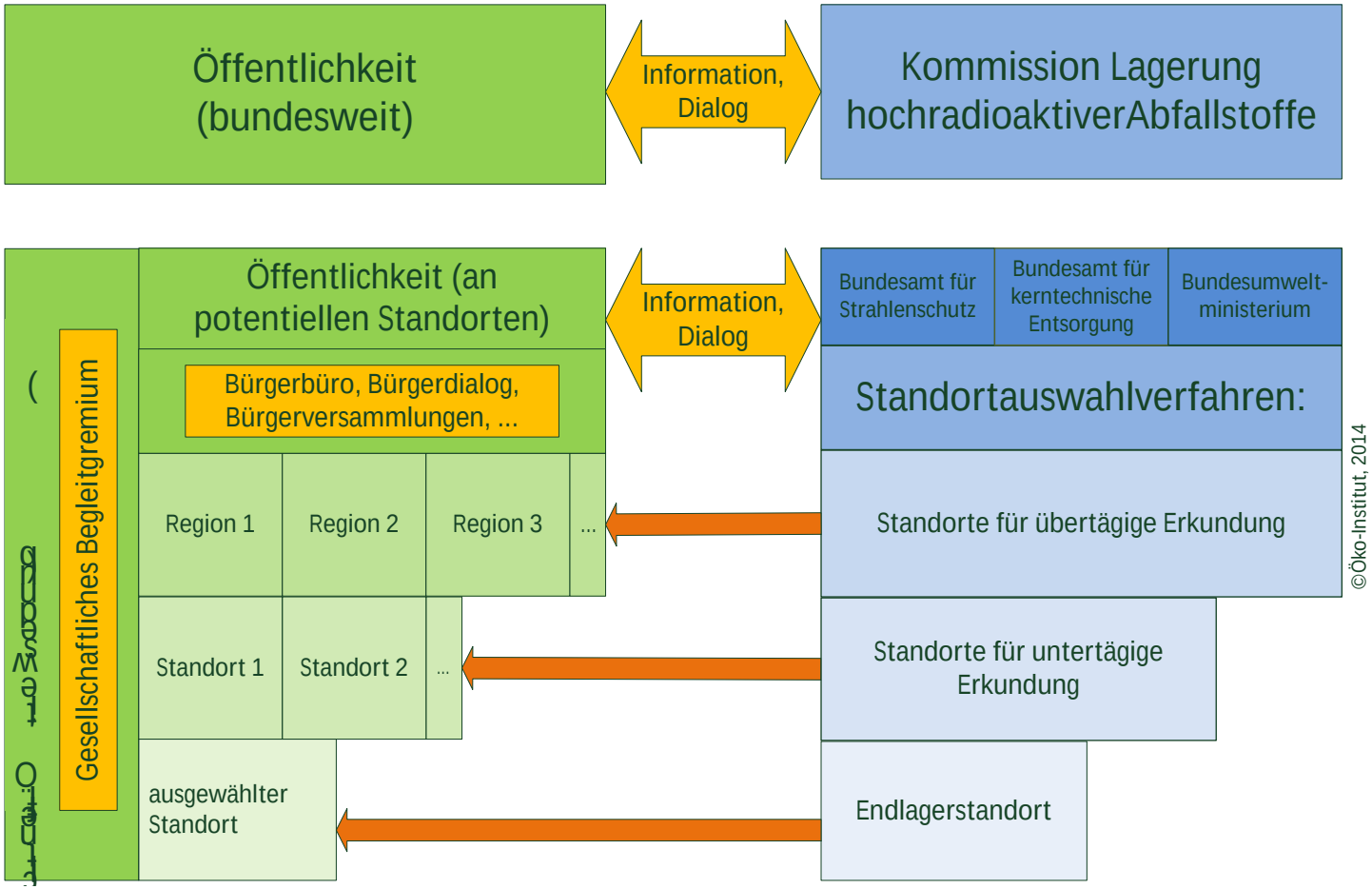
- Commission: approx. 40-60 years until site decision

- Weiterentwicklung der vorläufigen Sicherheitsuntersuchungen,
- Auswahl von Standorten für untertägige Erkundung per Gesetz beschlossen

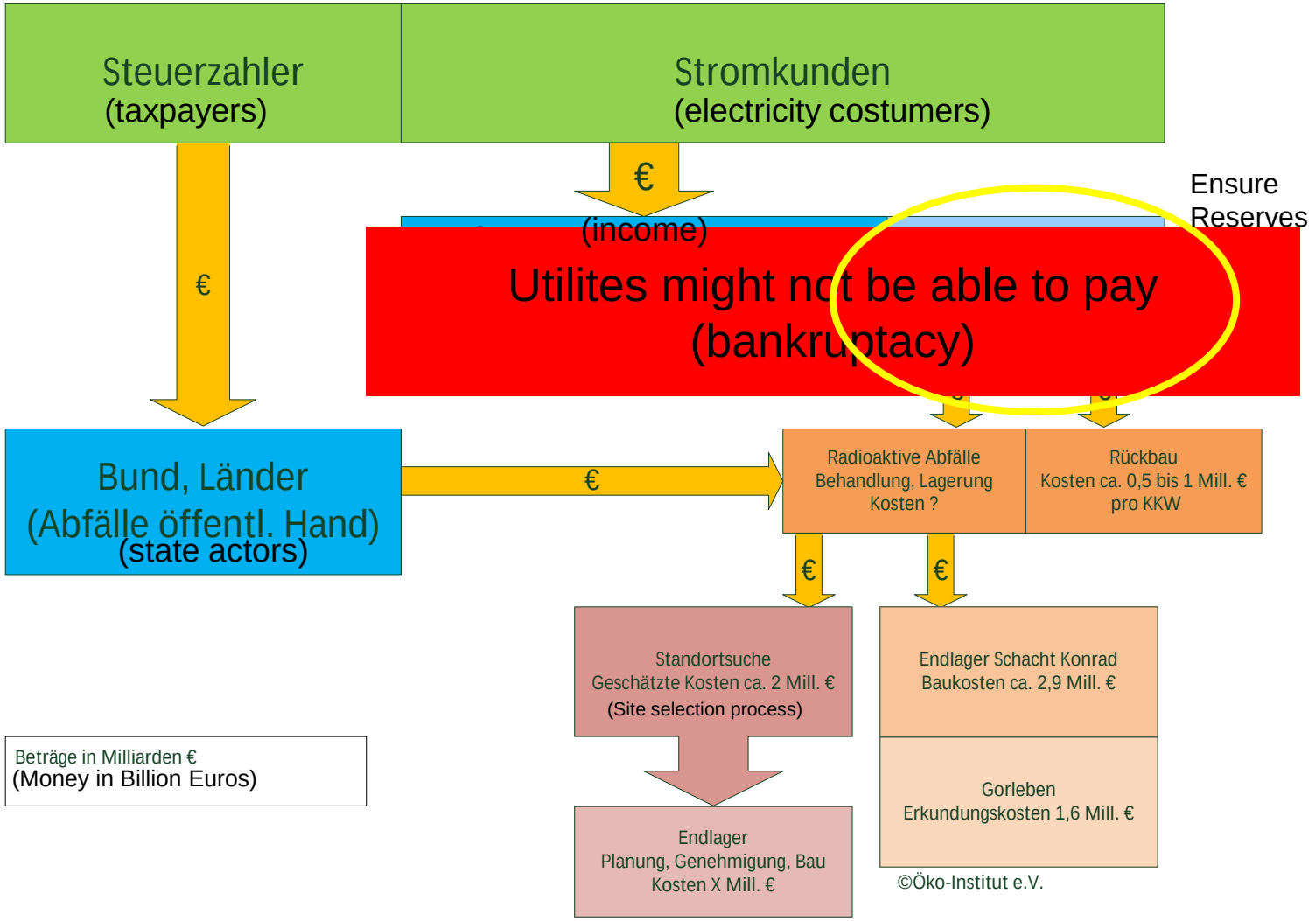
§§ 13, 14 Auswahl der Standorte für übertägige Erkundung
- Ausschluss ungünstiger Gebiete auf Basis von Ausschlusskriterien (Basis: evaluiertes Standortauswahlgesetz),
- Vorläufige Sicherheitsuntersuchungen für geeignete Standortregionen,
- Auswahl von Standorten für übertägige Erkundung wird per Gesetz beschlossen.

# Site Selection Act of 2013

## Public Participation §9



# Costs


Steuerzahler
(taxpayers)
Stromkunden
(electricity costumers)
€
(income)
Ensure
Reserves
€
Utilites might not be able to pay
(bankruptacy)
Bund, Länder
(Abfälle öffentl. Hand)
(state actors)
€
Radioaktive Abfälle
Behandlung, Lagerung
Kosten ?
Rückbau
Kosten ca. 0,5 bis 1 Mill. €
pro KKW
€
€
Standortsuche
Geschätzte Kosten ca. 2 Mill. €
(Site selection process)
Endlager Schacht Konrad
Baukosten ca. 2,9 Mill. €
Gorleben
Erkundungskosten 1,6 Mill. €
Endlager
Planung, Genehmigung, Bau
Kosten X Mill. €
Beträge in Milliarden €
(Money in Billion Euros)
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# Fazit

- Currently all radioactive wastes are stored intermediatly at central and decentral interim storage facilities
- Mainly dry cask storage of high level waste
- Cancellation of reprocessing
- Final geologic disposal is seen as the only justifiable option for long term storage of high level waste
- Transparent and comprehensible site selecion process is paramount for a possible success

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# Vielen Dank für Ihre Aufmerksamkeit!
# Thank you for your attention!

Haben Sie noch Fragen?
Do you have any questions?