Nagra

National Cooperative for the Disposal of Radioactive Waste Switzerland

Aspö 14 May 2014, Hanspeter Weber

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Nagra – purpose and organisation

In 1972, Nagra (National Cooperative for the Disposal of Radioactive Waste) was established by the Swiss waste producers

- Cooperative of the waste producers (utilities and Government)
- Legal mandate contained in the Nuclear Energy Act of 2003
- Financed by the waste producers – NPPs 97%, Government 3%; contained in the electricity price: ~1 cent / KWh
- Around 100 employees, mainly scientists and engineers
- Head office in Wettingen, Canton Aargau
- Research in 2 underground rock laboratories (Grimsel & Mont Terri)
- Collaborative research with more than 10 countries
- Expenditure: around CHF 35 million per year

Nagra – mission and strategy

Mission:

- To construct safe geological repositories for all types of radioactive waste arising in Switzerland, without undue delay and at reasonable cost.

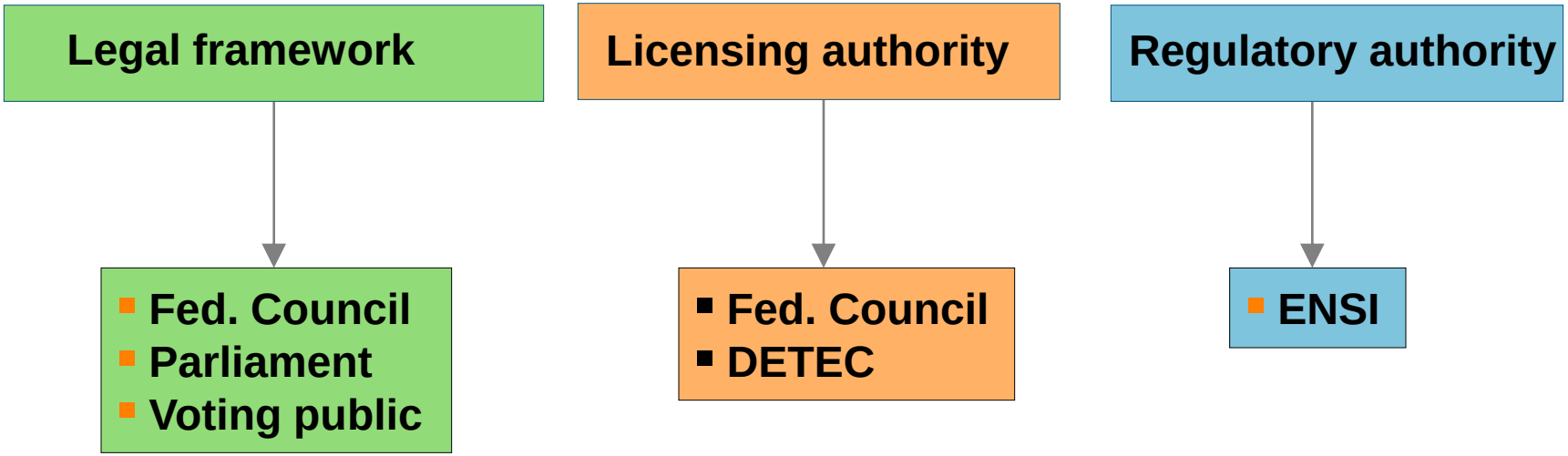
Strategy:

- To identify sites for the L/ILW and HLW repositories within the framework set out by the Sectoral Plan for Deep Geological Repositories and to submit the required general licence applications.
- To ensure sufficient interim storage capacity for waste from the power plants until the heat production from high-level waste has decayed sufficiently and the required geological repositories are available.

Nagra – tasks

- Maintaining a national inventory of all waste
- Developing concepts for deep geological disposal
- Preparing for site selection / site investigations
- Performing safety analyses
- Carrying out research and development
- Public relations, information and communication activities
- Commercial services for third parties

Nagra – key players in the waste management programme



Expert bodies and commissions

- AGNEB Federal Interagency Working Group on Nuclear Waste Management
- KNE Commission for Nuclear Waste Management
- KNS Federal Commission for Nuclear Safety

Nagra – L/ILW programme

1978	Concept report; 100 potential sites, reduced to 20 then 3
1983	Applications for site explorations: Oberbauenstock, Bois de la Glaive, Piz Pian Grand
1985	Project Gewähr (Oberbauenstock) submitted
1987	Start of investigations at Wellenberg
1988	Approval of feasibility demonstration for L/ILW
1993	Wellenberg identified as first priority site for L/ILW
1994	GNW established; general licence application submitted
1995/2002	Wellenberg concession refused twice in cantonal referendum
2003	Re-start of Nagra‘s L/ILW programme
2008	Start of the Sectoral Plan process
from 2030	General licence for the L/ILW repository
from 2035	In situ rock laboratory / construction phase
from 2050	Start of repository operation

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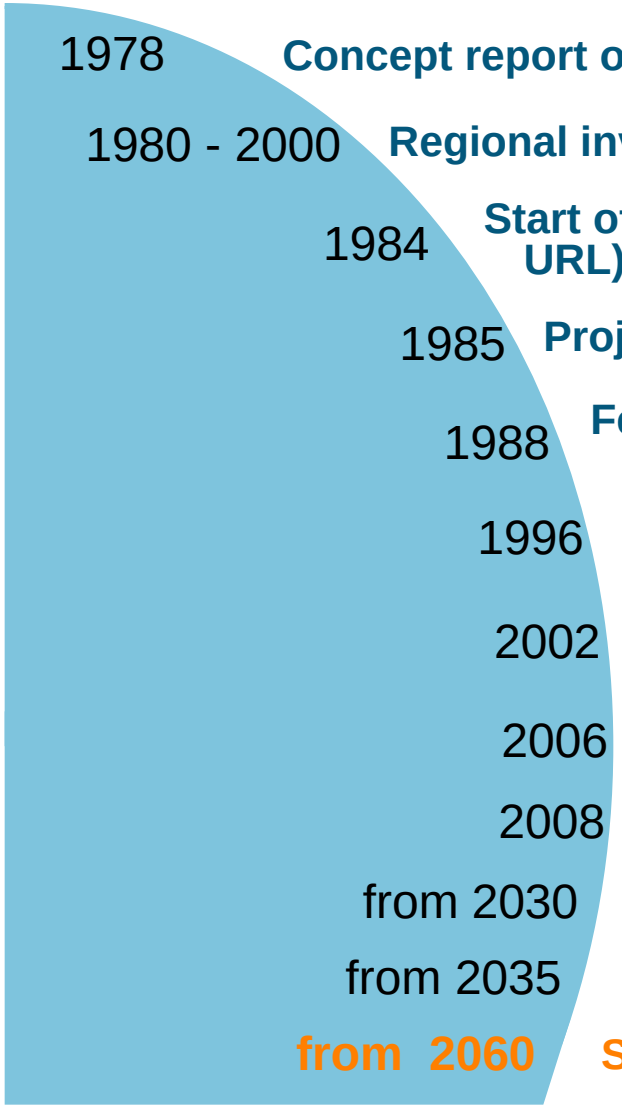
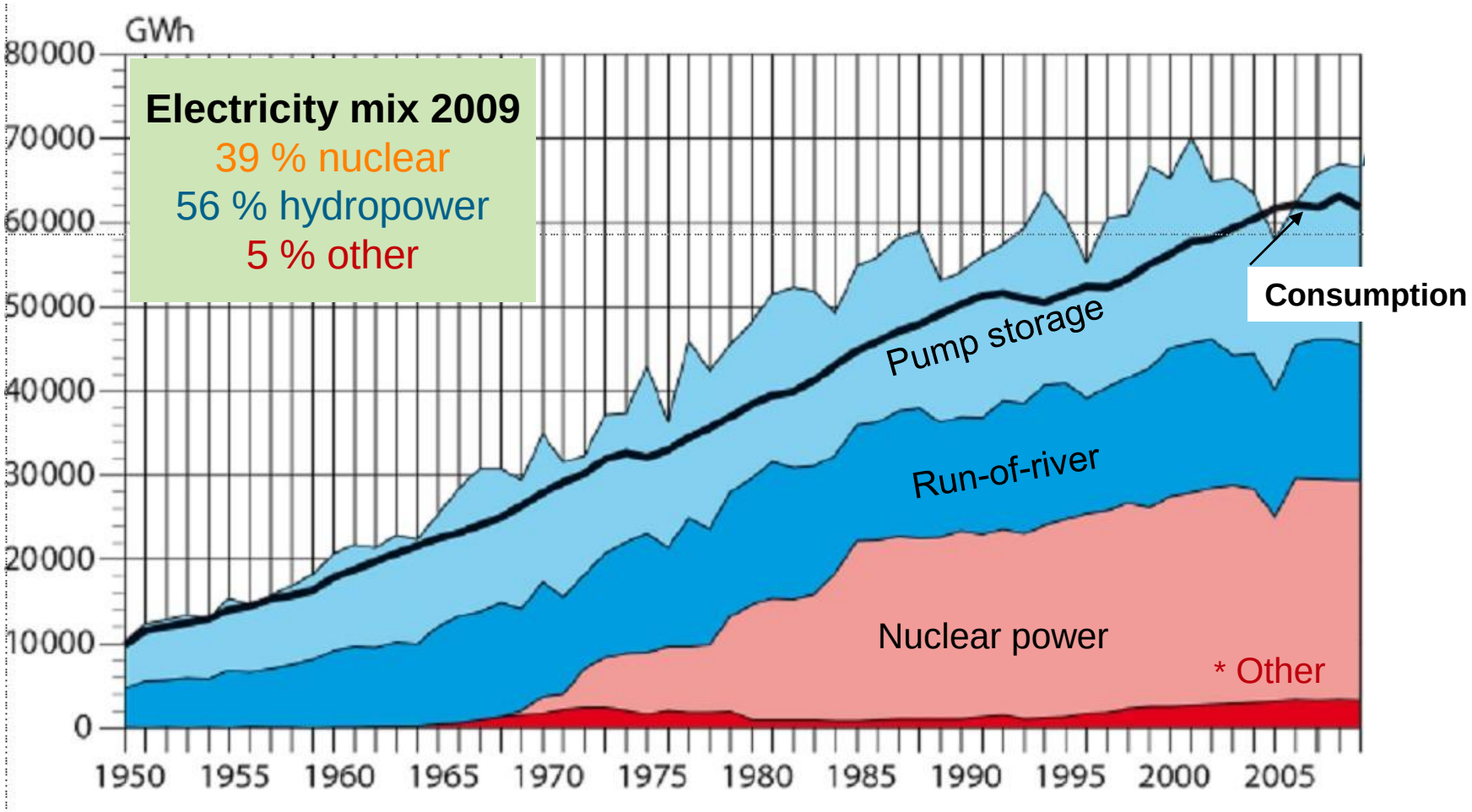
Nagra - HLW programme



1978	Concept report on nuclear waste management
1980 - 2000	Regional investigations in N. Switzerland (crystalline/sediments)
1984	Start of operation of the Grimsel Test Site (crystalline URL)
1985	Project Gewähr (crystalline) submitted
1988	Federal Council decision on Gewähr: investigations extended to clays / start of sediment programme
1996	Start of operation of Mont Terri (Opalinus Clay URL)
2002	Opalinus Clay project (feasibility study submitted to authorities)
2006	Feasibility study approved by Federal Council
2008	Start of Sectoral Plan process
from 2030	General licence for the HLW repository
from 2035	In situ rock laboratory / construction phase
from 2060	Start of repository operation

Production categories and consumption 1950 – 2007



* Production today comes mainly from waste incineration plants and cogeneration in industry and small plants; only 0.1 % comes from “alternative“ sources such as photovoltaics, wind, etc.

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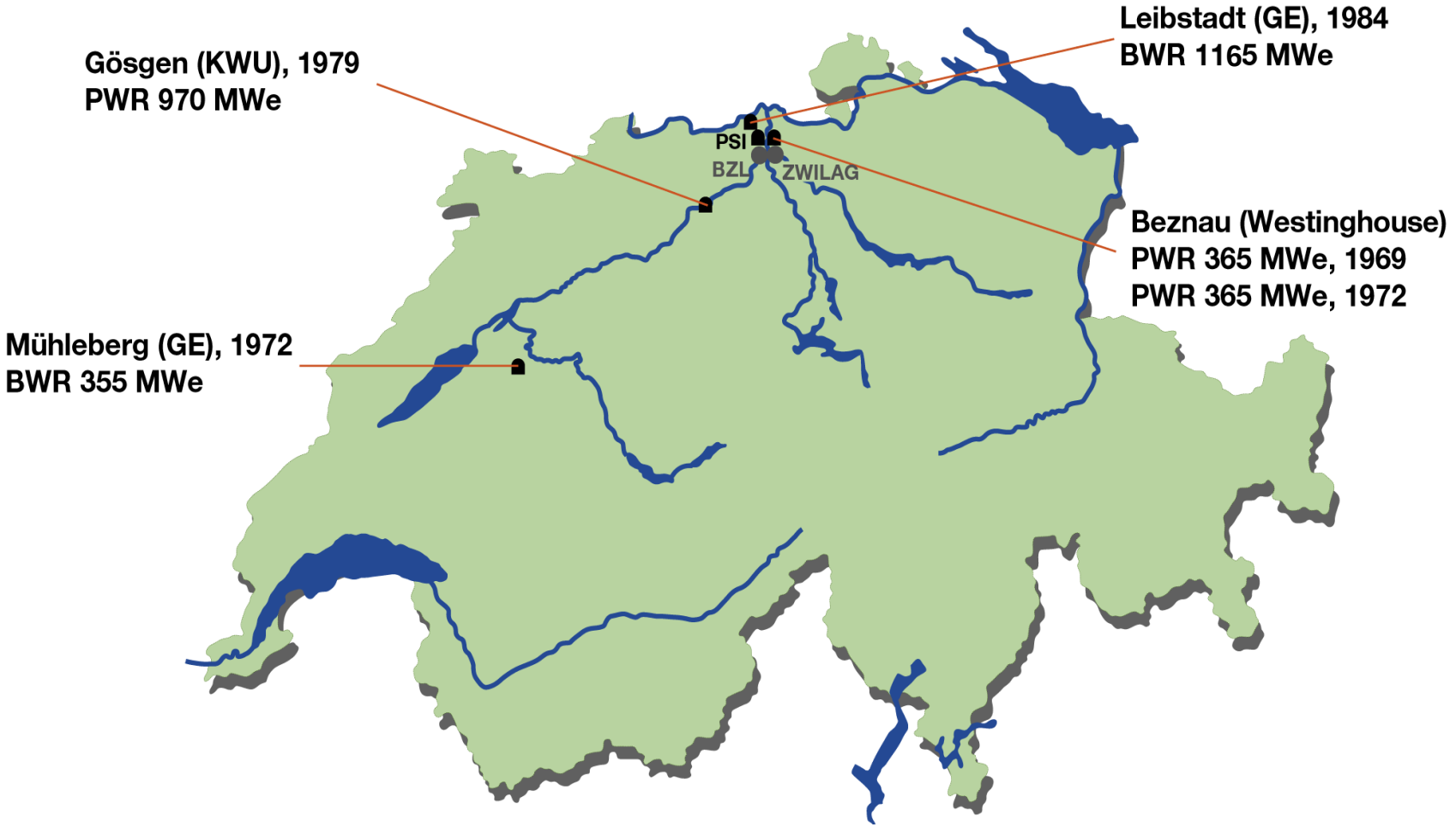
Production of the Swiss nuclear power plants

- 5 NPPs – installed output 3,200 MW
- Annual production ca. 26.5 bio. kWh
- Percentage of total power production ca. 40 %
- Average availability ca. 94 %

Nuclear power plants

- Leibstadt (KKL) 1165 MWe BWR
- Gösgen (KKG) 970 MWe PWR
- Beznau I (KKB-I) 365 MWe PWR
- Beznau II (KKB-II) 365 MWe PWR
- Mühleberg (KKM) 355 MWe BWR

Swiss nuclear power plants



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Volumes and radioactivity

	L/ILW repository		ILW repository		HLW repository	
	conditioned	packaged	conditioned	packaged	«non-packaged» [4] glass and SF	packaged
Volumes	**66,020 m³**	**89,410 m³**	**535 m³**	**2280 m³**	**1250 m³**	**7325 m³**
Percent %	97.3 %	90.3 %	0.8 %	2.3 %	1.9 %	7.4 %
[3] Inventory	4.7 x 10^{17} Bq		3.4 x 10^{16} Bq		3.0 x 10^{19} Bq	
Percent %	1.6 %		0.1 %		98.3 %	

1 Assumptions: **50-year operation** for all Swiss reactors;
fuel consumption 3574 t, 2435 t for direct disposal, 1139 t for reprocessing; substitution of equivalent volume of activity of L/ILW from reprocessing (BNFL) returned as HLW glass

2 **Volumes** are dominated by packaging in disposal containers - more space is required than for interim storage

3 Total **waste activity** is $3 \cdot 10^{19}$ Bq (reference year 2035)

4 **«Non-packaged»:** Volumes of «moulds» (steel casks with glass from reprocessing) and rectangular fuel assemblies, including spaces between fuel rods

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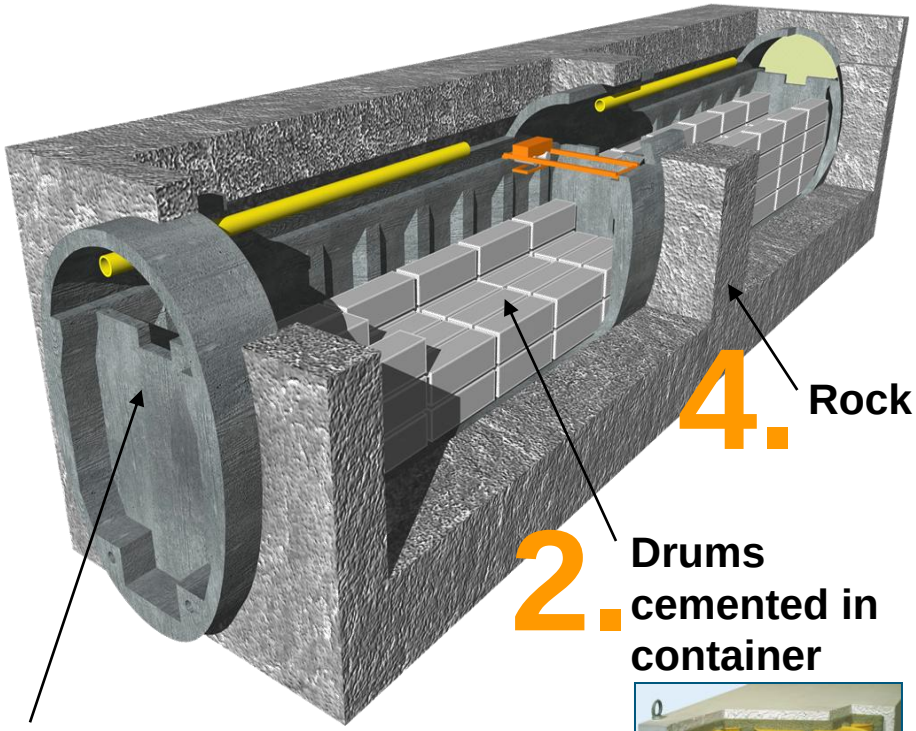
Safety barriers for low- and intermediate-level waste

- **L/ILW immobilised in cement**

- **Disposal caverns for L/ILW with emplaced containers**

1.

- **Drum with low-level waste**



4. **Rock**

2. **Drums cemented in container**

3. **Backfilling of caverns with special mortar**

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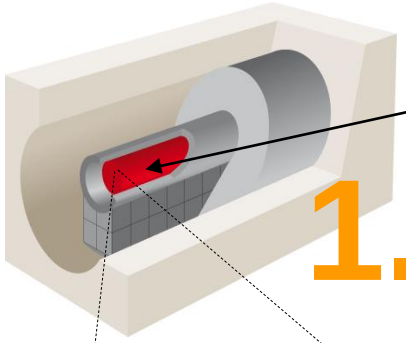
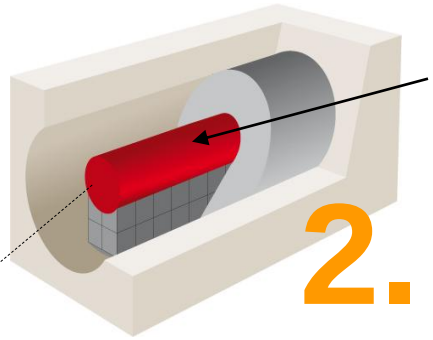
Safety barriers for high-level waste

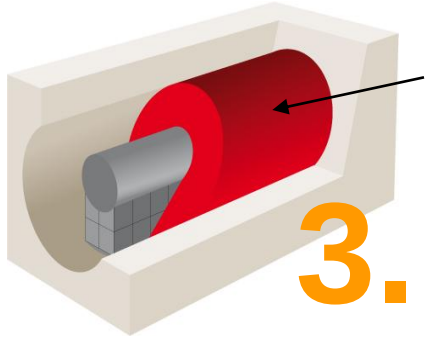


Matrix:
Radionuclides in low-solubility glass or fuel pellets

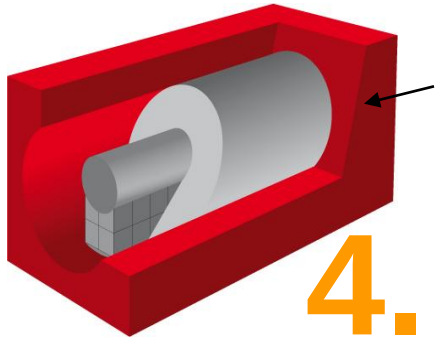
Disposal containers for vitrified HLW (left) and spent fuel (right)



Disposal container



Bentonite backfill



Host rock

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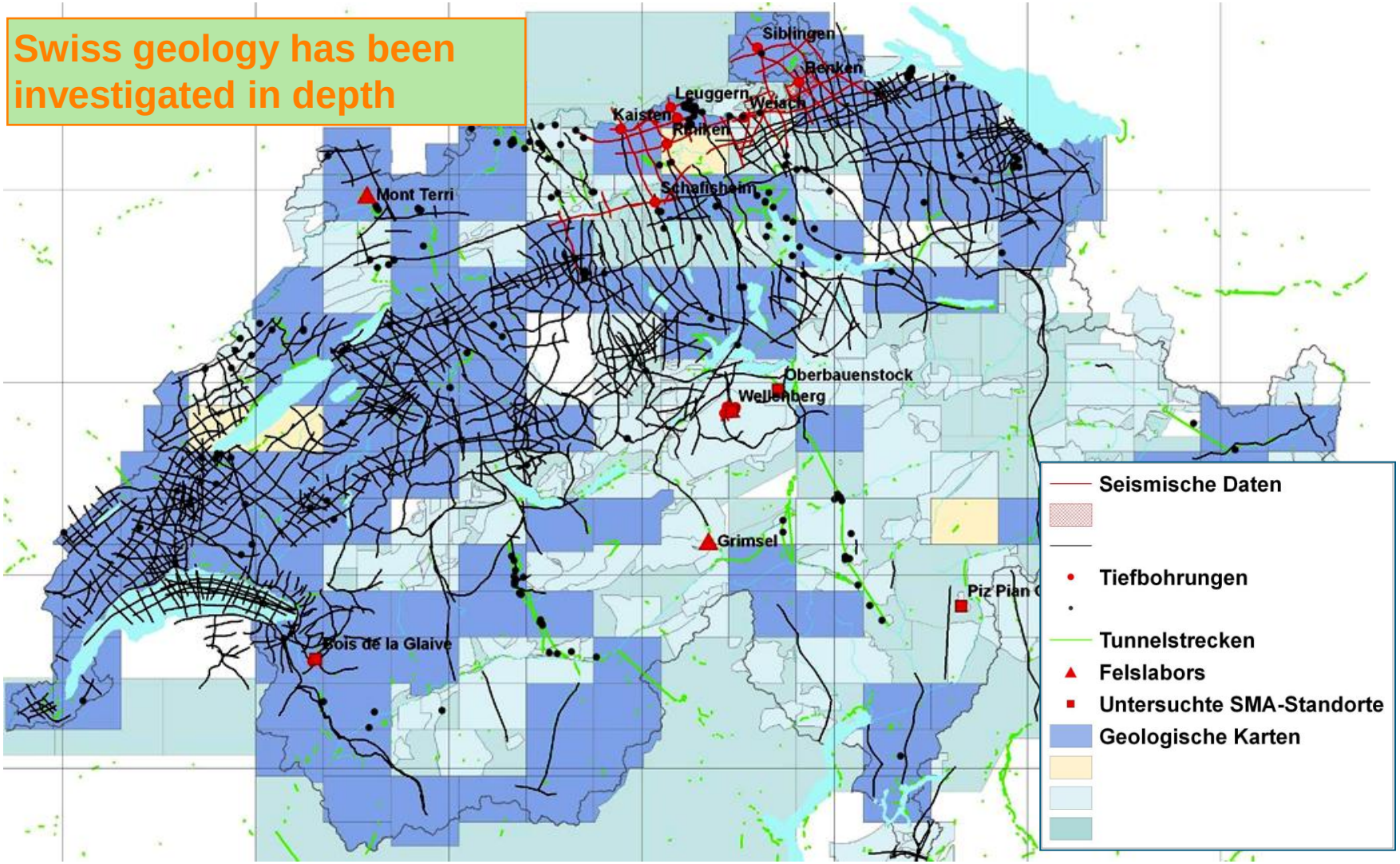
The geology of Switzerland

Swiss geology has been investigated in depth



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HLW programme – background

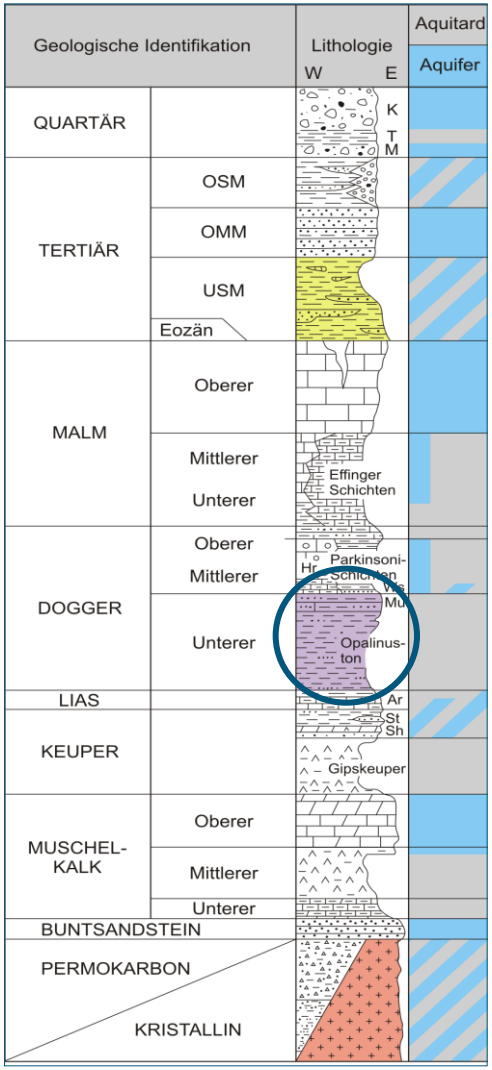
- 1980s: Investigation of the **crystalline basement** of Northern Switzerland
- Project **Gewähr 1985**: Feasibility study on safe disposal
- Given the poor predictability of the crystalline bedrock, the Federal Council calls for investigations to be extended to include **sedimentary formations**
- 1994: Selection of the **Opalinus Clay** option and the **Zürcher Weinland** area for extensive field investigations
- December 2002: Nagra submits the **Entsorgungsnachweis** (demonstration of disposal feasibility) for spent fuel, vitrified HLW and long-lived ILW
- 28th June 2006: Federal Council **approves** the Entsorgungsnachweis
- 2nd April 2008: Federal Council **approves** the conceptual part of the Sectoral Plan
- 6th November 2008: Nagra proposes **three siting regions** (Zürcher Weinland, North of Lägeren and Bözberg) for HLW

HLW programme – host rock

- **Opalinus Clay**

  Partly clay-rich, low-permeability rock formations located above and below the Opalinus Clay

- The potential host rocks considered up till 2008 - Lower Freshwater Molasse and crystalline bedrock – do not fulfil the stricter requirements in the Sectoral Plan (permeability, homogeneity and ease of characterisation) and are therefore now deferred. The Opalinus Clay remains as the preferred host rock.



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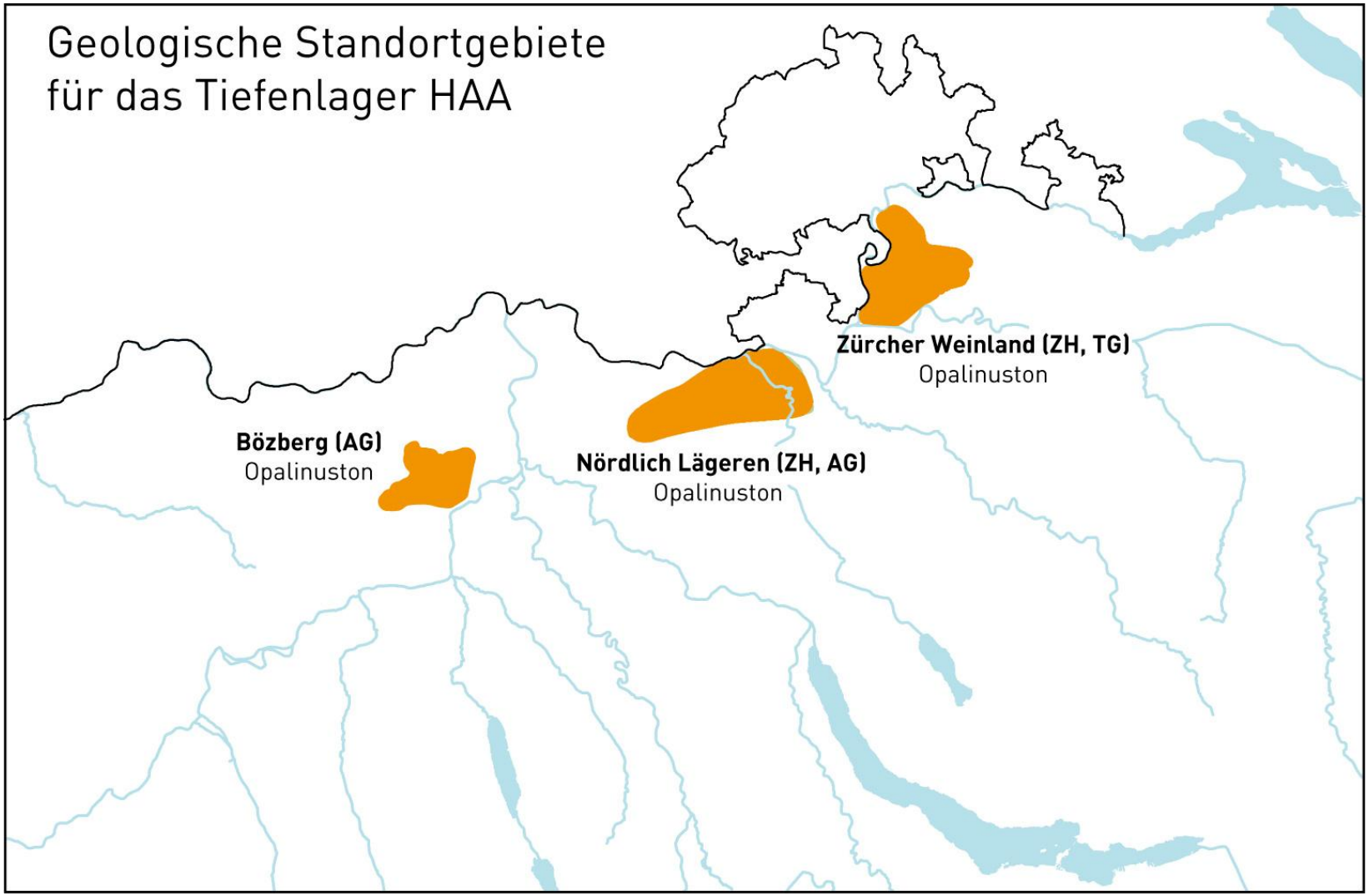
Geological siting regions



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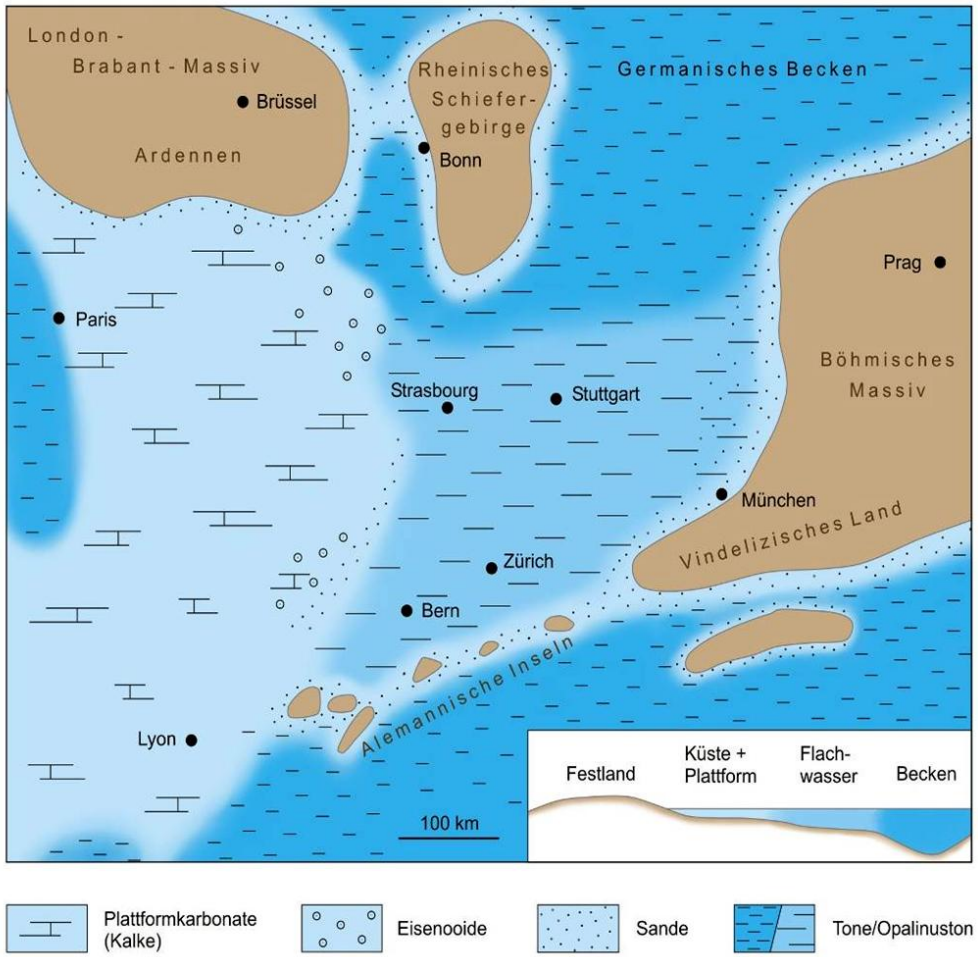
Opalinus Clay host rock – origin, properties



- Clay-rich marine deposit: **homogeneous, large spatial extent**
- **Very low permeability**
- Only **slight tectonic deformation** in certain areas (Tabular Jura)
- **Easy to investigate**

Opalinus Clay host rock: Nature's example

Fossil discovered in Benken

Name: **Leioceras Opalinum**

Stratum: Opalinus Clay

Depth: 652 m below surface

Preserved in the Opalinus Clay for around 180 million years

- **Mother of pearl layer preserved: clear example of conservation properties of clay**
- **Porewater still contains original seawater: no water flow**

Regional investigations (Zürcher Weinland)

3D seismic surveys using vibrator vehicles

Visitors at the Benken drillsite

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Regional investigations (Zürcher Weinland)

Benken borehole 1998

Regional investigations (Northern Switzerland)

2D seismic survey

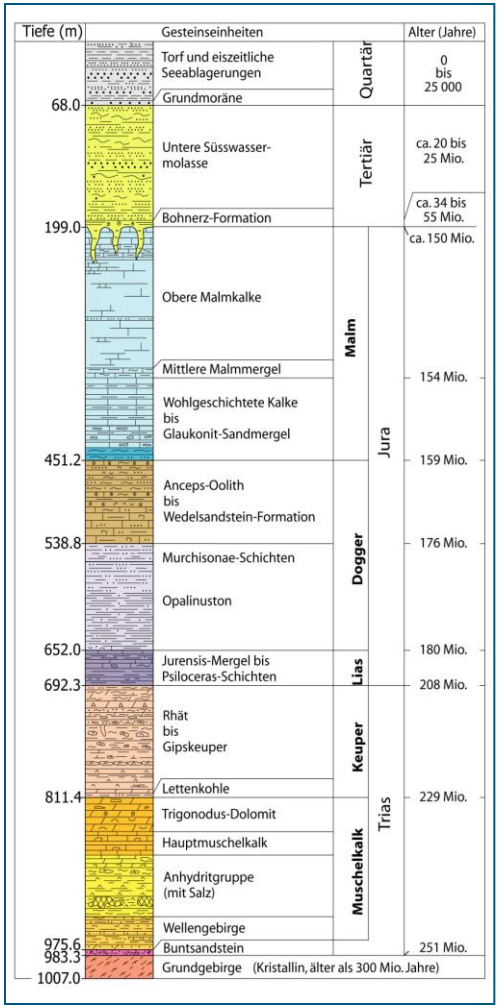
Weiach borehole

L/ILW programme – background

- 1970s: Investigation of a range of disposal concepts (surface/deep repositories) and host rocks
- Project **Gewähr 1985**: Feasibility demonstration of safe disposal
- 1987: Start of investigations at **Wellenberg (Canton Nidwalden)**
- 3rd June 1988: Federal Council approves Nagra's feasibility demonstration (Project Gewähr) for L/ILW for the Oberbauenstock model site in Canton Uri
- 1993: Selection of **Wellenberg** as the site for a L/ILW repository
- 1995/2002: **Concession applications rejected twice** by the voters of Nidwalden. Wellenberg project abandoned
- 2003: **Re-start** of the L/ILW programme
- 2008: Approval of the conceptual part of the Sectoral Plan; Nagra proposes **6 siting regions** for L/ILW

Geological situation and host rock

- At repository depth, the geology ensures spatial separation of the waste from the biosphere, where processes occur rapidly.
- The geology provides a physically and chemically stable environment in which the engineered barriers remain functional over long times.
- The geology has a further long-term barrier effect, in that it retards and restricts the migration of radioactive substances released from the repository.



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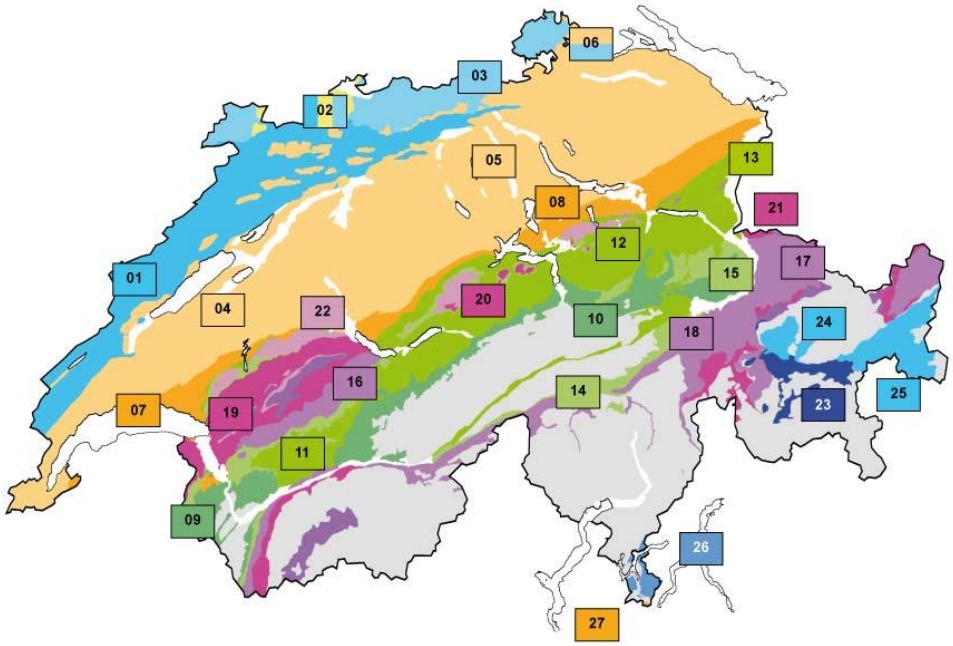
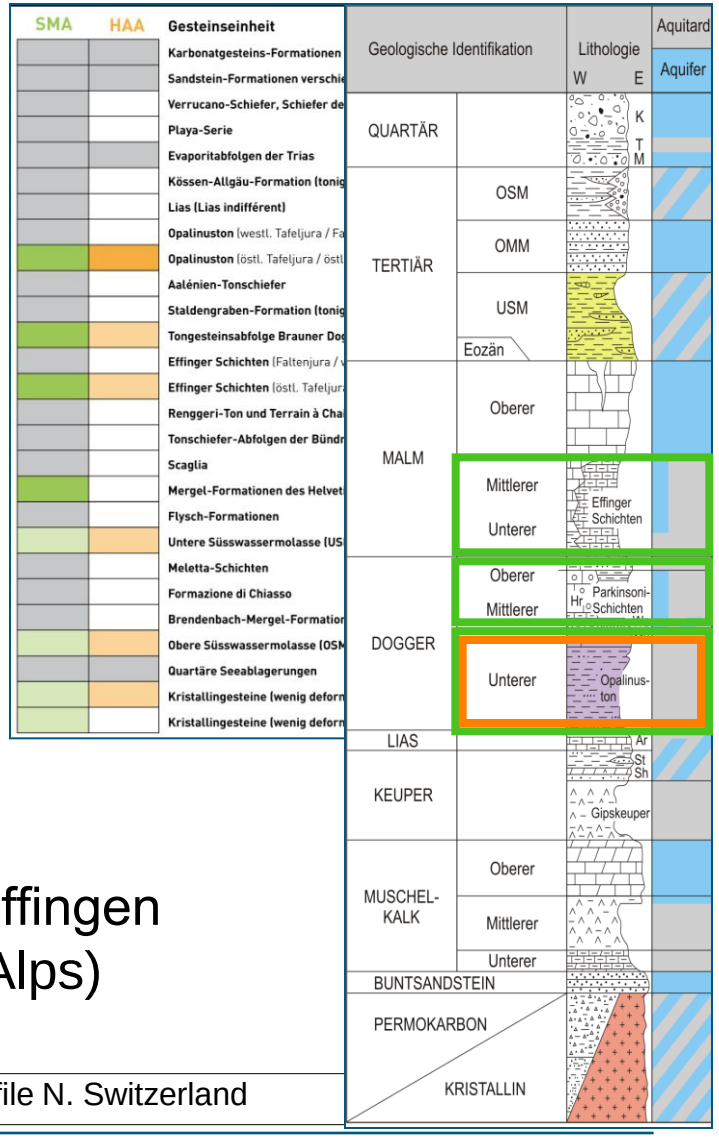
Which host rocks?





Pre-selection of 26 host rocks:

- **HLW**: Opalinus Clay
- **L/ILW**: Opalinus Clay, 'Brauner Dogger', Effingen Beds, marl formations of the Helveticum (Alps)

Example: profile N. Switzerland

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Where are the host rocks?

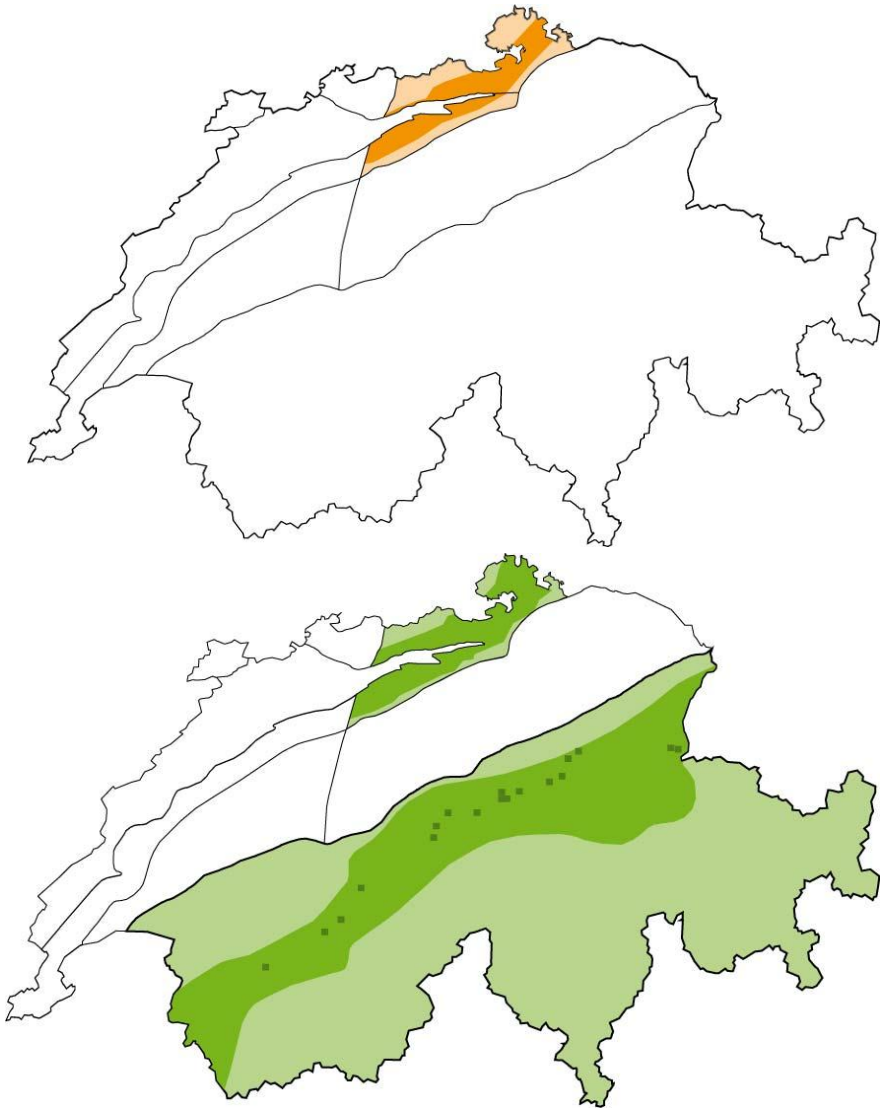
Large-scale areas for further consideration and preferred host rocks

HLW repository

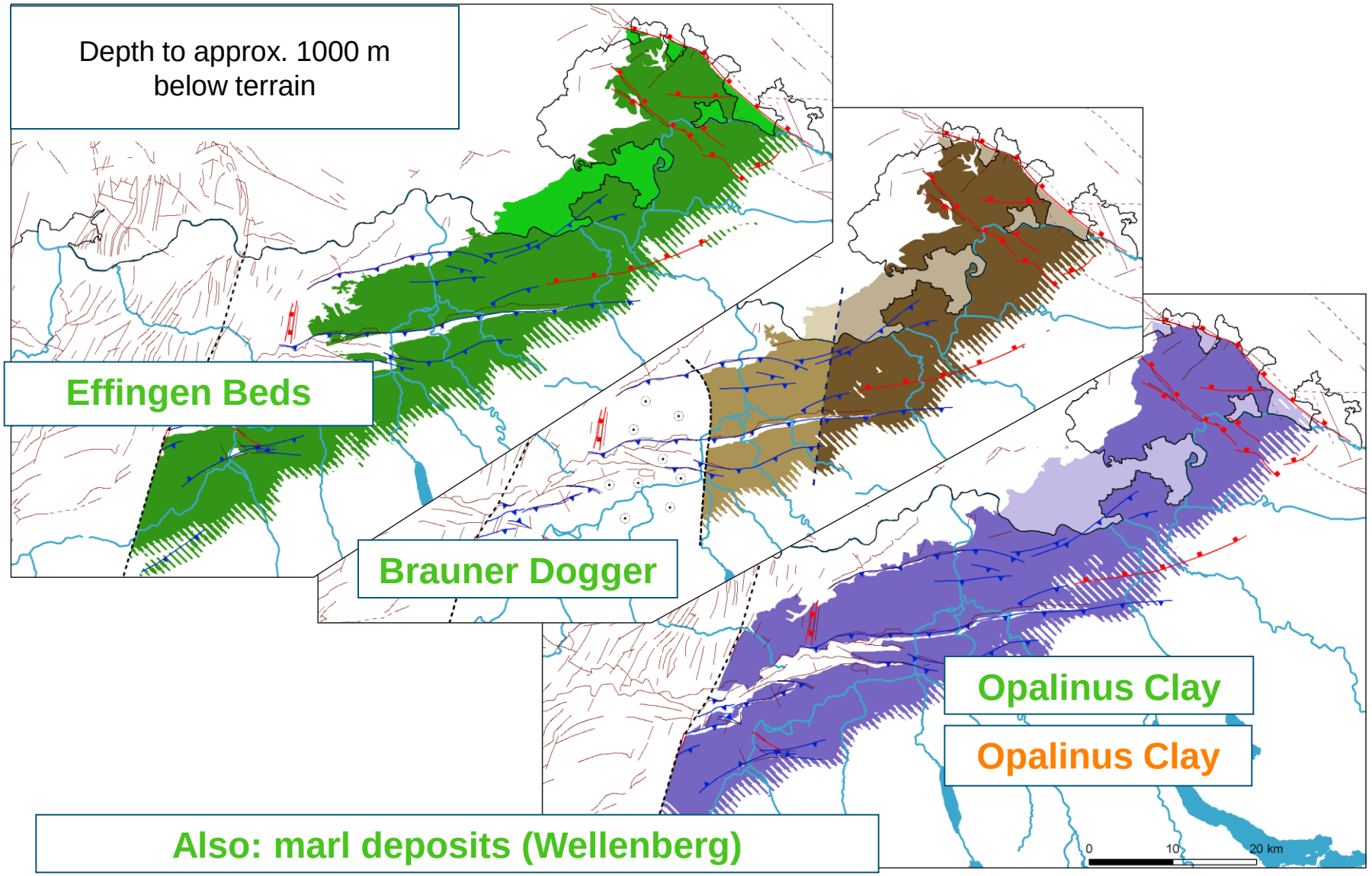
- N. Switzerland: Opalinus Clay

L/ILW repository

- N. Switzerland: Opalinus Clay, 'Brauner Dogger', Effingen Beds
- Alps: Marls of the Helveticum



Distribution of host rocks in Northern Switzerland



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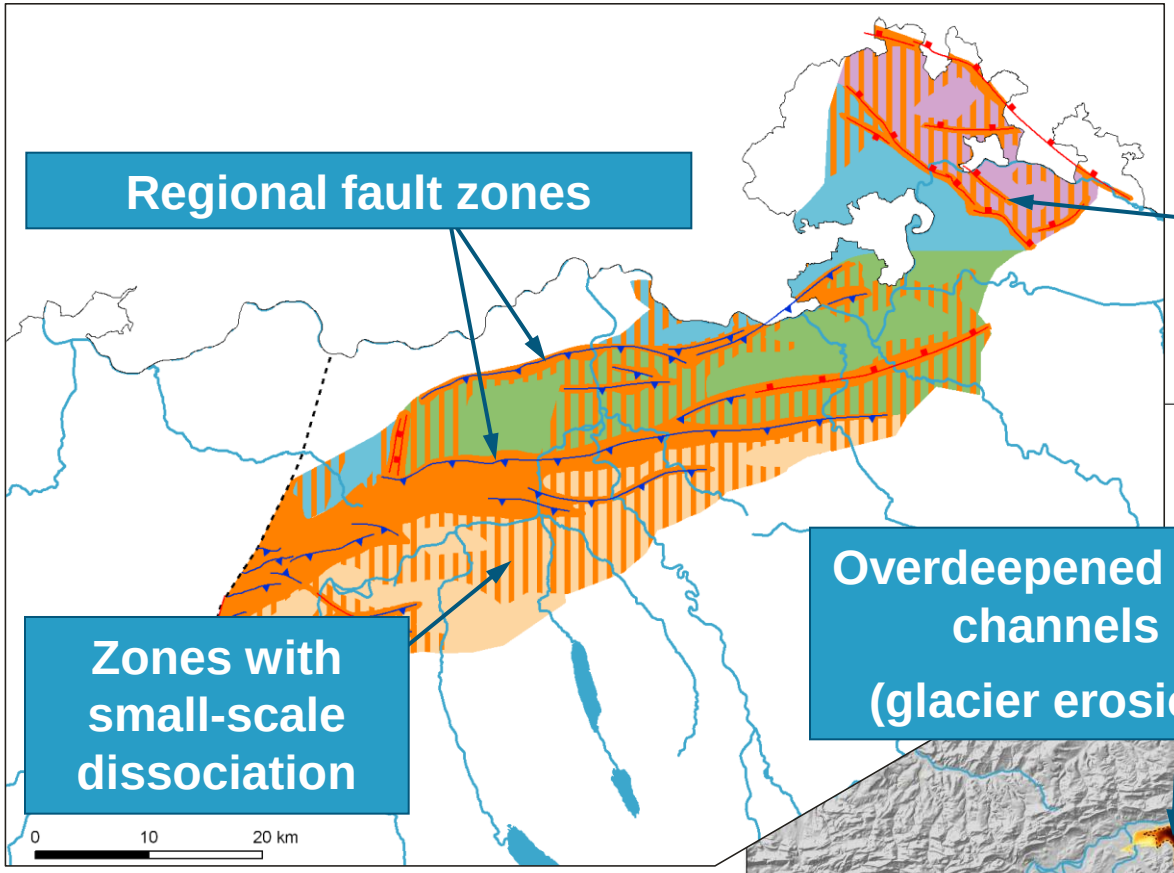
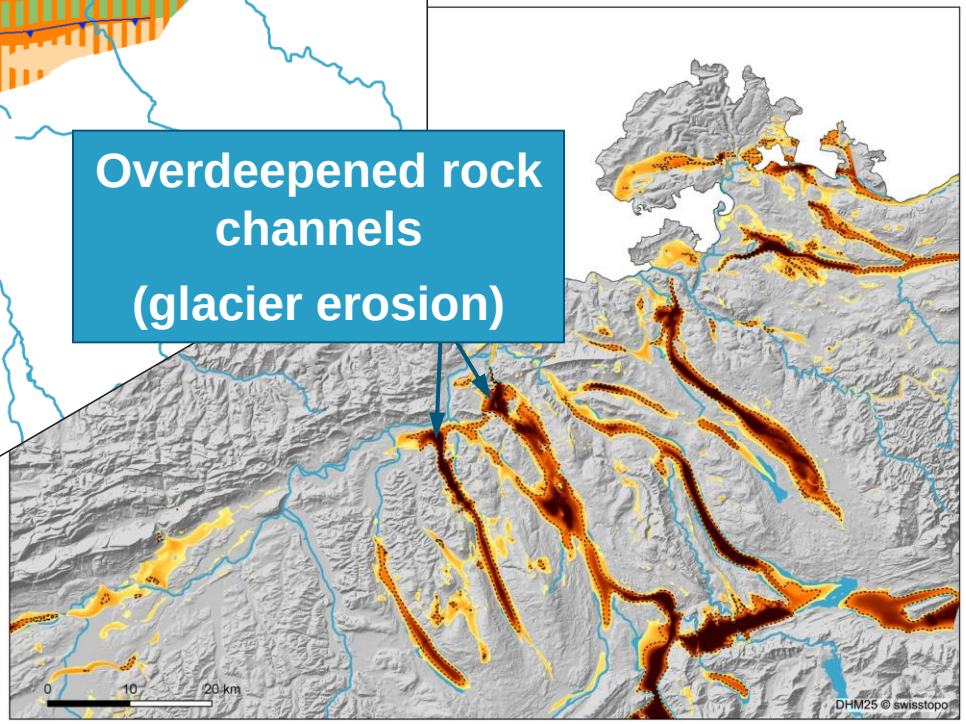
Siting regions: What has to be avoided?





… insufficient thickness and unsuitable depth of host rocks

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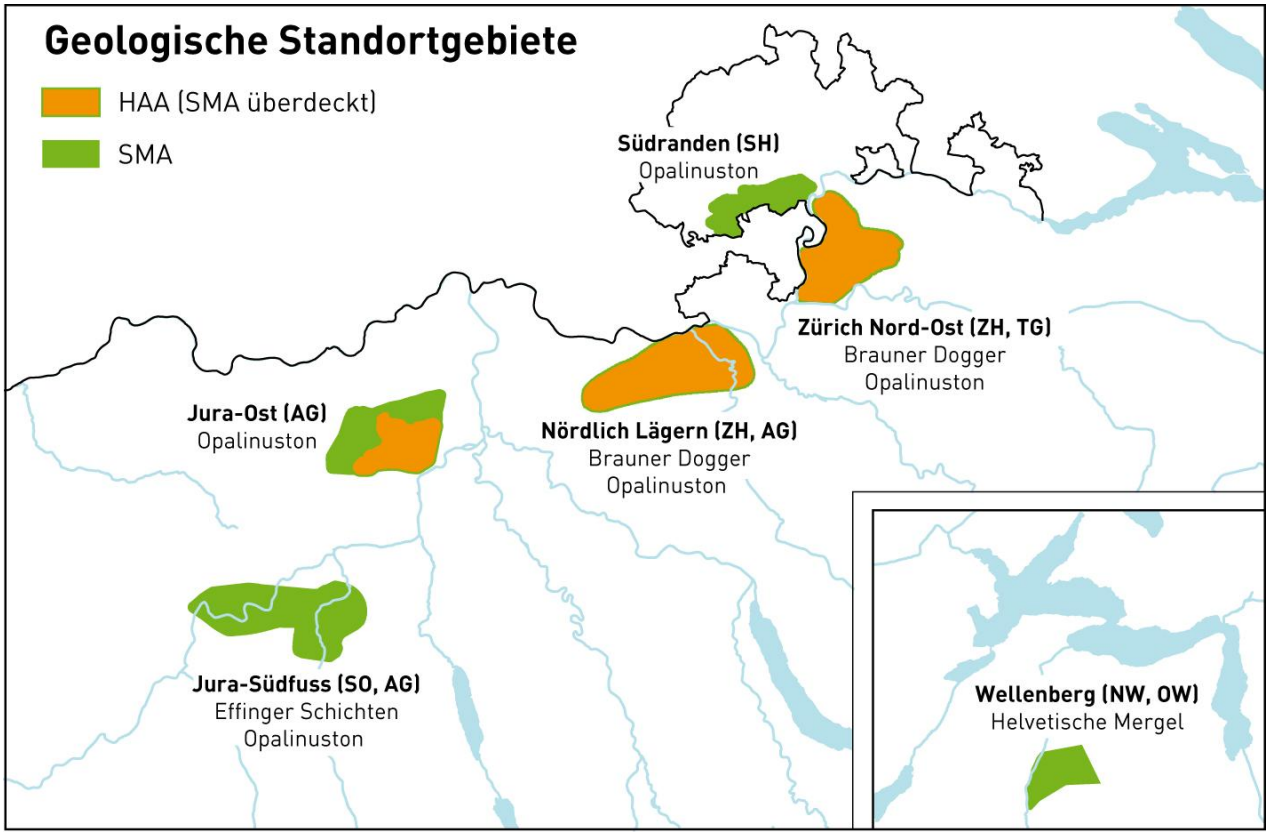
Proposed geological siting regions for L/ILW and HLW



- Result of systematic application of the **requirements in the Sectoral Plan**
- Takes into account geological possibilities in the **whole of Switzerland**
- Derived by systematic, **stepwise narrowing-down** from the viewpoint of **safety** and **engineering feasibility**

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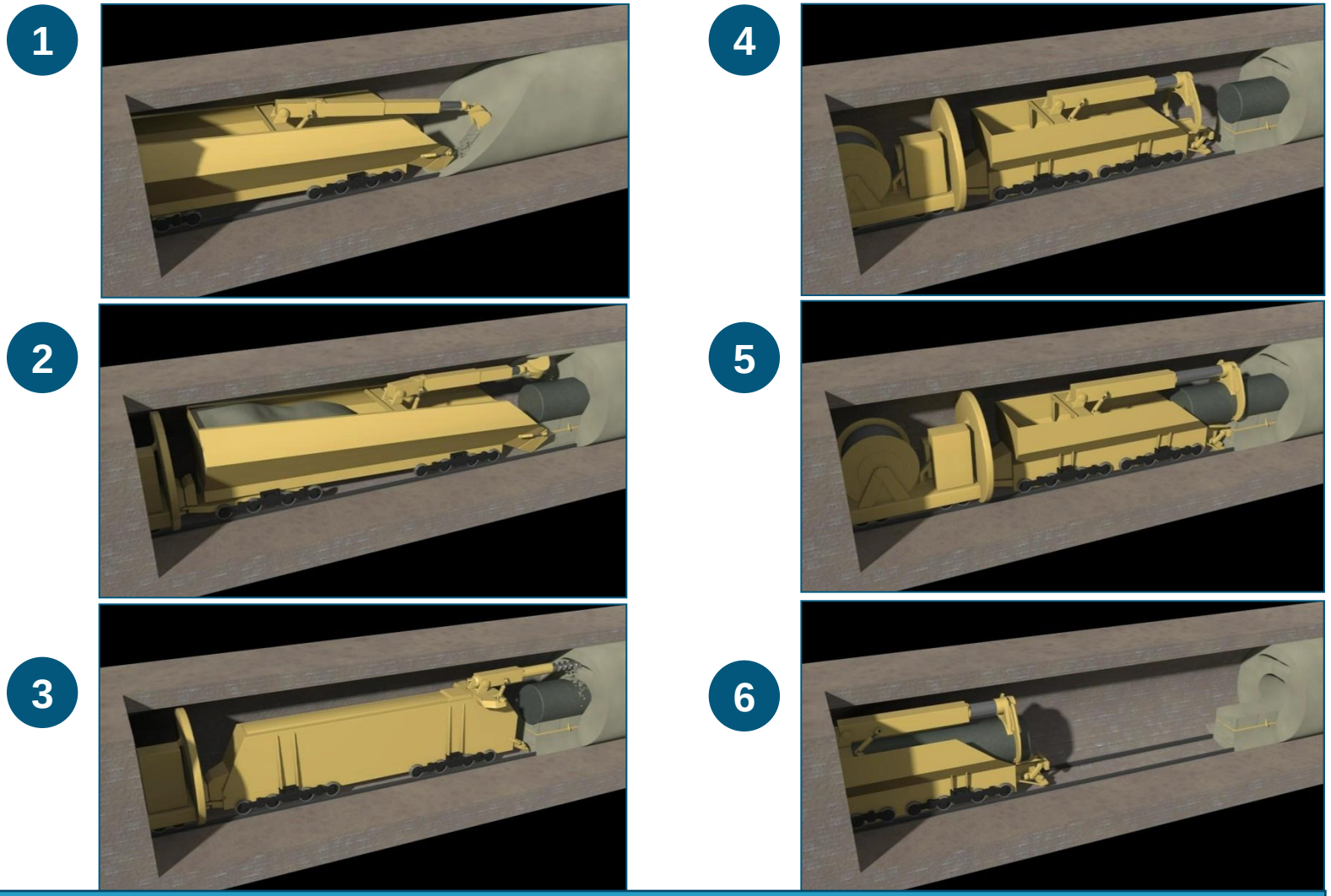
Retrieval of a HLW container



Retrievability / monitoring: legal requirement

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Pilot facility

- The pilot facility concept can be traced back to the recommendation of the EKRA expert group, who recognised the possibility of observing the physical and chemical processes presumed to occur in the main facility using a smaller but realistic facility with a representative waste volume.

- For this purpose, the pilot facility has to be representative of the main facility in terms of both construction and inventory and equipped with monitoring instrumentation.

- The functioning of the barrier system is monitored in the pilot facility and its surroundings; the results allow conclusions to be drawn about the correct functioning the main facility.

Monitoring

- *Environmental monitoring* includes environmental radioactivity in the vicinity of the geological repository.

- *Monitoring of the geological environment* in parallel with repository construction and operation includes state-of-the-art measurements that provide information on the behaviour of the repository and its surroundings as input for the assessment of operational and long-term safety.

- During the operational phase, *radiological monitoring* is also performed to ensure that radiological protection requirements are being met.

- The purpose of *monitoring in the pilot facility* is to observe processes relating to the waste and the safety barriers.

Retrieval of waste

- Waste retrieval without major effort has to be assured up to the end of the monitoring phase (Art. 37, Nuclear Energy Act).

- Retrieval of emplaced waste should be undertaken when deviations from design-conform behaviour in the repository cannot be remedied using technical measures; at the same time long-term safety must be assured.

- The concept for waste retrieval without major effort is to be submitted together with the construction licence application and must describe the method to be used for retrieving the waste.

Closure

- A geological repository has to be designed in such a way that it can be closed within a few years (Art.11, Nuclear Energy Ordinance, cf. former protection objective 3 of Guideline HSK R-21).

- Backfilling and sealing of a geological repository are to be carried out in such a way that long-term safety is assured (Art. 69, Nuclear Energy Ordinance).

- The plan for closure has to be reviewed every ten years and updated if necessary (Art. 42, Nuclear Energy Ordinance).

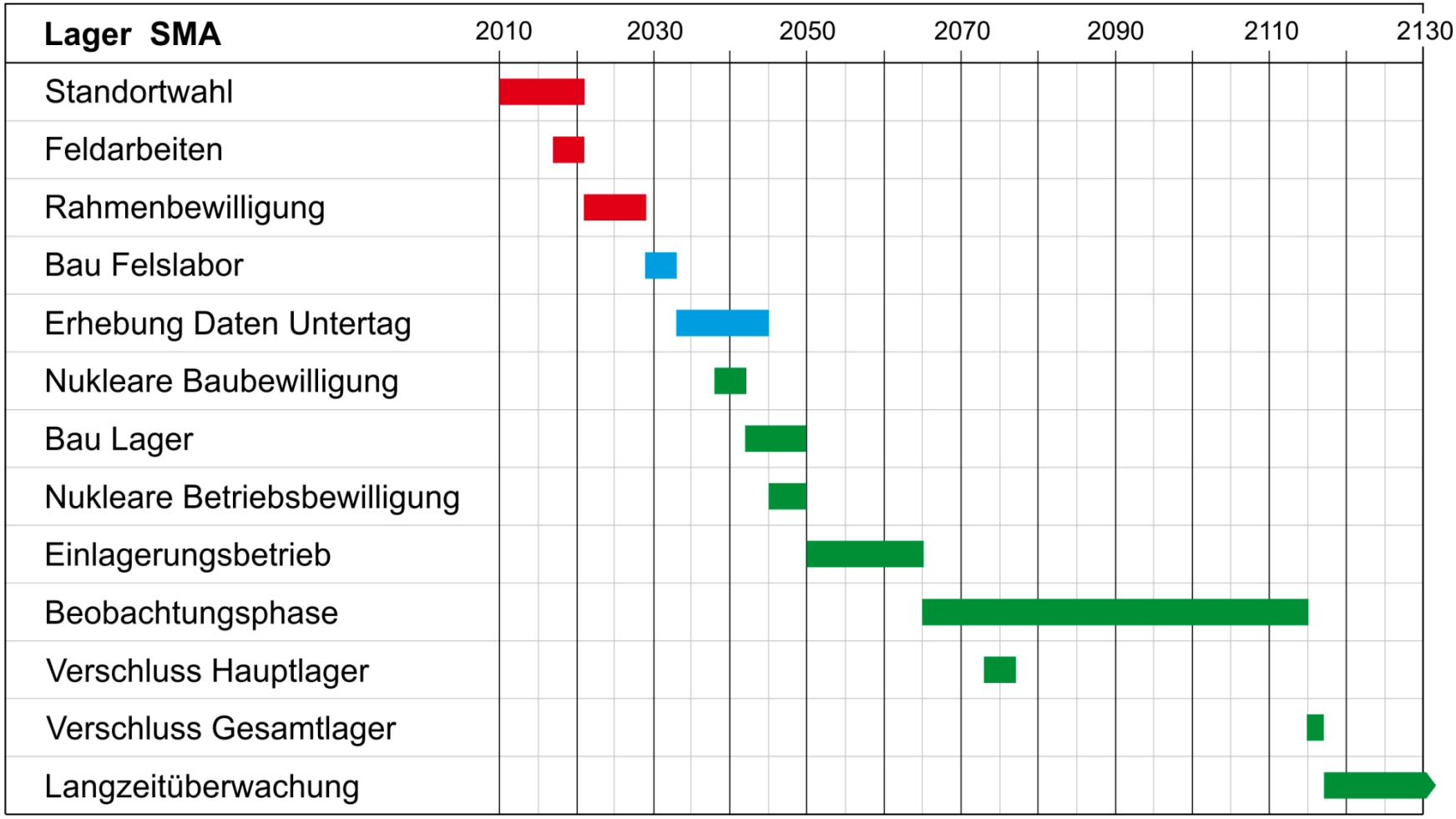
- An application for closure has to be submitted by the repository operator (Art. 63 and 50, Nuclear Energy Act).

- Closure activities are ordered by the Federal Council (Art. 39, Nuclear Energy Act).

Marking the repository

- The Federal Council prescribes the permanent marking of the repository (Art. 40 par. 7, Nuclear Energy Act).
- The Guideline requires the repository operator to develop suitable proposals.
- Marking of a geological repository has to be tailored to the actual site, host rock and disposal concept.
- The concept has to be submitted with the construction licence application and becomes more detailed in subsequent project phases. Concepts for repository marking are the subject of international discussion.
- To date, the IAEA has made no recommendations regarding implementation of repository marking.

Zeitplan Realisierung Tiefenlager SMA



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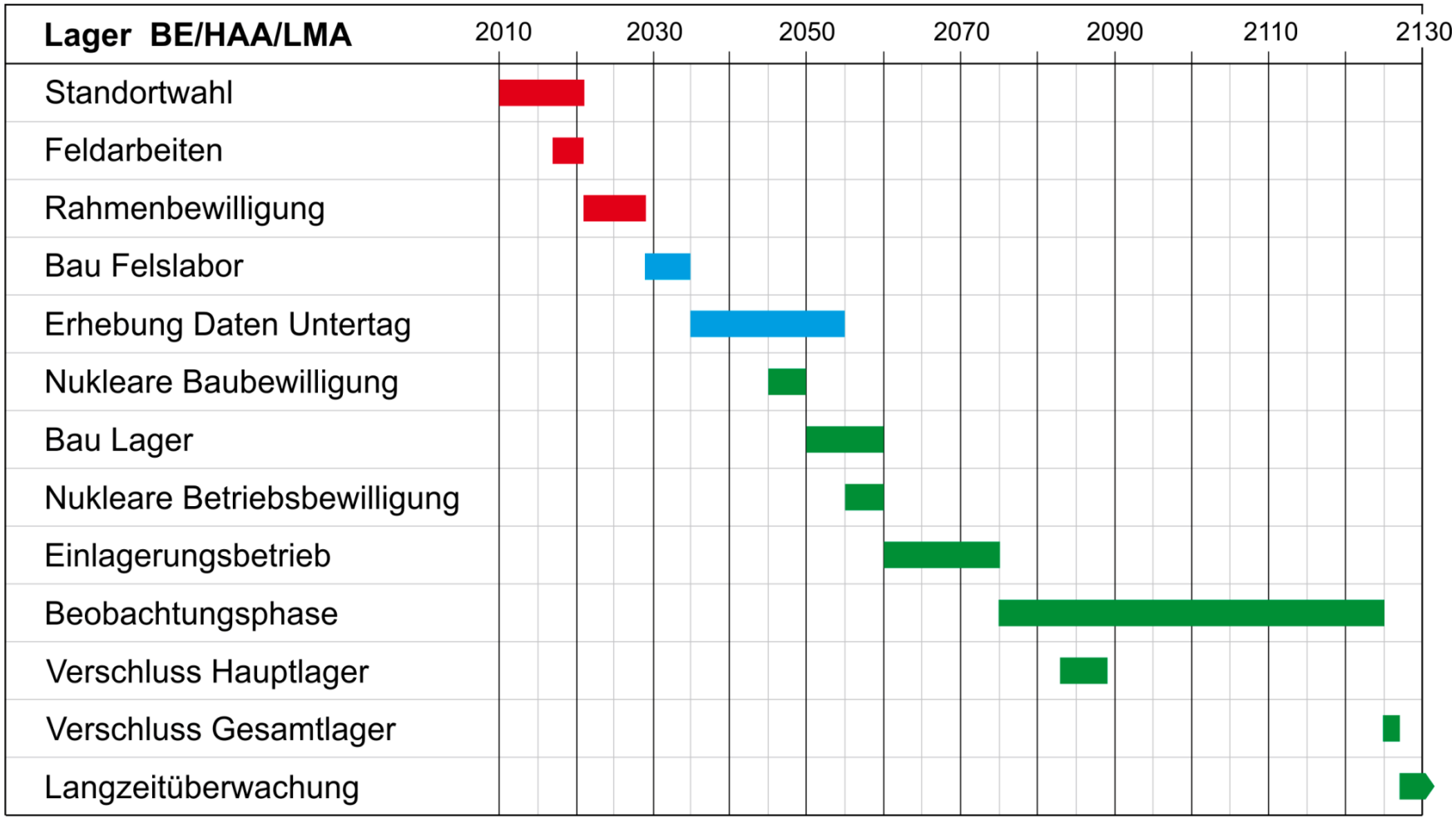
Zeitplan Realisierung Tiefenlager HAA



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Thank you for your attention

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