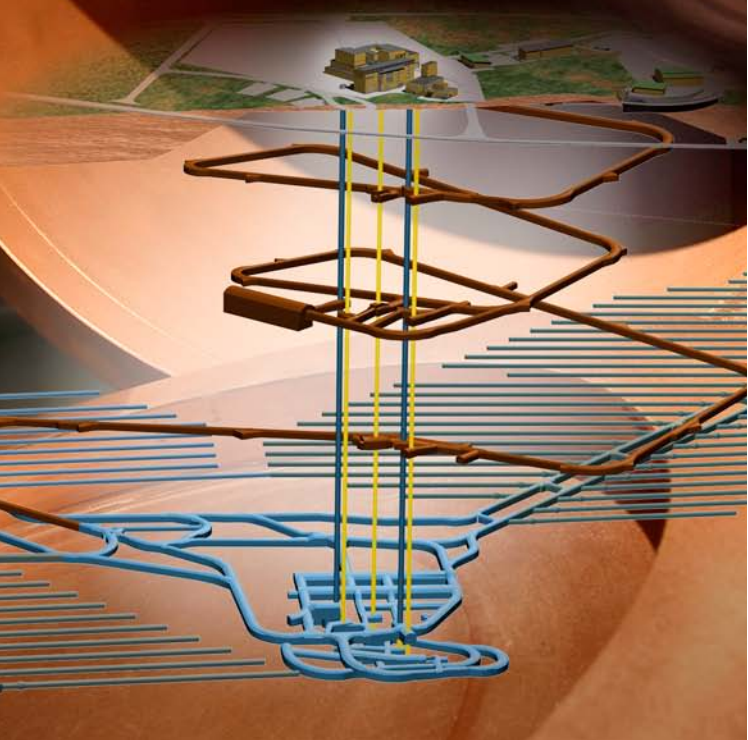
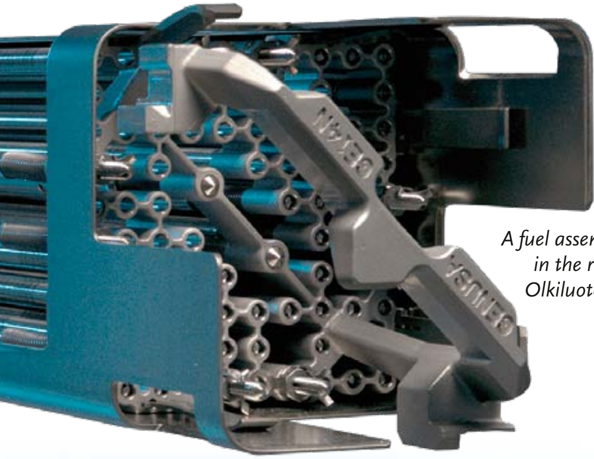
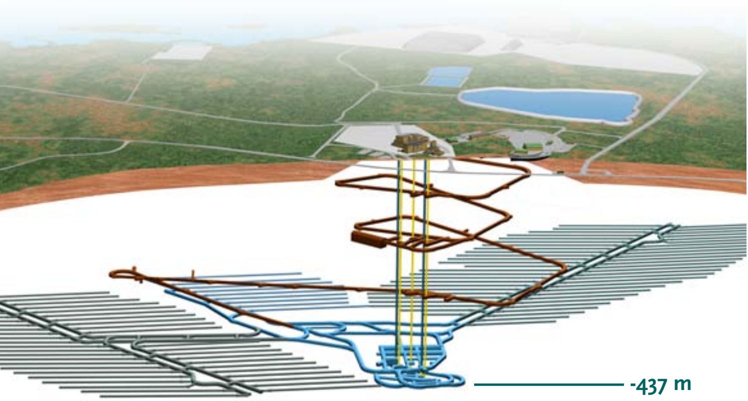
POSIVA

Safe Final Disposal of Spent Nuclear Fuel





A fuel assembly used in the reactors of Olkiluoto 1 and 2.



The spent nuclear fuel will be placed at a depth of about 400 metres. Two metres of rock alone is sufficient to attenuate the radiation to the level of natural background radiation.

Safety through research

For fuel, nuclear power plants use uranium, which becomes highly radioactive during use. Due to its radioactivity, spent nuclear fuel must be taken care of so that it will not cause any harm to living organisms, even over the long term. Final disposal is based on isolating radioactive substances from the habitats of people. Radioactivity attenuates over time: in a year, it reduces by one-hundredth and in 40 years by one-thousandth of the level it was when it was removed from the reactor.

Power companies are responsible for nuclear waste management. The Finnish nuclear power companies Teollisuuden Voima Oyj and Fortum Power and Heat Oy have assigned the duties related to the final disposal of spent nuclear fuel to Posiva Oy.

Posiva is surveying the bedrock of Olkiluoto and developing a safe final disposal solution. The objective of research and development is to ensure that all the specified requirements are met, and construction and operating licenses may be granted for the final disposal facility.

A decision-in-principle issued in 2000

The Finnish Government has issued decisions-in-principle on final disposal in Olkiluoto in Eurajoki with regard to the spent fuel of the four existing plant units (OL1, OL2, LO1 and LO2) and the OL3 unit under construction.

Moreover, Posiva has submitted applications for a decision-in-principle on the spent nuclear fuel of the Olkiluoto 4 and Loviisa 3 units planned by Posiva's owners.

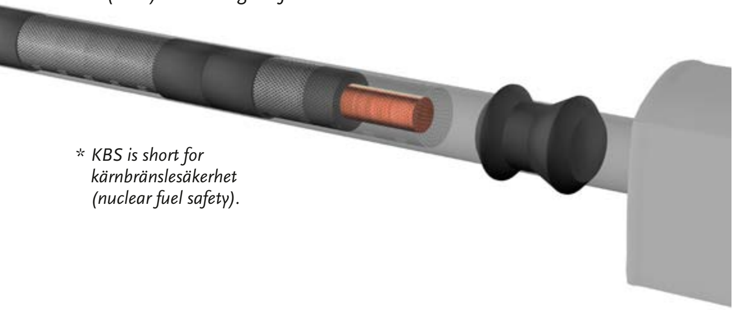
The bedrock and conditions in Olkiluoto are known

The bedrock in Olkiluoto is a 1,800–1,900-million-year-old compound of mica gneiss and granite. The implementation of the final disposal requires research information on the bedrock structure, the groundwater chemistry and the flow conditions. Based on this information, models are created for assessing the functionality and safety of the final disposal solution.

The Olkiluoto bedrock has been studied since the 1980s by means of deep drilling. The studies show that the groundwater at a depth of hundreds of metres is devoid of oxygen, and the groundwater flows are minor.

The excavation of the underground rock characterisation facility, ONKALO, was started in 2004. On the basis of information obtained from the facility, it is possible to verify the Olkiluoto bedrock's suitability for final disposal and to test technical solutions, thus achieving confidence in the safety of the final disposal. ONKALO provides the opportunity to develop rock construction and final disposal technology in genuine conditions.

Posiva's final disposal solution is based on a model called KBS-3 which is developed by Svensk Kärnbränslehantering AB (SKB). The designs of the disposal facility is based on the vertical disposal solution of canisters (KBS-3V). The horizontal disposal solution (KBS-3H) may also be used.*



** KBS is short for kärnbränslesäkerhet (nuclear fuel safety).*

Final disposal solution

According to the final disposal solution, the spent nuclear fuel is encapsulated and placed in the bedrock.

The final disposal facility consists of an aboveground encapsulation plant and a final repository deep in the bedrock.

In the future, ONKALO will be part of the final repository. ONKALO's access tunnel and shafts will be used when constructing and using the repository.

The intention is to build the final disposal tunnels at a depth of about 400 metres.

The spent fuel will be packed in final disposal canisters in the encapsulation plant. The canisters will be placed into vertical holes (KBS-3V solution) drilled in the floor of the final disposal tunnel. In the holes, hard-compacted bentonite will be used as barrier material between the canister and the rock. The tunnels will be filled with clay bars along with the final disposal of the canisters.

Global reserves of natural copper have shown that the copper also used in the final disposal canisters can remain unchanged inside the rock for very long periods. The metallic copper in the picture is over 50 million years old. Its surface has patinated, but its inner part has remained unchanged.

In clay, various materials remain unchanged for millions of years. For example, an eight-million-year-old, well-preserved cypress forest in clay was found in a mine in Hungary.

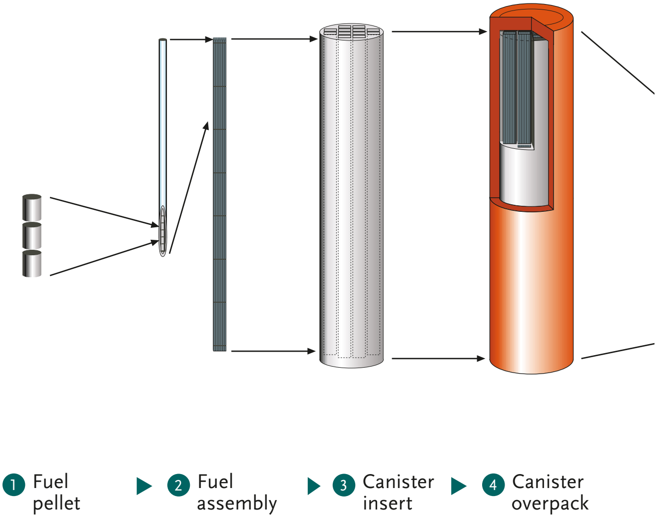
Analogies in nature support a safe solution

Besides field research, theoretical analysis models and calculations, the safety of the final disposal can be assessed by means of analogies in nature.

These are examples identified from around the world of how naturally occurring materials have behaved in different conditions over long periods of time.

Natural copper formations have lasted up to millions of years in various parts of the world, which can be considered as evidence of the long-term durability of copper canisters deep inside the rock. For example in Hyrkkölä and Askola, Finland, copper is found in its original form within granite stones, even though the copper has been exposed to sulphate-rich groundwater under oxidizing conditions.

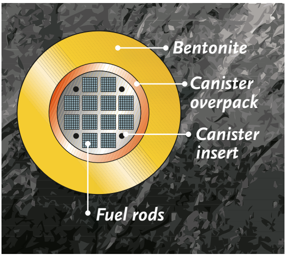
Several release barriers back up each other and ensure long-term safety.



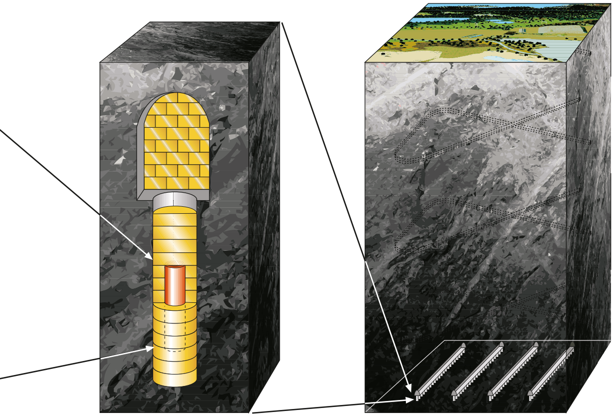
The multibarrier principle ensures safety

Final disposal will be carried out in natural materials according to the multibarrier principle. According to the principle, the spent nuclear fuel is isolated deep inside the rock with several release barriers supplementing each other. The principle is that a defect in the capacity of one release barrier will not compromise long-term safety.

The release barriers include the final disposal canister, the bentonite barrier, tunnel backfill and the intact bedrock around the disposal facilities. The safety of final disposal is based on stable and predictable conditions prevailing in the bedrock.



There are several release barriers around the disposed fuel (horizontal section).



1 Fuel pellet
The uranium of the spent fuel is in a ceramic form which dissolves very slowly.

2 Fuel assembly
consists of gas-tight metal zirconium rods; the uranium fuel is inside the rods as ceramic pellets. A fuel assembly from Olkiluoto's existing reactors comprises about 100 rods.

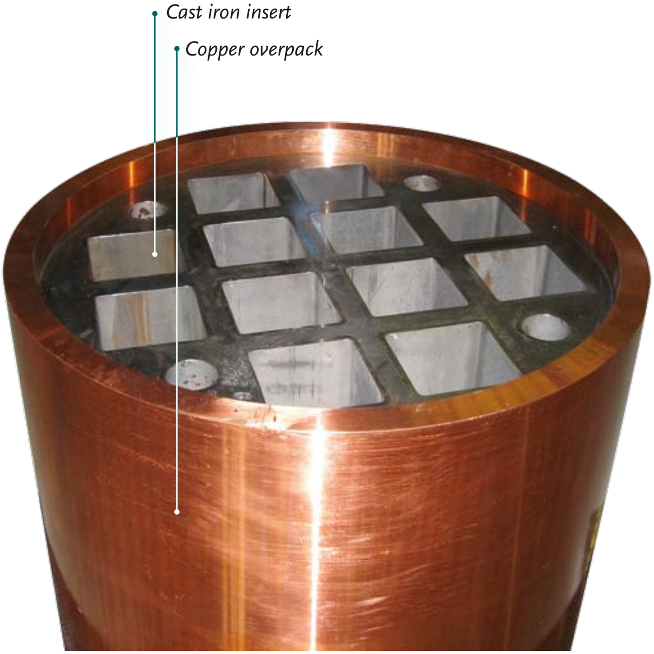
3 Canister insert
The fuel assemblies are in the solid interior made of nodular graphite cast iron. The interior protects the assemblies from mechanical strain deep inside the rock.

4 Canister overpack
is very corrosion-resistant copper.

5 Bentonite
acts as a barrier isolating the final disposal canister from the surrounding rock. The bentonite swells when it comes into contact with water, and prevents water movement around the canister.

The tunnel backfilling material's
purpose is to prevent water flow, keep the barrier material in place, and retain the mechanical stability of the tunnels.

6 400–700 metres of bedrock
isolates the disposed fuel from living organisms. Placing the fuel at this depth will prevent terrestrial changes from affecting the surroundings of the final disposal canisters.

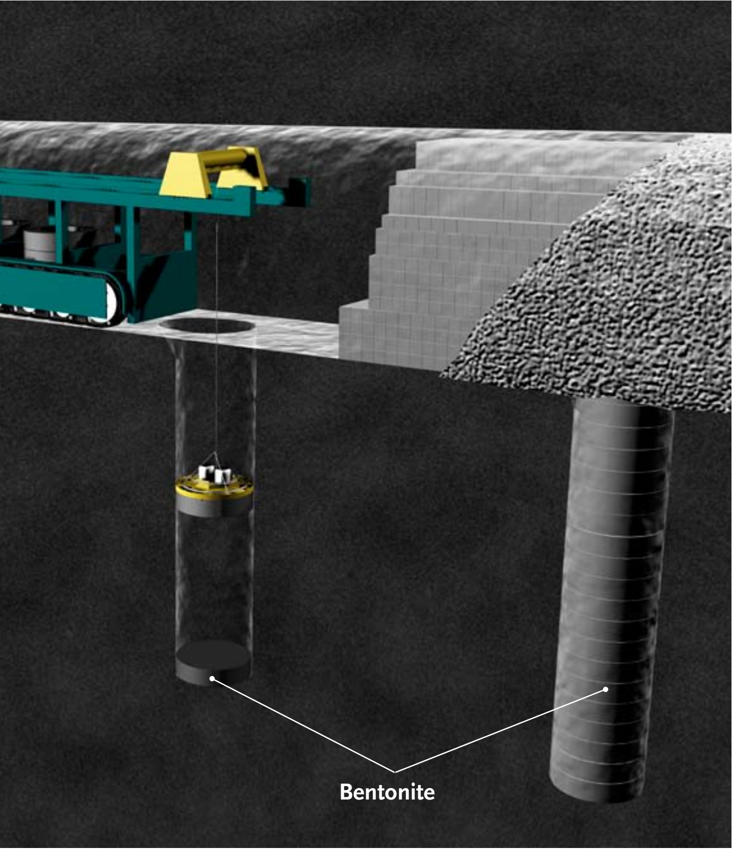


The final disposal canister is designed to last

After an interim storage of dozens of years, the spent fuel assemblies are packed into a gas/water-proof copper cast iron canister. The canister insert is filled with protective gas, so the internal corrosion caused by humidity and radiation will be insignificant.

As a result of the cast iron insert, the canister will endure mechanical strain in the bedrock, such as possible earthquakes and pressure caused by the ice sheet.

The copper overpack protects the canister from the corrosive effect of groundwater. According to surveys, the groundwater deep inside the bedrock is oxygen-free, which is why its ability to corrode copper is weak. The copper canister will retain its tightness in the final disposal conditions for millions of years.

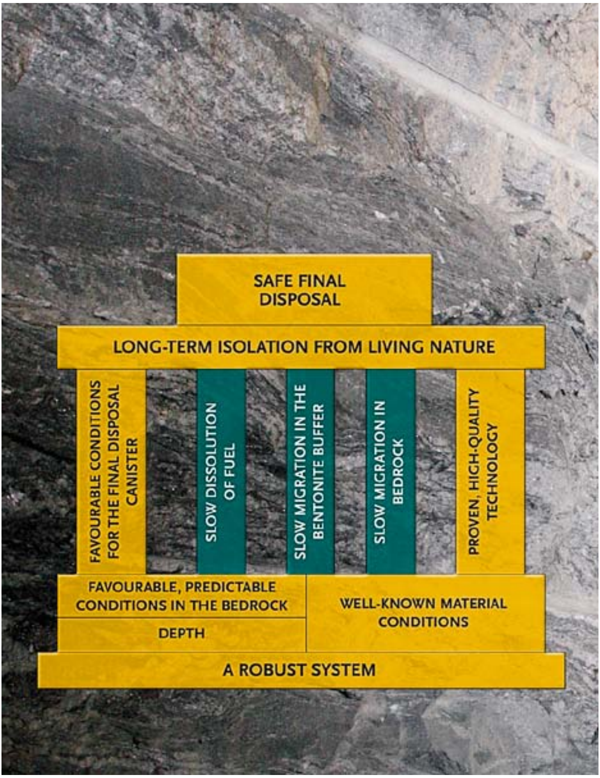


Bentonite – a dense and flexible barrier material

Bentonite is a natural clay which has emerged from the ash of volcanic eruptions. Bentonite occurs commonly around the world.

As a result of its waterproofing features, bentonite has been used for a long time in various earthworks applications. Its density and long life make bentonite clay a suitable material for final disposal.

Hard-compacted bentonite is used as a barrier protecting the fuel canister. The groundwater is absorbed by the bentonite, which then swells and forms a dense, flexible and long-lasting seal around the copper canister. The density of the bentonite prevents harmful substances to access the canister surface, and its flexibility protects the canister from possible rock movement as a result of, for example, earthquakes.



Safety case

According to the Nuclear Energy Decree, "*Compliance with long-term radiation protection objectives as well as the suitability of the disposal concept and site shall be justified by means of a safety analysis that addresses both the expected evolutions and unlikely disruptive events impairing long-term safety.*"

The requirement for the safety grounds will be met with report material, reviewing the capability of the final disposal location and facilities as well as the technical release barriers. The review period spans up to 250,000 years, including at least one ice age cycle. After this period, the activity of the disposed fuel is at the same level as that of a large uranium deposit.

On the basis of the studies and surveys conducted so far, the final disposal of the spent fuel will not cause any significant harmful effects to people or nature.

Society specifies strict radiation limits for final disposal

In the safety regulations for final disposal, the requirements for long-term safety are grouped separately: 1. in the predictable period of the next thousands of years, and 2. in the longer period covering major climate changes.

For the predictable period, the upper limit for annual human radiation dosage caused by final disposal has been specified as **0.1 mSv/year**.

Assessing the radiation dosages of individual people is the more difficult the further one looks into the future. Therefore, instead of radiation dosages, the assessment criterion for the long-term impact on people and the environment is the quantity (as activity levels) of radioactive substances released from the final disposal facilities to living organisms (specified in Bq/year).

The guidelines of the Radiation and Nuclear Safety Authority require that scenario analysis must include both probable developments and unlikely events weakening long-term safety.

The scenarios are formed from phenomena, events and processes which may be significant for long-term safety. Unlikely events considered include, among others, the following:

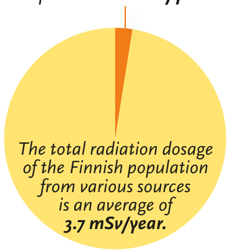
– Constructing a deep drilled well at the final disposal location

– Rock sample drilling impacting a final disposal canister

– A significant movement of the bedrock near the final repository.

Information on radiation sources and radiation doses in Finland

*The upper limit for radiation dosage allowed from the final disposal is **0.1 mSv/year.***



*Half of the annual average radiation dosage of the Finnish population, which is about **2 mSv**, originates from indoor air radon.*

*The radiation dosage from the environment in Finland is about **1 mSv**. Medical procedures account for an average of about **0.5 mSv**.*

FAQs

When Finland carries out final disposal of nuclear waste, is it possible that nuclear waste would be imported from elsewhere to be disposed of in Finland?

"While the Nuclear Energy Act requires that Finnish nuclear waste is finally disposed of in Finland, the Act also forbids the import of nuclear waste into Finland."

What will be the outcome of the final disposal of the spent nuclear fuel in Olkiluoto from the intended new nuclear plant units (OL4 and LO3)?

"The number of canisters to be finally disposed of will increase. Consequently, it is estimated that the number of defective canisters or canisters possibly becoming defective in the final disposal facilities will increase. However, the resulting emission increase will not have significant effects on people or other living organisms, since also in that case the possible radiation dosages would be below the dosage limits set by the authorities."

Have the effects of permafrost and an ice age been sufficiently observed in designing the final disposal?

"The effects of permafrost and an ice age on the final disposal solution have been studied in Finland and elsewhere. In these matters, Posiva carries out research co-operation with, for example, the Swedish nuclear waste company SKB.

The study results suggest that in Olkiluoto the creation of permafrost and ice and the back and forth movement of the ice sheet have only a minor effect on the temperature at the final repository level. On the other hand, Posiva is also investigating what will happen in the repository if the temperature of the bedrock falls below the freezing point of water."

What will happen if, contrary to expectations, a final disposal canister corrodes in the final disposal facilities and starts to leak?

"If a final disposal canister corrodes and begins to leak, groundwater may come into contact with the fuel assemblies inside the canister. However, the uranium fuel is inside zirconium metal rods, which are highly corrosion resistant. Moreover, the fuel is in a solid form which does not dissolve easily. Therefore, the fuel dissolving or chemical transformation and the release of radioactive substances will probably take millions of years."

What would happen if a large earthquake hit the final disposal facility?

"Earthquakes are accounted for when designing the final disposal facilities.

In a highly pessimistic scenario, which does not take into account the opportunity to avoid larger gaps, several canisters could be damaged due to rock displacement. Even in that case, the largest possible annual radiation dosage for an individual would only be about one-thousandth of the total average annual dosage of the Finnish population from all radiation sources."

How much will the final disposal cost? Who will pay the costs?

"According to the current estimate, the final disposal of the spent fuel from the existing nuclear plant units and the OL3 unit under construction will cost about EUR 3 billion. The majority of the costs, over EUR 2 billion, is caused by the final disposal plant operation, which will take about 100 years.

The final disposal costs are met by the nuclear power companies. The price of nuclear electricity covers the costs of nuclear waste management."

When will the final disposal begin?

"According to a schedule determined by the Finnish Government, the intended launch of the final disposal is in 2020. The planning of the final disposal has progressed according to that schedule."

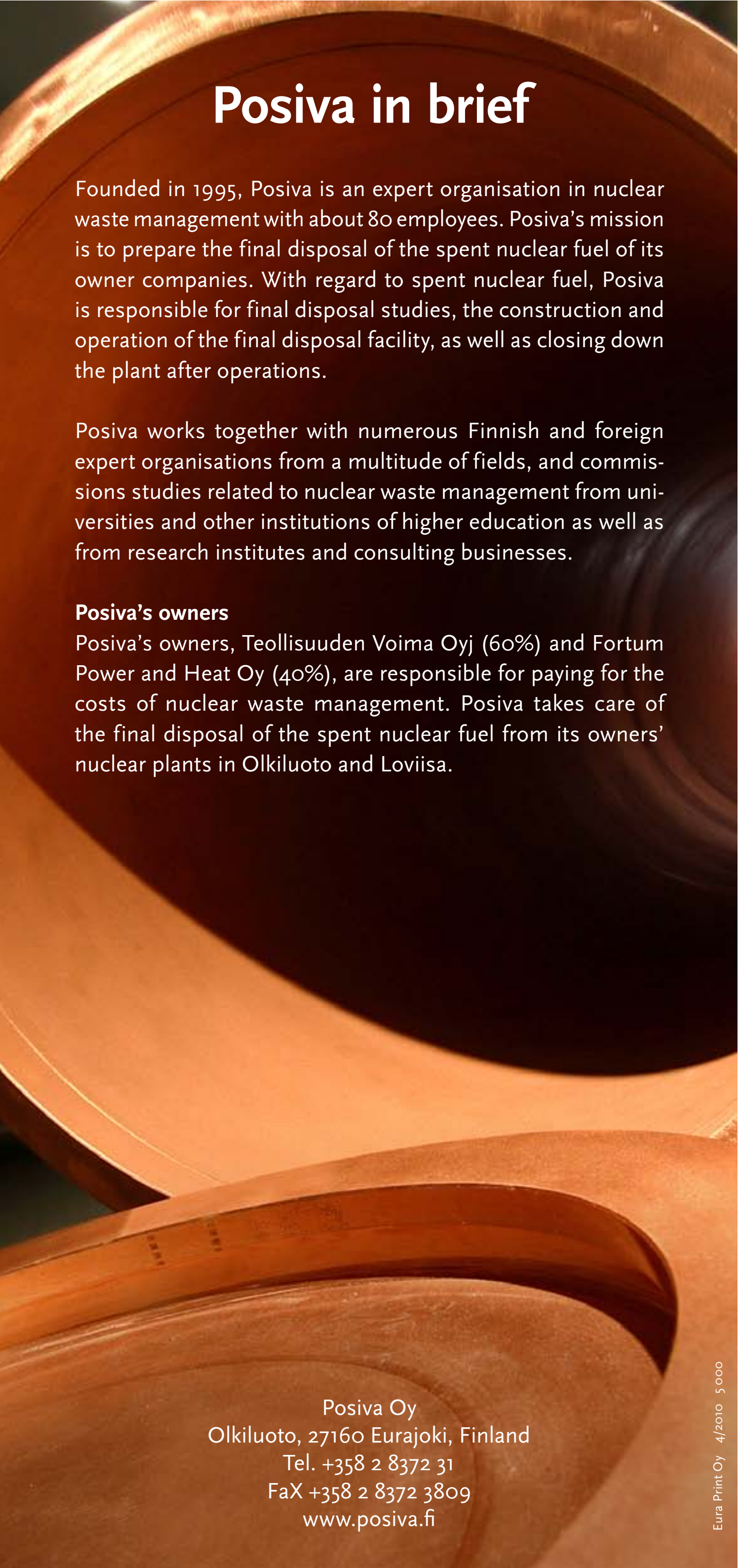
How long will the final disposal of the spent fuel take?

"The final disposal of the spent fuel from the existing nuclear power plant units and the Olkiluoto 3 unit under construction will take about 100 years."

Where are the spent fuel assemblies stored before they are taken to the final disposal facilities?

"Immediately after use, the spent fuel is highly radioactive. After removing it from the reactor, it is first stored in water pools in the reactor hall for a few years. Then the assemblies are transferred to water pools in the interim storage for spent fuel.

The spent fuel of the existing plant units will be in the interim storages for at least 20 years, and the fuel assemblies of the OL3 unit under construction will be in the interim storages for about 60 years. Interim storage is required because, among other things, the heat production of the fuel assemblies has to be reduced to the level required for final disposal."



Posiva in brief

Founded in 1995, Posiva is an expert organisation in nuclear waste management with about 80 employees. Posiva's mission is to prepare the final disposal of the spent nuclear fuel of its owner companies. With regard to spent nuclear fuel, Posiva is responsible for final disposal studies, the construction and operation of the final disposal facility, as well as closing down the plant after operations.

Posiva works together with numerous Finnish and foreign expert organisations from a multitude of fields, and commissions studies related to nuclear waste management from universities and other institutions of higher education as well as from research institutes and consulting businesses.

Posiva's owners

Posiva's owners, Teollisuuden Voima Oyj (60%) and Fortum Power and Heat Oy (40%), are responsible for paying for the costs of nuclear waste management. Posiva takes care of the final disposal of the spent nuclear fuel from its owners' nuclear plants in Olkiluoto and Loviisa.

Posiva Oy
Olkiluoto, 27160 Eurajoki, Finland
Tel. +358 2 8372 31
FaX +358 2 8372 3809
www.posiva.fi

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