Final storage – it’s all rock and rules

High-level radioactive waste (HLW) will remain dangerous for time spans beyond human comprehension. Depending on the half-life and quantity, it can take hundreds or even millions of years for a radioactive element to decay to the point where its radiation load no longer poses an unacceptable threat to human health and the environment. No building, facility, technology or social institution created by human communities can realistically guarantee the safe storage of radioactive waste for such long time spans.

That being the case, there is no alternative to permanent disposal in deep geological formations. This requires dense rock and geological conditions which will remain stable over very long periods of time. Suitable types of host rock include rock salt, clay stone and crystalline rock such as granite. These formations exist in Germany. Their geological history has remained largely unchanged for a very long period of time, and they are highly unlikely to be affected by any anticipated future developments, partly because they are sufficiently thick and solid and are located at adequate depth.

It seems feasible that radioactive waste stored in this type of repository would remain isolated from the biosphere for very long periods of time. Using geoscientific techniques, it is possible in principle to predict a storage period of around one million years for a suitable site. In other words, the scientific community can make a well-founded prediction, based on extensive studies, that nuclear waste can be stored securely and safely in these formations for at least one million years.

Site selection: open-ended, scientifically based, transparent

Germany has yet to select a site for a repository for high-level radioactive waste from its nuclear power plants. However, with the Repository Site Selection Act (Standortauswahlgesetz – StandAG), which came into effect in May 2017, Germany’s policy-makers have risen to the challenge. The objective is to identify, in a scientifically based and transparent procedure, a site for a repository “that delivers the best possible safety […] for a period of one million years” (Repository Site Selection Act, Section 1).

The Repository Site Selection Act stipulates minimum specifications and exclusion criteria:

The permeability of the rock under consideration must be minimal.
The thickness of the rock layer must be at least 100 metres.
The area of rock under consideration must be located a minimum of 300 m below the ground surface.
It must also be large enough to serve as a repository for all of Germany’s nuclear waste.

Areas where seismic or volcanic activity or large-scale movements have been observed or may be expected are not considered suitable for a repository. Other exclusion criteria include active geological fault lines or the presence of relatively new bodies of groundwater that may be indicative of contact with the biosphere.

Each potential repository site has its own specific characteristics, which must be compared with conditions at other sites using predetermined criteria. This step-by-step process enables the best option to be identified.

Steps in the search for a repository site

The Repository Site Section Act provides for a stepwise process based on scientific criteria. During each phase, the regions which appear to offer potential are narrowed down further, towards the most suitable site. Each phase concludes with the adoption of federal legislation, enhancing the binding effect of the process. Extensive public consultation is envisaged at every stage.

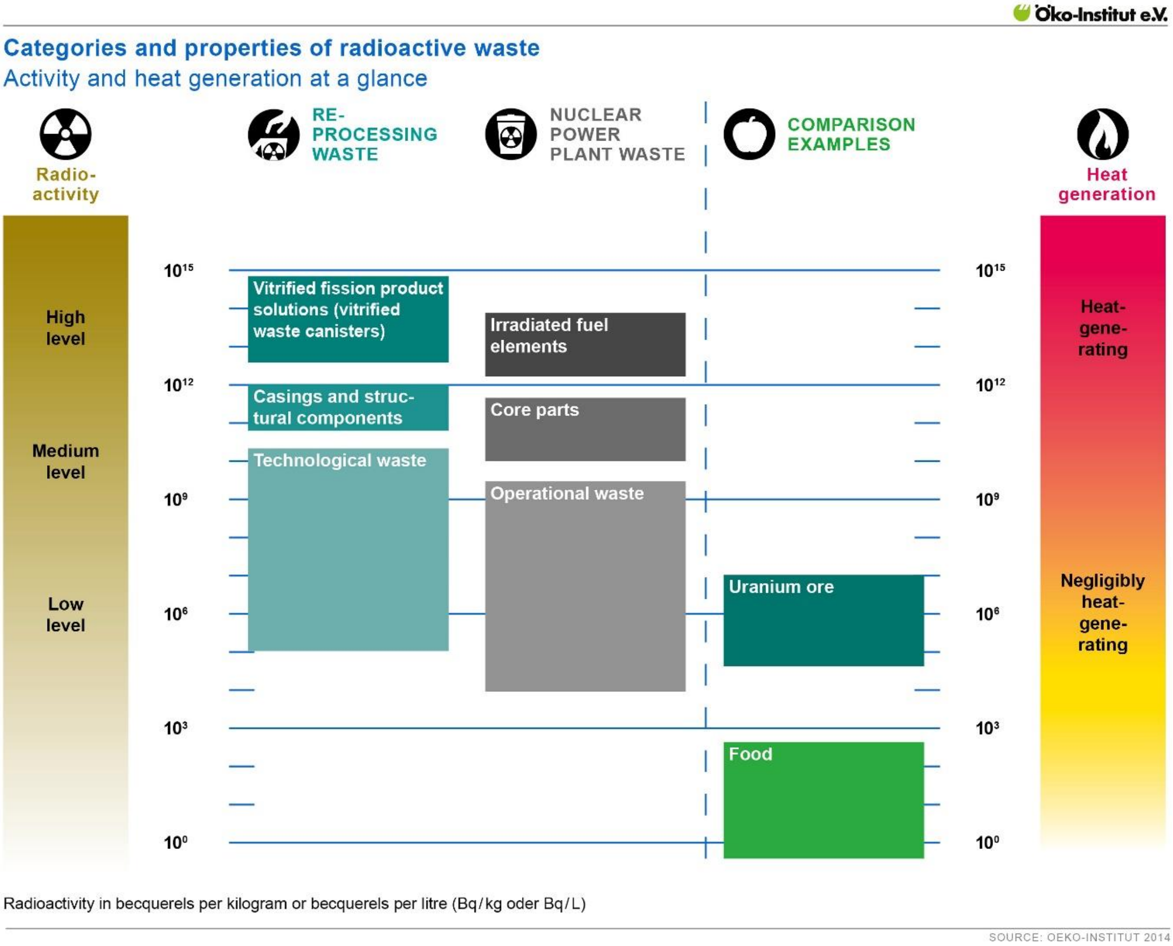
Phase 1 began in 2017 with the whole territory of the Federal Republic, i.e. a white map of Germany showing all the potentially suitable regions. At this stage, the BGE – the federal company for radioactive waste disposal – uses geological data from the German states to identify subregions that offer potential. During this and subsequent phases, the exclusion criteria, minimum specifications and assessment criteria mentioned above are critical to the evaluation.

In **Phase 2**, the BGE carries out surface exploration of the possible site regions identified in Phase 1, further narrowing down the options. Underground exploration will not start until Phase 3. Following on from this, a site proposal will be produced, with a comparative analysis of at least two potential sites. In each phase, the Federal Office for the Safety of Nuclear Waste Management (BASE) reviews the studies produced by the BGE.

Low-, intermediate- and high-level radioactive waste: how must each be stored?

Radioactive waste varies in terms of its composition, half-life and activity. It is always a mixture of various radioactive substances (radionuclides). The half-life – in other words, the time required for half of the amount of a radioactive substance to decay into other substances, some of which may also be radioactive – is the metric used to determine a radioactive substance's longevity. Activity means the number of decays per unit time and the thermal energy released. Radioactive waste is classified on the basis of these properties, and the various types of waste require different management approaches. In Germany, decay heat is the key determinant of the type of final disposal used.

Figure: Categories and characteristics of radioactive waste



Source: Oeko-Institut

The Repository Site Selection Act is concerned solely with the final storage of high-level radioactive waste, which Germany classes as heat-generating waste. It mainly consists of spent fuel elements from nuclear power plants and vitrified fission products from reprocessing. These waste streams are highly radioactive and generally have very high longevity. Their permanent disposal therefore poses particular challenges in terms of long-term safety and security.

In addition, there are large quantities of low- and intermediate-level radioactive waste to be disposed of; this radioactive waste with negligible decay heat comprises more than 90 per cent of the volume of radioactive waste and accounts for around one per cent of total radioactivity. Radioactive waste with negligible decay heat is produced during the operation, maintenance and repair of nuclear power plants and other nuclear facilities, and during decommissioning. It is also generated through the use of radionuclides in research, medicine and industry.

For this non-heat-generating radioactive waste, a repository is currently under construction at Schacht Konrad (Konrad pit) near Salzgitter. The facility at this former iron ore mine is now due to come into operation in 2027. Germany also has a disposal site at Morsleben, a former salt mine dating back to the GDR era. Nuclear waste storage in Morsleben continued until 1998 but its closure has been applied for. Due to instability and solution inflows, all the waste stored at the Asse II research mine is to be removed. The various schemes have been, and continue to be, the subject of intense debate in their respective regions.

Isolated “for eternity” – strategies for final storage

The extremely long time periods over which radioactive waste must be stored mean that various difficult questions arise:

- Is it indeed feasible, from a technical safety perspective, to make firm predictions for such a long timeframe?
- Can today’s technology provide adequate protection for future generations?
- How much scope should future generations have to manage the waste, without facing undue burdens?

From a scientific perspective, there is currently no alternative to underground storage of high-level radioactive waste. In this scenario, geological barriers prevent radioactive substances from reaching the Earth’s surface, and additional engineered barriers are put in place to close any gaps in protection if the final storage solution itself interrupts the geological barrier. Depending on the scheme’s design, these technological solutions would only last until the rock itself closed the gap.

Besides being located in a stable geological zone, the repository must withstand possible climatic changes, such as ice ages or periods of extreme heat, and offer security from attacks or misuse. The criterion of the maximum possible level of passive safety means that continued safe disposal should not depend on the adoption of active safeguard measures by successive generations. As individuals and as a society, we cannot guarantee that the waste will be safely stored and monitored for a one-million-year time span.

A deep underground repository takes this into account. After the facility is sealed once and for all, there must be no need for long-term checks. The most important prerequisite for this is evidence of the functionality of the facility. A monitoring phase, when the waste could still be removed from the facility, could provide additional information of relevance to the decision on sealing, but cannot be an end in itself or a substitute for final disposal.

The Oeko-Institut’s role

Researchers from the Oeko-Institut have been sharing their expertise in independent reports and statements on interim and final storage of nuclear waste for many years. They sit on various expert commissions, provide advice to government, technical authorities and policy-makers and support public consultation processes.

Learning about final storage

The final storage of radioactive waste is an intergenerational challenge. Recognising that an informed understanding of the issue is a prerequisite for the public’s participation on equal terms, scientists at the Oeko-Institut and the Independent Institute for Environmental Issues (UfU) have developed a package of learning materials.

The materials are suitable for Year 10 onwards and facilitate interdisciplinary learning in politics, social studies, German, chemistry, geography and physics. Using the materials, the young people build their knowledge in the various subjects and then discuss what they have learned in mixed teams. After that, they work together on developing their own set of criteria for a repository.

The purpose of the teaching units is to enable young people to reach an informed opinion on the issue by engaging actively with the topic of final storage during discussions and exploring it from various angles. The materials can be downloaded free of charge here:

Further information

Transdisziplinäre Forschung zur Entsorgung hochradioaktiver Abfälle in Deutschland – Forschung zur Verbesserung von Qualität und Robustheit der soziotechnischen Gestaltung des Entsorgungspfades (TRANSENS) [Transdisciplinary research on the disposal of high-level radioactive waste in Germany – Research to improve the quality and robustness of the sociotechnical disposal pathway (TRANSENS)]: Joint project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and the Volkswagen Foundation involving 16 project partners, including institutes and departments from nine German and two Swiss universities, and other research institutions

Wissenschaftliche Beratung und Bewertung grenzüberschreitender Aspekte des französischen Endlagervorhabens „Cigéo" in den Nachbarländern Rheinland-Pfalz, Saarland und Großherzogtum Luxemburg" [Scientific advice and evaluation of cross-border aspects of France's "Cigéo" final storage project in the neighbouring states of Rhineland-Palatinate, Saarland and the Grand Duchy of Luxembourg]: Oeko-Institut study

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