underground resources and deep geological repositories – a conflict?

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What is at issue?

In order to protect humans and the environment, radioactive waste has to be disposed of underground in deep geological repositories. This is called for by both the scientific community and by existing legislation. However, the underground environment may also contain resources such as natural gas, oil, coal, salt, rocks and soils, as well as ores and mineral and thermal waters. It can also be used to produce geothermal energy or to store gases.

Legislation protects the repository and regulates the exploitation of resources

The Cantons grant concessions for the use of natural resources. These are based on cantonal laws on the use of the underground, as known, for example, in the two Cantons of Aargau and Thurgau. Canton Zürich is currently considering a draft law. In accordance with the Nuclear Energy Act, a deep geological repository (see glossary) for radioactive waste must be protected from intrusion, which can result in restrictions on other uses of the underground. At the same time, a deep geological repository may not unnecessarily restrict foreseeable future uses of natural resources. The Federal Government is leading the repository site selection process according to the three-stage Sectoral Plan for Deep Geological Repositories and has to ensure that divergent interests with regard to the use of the underground are taken into consideration.

Nagra has substantial knowledge of the underground environment

According to the Sectoral Plan, and based on current knowledge, Nagra has evaluated whether a planned repository could lead to a potential conflict of use now or in the foreseeable future. This included examining the extent of the potential for exploitable resources in the geological siting regions (see glossary) for deep geological repositories. The database used by Nagra included results from its own underground investigations and those of third parties. The results are documented in Nagra Technical Report NTB 14-02, Dossier VII. This brochure presents the results for the potential siting regions Zürich Nordost, Nördlich Lägern and Jura Ost, which will undergo further detailed investigation in the coming years.

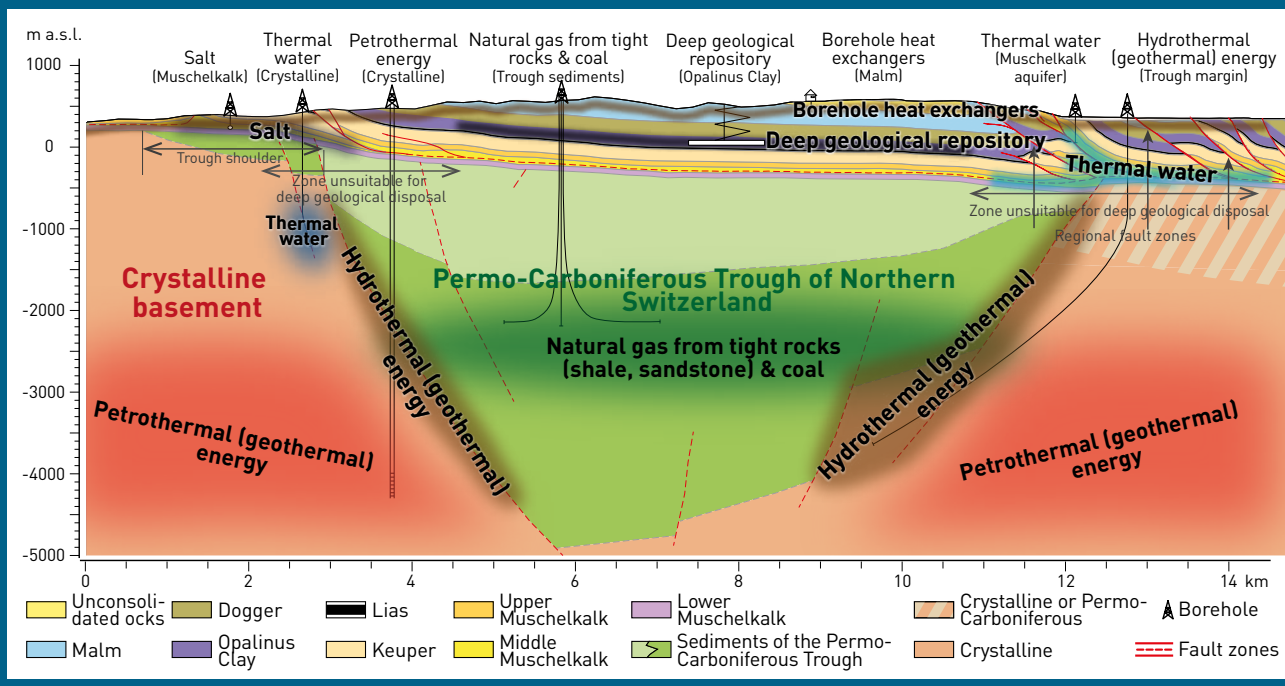


Figure 1:
Potential uses of the underground of Northern Switzerland (schematic); geological profile based on Nagra Technical Report NTB 14-02, Dossier II, Appendix 4-4.

Coal and hydrocarbon resources

HLW siting regions
L/ILW siting regions
Disposal perimeter HLW
Disposal perimeter L/ILW

Legend for the figures on pages 3, 4 and 5.

Various types of natural gas and oil

For hydrocarbon deposits (natural gas and oil), a rough distinction is made between conventional deposits in porous reservoir rocks (porous sandstones, fractured carbonate rocks) and unconventional deposits in tight rocks (shales, tight sandstones, coal) that can only be extracted by fracking. The component of organic materials in a rock layer as well as its degree of maturity (see glossary) are indications of the potential presence of shale gas (and oil).

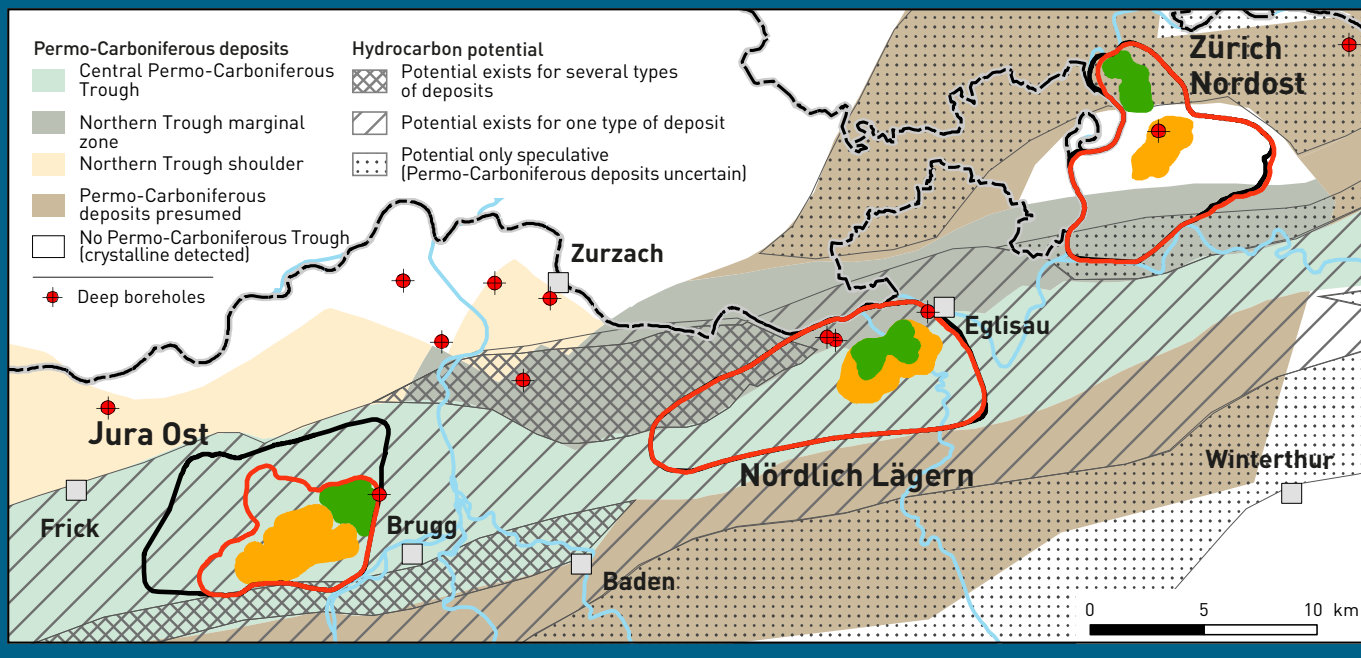
Nagra has assessed the potential

Coal and hydrocarbon deposits are to be expected in the sedimentary rocks of the Permo-Carboniferous Trough of Northern Switzerland (see Figs. 2 and 3). The likelihood of a larger conventional gas deposit is low because the porosities of the sedimentary rocks in the Permo-Carboniferous Trough are generally low. Unconventional deposits cannot be ruled out at greater depths. In contrast with uses of conventional gas deposits, exploiting unconventional deposits is confined to a spatially small area (fracking range) and is not associated with large-scale subsidence phenomena (see glossary) at the earth's surface. To date, no economically workable coal or hydrocarbon deposits have been confirmed but, due to the development of new extraction technologies, this cannot be completely ruled out in the future. Nagra must therefore assess the potential for fossil resources and identify potential future conflicts of use.

The potential siting regions Nördlich Lägern and Jura Ost may have coal and hydrocarbon resources in rock layers far beneath the Opalinus Clay in the Permo-Carboniferous Trough. Both siting regions are located above the Permo-Carboniferous Trough. There is no Permo-Carboniferous Trough, and therefore no associated hydrocarbon deposits, beneath the planned disposal perimeter for high-level waste (HLW) in Zürich Nordost. It is not yet clear whether the Permo-Carboniferous Trough lies beneath the disposal perimeter for low- and intermediate-level waste (L/ILW) located further to the north (see Fig. 2).

Further data will be collected in Stage 3 of the Sectoral Plan, including analyses of the geometry and the resource potential of the Permo-Carboniferous troughs. The data will also provide an insight into whether a Permo-Carboniferous trough

Figure 2:
Potential for coal and hydrocarbon deposits in the Permo-Carboniferous Trough of Northern Switzerland in the area of the potential siting regions.



exists in the northern part of the Zürich Nordost region.

Shale gas in the Opalinus Clay?

In Switzerland, the Opalinus Clay has been selected as the host rock for both waste types. It is characterised by an extremely low permeability and the ability to self-seal small fissures. There are no workable hydrocarbon resources within the Opalinus Clay in the potential siting regions for a deep geological repository: the organic material content and degree of maturity of the clay are too low, meaning that no shale gas deposits are to be expected. Further to the south, and particularly towards western Switzerland, the content and degree of maturity of organic materials increase in the Opalinus Clay as well as in the underlying Posidonia Shales, meaning that there is a potential for shale gas.

No relevant restrictions

The Permo-Carboniferous Trough of Northern Switzerland has a total area of around 1,500 km^2. Compared to this, the space required for a deep geological repository is very small (HLW: max. 4 to 6 km^2, L/ILW: max. 2 to 3 km^2, in both cases including reserves). The proportion of the Permo-Carboniferous deposits for which the exploitation of potential fossil fuel resources could be restricted by a deep geological repository is therefore very small.

The Permo-Carboniferous Trough of Northern Switzerland

There are numerous Permo-Carboniferous troughs in Switzerland. The Permo-Carboniferous Trough of Northern Switzerland extends from Lake Constance to the Canton of Jura and the siting regions Nördlich Lägern and Jura Ost lie above it. The Trough is several kilometres wide and delimited by zones that are not suitable for a deep geological repository (see Fig. 1); however, these contain thermal waters and can be used to produce hydrothermal (geothermal) energy. The base of the Trough is formed by the subsided crystalline basement and can be up to several thousand metres deep. It was filled primarily with sediments from the Carboniferous and Permian periods (approx. 360 to 250 million years old). These sediments can contain coal and hydrocarbons.

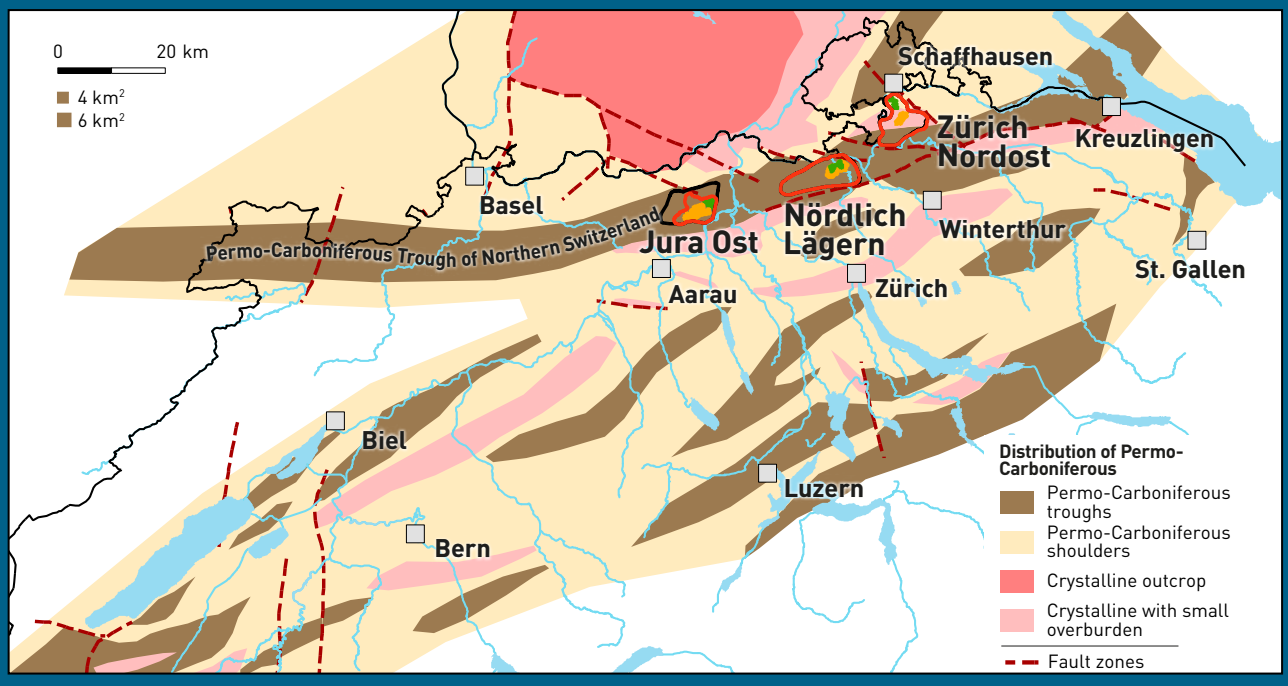


Figure 3:
Compared to the extent of the Permo-Carboniferous Trough of Northern Switzerland, a deep geological repository would only require a very small amount of space.

Mineral and thermal water resources

Areas with mineral and thermal water resources were avoided when defining the disposal perimeters (see Fig. 4). Investigations show that a deep geological repository will have neither qualitative nor quantitative effects on such uses. The only borehole where an impact cannot be entirely ruled out due to the access structures of a deep geological repository is the unused thermal water borehole in Lottstetten-Nack (Germany). The hydraulic tests and hydrochemical analyses to be conducted by Nagra as part of the investigations in Stage 3 of the Sectoral Plan will provide further information on deep groundwater aquifers.

A deep geological repository does not affect groundwater flow

Mineral and thermal waters generally originate from water-bearing rock layers at a depth of a few hundred metres, called deep groundwater aquifers. Radioactive waste will be isolated in the extremely low-permeability Opalinus Clay. The deep geological repository is thus hydraulically separated from the groundwater layers lying above and below it.

Access structures: construction engineering measures can be implemented

The access structures leading from the surface facility to the deep repository have to be designed to ensure a permanent separation of the groundwater aquifers from one another as well as from the repository. Particularly where excavation work passes through water-bearing strata, the structures must be sealed against water penetration. In addition, they are backfilled and sealed when the repository is closed. This prevents any influence on groundwater aquifers and their use. Preferably, access structures are designed to avoid passing through water-bearing strata or fault zones.

Access structures will not affect the mineral and thermal waters in Baden, Ennetbaden, Bad Schinznach, Bad Zurzach, Bad Säckingen and Waldshut-Tiengen – the groundwater aquifers being used lie below the Opalinus Clay and will not be disturbed. One groundwater aquifer is passed through in Nördlich Lägern, but, based on current understanding, this will not affect the former mineral spring at Eglisau.

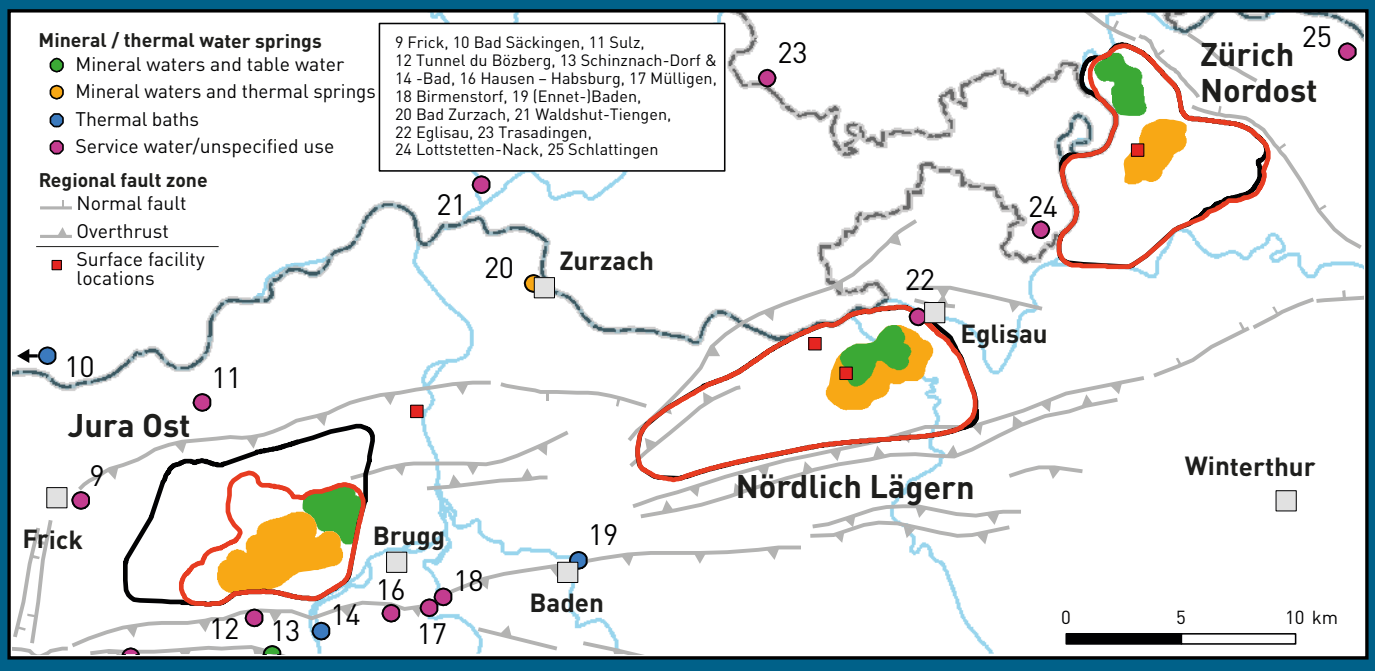


Figure 4:
Mineral and thermal water uses are often linked to regional fault zones such as the main Jura overthrust, for example in Bad Schinznach. Such zones are avoided when constructing the repository (see Fig. 1).

Geothermal resources

In Switzerland, geothermal systems are used to produce heat. A deep geological repository will not restrict either existing or planned systems. Likewise, there will be no unavoidable conflicts of use in the future: areas of interest as geothermal sources were either avoided for tectonic reasons (fault zones), or geothermal systems could be installed outside the disposal perimeters.

Different types of geothermal systems

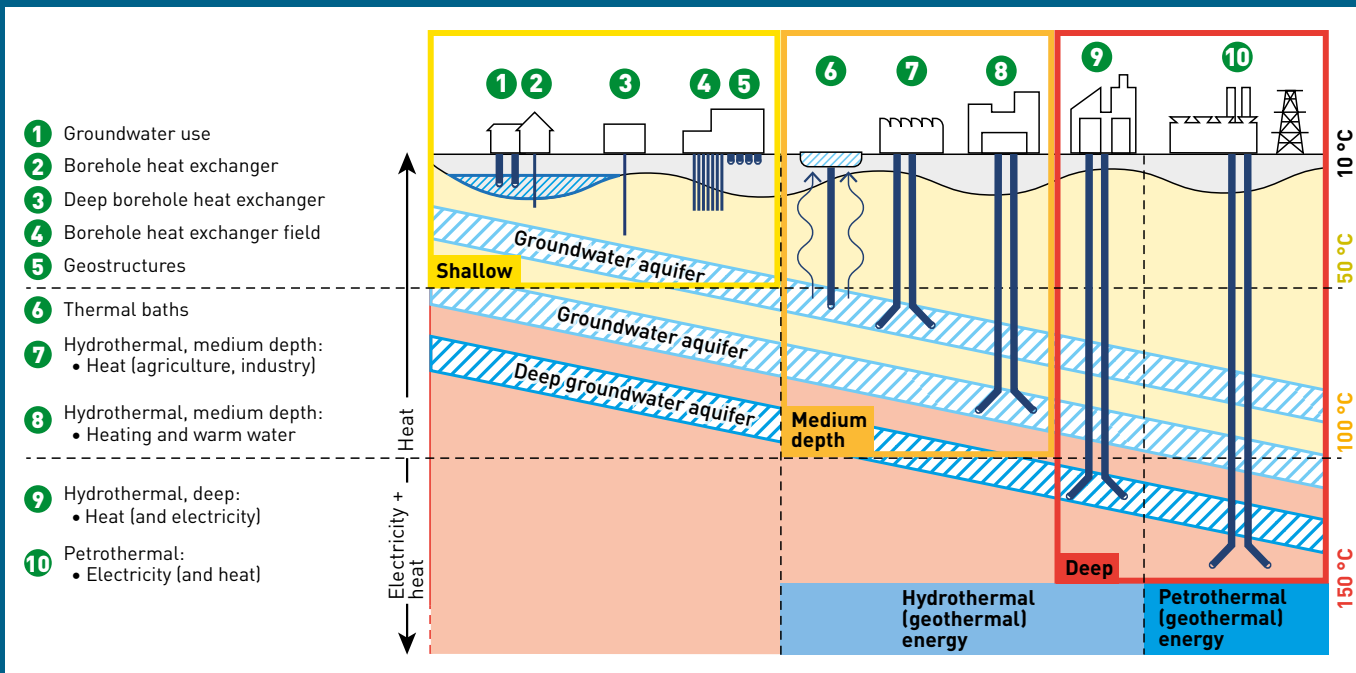
Geothermal systems can be shallow, as in the case of borehole heat exchangers, or deep, for example the exploitation of hydrothermal and petrothermal energy (see Figs. 1 and 5). Hydrothermal systems use the heat from thermal waters found in deep sedimentary rocks or in the crystalline basement. Towards the south, these rock layers lie at an ever-increasing depth and the thermal waters thus become increasingly warm; in Northern Switzerland, however, the temperatures in the sediments (e.g. Malm, Muschelkalk) are too low for electricity production. Petrothermal systems work by first pumping water under pressure into the deep crystalline basement in order to break up the rock (fracking) and open water flowpaths. Cold water can then be pumped into this zone where it heats up in the hot rock and is then extracted via a second borehole.

Potential future uses

Deep groundwaters might circulate in marginal zones of the Permo-Carboniferous Trough of Northern Switzerland, which could make these zones attractive locations for future hydrothermal systems. The disposal perimeters in the siting regions Zürich Nordost, Nördlich Lägern and Jura Ost are partially restricted by such zones. In the immediate vicinity of a deep geological repository, the hydrothermal use of trough margins could be locally restricted. Due to the wide distribution of the Permo-Carboniferous troughs (see Fig. 3) and the abundance of possibilities for geothermal exploitation, this restriction would be very small.

Petrothermal systems use hot crystalline rocks deep underground and are not associated with fault zones or groundwater aquifers. They can be constructed almost anywhere, so it is possible to avoid a deep geological repository.

Figure 5:
Various types of geothermal systems (source: Geothermie-Schweiz / EnergieSchweiz). Due to technical and economic challenges, there are no petrothermal systems in Switzerland at present.



Spatial requirements and protection of a deep geological repository

Further potential resources

With regard to conflicts of use, Nagra has also investigated resources such as rocks and soils, ores and salt as well as the storage of gases. Given the location and extent of the resources and the protection measures for a deep geological repository, no notable conflicts of use exist, either in the host rock layer or in the over- and underlying rock layers.

The siting regions and disposal perimeters (see glossary) for a deep geological repository potentially hold resources (see pages 3 to 6). The safe construction of a repository is nonetheless feasible: both present-day and future resource exploitation do not present any unavoidable conflicts with the use of the underground for a deep geological repository. Protective measures ensure the safety of the repository but place only a minimal restriction on other uses. Aside from this, exploiting a resource in the future would only be economical if it were sufficiently abundant and located at neither too great a depth nor too dispersed. Based on current investigations, for example, there are no known economically exploitable hydrocarbon deposits. Further underground geological investigations conducted in Stage 3 of the Sectoral Plan will expand the knowledge base.

The priority is protecting the repository

In the Sectoral Plan, different interests in using the underground are weighed against one another (see box). With the decision to construct a deep geological repository, the Federal Government will have to surround it with a protection zone. Within this zone, uses such as small-scale heat exchange boreholes for single-family homes will still be possible, but the maximum depth will be restricted to approximately 200 metres. By contrast, deeper boreholes, tunnel construction, blasting and other projects that can affect the underground protection zone require a permit demonstrating that they do not compromise the safety of the repository.

Modest space requirements

A deep geological repository does not require a lot of space, especially compared to the total area that might contain fossil resources (see page 4). These resources can be explored outside the disposal perimeter and can be exploited at an appropriately safe distance. The modest space requirement of a repository also contributes to the fact that drilling into it in the foreseeable future is unlikely. Disposal canisters for high-level waste make up less than 2% of the effective repository area and the likelihood of drilling into them in the distant future is correspondingly low. This would only be an issue in the unlikely event that the presence of the repository is forgotten while drilling technology becomes sufficiently far advanced. Even if a canister with spent fuel assemblies in the repository were penetrated by drilling*, the worst-case radiation dose to the population would still lie below the strict ENSI protection criterion (see glossary) and hence clearly below the level of natural radioactivity.

* For the "Entsorgungsnachweis" for HLW (demonstration of disposal feasibility; see Nagra Technical Report NTB 02-05), Nagra investigated several variants and time points for drilling into disposal canisters. These dose calculations were further supplemented within the framework of ENSI's Technical Forum on Safety.

Within the context of the Technical Forum on Safety, ENSI stated the following:

Society is responsible for making decisions in the case of foreseeable conflicts of use. According to Art. 40 of the Nuclear Energy Act, once a deep geological repository has been constructed, the site must be protected from other uses by a protection zone.

The Federal Government is also obliged to preserve information on the repository and the protection zone.

Glossary/References

ENSI protection criterion 1: The maximum additional radiation dose to the population from a deep geological repository is 0.1 millisieverts per year. This is equivalent to around one-fiftieth of the average annual radiation dose for a person living in Switzerland.

Geological siting regions: These are defined by geological rock bodies that are suitable for the deep underground disposal of radioactive waste.

Deep geological repository: The repository consists of a surface facility, access structures (access tunnels, shafts) and an underground disposal zone. This disposal zone for emplacement of either high-level waste (HLW) or low- and intermediate-level waste (L/ILW) is located in the Opalinus Clay (host rock).

Carbonate rocks: Carbonate rocks include e.g. limestones and dolomites. The majority of carbonate rocks are sedimentary rocks: they are formed by chemical precipitation from waters containing carbonate or by organisms (shells, skeletons).

Disposal perimeter: This comprises the underground host rock area of a geological siting region that, from a safety viewpoint, is the most suitable for constructing a deep geological repository.

Degree of maturity: The degree of maturity (thermal maturity) of an organic material (plant residues, plankton, etc.) is a measure of the degree to which organic material has altered into petroleum or natural gas. Temperature and pressure influence the alteration process.

Subsidence effects: Excavating a large conventional deposit can cause the overlying rock layers to subside. When pumping gas from tight, cemented sandstones (unconventional gas deposits), such subsidence effects have never been observed worldwide.

Further reading

- Nagra Technical Report NTB 14-02 "SGT Etappe 2: Vorschlag weiter zu untersuchender geologischer Standortgebiete mit zugehörigen Standortarealen für die Oberflächenanlage – Geologische Grundlagen, Dossier VII: Nutzungskonflikte" (in German)
- Nagra Work Report NAB 14-70 "Potenzial der Kohlenwasserstoff-Ressourcen in der Nordschweiz" (in German)
- Nagra Work Report NAB 14-18 "Temperaturkarten für definierte Horizonte im Untergrund der Nordostschweiz" (in German)
- Brochure "Standortgebiet Jura Ost – Geologie, Grundwasser" (in German)

These documents can be found under www.nagra.ch → Publications/Downloads.

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