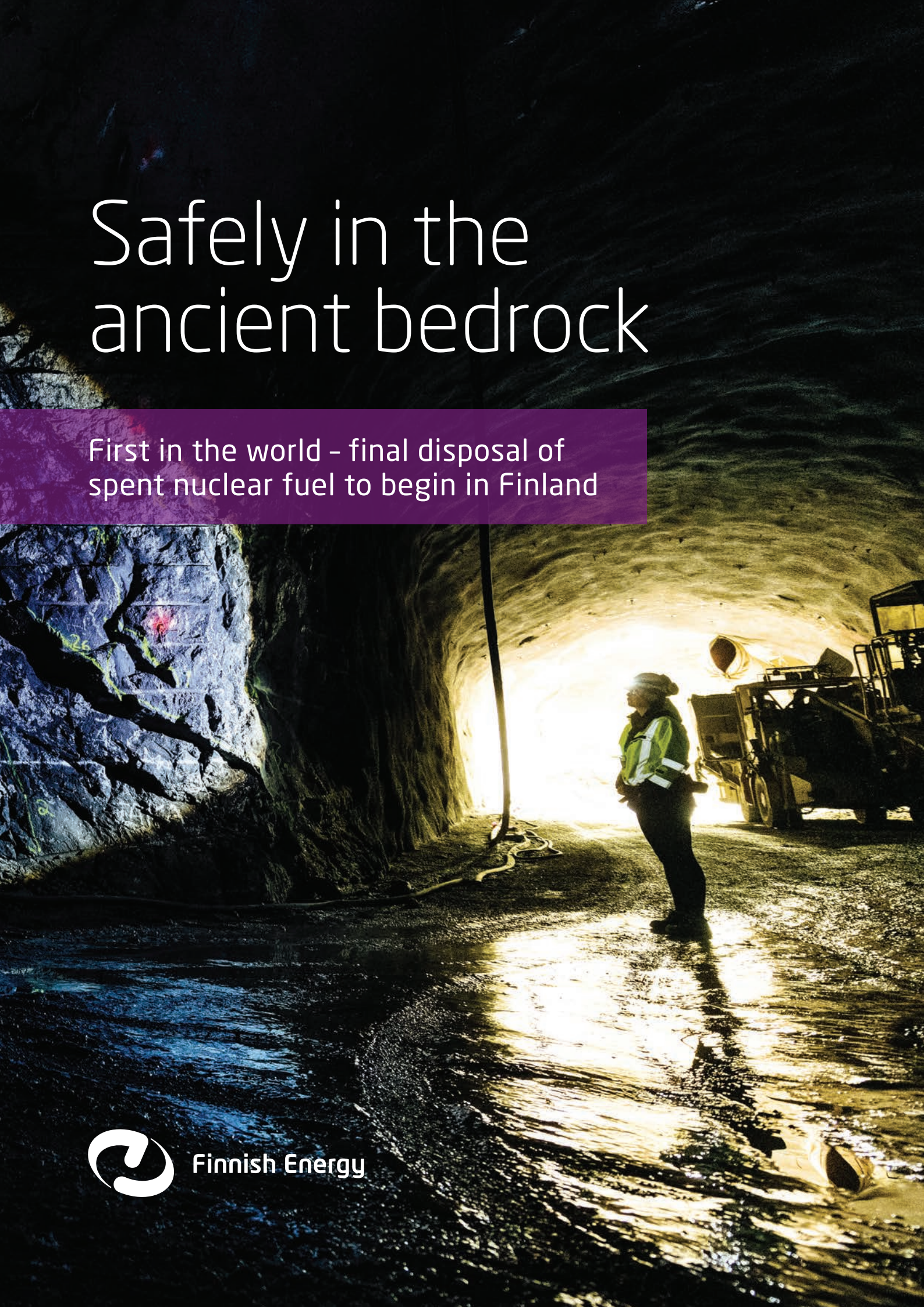
Safely in the ancient bedrock

First in the world – final disposal of spent nuclear fuel to begin in Finland



Finnish Energy

Nuclear power has a vital role to play in helping humanity to reduce CO_2 emissions from energy production. This presentation describes how one of the key issues related to sustainable nuclear energy has been solved in Finland. The road to the solution was not straightforward, easy or quick. Many technical, political and social challenges had to be overcome. It has all been about people. Nuclear power produces almost one-third of the Finnish electricity demand. Finns consider nuclear power to be a reliable and environmentally sustainable energy source.

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The failure of one barrier must not jeopardise the performance of the isolation as a whole.

The final disposal facility project has prepared for post-glacial rebound after future ice ages as well as other major changes taking place on Earth. The dark parts of the rock represent fragmented zones in the bedrock. The canisters are placed in solid bedrock.

Finland is one of the most successful countries in utilising nuclear energy. In the 21st century, Finland's four nuclear power plant units have been among the world leaders every year in terms of plant load factors.

Finland is also the first country in the world where the challenge of spent nuclear fuel disposal has been solved. Spent fuel will be disposed of in the bedrock at a depth of approximately 430 metres and isolated from the organic environment by multiple safety solutions called release barriers.

The result is nuclear waste management that is timely, cost-effective and, above all, safe. The Finnish solution considers the development of the disposal site conditions and the performance of the engineered release barriers as far as 250,000 years into the future.

The release barriers include the fuel's physical state, the disposal canister, the bentonite buffer, the backfilling of the tunnels and the stable, almost two billion years old bedrock. The barriers prevent the spent nuclear fuel from coming into contact with the organic environment or people under any circumstances. The failure of one barrier must not jeopardise the performance of the isolation. It must withstand any potential geological changes, such as future ice ages.

In Finland, nuclear power is produced by two private companies, Teollisuuden Voima (TVO) and Fortum. The owners of Teollisuuden Voima include some of the country's largest industrial companies and more than a hundred municipal electricity companies. Fortum is a listed company with the Finnish Government being the largest owner with a 51% share.

In 2000, based on the Finnish Government's decision-in-principle and the Parliament's endorsement on their joint application, TVO and Fortum agreed to dispose of their spent nuclear fuel in one location on the island of Olkiluoto at Eurajoki in western Finland. The repository is built and operated by Posiva, a company specifically established for the purpose.

Posiva started constructing the underground parts of the final disposal facility in 2016, and the cornerstone of the above-ground encapsulation plant was laid in 2019. The plant is due to be completed by the mid-2020s, after which final disposal can begin.

How did the solution come about?

Finland first became interested in nuclear power at the same time as most other Western countries. The training conditions required for the development and use of nuclear energy were fulfilled in 1962 with the first research reactor completed in Espoo. Fortum's predecessor, Imatran Voima (IVO), commissioned pressurised water reactors in Loviisa in 1977 and 1980, and TVO's two boiling-water reactors were completed in 1978 and 1980.

The Finnish State controlled the development of the nuclear energy sector tightly from the very beginning. The authorities and the Government only granted TVO's first plant a five-year operating license, because the company could not present a sufficient long-term plan for the management of spent nuclear fuel. The terms of the licence required for preparing for the future costs of nuclear waste management.

TVO applied for a new operating licence in 1982. The application was accompanied by a plan for

The bedrock has been excavated since 2004 and tens of kilometers of tunnels have been created. The disposal depth is approximately 430 meters.

delivering the spent nuclear fuel abroad. However, at the same time, the company also made preparations for final disposal in Finland. The solution was based on a Swedish concept where fuel assemblies are packed in canisters made of copper and cast iron. These would then be disposed of in the bedrock at a depth of 400 to 700 metres. The first disposal was scheduled to take place around 2020.

The Finnish Government approved TVO's plan. In its decision-in-principle, the Government also

outlined a roadmap for searching for a final disposal site in Finland.

The decision has directed Finland's nuclear waste management to this day. Finnish decision-makers have concluded that radioactive waste is managed in Finland as it is Finland that benefits from the use of nuclear energy..

Not In My Back Yard

After obtaining the new licence, TVO started to gather information on the technology and geology related to final disposal in 1983.

A review of the existing geological data of the Finnish area revealed over a hundred sites likely to be suitable for final disposal, of which five were selected for preliminary site surveys conducted in 1987–1992. Of these, three were selected for detailed site surveys. At this point Loviisa, where Imatran Voima's nuclear power plants are located, became the fourth possible site as the export of nuclear waste, which IVO had relied on until then, was prohibited by law in 1994. It led to the founding of Posiva Oy to take care of the final disposal of both companies' spent fuel.

Detailed site surveys lasted from 1993 to 1999. During both the preliminary and detailed site surveys, interaction with different stakeholders was very active. People and stakeholders were heard, and their questions answered.

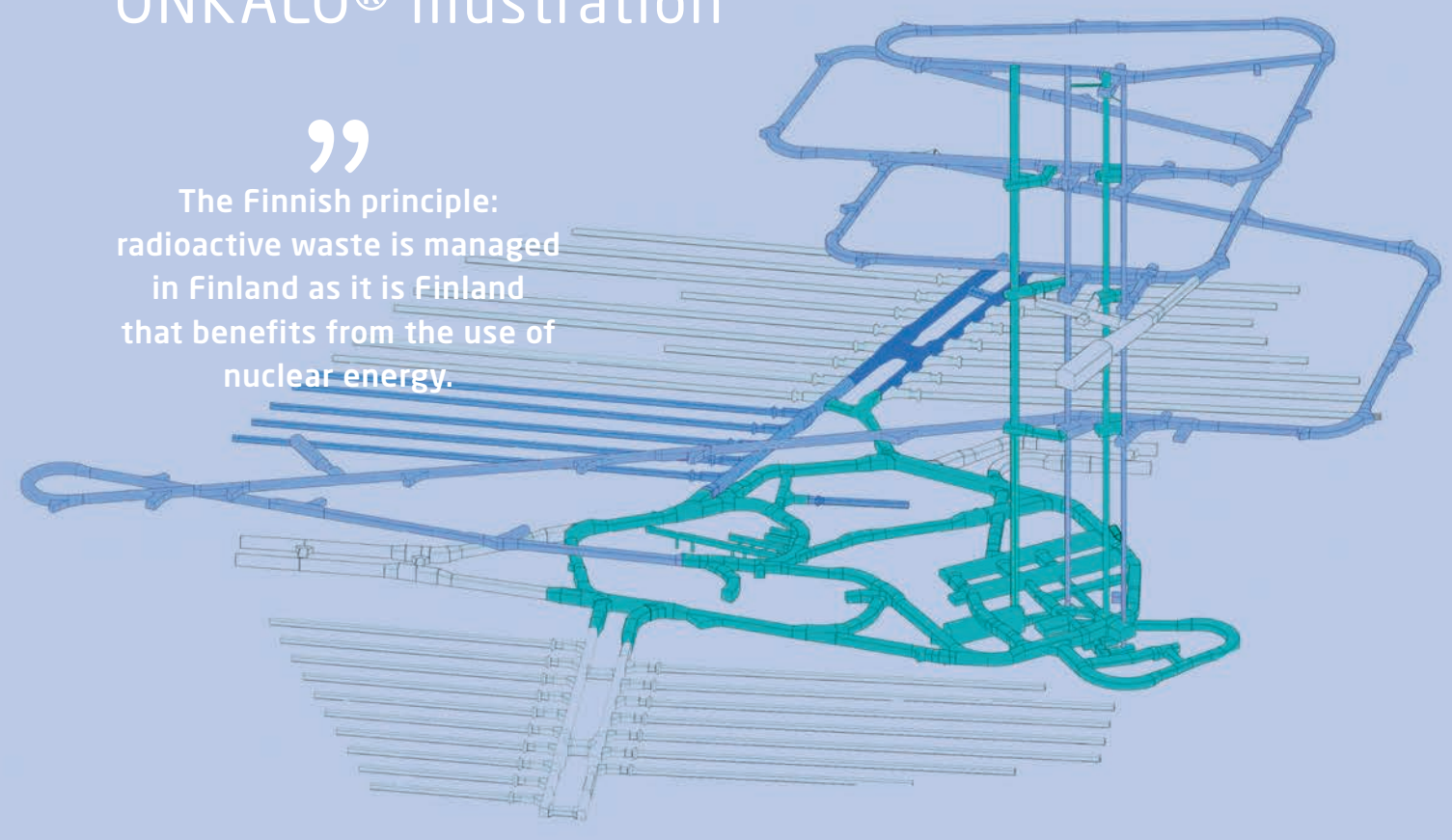
Local offices set up in all the survey localities organised briefings, exhibitions and meetings. The views of the municipalities and their residents were also emphasised in the new Nuclear Energy Act which entered into force in 1988. A procedure in the Act guaranteed municipalities veto right over the construction of any nuclear facility. Municipalities could, therefore, reject any final disposal project in their respective area.

Another significant factor from the project interaction point of view was the Act on Environmental Impact Assessment Procedure (EIA), which entered into force in 1994. The subsequent EIA procedure between 1995 and 1997 with the associated socio-economic impact assessments and multi-level interaction arrangements was by far the most extensive of the EIA procedures at that time. It would still be on a par with the current EIA procedures even though the level of requirements and quality has substantially tightened over the past 25 years.

In the encapsulation plant, the lid is closed by friction stir welding, creating a tight and durable seam. The seam is checked by an ultrasonic examination. Inspected and approved canisters are transferred to the ONKALO® final disposal facility.

ONKALO® illustration

The Finnish principle: radioactive waste is managed in Finland as it is Finland that benefits from the use of nuclear energy.



ONKALO® in numbers

- Disposal facility with a capacity of approx. 3,300 canisters
- Disposal depth of approx. 430 metres at an area of approx. 2 km²
- Encapsulation plant with a service life of approx. 100 years
- Total length of tunnels approx. 42 km

Spent nuclear fuel is encapsulated in the above-ground encapsulation plant and placed in the deposition tunnels deep in the bedrock. The canister is installed into the deposition hole, as shown in the figure, and surrounded with bentonite clay. The tunnels are also filled and then sealed with a massive plug. Finally, all structures are dismantled, and all underground facilities are filled.

Posiva sought to ensure that the EIA procedure would entail genuine dialogue with local residents. People's concerns could be reduced through open and respectful discussion.

Prohibition of the export and import of waste

When preparing its application for EU membership, Finland decided that the export of nuclear waste, and the possibility of importing it into Finland, must be banned. This was incorporated in the Nuclear Energy Act of 1994. On 1 January 1995, Finland became a member of the EU.

TVO and Fortum, the owners of the nuclear power plants, had to develop a new waste management strategy. Set up for this purpose, Posiva Ltd began operations in 1996.

In 1999, based on the site surveys, close interaction, people's opinions and many other factors, Posiva chose Olkiluoto in Eurajoki as the final disposal site and submitted the single most significant project application, the application for a decision-in-principle.

The subsequent decision-in-principle would be taken by the Finnish Government. The Finnish Parliament would then either approve or reject the decision. The most important parts of the decision-in-principle application are the safety assessment carried out by the Radiation and Nuclear Safety Authority (STUK) and the Environmental Impact Assessment Report.

Before a decision-in-principle can be made, the municipal council of the disposal site location must approve the project. In 2000, the Eurajoki municipal council voted 20–7 in favour of the project. Eurajoki residents were accustomed to trusting nuclear power plants which had operated reliably and brought work and tax revenue to the municipality. The attitude towards the project was generally positive, and Eurajoki people also felt responsibility for resolving the waste issue related to nuclear power, which had brought a lot of good to the municipality.

Then, the Finnish Government added a new implementation requirement for the project, called the retrievability of disposed spent nuclear fuel.. It meant that the disposal facility should be planned so that retrievability of the waste canisters is maintained to provide for such development of technology that makes it a preferred option. This had a positive effect on the discussion in the Finnish Parliament concerning the acceptability of final disposal. The Parliament also justified the acceptability of the project by the fact that the current generation should resolve the issue of spent fuel and not pass it on to future generations. In May 2001, the Parliament approved the project by 159 votes to three.

After the favourable decision-in-principle, Posiva concentrated its operations in Olkiluoto and began constructing an underground research facility in 2004. It was named ONKALO®, and it will be a part of the actual disposal facility.

The one who benefits, pays

The preliminary research phase in ONKALO® ended in the early 2010s. Thorough geological, hydrological and geochemical surveys showed Olkiluoto bedrock to be a stable and sufficiently intact site for nuclear waste disposal.

In 2012, Posiva submitted an application for the construction of the actual disposal facility to the Government. With the Government's approval in 2015, Posiva received the world's first construction licence for a geological disposal facility.

The next step in the project is to submit an operating licence application. The final disposal will begin in the mid-2020s and continue for about 100 years, because the third Olkiluoto nuclear reactor to be commissioned in the early 2020s will produce spent fuel until at least the 2080s. During this period, approximately three thousand five-metre containers will be disposed of in ONKALO®, each of which will hold about two tons of waste. The tunnels are then filled one by one with bentonite clay and sealed with a steel and concrete plug.

The costs of the long and demanding operation have been taken into account in the electricity production costs starting from the beginning of the nuclear power plants' operation. To cover the final disposal costs, the nuclear power companies have transferred funds into the National Nuclear Waste Management Fund managed by the Finnish State. This way, the State ensures that there is enough money in the fund to cover the costs now and in future.

Support for nuclear power in Finland has always been on a relatively high level, and concerns about the climate change combined with the solution for the waste question have raised it to a record level in recent years.

The final disposal has been prepared for by exploring the Finnish bedrock since the 1980s. That period also saw the start of surveys related to the engineered release barriers and long-term safety.

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Responsibility requires transparent and factual communication. People's concerns can be reduced by an open and honest discussion on the respective topics.

The canister has been placed in the bedrock, and the tunnel leading to it filled with bentonite clay.

Companies pay the final disposal costs in advance

In 1988, the Finnish State established the Nuclear Waste Management Fund to collect, preserve and invest the funds needed for future handling and storage of nuclear waste, thus ensuring the financial possibilities for nuclear waste management under all circumstances.

The fund capital consists of annual fees paid by the companies under nuclear waste management obligation, and the yield of the fund.

The companies make payments into the fund, managed by the Ministry of Economic Affairs and Employment of Finland, in proportion to the nuclear power they produce. The Ministry is responsible for ensuring that the payments cover the costs of future nuclear waste management. The costs also include research and development activities as well as regulatory control and administration.

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Energiateollisuus

Finnish Energy (ET) is a branch organisation for the industrial and labour market policy of the energy sector. It represents companies that produce, procure, distribute and sell electricity, gas, district heat and district cooling and related services.

Images: Posiva Oy, TVO, Taju

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