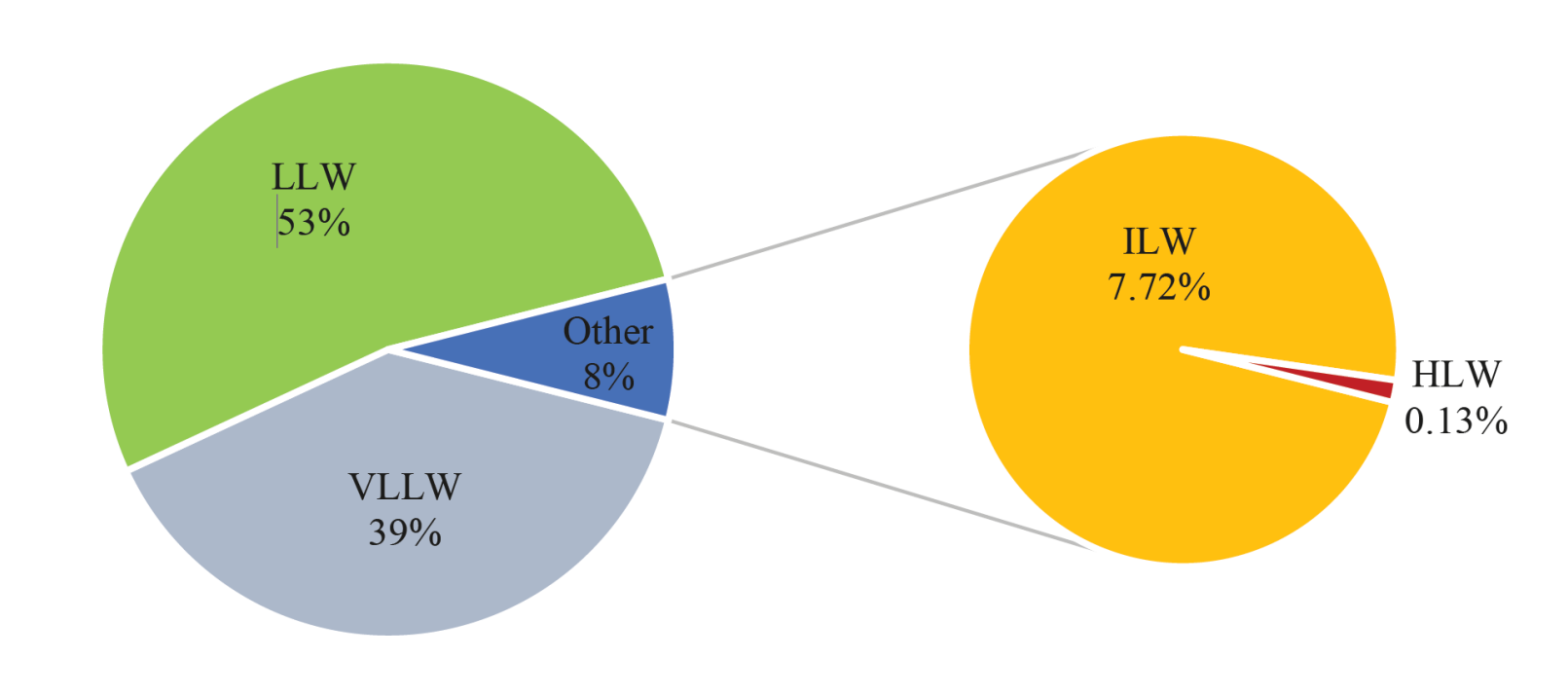
Gerhard Proehl

# Overview on projects on disposal of high level radioactive waste in Europe

# CLasses of radioactive waste in total volumes in storage and disposal, based on the 2016 inventory data (IAEA, 2022).




- VLLW and LLW comprise more than 90% of the total volume
- ILW and HLW typically comprise more than 95% of the total radioactivity.

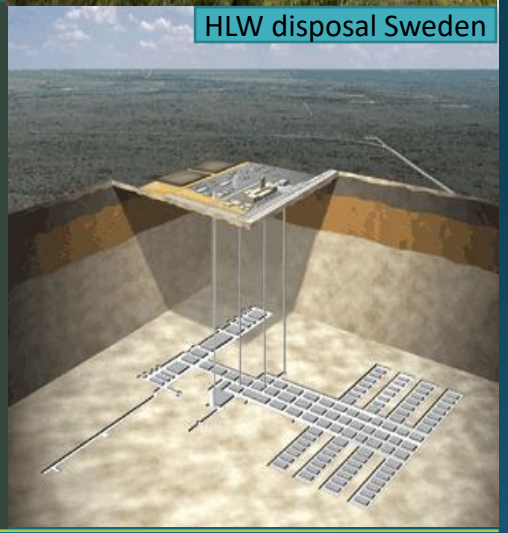
# Aims of Disposal of Radioactive Waste

- To contain the waste
- To isolate the waste from the accessible biosphere
- To reduce likelihood of inadvertent human intrusion into the waste

# Disposal Options for Radioactive Waste

| | |
|---|---|
| **Near surface** | • Short-lived radioactive waste<br>• Low-level waste ( LLW)<br>• Iintermediate level waste (ILW)<br>• Available in many countries |
| **Geological** | • For all types of radioactive waste and disused sources<br>• **Especially for high level waste: Spent nuclear fuel and reprocessing waste**<br>• Not yet available in most countries |


El-Cabril (Spain)


HLW disposal Sweden

## Host rocks for disposal of HLW

- Salt
- Clay
- Crystalline

# Characteristics of salt

- **Rock salt behaves plastically under pressure**
  - The formation of cracks and fissures is largely prevented.
  - If cracks do form, they heal quickly.
- **Permeability**
  - The permeability of rock salt is extremely low.
  - It can be considered almost impermeable, which ensures the insolation of the waste.
- **Thermal conductivity**
  - Higher specific thermal conductivity than granite or clay.
  - Heat-generating radioactive waste can be packed more densely than in granite or clay.
- **Engineering**
  - Due to its mechanical properties, the construction of large cavities in rock salt is possible
- **Salt is a commodity**
  - If the knowledge on the disposal facility gets lost, the likely hood for human intrusion increases

Cavity in a salt dome

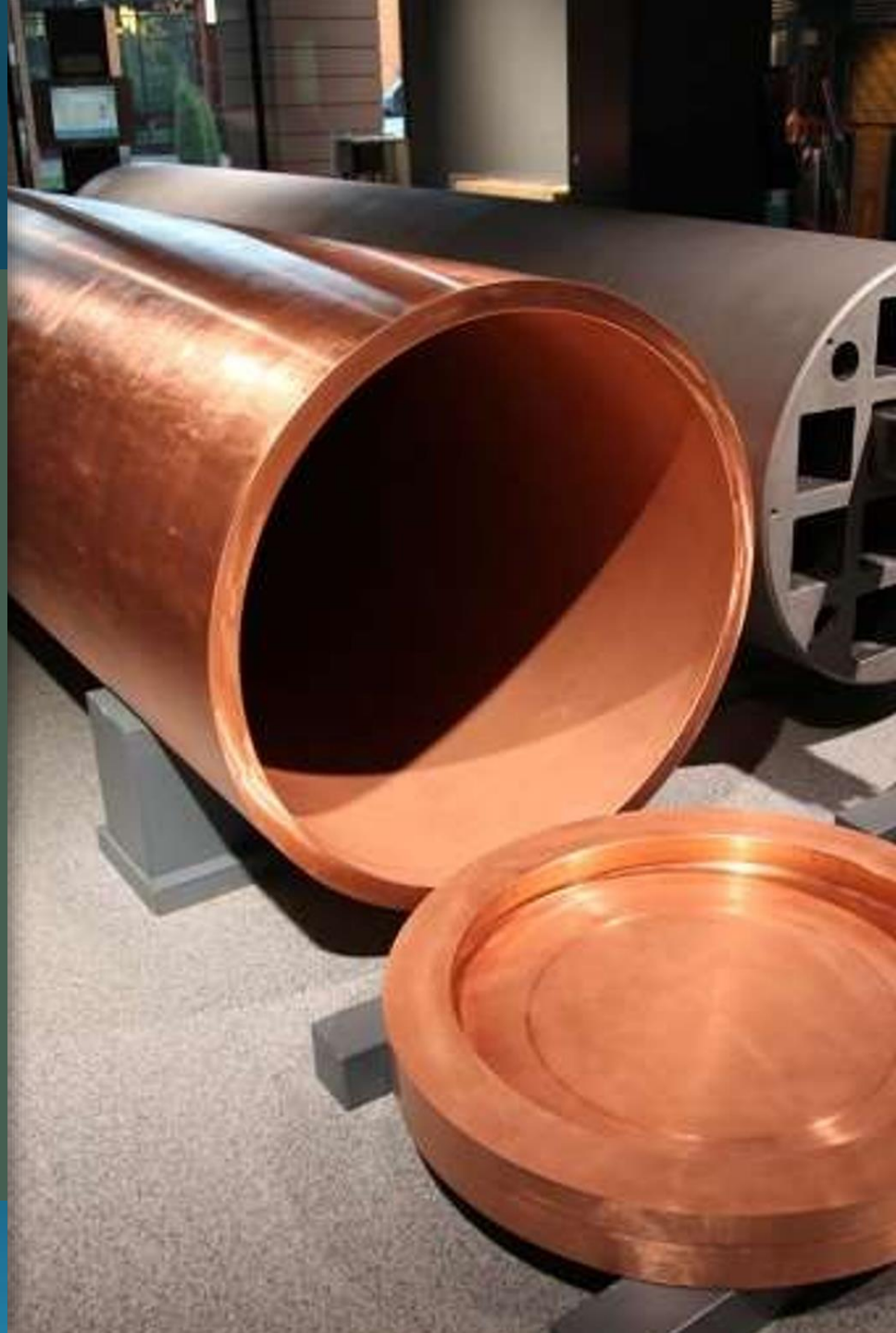
# Characteristics of clay

- **Clay is impermeable to water**
  - Once the radioactive waste are disposed, they will remain there in the disposal.
  - The water with the dissolved substances in the rock pores is practically immobile.
- **Clay minerals are negatively charged**
  - High sorption capacity for cations, most radionuclides in the wastes are cations
  - Cations in contact with clay will be strongly bound
  - But anionic radionuclides as e.g., I-129, Tc-99, Se-79 are not bound
- **Swelling in contact with water**
  - In contact with water, it swells and – if there are any cracks – the cracks are sealed.
- **Disadvantage**
  - Clay is demanding from a structural engineering point of view.
  - The heat conductivity is low.

Clay formations

# Characteristics of crystalline (granite)

- **Crystalline is a hard rock**
  - Usually occurring in massive form
  - It may be dissected into cuboid blocks by horizontally and vertically running fissures
- **Permeability**
  - The permeability is low for unfractured crystalline
  - Fissures in fractured crystalline cause high permeability
- **Isolation of waste**
  - Engineered barriers have a key role for ensuring the long-term isolation of the waste from the surrounding environment
  - The waste will be packed in welded copper canisters



# Characteristics of host rocks for disposal in geological formations

| Host rock | Salt | Clay | Crystalline (Granite) |
|---|---|---|---|
| Thermal conductivity | High | Low | Medium |
| Permeability | Practically impermeable | Very low to low | • Very low, if unfractured<br>• High, if fractured |
| Firmness | Medium | Low to medium | High |
| Deformation characteristics | Viscous (creeping) | Plastic to brittle | Brittle |
| Stability of cavities | Stable | Requires engineered stabilization | • Very high, if unfractured<br>• Low, if fractured |
| Tension in the rock | low | Potentially high | Potentially high |
| Solubility | Very high | Very low | Very low |
| Sorption | Very low | Very high | Medium/high |
| Temperature resistance | High | Low | High |

| Favorable feature | Unfavorable feature | Medium |
|---|---|---|

# Examples of disposal facilities planned or under construction

# Finland: Disposal facility for HLW in granite

- Most advanced project for HLW in Europe, under construction since late 2016
- Located near the Baltic coast in south-west Finland
- Disposal of spent fuel in crystalline rock at a depth of 400 m
- The waste will be enclosed in copper canisters
- In 2021, *Posiva*, the Finnish waste management organisation, started constructing the first emplacement drift
- To come into operation in the mid-2020s

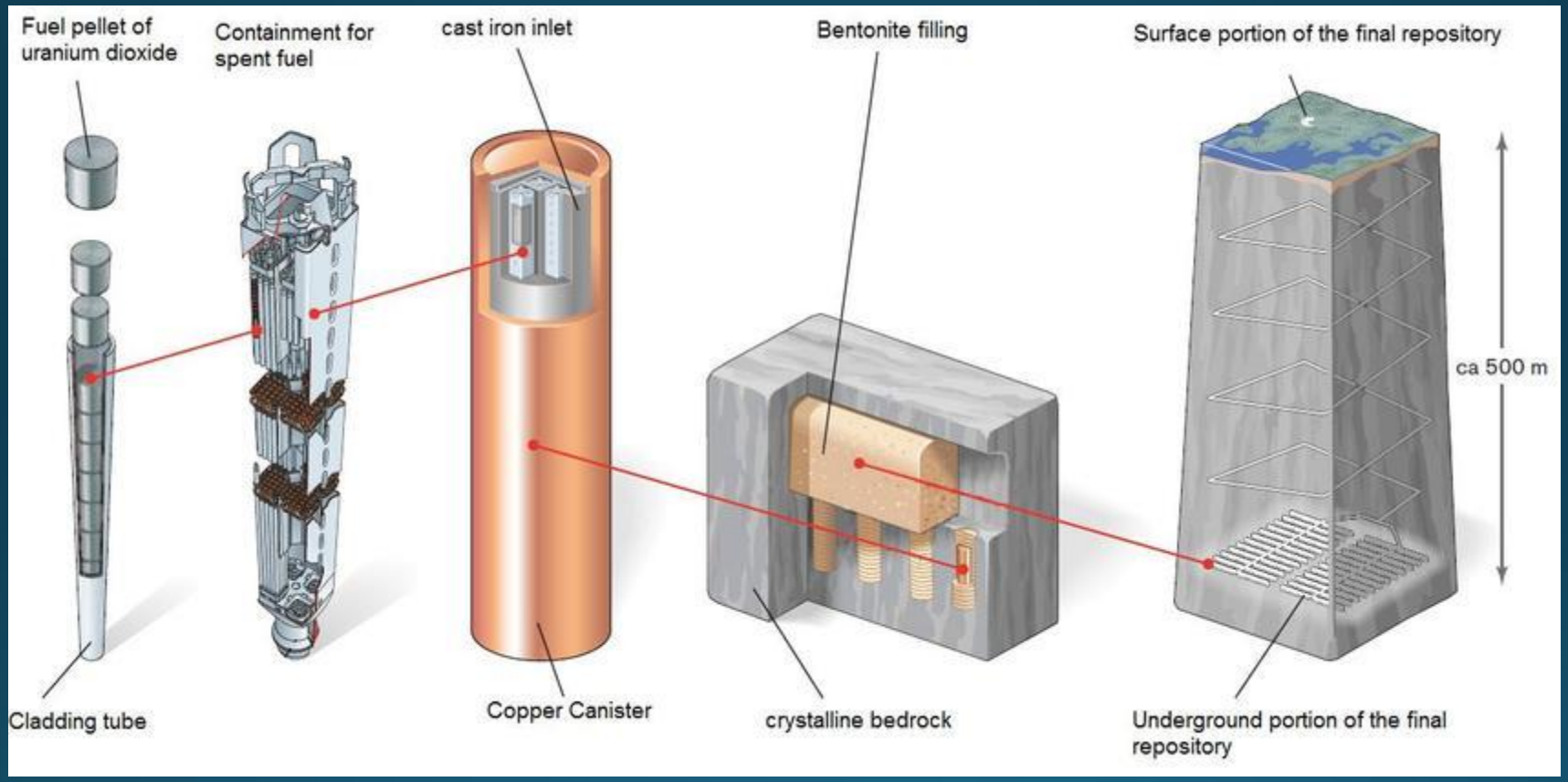
# The Onkalo disposal facility for spent fuel Olkiluoto, Finland

*(Photo: Posiva Oy)*

- Disposal of spent fuel
- Built in granite
- Consists of an engineered system of tunnels.

- The underground laboratory in Onkalo:
  - To study the host rock
  - To support the safety assessment

# Multi-barrier system in for high level waste

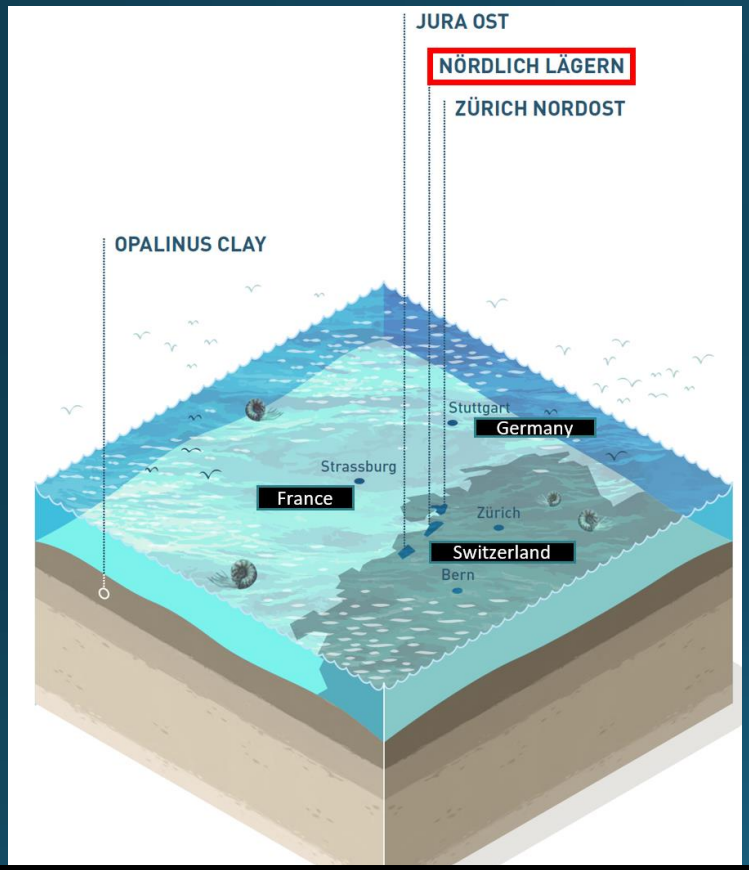



Canisters are surrounded by bentonite clay
in individual deposit holes
at 500 m depth in granitic bedrock

# France:
# Disposal facility for HLW in clay

- An underground laboratory is in operation since the year 2000 by ANDRA (French waste management organisation)
  - Located about 250 km east of Paris in the municipality *Bure*
- The potential site for disposal of reprocessing waste is **Cigéo,** which is nearby
- The waste will be disposed in a  clay rock formation at a depth of about 500 m
- The construction licence application will be submitted soon
- The disposal facility could go into operation around 2040

# Switzerland
# Disposal facility for LLW, ILW, and HLW in clay




- 2008: Start of the site selection process
- 2022: Selection of a clay formation "**Nördlich Lägern**" in North Switzerland near the German border
- 2024: Submission of a general license application
- 2034: Construction work for underground studies
- 2045: Construction of the section for LLW and ILW
- 2050: Starting disposal for LLW and ILW
- 2055: Construction of the section for HLW
- 2060: Starting disposal for HLW
- 2085/2090: Closure

- The Opalinus Clay was formed 175 million years ago.
- At that time, Northern Switzerland was covered by a shallow sea.
- Opalinus clay is solidified fine mud that was deposited on the seabed.
- The name comes from the extinct mollusc "Leioceras opalinum" found in it.

# Netherlands:
# Interim Storage Facility for spent fuel

- The Netherlands has only small amounts of HLW to be disposed of.

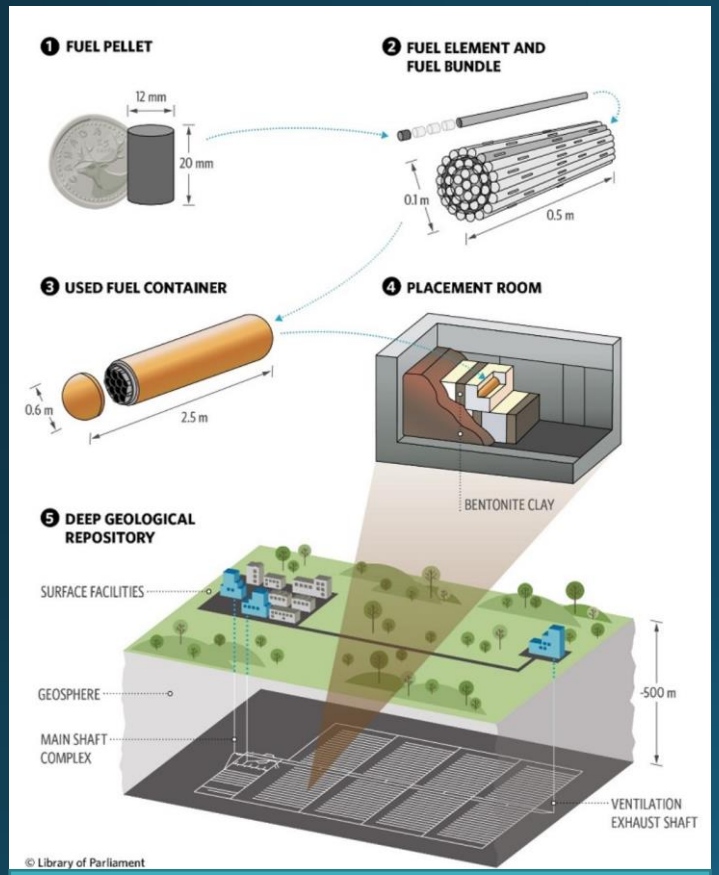
- An above ground storage facility for HLW was built in the South of Netherlands
  - The facility is dedicated for long-term interim storage for at least 100 y.
  - Constructed in compliance with very high safety standards, i.e. it can resist fire, earthquakes, explosions, direct aircraft impact and flooding
  - It is operated by COVRA (Dutch waste management organisation)
  - The facility in operation since 2003.

- Finally, the waste will be disposed in a deep geological formation
  - Site selection process to start by the end of this century?

# Sweden:
# Disposal facility for HLW in granite

- Spent fuel will be disposed in crystalline rock
  - Site is close to the Forsmark NPP near the Baltic Sea, 140 km north of Stockholm.
- License application for construction was submitted in 2011
  - The government's assessment is ongoing
  - Questions regarding the corrosion resistance of the copper disposal canister came up
  - Additional material was submitted
- Construction of the facility could start in the mid-2020s.
- At the same site, a disposal facility in crystalline rock for LLW and ILW is in operation since 1988.

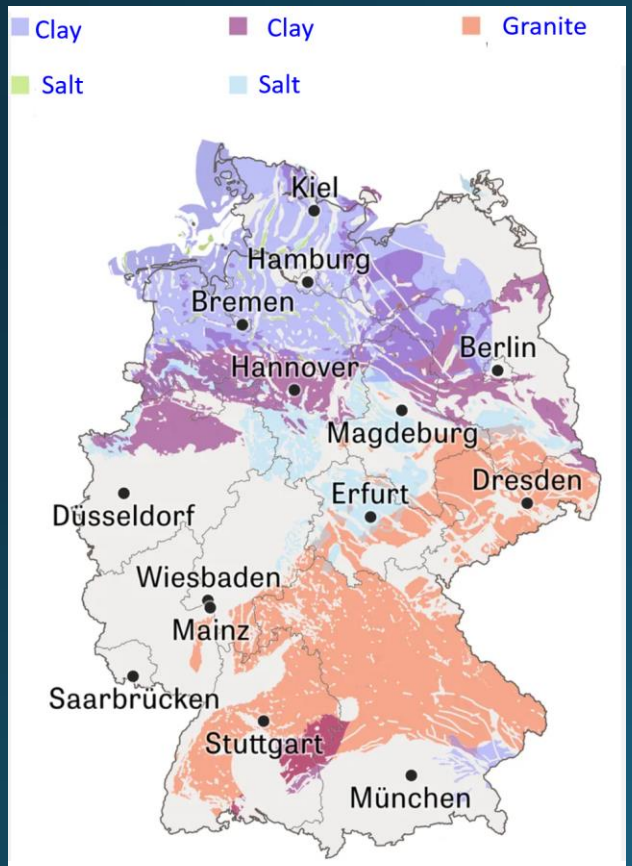
# Canada




Concept for disposal of spent fuel

- Spent fuel assemblies to be disposed of in a deep geological disposal
- The site selection process:
  - Based on ***voluntary*** applications from potential siting communities
  - Ongoing since 2010
- The last two remaining sites are in the Province of Ontario (East Canada).
  - South Bruce: Sedimentary rock (argillaceous limestone)
  - Ignace: Crystalline rock (granite)
- In 2021, the South Bruce site will be further explored by drilling deep boreholes.
- The siting decision is expected for around 2023.

# Germany: Site selection process restarted




Areas that could be considered for siting a disposal facility for HLW

## Gorleben

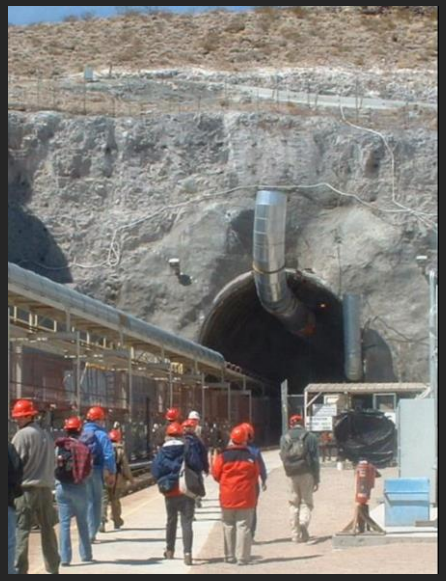
- Gorleben (North Germany) was selected in 1977 for disposal of HLW in rock salt
  - Underground Investigations from 1979 - 1999. (In 1999, the Green Party became part of the federal government for the first time).
  - Finally excluded as a site in 2020

## A new process for site selection

- The site selection process for a deep geological disposal for spent fuel and reprocessing waste restarted in 2017
  - It began with a “white map of Germany”.
- Potential host rocks include granite, salt and clay.
- An interim report was published in 2020 on the 1st phase of site selection
  - The report lists the regions that have already been excluded from the selection process
  - It names those regions that will be examined in more detail during the next phases.
- Originally, the most suitable site should be identified by 2031 in a three-stage process.
  - In the meantime, a delay of 15 years has been announced.

# United States

Yucca Mountain



Yucca Mountain tunnel entrance

## Waste Isolation Pilot Plant (WIPP)

- WIPP is in operation in Carlsbad, New Mexico, since 1999.
- Dedicated for military transuranic waste built into rock salt at a depth of 655 metres.
- The closure of the WIPP is expected around 2050. The USA has several near-surface disposal facilities for LLW and ILW.

## Yucca Mountain

- Yucca Mountain is a volcanic ridge in Nevada Test Site about 160 km northwest of Las Vegas.
- The host rock is tuff
  - Yucca Mountain is made of layers of ashes from volcanic eruptions that happened more than 10 million years ago.
  - The facility would be about 300 m below the top of Yucca Mountain and about 300 m above the aquifer underlying the disposal.
- Natural and engineered barriers would be used to isolate the waste from the surrounding environment.
  - If constructed, it would use a tunnel complex in the mountain.
- Dedicated for disposal of 70000 tons of spent fuel (SNF) and reprocessing waste
- Application for licensing in 2008, no decision so far.

# A long way from
# the concept to start of disposal

# Comprehensive safety assessment

**The near field**

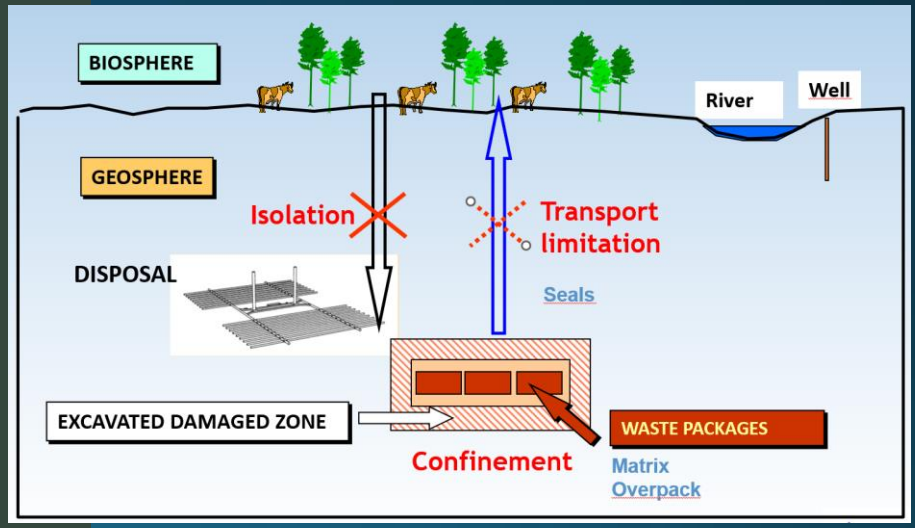
- Types of waste
  - Origin, nature, quantities and properties of waste
  - Radionuclide inventory
- System engineering
  - Waste conditioning and packaging, disposal units
  - Engineered barriers, cover of the disposal facility, drainage features
- Extent and properties of the zone disturbed by any excavation or construction work

**The far field (from waste to biosphere)**

- Geology, hydrogeology, hydrology, geochemistry
- tectonic and seismic conditions, erosion rates

**The biosphere**

- Location of the disposal facility
- Climate and atmosphere, water bodies
- Biota, soils, topography and the geographical extent and
- The local population, human habits



# Comprehensive safety assessment

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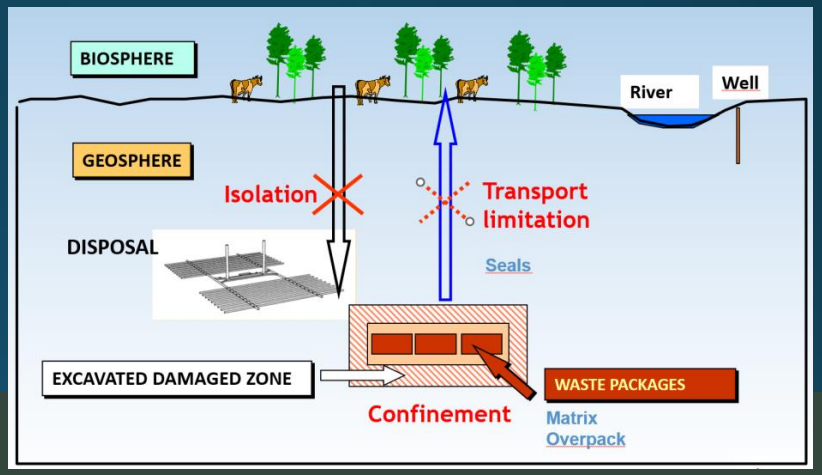


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# Why do disposal projects for HLW need so much time ?

- **Site characterization is time-consuming**
  - Development of geosphere, hydrosphere, lithosphere, biosphere, climate …
  - Engineering has to be adapted to results of site conditions
- **A comprehensive assessment is required including all aspects**
  - Demonstrate compliance with safety requirements and standards
  - Demonstrate compliance with radiological criteria
  - Need to cover time frames of up to 1 million years
- **Radioactive waste disposal projects are very unpopular**
  - Lack of public acceptance in many countries
  - A lot of objections and court cases
  - Reluctance of politicians to move these projects forward: Commitment to a repository is not good for the next elections
- **Time-consuming evaluation of the license application**
  - Complex system with many interaction between biosphere, geosphere, hydrosphere
  - Availability of experts for evaluation who are not directly or indirectly involved in disposal projects


**“Atomic garbage disposal”**

**“Not with us”**


“Stop Gorleben”

*Thank you!*