Deep Geological Repository Siting in the Czech Republic

From Site Screening to Final Site Selection

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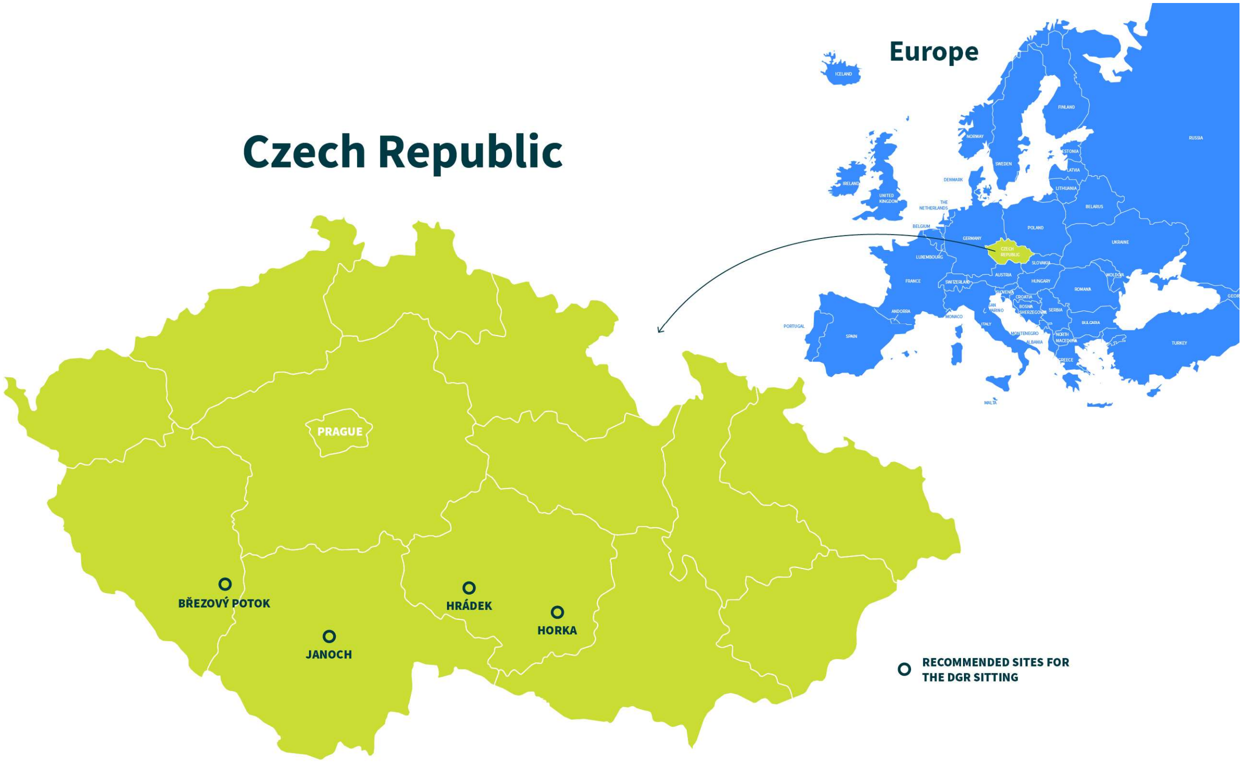
SÚRAO | RADIOACTIVE WASTE REPOSITORY AUTHORITY

The Czech Republic



SÚRAO | RADIOACTIVE WASTE REPOSITORY AUTHORITY

Mission of SÚRAO

- State administrative body
- Established by the Ministry of Industry and Trade in 1997
- According to Act No. 18/1997 Coll. (the Atomic Act; currently Act No. 263/2016 Coll.)
- Financed from an independent **Nuclear Account** established by law, waste producers contribute for each MWh produced

Ensure the long-term safe disposal of radioactive waste

Operate and develop national radioactive waste repositories

Develop the Czech deep geological repository (DGR)

Build public trust through transparency and dialogue

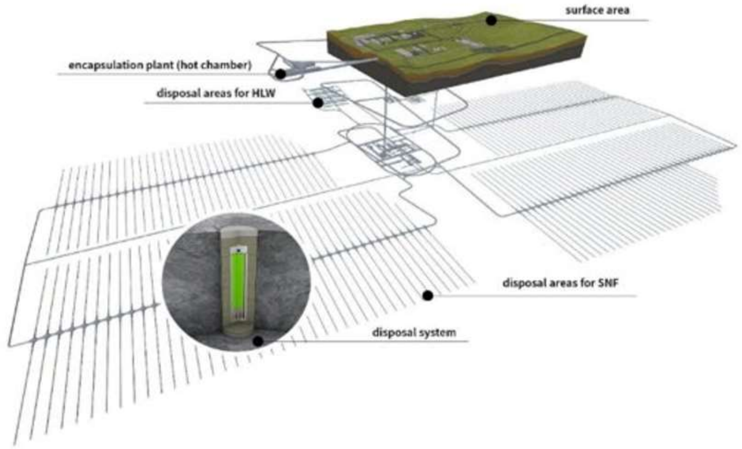
Reliable and Safe Waste Disposal – A Czech Experience

- **Czech Republic has been safely operating radioactive waste repositories for decades**, proving that well-managed solutions work in practice.
- The Czech Republic **operates three near-surface repositories** for low and intermediate level radioactive waste:
- **Richard repository** (in operation since 1964) – for institutional waste from medicine, research, and industry
- **Dukovany repository** – serving nuclear power plants since 1995
- **Bratrství repository** – for waste with natural radionuclides
- All facilities are operated in compliance with international safety standards and under regulatory oversight
- **Richard repository has been in safe operation for over 60 years** and continues to meet national capacity needs

Czech DGR Program

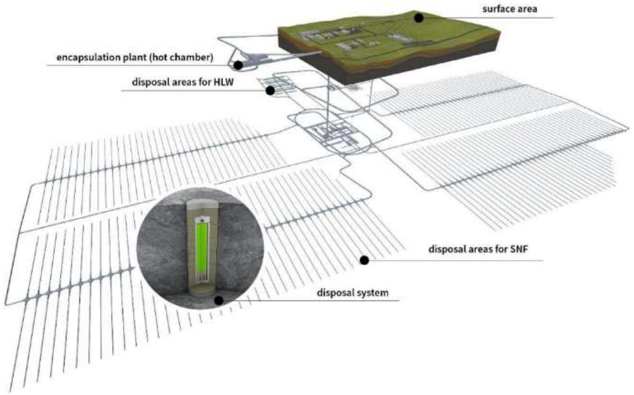
SÚRAO — Radioactive Waste Repository Authority of the Czech Republic

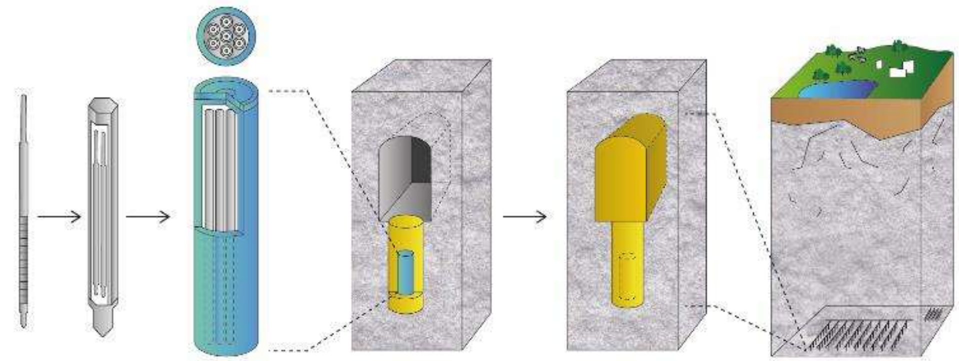
- **Deep Geological Repository (DGR)** — ongoing development with the aim of being in operation by 2050, in line with EU Taxonomy.
- **Site selection process** — current priority; feasibility studies across four shortlisted sites.
- **Technical design** — continuous development of the repository concept, aligned with site-specific conditions.
- **R&D of EBS** — strong focus on engineered barrier systems, including long-term safety assessments and in-situ testing.
- **Safety Case 1** — preliminary safety assessment underway to evaluate robustness of the Czech disposal concept.
- **Bukov Underground Research Facility** — supporting technical and scientific studies at depth.



Czech deep geological repository project

- Depth 500 m in crystalline host rock
- Multi-barrier concept–bentonite barrier–steel-based waste disposal package
- Underground part (approx. $3 km^2$), surface area (15 ha)
- SNF
- Other RAW (LLW, ILW)





Estimated inventory

- **Existing Sources**
- NPP Dukovany
- NPP Temelín
- Research Reactors

- **Future Sources**
- 4 New Large Nuclear Reactors
- Up to 6 SMRs

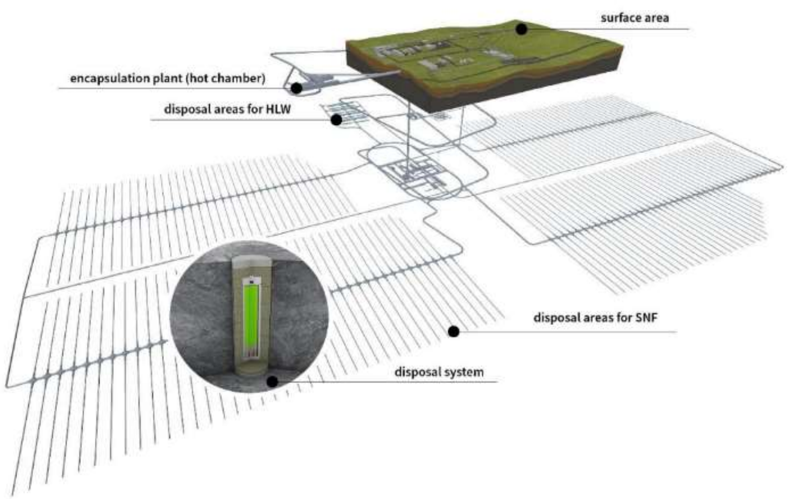
- Included in the new Czech National Policy on RAW and spent fuel management (2025).

14 500 t SNF

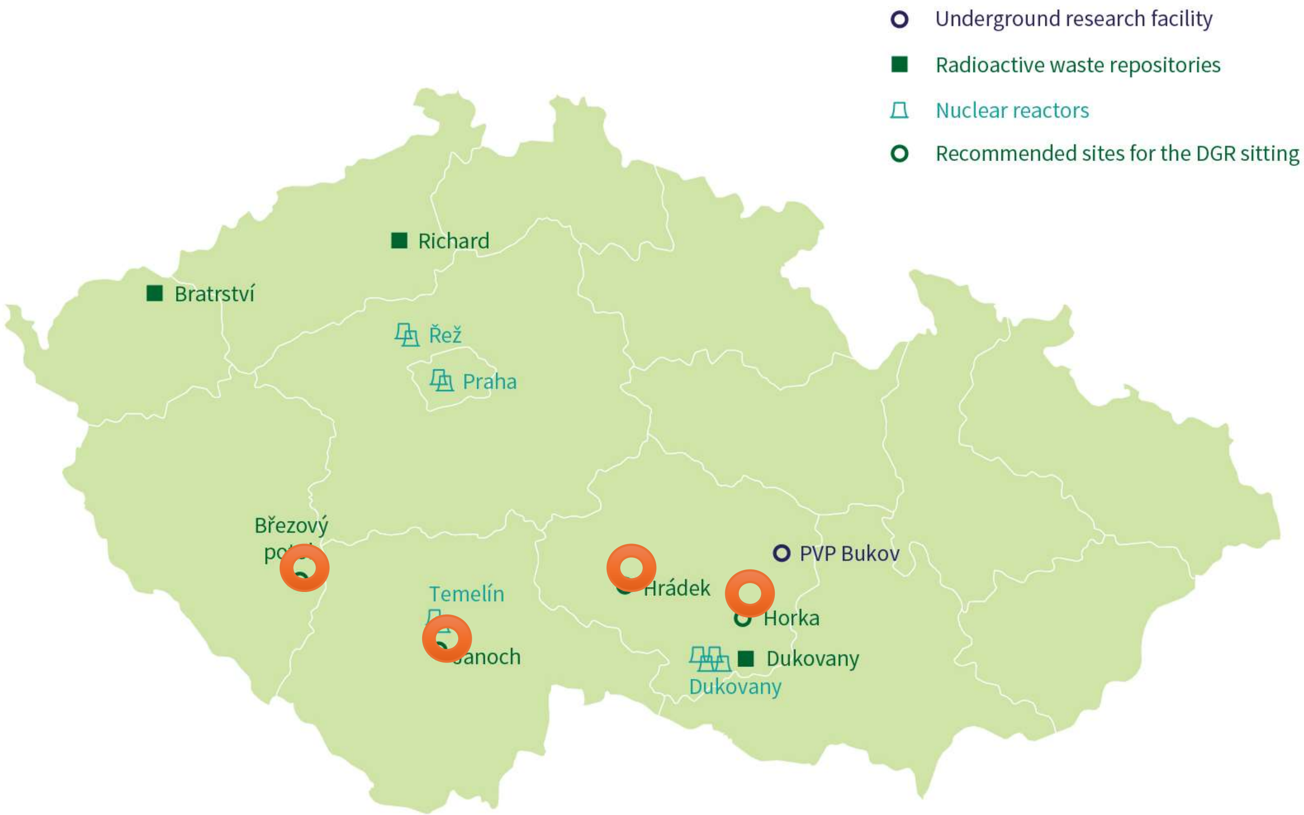
Spent nuclear fuel

38 500 m^3

Other radioactive waste



Czech DGR Candidate Sites



Czech DGR Programme — Context & Roadmap

14 500 t SNF
Spent nuclear fuel

38 500 m³
Other radioactive waste

500 m depth
Crystalline host rock

Multibarrier concept
Bentonite + steel waste disposal package

2020	2027	2030	2032	2037	2050	2167
4 sites selected	Safety Case I	Final & backup sites	Siting license	Construction license	Start of Operation	End of Operation

Inventory update 2024–2025 in progress — includes new sources and SMR scenarios

Policy and Regulatory Framework

Regulatory Framework

Government / Ministry

National Policy of Radioactive Waste Management (2025)

▼

SÚJB

Nuclear regulatory authority

▼

SÚRAO

Programme implementation, siting & R&D plan

▼

Licensing Process

Siting, construction, operation & closure

Key Legislation

Act 263/2016
Atomic Act — primary nuclear legislation

Decree 378/2016
SUJB decree on site requirements (§18 DGR requirements)

Act 53/2024
DGR proceedings act

Act 100/2001
Environmental impact assessment (EIA)

Act 62/1988
Geological works act

Policy 2025
National radioactive waste management concept

Regulatory Requirements for Site Selection

National Policy of RAW Management 2025 *Process & Strategy*

- Stepwise site reduction: 9 → 4 → final + backup site (2028–2030)
- Technical studies confirming compliance with Decree 378/2016 required at each stage
- Government approves final & backup site (Act 53/2024); ministry leads process with SÚRAO
- Selection based on geological, hydrogeological properties & long-term safety demonstration
- EIA, siting permit (Act 263/2016) & land-use planning documents mandatory before construction
- Transparent, science-based process — public, municipalities & government

Decree 378/2016, §18 — Site Requirements

Long-Term Safety

Isolation & retardation of host rock + EBS must keep dose below optimisation limit (§18(1))

Geological & Structural

Rock mass extent, tectonic faults, structural geology, brittle/ductile tectonics, endogenic/exogenic processes (§18(2)a,b,c,g)

Hydrogeological

Groundwater circulation, transport time, retardation, palaeohydrology, climate evolution, permafrost vulnerability (§18(2)h,i,j)

Geomechanical & Geochemical

Rock strength, deformation, in-situ stress, physico-chemical & microbiological properties, gas permeability, thermal gradient (§18(2)k,l,m,n)

Modellability & Predictability

Site must allow construction of 3D geological, hydrogeological and geomechanical models (§18(2)q, §18(4)b)

Exclusion Criteria §18(4)

Dose limit exceedance, inability to build 3D models, or presence of geothermal resources — siting prohibited

Site selection methodology

National Screening: From 32 Areas to 4 Sites

32 — **Areas** — 1990s
Initial national review by Ministries

▼

13 — **Localities** — 1998
First reduction — geological desk study

▼

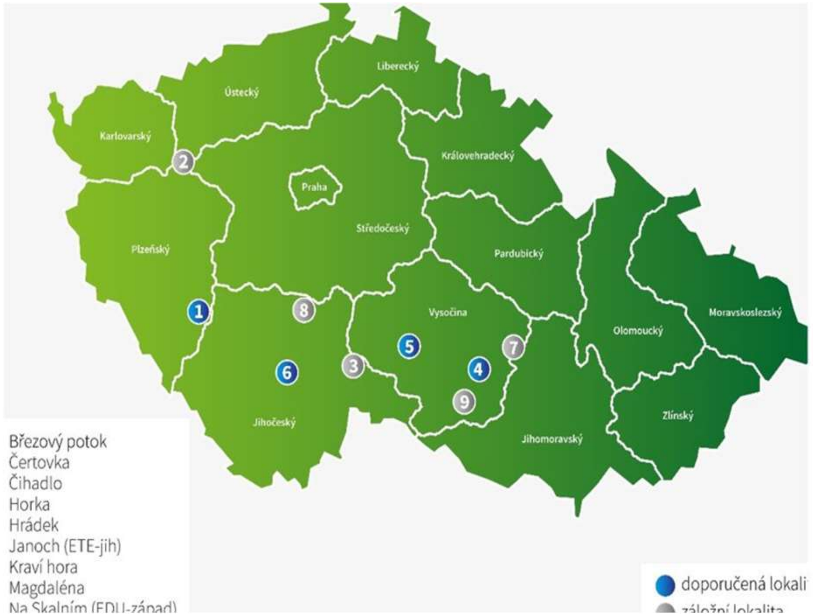
6 — **Localities** — 2003
Further screening — surface characterisation

▼

9 — **Localities** — 2011–2015
+Kraví hora added; sites near nuclear power plants included

▼

4 — **Shortlisted Sites** — 2020
Březový potok, Janoch, Hrádek, Horka — active since 2020



Site Selection Strategy

9

Candidate Localities

Surface geology, geophysics — no drilling boreholes Exclusion criteria applied

2014–2020

4

Shortlisted Sites

Deep boreholes, geophysical & hydrogeological surveys, Safety Case I, feasibility studies.

2020–2030

1+1

Final + Backup Site

Government decision (Act 53/2024). Selection based on geology, hydrogeology & long-term safety.

2028–2030

4 shortlisted sites:

Březový potok • Janoch • Hrádek • Horka

Methodology for Site Selection by 2030

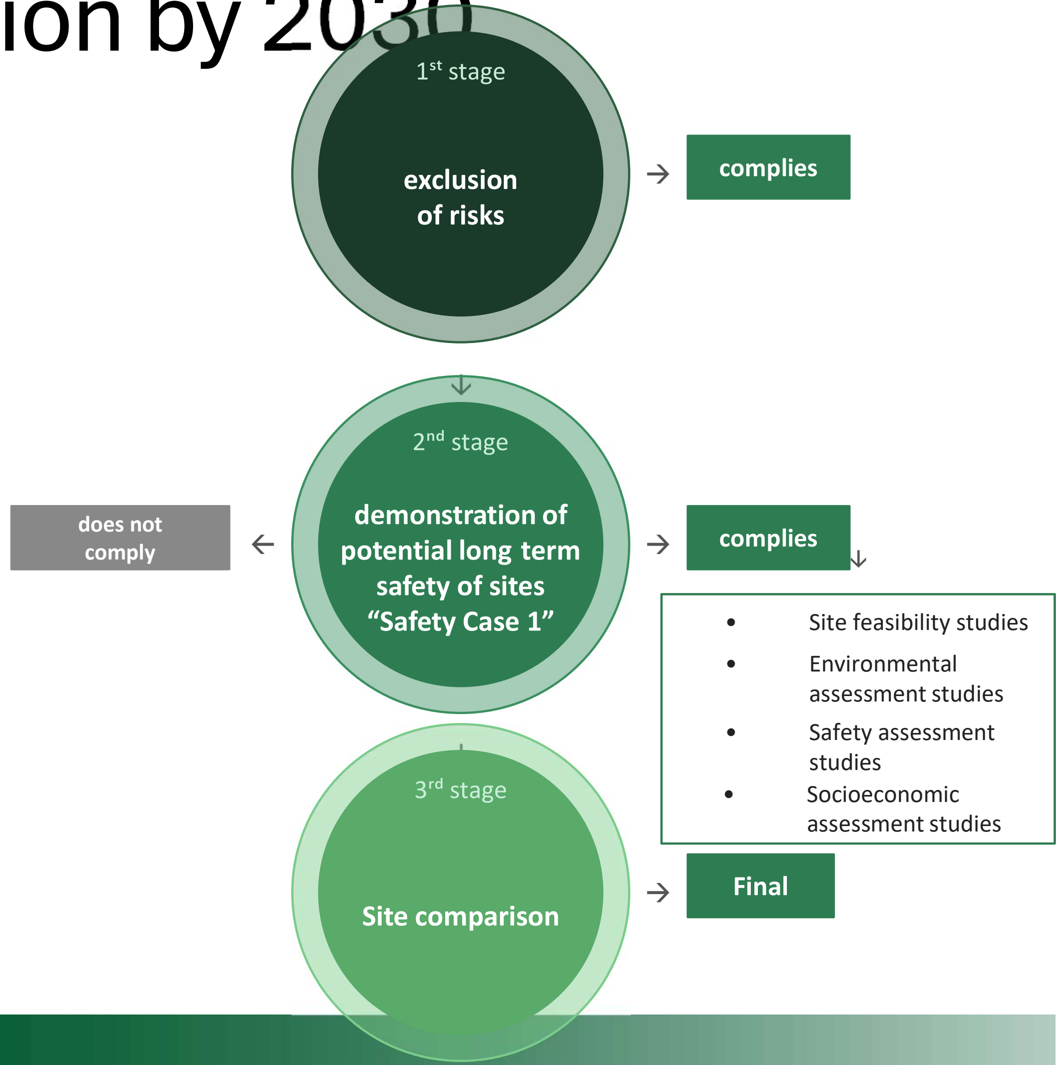
- **Developed specifically for the DGR programme** to ensure a structured, transparent and evidence-based approach.

- **Defines clear rules, procedures and evaluation criteria** for assessing and comparing the four candidate sites.

- **Implements a three-stage evaluation process:**
1) legal exclusionary criteria →
2) safety-based feasibility →
3) multi-criteria comparison of sites.

- **Reviewed by national and international experts.**

- **Discussed and endorsed by the Director's Advisory Panel of Experts II**, an independent external expert body supporting the scientific robustness of the process.



Step 1: Screening and Exclusion of Unsuitable Sites

Identify conditions that could prevent repository implementation or compromise long-term safety.

Assessment Basis

- IAEA SSG-35 recommendations
- Czech Decree No. 378/2016 Coll., §18(4)
- Site Descriptive Models
- Geological investigations

Key Questions

✓ Is the site compatible with regulatory requirements?

✓ Are there any non-mitigable exclusion factors?

✓ Can the site be characterised and modelled?

Examples of Exclusion Criteria

- Active faults and tectonic deformation (within 5 km)
- Significant groundwater bodies at risk of contamination
- Volcanic activity or post-volcanic phenomena
- Mining activities and underground structures
- Presence of geothermal energy sources
- Inability to develop reliable 3D geological, hydrogeological or geomechanical models

➞ Site progresses to Step 2 ✕ Site excluded — conditions cannot be mitigated

Step 2: Preliminary Long-Term Safety Assessment

Assess whether the Czech repository concept can be considered potentially safe under site-specific conditions.

Inputs

Safety Case 1

- Reference concept
- Reference site
- Long-term safety assessment

→

Transferability Parameter Ranges

← *compare*

Candidate Site Data

- Geological model
- Hydrogeological model
- Geochemical model
- Transport properties

Possible Outcomes

- **Potentially safe:** All key parameters within transferability ranges — site progresses to Step 3
- **No conclusive conclusion:** One or more parameters outside ranges — further analyses required; site may still progress
- **Potential safety concern:** Critical parameter significantly reduces barrier performance — site may be excluded

→ Site progresses to Step 3 ✕ Site excluded — critical barrier performance concern

Reference Site and Safety Case Approach

"We first prove the Czech DGR concept is safe — then we check whether each candidate site meets the conditions for which safety has been demonstrated."

1 Reference Site

A model site — not real. Represents typical Czech crystalline rock conditions.

"What would a typical Czech DGR site look like?"

→

2 Safety Case 1

Full safety assessment on the reference site.

Does the concept work? Are safety functions fulfilled over hundreds of thousands of years?

→

3 Transferability Parameters

Which parameters matter most for safety?

For each: define the acceptable range that ensures the concept performs safely.

→

4 Site Comparison

Measure real data at Horka, Hrádek, Březový potok, Janoch.

Do the measured values fall within the safe ranges?

✓ Site data within range: concept is transferable ✗ Site data outside range: site may not be suitable or concept needs adaptation

Transferability Parameters

From Safety Case 1 we identify the parameters that matter most for long-term safety and define their acceptable ranges. Candidate site data is then compared against these ranges.

Parameter	Why it matters for safety	Acceptable range (indicative)
Hydraulic conductivity	Controls groundwater flow and radionuclide transport speed	Low — bulk rock mass $< 10^{-12}$ m/s
Groundwater flow velocity	Determines how quickly radionuclides could reach biosphere	Very low — long transport times required
Fracture density / EDZ	Preferential pathways can bypass engineered barriers	Low fracture density in repository zone
Geochemical conditions	Determines bentonite stability and corrosion of steel canisters	Reducing, low oxygen, near-neutral pH
In-situ rock stress	Affects tunnel stability and engineered barrier performance	Compatible with repository layout depth

Transferability parameters are not an academic exercise — they are the direct instrument for evidence-based site selection.

Step 3: Comparative Assessment of Sites

Identify relative advantages and disadvantages of candidate sites that have passed Steps 1 and 2.

Only sites that ✓ pass exclusion screening and ✓ demonstrate potential long-term safety are compared against each other.

Key Comparative Criteria

K1 **Geological & Structural Properties**

Degree of faulting · Fracture intensity · Geological variability

K2 **Mechanical & Physical Properties**

Rock strength (UCS) · Deformation moduli · In-situ stress state

K3 **Site Stability**

Seismic hazard (PSHA) · Long-term geomorphic evolution · Climate change vulnerability

K4 **Hydrogeological & Transport Properties**

Groundwater flow at repository · Transport resistance · Contaminant dispersion (Shannon entropy) · Retardation parameters

K5 **Geochemical Properties of Groundwater**

pH, Eh, mineralisation · Reducing conditions · Compatibility with EBS

K6 **Repository Size & Rock Mass Reserve**

Repository footprint on disposal horizon · Rock mass reserve ratio

Output Studies — Evidence of Site Suitability

Output studies synthesise all site investigation data and demonstrate that each site is technically feasible, environmentally acceptable and safe. They are produced for all four candidate sites.

01 Site Feasibility Study

Verifies that the underground and surface repository can be physically placed within the designated investigation territory.

Assesses usable rock mass volume, excavation quantities, surface facility layout and infrastructure connections.

SÚRAO requirement

02 Safety Assessment Study

Preliminary safety assessment in the scope of §18 Decree 378/2016 Coll.

Evaluates all known site properties, radiation dose at expected repository evolution, modelability and absence of geothermal sources.

§18 Decree 378/2016

03 Environmental Impact Assessment

Preliminary evaluation of DGR impacts on soil, water, air, landscape, fauna, flora, ecosystems, public health and cultural heritage.

Prepared in the structure of Annex 4, Act No. 100/2001 Coll.

Act 100/2001

04 Socioeconomic Impact Studies

Assessment of economic and sociodemographic benefits and risks for the host region.

Submitted to the Ministry of Industry and Trade together with the final and backup site recommendation.

RAW policy 2025

If any mandatory study cannot be resolved for a given site, that site cannot be selected. Additional supplementary studies may be prepared where needed.

Site Evaluation and Decision-Making Process

The final and backup site will be selected through a transparent, criteria-based comparison without applying weighting factors.

STEP 1
Exclusion Criteria
Pass / Fail

↓

STEP 2
Preliminary Safety Assessment
Potentially Safe

↓

STEP 3
Comparative Assessment
Advantages · Neutral · Disadvantages

↓

Final Site + Backup Site

Government Decision (Act 53/2024) by 2028–2030

Evaluation Principles

- ✓ Steps 1 and 2 are mandatory requirements
- ✓ Only sites meeting minimum requirements proceed to Step 3
- ✓ Sites are compared using key criteria and indicators (K1–K6)
- ✓ No weighting factors are applied
- ✓ All criteria are considered equally important

Comparative Assessment — each criterion evaluated as:

- ● **Advantage**
- ● **Neutral**
- ● **Disadvantage**

Tie-Breaking Principle

If sites perform equally ➞ Reserve Capacity of the Host Rock Block becomes the deciding factor.

Site Investigation and Screening Methodology

From Data to Decision

Site selection is based on a progressive integration of field data into Site Descriptive Models supporting safety assessment and decision-making.

Field Investigations

↓

Site Data

↓

Site Descriptive Models

↓

Safety Assessment

↓

Site Comparison

Geological Investigations

- Geological mapping (1:25 000 & 1:10 000)
- Deep boreholes & borehole testing
- Geophysical surveys
- Hydrogeological monitoring
- Seismic monitoring
- Rock mechanics & laboratory testing

Environmental Investigations

- Ecosystem surveys
- Environmental monitoring
- Baseline studies
- Noise & dispersion studies
- Soil & dendrological surveys
- Socioeconomic data (Czech Statistical Office)

Data acquisition period: 2000–2028 — "The objective is not simply to collect data, but to transform data into evidence supporting long-term safety."

Site characterisation programme

Geological Mapping

Surface & underground structural mapping of rock units and discontinuities

Geophysics

2D/3D seismic, gravity, magnetic and electrical surveys for subsurface imaging

Hydrogeology

Groundwater monitoring networks, pumping tests, hydrochemistry

Seismic Monitoring

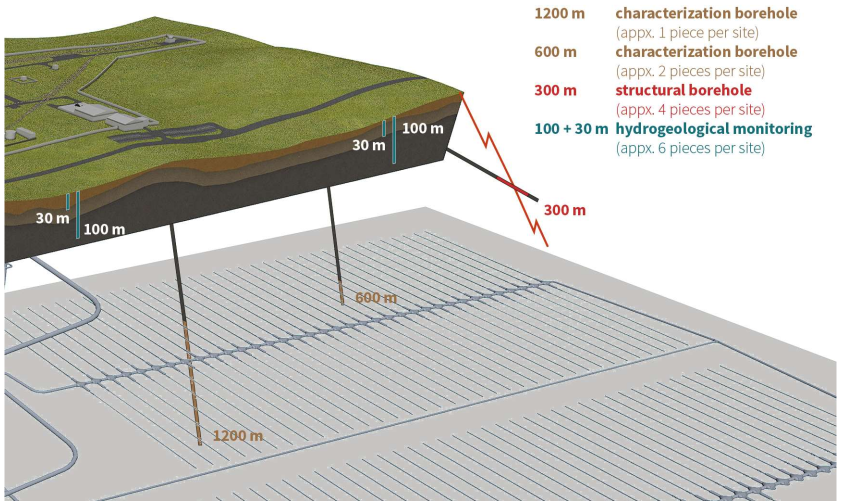
Local seismic networks for microseismicity and hazard assessment

Deep Drilling

Characterisation boreholes: core samples, in-situ tests, borehole logging

Laboratory Testing

Rock mechanics, permeability, sorption, diffusion coefficient measurements



Site Descriptive Models (SDMs)

Site Descriptive Models provide an integrated and predictive understanding of each candidate site.

Structural Geological Model

Rock mass geometry, faulting, DFN

Hydrogeological Model

Groundwater flow, fracture networks

Hydrogeochemical Model

Groundwater chemistry, redox conditions

➞ **Transport Model**

Retardation, diffusion, sorption

Geothermal Model

Thermal properties, heat dissipation

Geomechanical Model

Rock strength, stress state, deformation

Climate & Geodynamic Model

Long-term evolution, seismicity, erosion

Ecosystem Model

Surface ecology, biosphere baseline

Key Functions

- Integrate multidisciplinary data into a coherent 3D site model
- Describe current site conditions at repository depth (~500 m)
- Support prediction of future site evolution over 1 million years
- Demonstrate site characterisability and predictability
- (§18 Decree 378/2016 — regulatory requirement)

"If a site cannot be adequately characterised, modelled and predicted, it cannot be considered suitable for repository development."

How Site Descriptive Models Support Siting

The same models support all three steps of the siting methodology.

Siting Step	Role of Site Descriptive Models
Step 1 **Screening**	
Step 2 **Safety Assessment**	
Step 3 **Comparative Assessment**	

Site Data → Site Descriptive Models → Reduced Uncertainty → **Evidence-Based Decision**

Managing Uncertainty

Managing Uncertainty

"Managing uncertainty is more important than eliminating it."

Data Uncertainty	Limited borehole coverage at depth; measurement precision; temporal variability in groundwater conditions.	**Response:** Expand monitoring networks; statistical treatment of parameter ranges.
Conceptual Uncertainty	Alternative geological interpretations of the same dataset; ambiguity in fault geometry or hydrogeological connectivity.	**Response:** Multiple working hypotheses; expert elicitation; peer review.
Model Uncertainty	Limitations in safety assessment codes; uncertainty in long-term evolution scenarios; climate projections.	**Response:** Conservative assumptions; scenario analysis; model benchmarking.

Lessons Learned

What Worked Well

- Clear regulatory framework established early in the programme
- Phased decision-making reduced risk of premature commitment
- Integration of safety assessment into each siting step
- Independent expert review panels at key decision milestones
- Strong national and international R&D programme
- Active international cooperation (EURAD 2, IGD-TP, SKB, Posiva, ANDRA, NAGRA,...)

Challenges and How We Addressed Them

Challenge	Response
Public opposition to siting process	Transparency programme and structured dialogue
Deep drilling delays at candidate sites	Phased investigation strategy with decision gates
Data gaps in deep subsurface geology	Uncertainty management framework; conservative bounds
Programme acceleration (2030 target)	Prioritisation matrix; parallel workstreams

Key Lessons Learned

01	Safety must drive siting decisions from the very beginning of the programme.
02	Site characterisation and safety assessment must evolve together — not sequentially.
03	Managing uncertainty is more important than eliminating it. Elimination is not possible.
04	Decisions should be traceable, evidence-based and independently reviewable at each step.
05	Long-term programme stability is essential — continuity of expertise and institutional memory.

Lessons Learned

Key insights from the Czech DGR siting process — applicable to any national repository programme.

01

Start early and define the process clearly

A well-defined, legislatively grounded methodology must be in place before investigations begin. Retroactive definition of criteria undermines credibility and creates legal risk.

02

Communicate with all stakeholders throughout

Public, municipalities, Parliament and regulators must be engaged continuously — not only at decision points. Transparency is a regulatory requirement (Act 53/2024) and a programme necessity.

03

Manage uncertainty — do not attempt to eliminate it

Three types of uncertainty must be addressed: aleatory (natural variability — quantifiable but irreducible), epistemic (knowledge gaps — reducible through data) and ontological (methodology bias — managed through transparent documentation and peer review).

04

Data and models must be traceable and reviewable

Every decision must be supported by documented, reproducible evidence. Independent expert review (Director’s Advisory Panel of Experts II) adds credibility and identifies blind spots.

05

Allow sufficient time — the process cannot be compressed

Deep boreholes, long-term monitoring networks and safety assessments take years. Schedule pressure risks data gaps that cannot be compensated later. The 2028–2030 target requires sustained parallel workstreams.

06

Safety must drive every decision from the outset

Criteria derived from safety functions — not engineering convenience. The reference site and transferability parameter approach ensures that long-term safety assessment is integrated into siting from day one.

Acronyms and References

Acronyms

DGR	Deep Geological Repository	**SÚJB**	State Office for Nuclear Safety (CZ)
SDM	Site Descriptive Model	**MPO**	Ministry of Industry and Trade (CZ)
EBS	Engineered Barrier System	**EIA**	Environmental Impact Assessment
SC1	Safety Case 1	**DFN**	Discrete Fracture Network
DOM	Dose Optimisation Limit	**PSHA**	Probabilistic Seismic Hazard Assessment
SÚRAO	Radioactive Waste Repository Authority (CZ)	**UOS**	Disposal Package

Key References

Methodology

- Dohnálková M. et al. (2024): Methodology of Site selection process. MS SÚRAO TZ 759/2024
- Mikláš O. et al. (2023): Modeling strategy of DGR Safety assessment. MS SÚRAO TZ 698/2023
- Hausmannová L. et al. (2024): Research and development plan 2024–2028. TZ 746/2024
- Hausmannová L. et al. (2023): Technical design od DGR2023. MS SÚRAO TZ 711/2023

Legislation

- Act 263/2016 Coll. — Atomic Act
- Decree 378/2016 Coll. — Siting of Nuclear Installations (SÚJB)
- Act 53/2024 Coll. — DGR Proceedings Act
- Act 100/2001 Coll. — Environmental Impact Assessment
- Act 62/1988 Coll. — Geological Works Act
- National Policy of RAW Management (Koncepce 2019/2025)

Thank you for your attention!