deep geological repositories for radioactive waste

retrievability

nagra. we care

What is at issue?

In order to protect humans and the environment, radioactive waste has to be enclosed for tens to hundreds of thousands of years. Several hundred metres below the earth's surface, deep geological repositories (see Figure 1) provide long-term passive safety through safe confinement of the waste. Society therefore will not have to concern itself with the waste in the future. These principles have been established by the International Atomic Energy Agency (IAEA)[1] and meet with worldwide consensus: Switzerland[2] and many other countries support them. If waste that emits radiation over long time periods were to be stored at or close to the earth's surface, it would have to be safeguarded permanently. However, no one can predict how long society would be able to perform this active task.

Nagra's mandate is to plan and realise deep geological repositories. This includes considering society's wish to monitor the repositories and potentially retrieve the waste.

Legal framework
Among other things, the nuclear energy legislation (see text-box below) calls for radioactive waste to be retrievable from a deep geological repository and for this to be demonstrated experimentally. Retrieval without undue effort has to be possible up to the time when the repository is completely closed.

Nagra's technologically advanced repository project
Nagra is developing a repository project that provides considerable safety reserves. It is therefore very unlikely that waste would have to be retrieved for reasons of safety. The geology at the repository site has to meet very stringent requirements. For this reason, Nagra is conducting thorough investigations of the geological underground and potential impacts on a repository. In order to be prepared for all eventualities and to provide future generations with the freedom to make their own decisions, Nagra has to devise a retrieval concept that is developed as part of a stepwise process.

[1] IAEA Fundamental Safety Principles

[2] Nuclear Energy Act

(for literature references, see bibliography)

Legal provisions relating to waste retrieval

An operating licence for a deep geological repository is granted if […]
- it is possible to retrieve the radioactive waste without undue effort until closure of the repository.
  (Article 37, Paragraph 1, Letter b of the Nuclear Energy Act)

A deep geological repository must be designed to ensure that […]
- steps to ease surveillance and repairs of the repository, or for the recovery of the waste, in no way impair the effectiveness of the passive safety barriers after closure of the repository.
  (Article 11, Paragraph 2, Letter c of the Nuclear Energy Ordinance)

Before a deep geological repository may be put into operation, the technologies of relevance to safety must be tested and their functional capacity must be ascertained. This concerns in particular […]
- the removal of backfill material for the purpose of recovery of waste packages;
- the method of recovery of waste packages.
  (Article 65, Paragraph 2, Letters b and c of the Nuclear Energy Ordinance)

Stipulations on retrievability

Disposing of radioactive waste in deep geological repositories (see Figure 1) means that responsibility for the waste is not passed on to future generations. However, they will still have options on how to deal with it.

Waste retrieval options

The Swiss Federal Government's Expert Group on Disposal Concepts for Radioactive Waste (EKRA) already established in 2001[3] that society also has a need for waste to be retrievable. As a result, retrievability was anchored in the Nuclear Energy Act. This also includes a monitoring phase before the final closure of the repository as well as a pilot repository where a representative portion of the waste can be monitored.

If, despite careful planning, monitoring reveals an unforeseen or currently unknown safety issue, the authorities would order the waste to be retrieved.

As part of the radioactive waste consists of spent fuel assemblies, future generations could recover and use these as resources for energy production.

Waste could also be retrieved if an alternative disposal option becomes available in the future.

Not only Switzerland, but also other countries such as France, include waste retrieval in their repository concepts.[4]

Long-term safety must not be jeopardised

Retrievability measures must not impair the functioning of the safety barriers or jeopardise long-term safety.[5] If a repository remains open over long time periods, this could have an increasingly negative impact on the conditions underground. For this reason, full emplacement drifts and caverns are continuously backfilled, and the repository may only remain open for a limited monitoring period.[6]

[3] EKRA Final Report

[4] OECD/NEA, IAEA 2009

[5] ENSI-G03 Guideline: Chapter 4.2, Paragraph g

[6] SFOE Assessment Report

(for literature references, see bibliography)

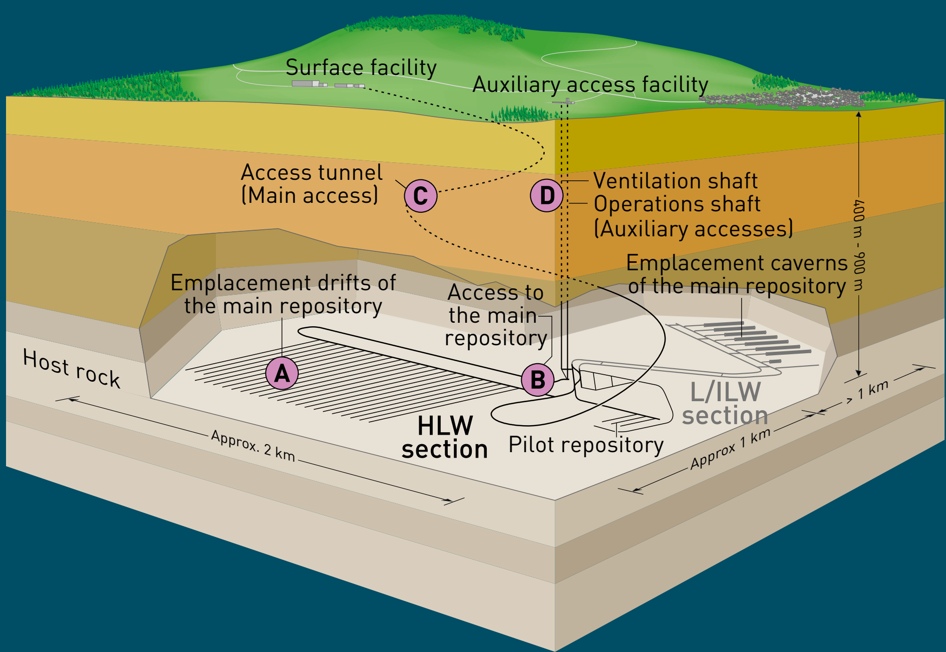


Figure 1
Illustration of a deep geological repository (combined repository). From the main access tunnel (C), the high-level waste is brought to the emplacement drift (A) via the access to the main repository (B). Further access is provided by two shafts (D). Similarly, low- and intermediate-level waste is disposed of in emplacement caverns.

Facilitating waste retrieval

It is possible to ensure that waste is retrievable without undue effort by precisely documenting waste emplacement, by laying out the drifts and caverns in a manner advantageous for retrieval and by selecting an easily removable backfill material. Mechanically stable disposal canisters and the timely development of the equipment required for retrieval are also important.

Stepwise approach

Around 2029, the Federal Council will decide where the repositories will be constructed. As the basis for this decision, Nagra will submit the corresponding reports around 2024 and apply for a general licence. This has to include a basic retrieval concept (see Figure 2) and explain when and how a deep geological repository will be closed. By the time the construction licence application has to be submitted, Nagra will have developed the retrieval concept in detail. This will describe how the waste can be retrieved if necessary and includes information on costs, time requirements and radiation exposure. In a demonstration experiment carried out under realistic conditions, Nagra will have to show the technical feasibility of waste retrieval by the time it submits the operating licence application. Nagra will always consider the state-of-the-art in science and technology in its concepts.

Safe repositories can be constructed

The Nuclear Energy Act stipulates the need to demonstrate the feasibility of radioactive waste disposal. This demonstration confirms that deep geological repositories are fundamentally feasible in Switzerland. The Federal Council has approved Nagra's demonstrations of disposal feasibility: for low- and intermediate-level waste (L/ILW) in 1988 and for high-level waste (HLW) in 2006.

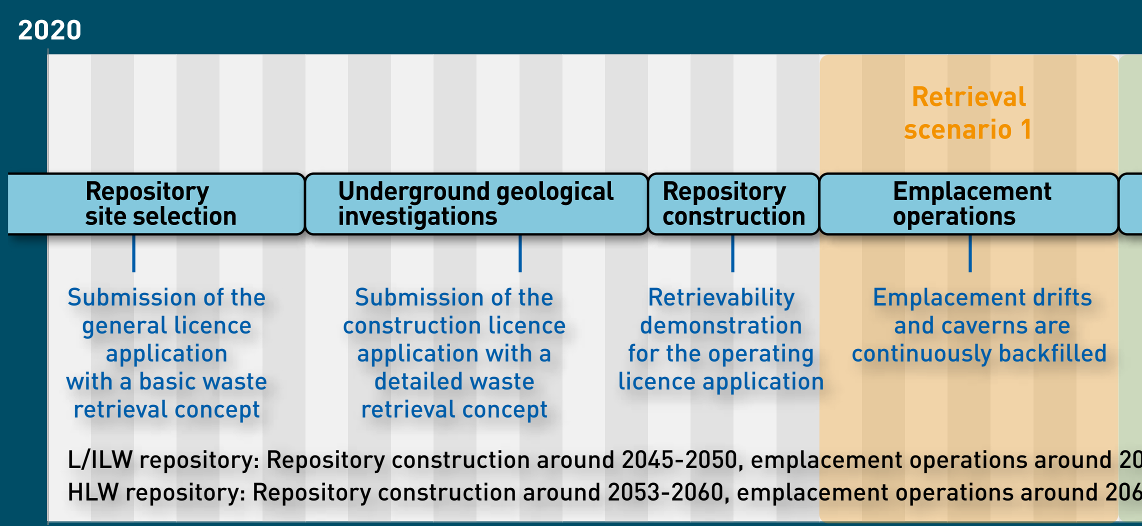


Figure 2
Schematic realisation plan for a deep geological repository with the three retrievability scenarios

Time sequence for waste retrieval

For reasons of simplification, three repository and retrievability scenarios are distinguished. In the case of high-level waste, these are (see Figures 1 and 2):

Scenario 1: The emplacement drifts (A) are continuously backfilled during waste emplacement. The access to the main repository (B) and the accesses from the surface (C and D) are still open.

Scenario 2: The emplacement drifts (A), the access to the main repository (B) and the main access (C) are backfilled and sealed. The auxiliary access (D) from the surface is open. The pilot repository is being monitored.

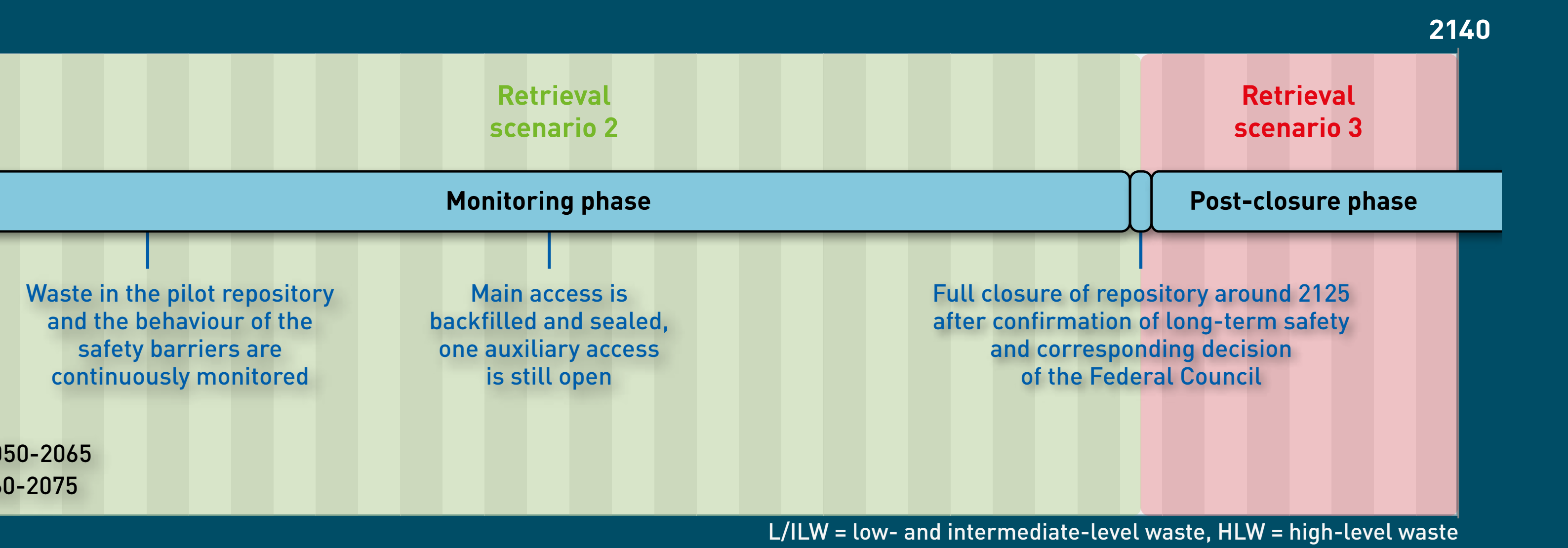
Scenario 3: All tunnels and all accesses leading to the surface are backfilled and sealed (A to D).

The effort needed to retrieve the waste depends on how far the repository has already entered a state of fully passive safety (see Figure 4). In Scenario 1, it is roughly identical to the effort required when the waste was emplaced. From Scenarios 1 to 3, the effort to retrieve the waste increases continuously.

During the monitoring phase lasting several decades, the waste in the pilot repository and the behaviour of the engineered safety barriers are monitored. The aim is to collect additional data to confirm the long-term safety of the repository. Only when this has been conclusively demonstrated can the Federal Council order the overall closure of the repository. The waste disposal canisters have to remain mechanically stable until the end of the monitoring phase to allow for possible retrieval.[7] In Scenario 3, retrieval is still possible, but it would require greater effort.

The longer a repository has already been fully closed, the more challenging the retrieval conditions underground become.

[7] In addition, the Swiss Federal Nuclear Safety Inspectorate (ENSI) stipulates in its G03 Guideline that, from a long-term safety perspective, the disposal canisters for high-level waste have to remain tight for at least 1000 years. Calculations show that the steel disposal canisters currently proposed will remain tight for approximately 10,000 years.



How would the waste be retrieved?

Retrieval from a HLW repository
The following describes how disposal canisters would be retrieved from a high-level waste emplacement drift in Scenario 2.

The backfill material would first have to be removed from the access to the main repository (B), and the tunnel might have to be secured. Following this, the seal of the emplacement drift (A) in question is removed, and a remotely operated vehicle removes the bentonite tunnel backfill. The disposal canister is pulled onto the vehicle (see Figure 3), which removes the canister from the emplacement drift so that it can be transported to the surface. The open emplacement drift is continuously inspected and secured. This procedure is repeated until all canisters in question have been removed.

Retrieval from a L/ILW repository
The low- and intermediate-level waste (L/ILW) is enclosed in concrete containers that are emplaced underground in caverns. Upon emplacement, voids between the individual containers are backfilled with soft mortar that can easily be removed again. It is thus possible to expose the affected containers and retrieve them from a cavern.

Vehicles already in place
A wide variety of vehicles already exist today for use in underground construction projects around the world where spatial conditions are as restricted as they are in a repository. These vehicles can drill holes into rock, secure tunnels, remove excavated material and lift and transport very heavy loads such as a disposal canister. From a technical point of view, retrieval can be implemented successfully using such vehicles. From a legal perspective, Nagra has to confirm retrievability in a demonstration experiment.

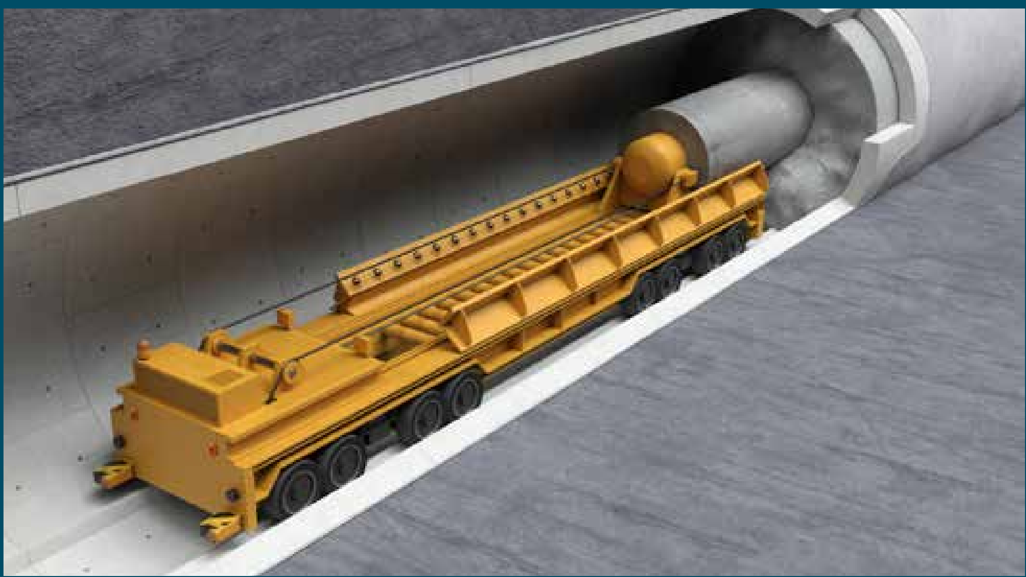


Figure 3
Examplary illustration of the retrieval of high-level waste: The disposal canister is recovered and removed from the emplacement drift using a waste retrieval vehicle.

Deep geological repositories provide passive safety

In a deep geological repository, engineered and geological safety barriers ensure a high degree of long-term safety. They protect humans and the environment and also protect the radioactive waste from any negative impacts. In a high-level waste repository, the engineered barriers consist of steel disposal canisters as well as the backfill of the emplacement drifts and the sealing of the repository accesses with swelling bentonite material.

The impermeable Opalinus Clay hosts the emplacement rooms[8] that contain the radioactive waste. Together with the confining geological units located above and below it, these rock formations form the geological barrier that ensures the long-term retention of the radioactive substances. In the siting regions for a deep geological repository, the Opalinus Clay lies at a depth of several hundred metres and, at suitable locations, it has remained stable over many millions of years.

Stepwise progress towards fully passive safety

Passive safety is increased step by step so that the repository will no longer have to be actively monitored once it has been closed (see Figure 4).

Simply emplacing waste in a repository increases safety, and the continuous backfilling and sealing of full emplacement rooms further increases passive safety. At the same time, the requirement for active monitoring decreases and it becomes more challenging to retrieve the waste. In the next step, all underground accesses to the main repository (see Figure 1) are closed. During the decades-long monitoring phase, one surface access remains open to monitor the pilot repository. Once this has also been closed, passive safety has been optimised to the maximum extent. Long-term monitoring[9] can also take place after final closure but it is not necessary for ensuring safety.

[8] The emplacement drifts for high-level waste and the emplacement caverns for low- and intermediate-level waste are called emplacement rooms.

[9] Nuclear Energy Act, Art. 39, Para. 3

(for literature references, see bibliography)

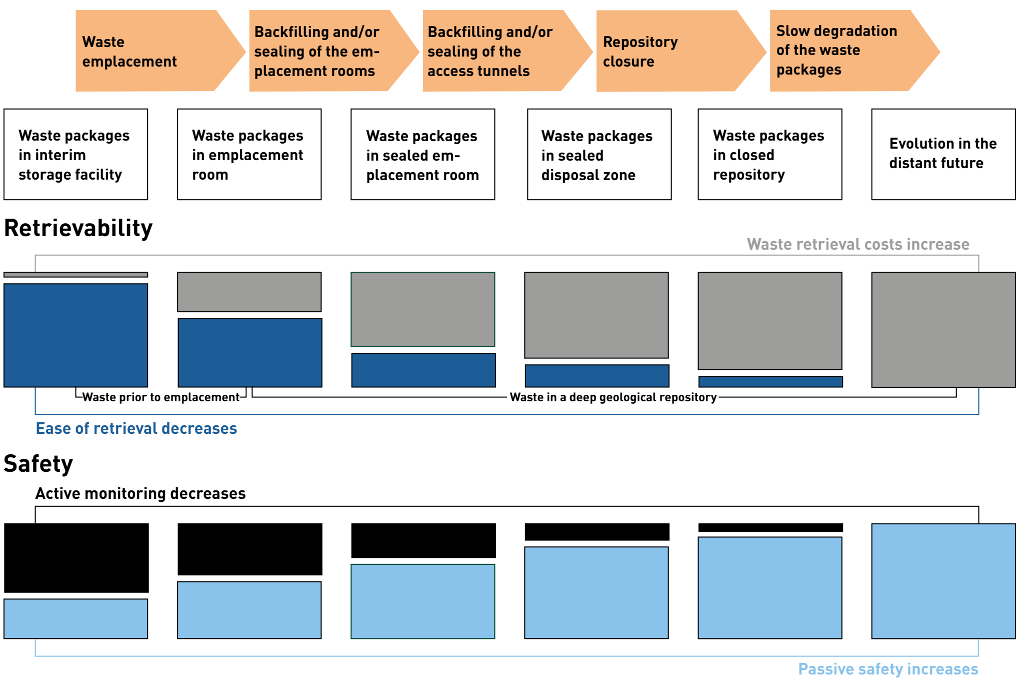


Figure 4
Stepwise increase in passive safety with every closure of a repository component (graphic based on an OECD/NEA illustration; see bibliography).

Bibliography/further reading

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