REVERSE LOGIC - SAFETY OF SPENT NUCLEAR FUEL DISPOSAL

NUCLEA

GREENPEACE

Antti Lempinen and Marianne Silvan-Lempinen
Ludus Mundi Oy
Commissioned by Greenpeace International

GREENPEACE

Executive summary

The political and public acceptance of nuclear power depends partly on the issues of nuclear waste and safety. Therefore, the nuclear industry has to show that it has a solution to the problem of spent nuclear fuel.

Finland intends to be a pioneer in the nuclear renaissance. The main reason for this is the special role the dependence on electricity plays. Despite its small population, Finland uses more electricity per capita as the OECD countries on average and its energy consumption is rising. Half of the consumed electricity in Finland is used by the industry, with the paper and metal industry playing a major part in this. Therefore, availability of cheap electricity is considered to be an important factor for the economical competitiveness of Finland.

Posiva is the company to whom its owners, the nuclear power operators in Finland, have given the task of disposal of the spent nuclear fuel. It has adopted the KBS-3 (Kärnbränslesäkerhet, version 3) as the method for disposal. KBS-3 is a deep geological repository concept originally developed in Sweden. Most of the research and development work relies on the co-operation with Svensk Kärnbränslehantering (SKB), which is the company responsible for the implementation of spent nuclear fuel disposal in Sweden. The technical core of KBS-3 has only changed a little since the introduction of its first version in 1977: the waste is placed in copper canisters into deposition holes with bentonite buffer surrounding the canisters at a depth of several hundred meters in the bedrock.

This report presents a historical analysis of administrative and political decisions in Finland regarding nuclear power with respect to Posiva's work to demonstrate the safety of the planned repository for spent nuclear fuel. The material used is mainly Posiva's publications and the Finnish legislation and decisions of the authorities and the policymakers.

The Finnish legislative framework for nuclear safety, and in particular nuclear waste management, has been developed in the past three decades. The Government set the timetable of the nuclear waste management with a decision-in-principle in 1983, and the timetable is still followed. The nuclear energy act came into force in 1987. It states that construction of a nuclear facility requires a Government decision-in-principle that the project is compatible with overall benefit for the society, and that the decision has to be ratified by the parliament. Furthermore, the Government decides over both the construction license and the operation license. The Nuclear Energy Act of 1987 was amended in 1994, and it was stated that all nuclear waste that is produced with nuclear power generation in Finland, must be processed, stored and disposed of, in a way intended as final, within the territory of Finland. The legislation sets the overall requirements for the safety of the disposal, and the Finnish Radiation and Nuclear Authority STUK is given the power to give more detailed instructions and supervise their implementations. In 1994, the Act on the environmental impact assessment process came into force. It requires that the environmental impact assessment (EIA) process has to be taken into account in the related projects somehow. As a result, the EIA was given a lot of weight. However, since the demonstration of the safety of the disposal system is not part of this procedure but a separate task, EIA distorts the information on the demonstration of the safety by confusing performed work and plans .

When the authorities give statements about the state of the disposal project, formal acceptance is related to the timetable of the project. This may lead to misinterpretation. Formal acceptance of the current state of the project does not mean that the safety of the repository is demonstrated. A preliminary safety case, the collection of all the evidence and arguments to demonstrate the safety, is required in 2012 when Posiva should submit the application for the construction licence. The complete safety case will not be required before 2018, when the operation licence should be applied for. In other words, demonstration of the safety is not yet officially required.

Posiva has not yet completed the safety case, which is a collection of all the evidence and arguments to demonstrate the safety of the facility. Although Posiva's work fulfils mainly the requirements of the STUK at the current point of the formal administrative procedure, the authority has pointed out several shortcomings in the preliminary safety case material. These include

- Insufficient description of the initial state of the system;
- Open safety issues regarding the canister and the buffer;
- Unclear relation between the description of the disposal site and the long-time safety of the repository.
- Furthermore, some of the work is schedule-critical according to STUK.

Currently there are many open questions related to the safety of each barrier – the copper canister, the buffer around the canisters, the backfill of the tunnels and the rock – and the waste itself. The currently open questions include amongst other things:

- Initial state of the waste: there are uncertainties in the description of the amounts of different radionuclides;
- Corrosion of the copper canister: possibility of corrosion of copper in pure water is not yet ruled out;
- Erosion of the buffer: the buffer material may be transported away from the deposition hole in certain conditions;
- Alteration of the buffer;
- Piping in the backfill: the material used for tunnel backfill may be transported away by rapidly flowing groundwater coming from the rock.

Posiva has presented plans for finding solutions to most of these questions. However, the existence of the plans does not guarantee that a realistic solution will be found. Not every plan will always succeed. The belief in the capability of science and technology to solve any problem should not be the base for decisions having far reaching consequences.

Nuclear waste is an existing problem that needs a solution whether or not nuclear power is generated in the future. If nuclear power plants are in operation, it has to be openly admitted that also nuclear waste management involves – at least currently – uncontrolled risks, that may have consequences for very long time. This is an especially important issue when nuclear energy is discussed on a global scale, since trends of a global scale originate and accumulate from local decisions.

GLOSSARY 6

INTRODUCTION 7

FINNISH NUCLEAR SAFETY LEGISLATION. 10
THE NUCLEAR ENERGY ACT. 10
ACT ON THE ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE 11
GOVERNMENT DECREE ON THE SAFETY OF DISPOSAL OF NUCLEAR WASTE 12

MULTI-BARRIER SYSTEM 14
THE WASTE 15
THE CANISTER 16
THE BUFFER. 16
TUNNEL BACKFILL 17
THE ROCK 18

SAFETY CASE 19
FEATURES, EVENTS AND PROCESSES 19
FORMULATION OF THE SCENARIOS 20

RESEARCH AND DEVELOPMENT PLANS. 21
THE INITIAL STATE OF THE SPENT FUEL 22
CORROSION OF THE COPPER CANISTER 22
EROSION OF THE BUFFER 23
ALTERATION OF THE BUFFER MATERIAL. 23
PIPING IN THE BACKFILL 23

CONCLUSIONS 25

APPENDIX 30

SUMMARY OF FORMAL PROCEDURES 30

Table of Figures

Figure 1. The planned repository in Olkiluoto. 14
Figure 2. The multi-barrier system of a KBS-3 repository for spent nuclear fuel. 15
Figure 3. The distinction between KBS-3V and KBS-3H. 17

Table of Tables

Table 1. The number of open issues in the R&D plans for the current and the past two three-year periods in Posiva's research programme. 22

Glossary

BWR	Boiling water reactor, the reactor type of Olkiluoto-1 and Olkiluoto-2
DiP	Decision-in-Principle
EBS	Engineered barrier system
EIA	Environmental impact assessment
EPR	European pressurised water reactor, the reactor type of Olkiluoto-3
Fortum Oyj	Owner company of the Fortum Power and Heat, a nuclear power plant operator
MEE	the Finnish Ministry of Employment and the Economy
ONKALO	The underground rock characterisation laboratory in Olkiluoto
Posiva Oy	The company responsible for implementation of management of nuclear waste from nuclear power plants in Finland
SKI	The Swedish Nuclear Power Inspectorate
SKB	Svenska Kärnbrenslehantering Ab, the company responsible for the nuclear waste management in Sweden
STUK	The Finnish Authority for Radiation and Nuclear Safety
TKS	Reaseach and development plan
TVO	Teollisuuden Voima Oy, a nuclear power plant operator
VVER	The pressurised water reactor type of Loviisa-1 and Loviisa-2

Introduction

The political and public acceptance of nuclear power depends partly on the issues of nuclear waste and safety (European Commission, 2006, Section 2.1). Therefore, the nuclear industry has to demonstrate that it has a solution to the problem of spent nuclear fuel. This report deals with the current state and development of the chosen way to dispose of the spent nuclear fuel in Finland.

The problem of spent nuclear fuel is an undeniably existing challenge. There is currently about 1900 tons of this high level nuclear waste in the Finnish interim storage facility (MEE, 2009). Eventually, a permanent solution is needed. However, questions arise not only about the already existing waste, but also about the justification of producing more waste in nuclear power plants. One of the objectives of this report is to analyse the connection of these two aspects of nuclear waste management. They are not inseparable – although usually so considered – because the best possible solution, whatever it is, for existing waste is not necessarily safely scalable to a larger amount of waste. Maximising the safety may imply minimising the amount of the waste.

Finland intends to be a pioneer in the nuclear renaissance. There are several reasons for this. One is the special role the dependence on electricity plays (see Fact Box 1): Despite its small population, Finland uses twice as much electricity per capita as the rich industrialised countries on average and its energy consumption is rising. Half of the consumed electricity in Finland is used by the industry, with the paper and metal industry playing a major part in this. Therefore, availability of cheap electricity is considered to be an important factor for the economical competitiveness of Finland.

When the four currently running nuclear power plants in Olkiluoto (Olkiluoto-1 and Olkiluoto-2) and Loviisa (Loviisa-1 and Loviisa-2) were built in the 1970s, nuclear waste management was not a big issue in the public discourse in Finland. The reason was mainly that the spent nuclear fuel from the Loviisa power plants was exported to Chelyabinsk in Russia, and according to the report of the Work group for radioactive waste and fuel APO in 1978, all the high level waste should be exported for reprocessing (Raittila et al. 2002, p. 12). The working group emphasised though, that the international development of the fuel cycle should be observed, and the state should also prepare for long-term storage and possibly even final disposal in Finland. Thus, the Finns decided to wait for developments in Sweden, where, contrary to Finland, the attitude towards nuclear energy was an issue with great political importance.

In Sweden, the political controversy resulted in the Nuclear Power Stipulation Act (SFS, 1977, No. 140). According to the Act, the owner of a nuclear power plant had to show how and where the spent nuclear fuel could finally be stored with ”absolute safety” before fuelling of the reactor was allowed. To meet this demand, the Swedish nuclear power operators initiated the KBS project (an abbreviation of kärnbränslesäkerhet, nuclear fuel safety) and developed in 1977 in mere nine months a concept for deep geological disposal (KBS, 1978).

The KBS method is a multi-barrier system where the spent nuclear fuel is deposited in copper canisters into boreholes at depths of 400 to 500 metres and surrounded by buffer material with suitable properties (Posiva, 2010). The initial application for permit to fuel the Ringhals 3 reactor was rejected, because the review process brought up problems and uncertainties in the KBS method (Lindskog and Sundquist, 2004). For example, it was considered impossible to find a host rock with required properties.

Fact Box 1

Finland consumed about 81 TWh electricity in 2009, during the global recession (British Petroleum, 2010). This corresponded to about 0.78 % of electricity generation of OECD countries (Statistics Finland, 2010). However, the population in Finland is only about 0.45 % of the population in all the OECD countries. Thus, Finland uses 1.7 times more electricity per capita than the rich industrialised countries on average. Finland is the most northern industrialised country in the world, and energy is used for heating. However, heating is only a small part of the electricity consumption. Finland has the best ratio of combined heat and power generation and most of the heat is not generated through direct electrical heating. The industry uses about half of the electricity consumed in Finland, and majority of that is used by the paper and metal industry. Since the economy of Finland is strongly export driven, it is easy to understand the political pressure to find solutions for keeping the price of electricity low. In addition, 14 % of the electricity consumed in Finland in 2007 was imported, mostly

from Russia, hence the self-sufficiency requirements cause need to increase domestic electricity generation. At the same time, climate-change policies put conditions on choices of energy production. The industry promotes nuclear power as the solution to these energy. Nuclear power operator Teollisuuden Voima Oy (TVO) is currently constructing a reactor unit, Olkiluoto 3, and three applications for decisions-in-principle were submitted in 2008 and 2009. The Finnish Parliament accepted two of these in July 2010.

When the revised application was submitted, the Government had delegated the decisional power to the Swedish Nuclear Power Inspectorate SKI. It took a new stand on the meaning of 'absolute safety' in that

> *'the importance of the requirements on the geological barrier shall not be exaggerated, and the long-term processes in the rock are not that important anyway, as long as the other barriers are good' (SKI, 1979, p. 33).*

In other words, SKI stated that all the deficiencies in the host rock could be compensated by the proper design of the engineered barriers. SKI granted permission to fuel Ringhals 3 reactor in March 1979. The company that the nuclear power producers had given the responsibility for handling all the nuclear waste they produce to, the Swedish Nuclear Fuel and Waste Management Company SKB, has ever since worked to get public acceptance for the KBS method. SKB's work has been successful until recently, when demand for consideration of alternative methods has gained strength (Kärnavfallsrådet, 2011, p. 78).

When the Finns negotiated with the Soviet Union over the first nuclear reactor of Loviisa in the late 1960s, uranium reserves were estimated to be so small that reprocessing was considered as the most reasonable solution for spent nuclear fuel. Therefore, as a condition for the agreement, Atomenergoexport, the authority in the former Soviet Union responsible for the export of non-military nuclear technology, required that this strategically important material should be returned to the Soviet Union. The other nuclear power plant operator Teollisuuden Voima Oy (TVO) did not have this option for Olkiluoto-1. The Swedish supplier ASEA-atom could not accept the spent fuel and the Soviet Union only took care of the material from reactors it had delivered. Therefore, in the application for the construction licence in 1973, TVO merely referred to research work in Sweden. In the application for the operation permit in 1979, TVO proposed that the spent fuel should be kept in interim storage facilities at the power plant site for the time being and that a national organisation for nuclear waste management should be established. Since the Finnish Government was not completely satisfied with the nuclear waste management of TVO, the reactors in Olkiluoto were initially given operation permit for only five years, until the end of 1983. (Patrakka, 2007)

There are no statistics available about atitudes towards nuclear energy in Finland in the 1970s. A survey done by Kiljunen (2010, Chapter 2) in 1984 shows that there were more people opposing construction of the fifth nuclear power plant than supporting it, but the mode of the answers to the question about that was "difficult to say". Thus, the nuclear energy in Finland was politically not as hot an issue as in Sweden in the late 1970s, although the Three Mile Island incident (USNRC, 2009) brought up some anxiety.

In 1983 the Finnish Government made a decision-in-principle about nuclear waste management. It stated that the primary option should be exporting the spent nuclear fuel for reprocessing, but if that cannot be done, direct disposal – i.e. disposal without reprocessing – should be carried out in Finland so that the site should be selected by the year 2000 and operation should start in 2020. The schedule has not been changed since this decision. TVO started a research and development program including also site selection for disposal. The disposal method was based on the Swedish KBS-3 concept despite its problems and uncertainties identified during the review process. The research in Finland mainly concentrated on geological issues, and the development of the engineered barriers relied mostly on the work of SKB. The operator of the Loviisa power plants, state-owned Imatran Voima Oy (IVO) continued to export nuclear waste to the Soviet Union.

The 1994 amendment in the nuclear energy act forbid import and export of spent nuclear fuel by 1996, and IVO decided to join the nuclear waste management efforts of TVO. In 1995, IVO and TVO set up the company Posiva Oy, which was given the task to take care of the final disposal of spent nuclear fuel. Posiva Oy continued the site selection procedure from the point where four potential locations remained. It concluded that it was impossible to say which of these sites has the best geological and Olkiluoto was chosen as the most convenient option: the inhabitants of the nuclear municipality accepted the disposal facility – not completely without resistance, though – and the location near one of the power plants was an advantage (Kojo, 2009). Posiva submitted the application for decision-in-principle to dispose of the high level nuclear waste into the bedrock of Olkiluoto, and it was granted by the Government in December 2000 (Finnish Government, 2000) and ratified by the Finnish Parliament in May 2001.

It is worth mentioning that, although the Finns have officially chosen the once-through cycle with deep geo-

[1] *IVO was merged with Neste Oy in 1997, forming Fortum Oyj. The Loviisa power plant is currently operated by Fortum Power and Heat Oy, a company completely owned by Fortum Oyj.*

logical disposal, there are still experts within the nuclear energy field who believe that final disposal in the Finnish bedrock is a back-up plan and the spent nuclear fuel will be re-cycled. One of these experts is Jukka Laaksonen, the STUK Director General (Henriksson, 2008).

Most of the research and development work of Posiva relies on co-operation with SKB, and the core of the technical solution is still the same as in the KBS-3 method: the waste is placed in copper canisters into deposition holes with bentonite buffer surrounding the canisters at a depth of several hundred meters in the bedrock (KBS, 1983; Posiva, 2010).

The Finnish way of solving problems is more technocratic and administrative than in Sweden. Rather than viewing the disposal of nuclear waste as a political, let alone ethical problem, it is boiled down to a mere question of engineering skills. This feature of Finnish society is revealed in the final report of the Country Brand Delegation commissioned by the current Foreign minister of Finland (Country Brand Delegation of Finland, 2010, p. 81):

> *"In Finland, problems are usually not solved by eradicating the cause. Instead, we seek ways of solving the problem, often with the help of technology. [-] Thus, problems are rarely political, let alone moral. This belief in how the world can be modified to suit humankind brings with it a fundamental attitude to life. Finland is a country where engineering skill provides the answer even to the disposal of nuclear waste. In other countries this would be an ethical problem, here, it is a practical one."*

Nuclear technology involves risks that cannot be completely eliminated. Therefore, it may not be stripped of moral and ethical questions. Choice between different kinds of risks is not a technical problem only.

This report presents a historical analysis of administrative and political decisions in Finland regarding nuclear power with respect to Posiva's work to demonstrate the safety of the planned repository for spent nuclear fuel. The material used is mainly Posiva's publications and the Finnish legislation and decisions of the authorities and the

The Finnish legislative framework concerning the management of the high level nuclear waste is explained in Chapter 2.

In Chapter 3, the essential content of the KBS-3 concepts is described, with an analysis of the biggest challenges and changes in the design.

Chapter 4 is devoted to Posiva's safety case. The requirements for the safety case are described. Its current state and recent developments are analysed against the requirements and the analysis compared to official interpretations.

Chapter 5 gives an insight into the research and development plans of Posiva Oy, and provides an analysis of how they are related to progress of the work done so far. The current level of the technical knowledge is analysed against the requirements of the authorities and general scientific methods.

Chapter 6 contains conclusions and an analysis of the political decisions made in Finland regarding nuclear power and its licensing. It is shown that these are largely based on a reversed logic and an unwarranted faith in technology.

[2] *The somewhat obscure task of the Country Brand Delegation appointed by Minister of Foreign affairs Alexander Stubb in 2008 was to create a strategy for Finland that would convince the world to turn to Finland often and more effectively.*

Finnish nuclear safety legislation

The Finnish legislative framework for nuclear safety, and in particular nuclear waste management, has been formed in the past three decades. The timetable of the nuclear waste management was set by the Government with a decision-in-principle in 1983, and it is still followed.

The Nuclear Energy Act

The Nuclear Energy Act of 1987 (MEE, 2009b) gave the municipalities an absolute veto on the siting of the repository. It made public acceptance of the nuclear waste management vital for any plan of final disposal. The amendment to the Act in 1994 stated that all nuclear waste that is produced with nuclear power generation in Finland, must be processed, stored and disposed of, in a way intended as final, within the territory of Finland. This conclusively changed the strategy of IVO, which exported the spent nuclear fuel to Russia.

The Nuclear Energy Act states that

"Construction of a nuclear facility of considerable general significance shall require a Government decision-in-principle on that the construction project is in line with the overall good of society." (MEE, 2009b, Chapter 4)

The main point of this clause is to make decisions regarding nuclear facilities political instead of purely administrative. The parliament can either reject or approve the decision-in-principle (DiP); it cannot make any changes or put any conditions. When Posiva applied for a decision-in-principle on the disposal of high-level nuclear waste to the Government in 1999, the main focus of the discussion was on the selected site. Posiva proposed Olkiluoto in the Eurajoki municipality as the site for the final disposal and KBS-3 as the chosen method for executing the final disposal. Whether or not the construction project is "in line with the overall good of society" was mainly seen against the positively loaded intention to be a toprunner of nuclear technology and the need for electricity. The Government made a positive decision-in-principle in 2000, and the Parliament ratified it in May 2001. It is valid until May 2016, which is also the deadline for the filing of the construction license application.

The Government had five applications for decisions-in-principle at its hands in May 2009. Three of them were for new nuclear power plants and two for extensions of the repository in Olkiluoto. The applications for TVO's power plant Olkiluoto-4 and Fennovoima's first power plant (see Fact Box 2) were approved, as well as the application for extension of the Olkiluoto repository for the waste from Olkiluoto-4. One of the applications for new nuclear power plants was rejected, because the government decided not to give clear permission to export electricity produced with nuclear power (Finnish Government, 2010). The rejected application was for Fortum's Loviisa-3 plant. It is out of the scope of this report to discuss the reasons for Fortum being the company with negative decision. The Government rejected Posiva's application for expansion of the repository for wastes from Loviisa-3. There is no doubt that Posiva's application would have been approved, if the DiP about Loviisa-3 had been positive. Loviisa-3 project was not rejected because of rejection of Posiva's plans for expansion, but vice versa. Fennovoima stated in its application for the decision-in-principle (Fennovoima, 2010, p. 11) that it is going to manage the nuclear waste in co-operation with the other nuclear power operators. The decision of the Government was conditional (Finnish Government, 2010): Fennovoima has to either make an agreement of the co-operation or carry out an environmental impact assessment procedure (see Section 2.2) regarding its own repository in order to get a construction license. Thus far, Posiva and its owners have rejected categorically co-operation with Fennovoima. Since Posiva applied for the decision-in-principle for disposal of the waste from Loviisa-3, it's claim that there is no room for the waste from all the power plants accepted by the Government is contradictory.

Fact Box 2

Fennovoima is a company owned by Voimaosakeyhtiö SF (66 % of the shares) and E.ON Kärnkraft Finland Ab (34 %). Voimaosakeyhtiö SF is owned by 69 Finnish regional and local energy companies as well as companies in trade and industry (viite). Fennovoima was founded in 2007 to start a project for constructing a nuclear power plant.
Source: http://www.fennovoima.fi

According to the Nuclear Energy Act, the Nuclear Safety Authority STUK, is the authority with the decision power on the nuclear safety issues in Finland. It formulates the detailed safety requirements of nuclear facilities, including nuclear power plants and nuclear waste management. All the other administrative instruments within the nuclear power industry are at the hands of the Ministry of Employment and the Economy, which has formed a legal-administrative alliance with nuclear power industry and the formal procedure has neutralised the democratic political decision-making (Lampinen, 2009; Säynässalo, 2009).

Act on the Environmental Impact Assessment Procedure

The Act on the Environmental Impact Assessment (EIA) Procedure (Finnish Ministry of Environment, 1995) came into force in 1994. The act defines the concept of environmental impact as the direct or indirect effects inside and outside the Finnish territory of a project or operations on

- human health, living conditions and amenity,
- soil, water, air, climate, organisms, interaction between them and biodiversity,
- the community structures, buildings, landscape, townscape and the cultural heritage and
- utilization of natural resources.

According to the Decree on the Environmental Impact Assessment Procedure (Finnish Ministry of Environment, 2006) the Act applies to repositories for nuclear waste from nuclear power plants and the coordinating authority in procedures regarding nuclear facilities is the Ministry of Employment and the Economy (MEE). This is one example of concentration of the administrative tools concerning nuclear industry to the hands of the Ministry of Employment and the Economy. On the other hand, this kind of concentration of the decision power is typical for the Finnish administrative system.

The Act and the Decree on the EIA procedure define in a general way only, how the assessment should be performed. The EIA process is basically a formal conversation between the performer of the project, the general public and the authorities. The purpose of an EIA procedure is not to make any decisions concerning the project or its licensing issues. Its objectives are to produce information for decision-making and to increase the opportunities for citizens to be involved in the planning of the project and to express their opinions on it. This information cannot be ignored according to Section 13 of the Act on EIA procedure:

> *"An authority may not grant a permit for implementation of a project or make any other comparable decision before it has obtained an assessment report and the coordination authority's opinion on it.*
> *A permit or comparable decision on a project shall state in what way the assessment report and the coordination authority on it have been taken into account."*

In the case of nuclear waste management, the requirements on the long-term safety of the system and the timetable for demonstrating their fulfilment are defined elsewhere in the legislation. In the EIA procedure, it is sufficient to describe the requirements and the planned actions to demonstrate the safety.

Posiva performed an EIA procedure for the disposal of spent nuclear fuel during 1997 to 1999. This procedure was a prerequisite for the application for the decision-in-principle. It covered a total of 9,000 uranium tons of spent nuclear fuel, equalling the total amount of spent fuel from six nuclear power plants. In the assessment report (Posiva, 1999, pp.173, 182-183), Posiva refered to plans on the safety assessment and stated that nothing that compromises the safety was proven to exist. The fact that the safety of the disposal system had not been proven yet was hidden behind the amount of geological research work done during the site selection. The distinction between the design objectives and demonstrating the safety of the implementation was simply ignored.

In its statement about the EIA report (MEE, 1999), the coordinating authority seemed to give approval for this kind of description of the safety assessment:

> *"[-] the assessment of the essential parts of both the short term and the long term radiation effects as well as other health effects of the final disposal have been dealt with sufficiently in detail and duly taking into account the different stages of the final disposal."*

[3] The DiP is valid for five years, and the condition has to be fulfilled within six years. If Fennovoima applies for a construction licence before the condition is fulfilled, the license, if granted, will be conditional.

However, the sentence above is not a judgment of the safety of the repository, but it is an assessment of comprehension of the EIA report. The statement, when detached from its legal context, could be misinterpreted so that Posiva has demonstrated the safety of the repository. However, since demonstration of the safety is required only when the operation licence for the repository is applied, the correct interpretation is that Posiva has sufficiently detailed plans to demonstrate the safety.

The misinterpretation regarding EIA and the safety assessment gave Posiva's owners TVO and Fortum Power and Heat Oy an instrument to tie the decision-in-principle on the spent nuclear fuel repository to cover waste from two new nuclear power plants and back up their licensing procedures. Once the EIA procedure was carried out in February 2000, Posiva submitted an application for a DiP regarding the repository in November 2000. After that, in December 2000, Posiva specified in its letter to the Government that its application covered waste from only five power plants (6500 uranium tons instead of 9000 uranium tons), and asked to separate the decisions regarding the existing power plants and the fifth one (Finnish Government, 2000). TVO had already carried out an EIA procedure concerning a new power plant (TVO, 1999, p. 134), where TVO referred to POSIVA's EIA report in the section concerning the spent fuel. The positive DiP regarding the waste from the fifth power plant was made after a decision-in-principle was granted in 2002 for Olkiluoto-3, the power plant presently still under construction. Thus, regarding waste management within licensing of Olkiluoto-3, EIA procedure was given priority over DiP. Instead of providing information, the EIA procedure seems to have distorted knowledge about the safety of the spent nuclear fuel disposal.

In 2008, Posiva updated the 1990s EIA report on the request of the coordinating authority Ministry of Employment and the Economics. The updated report was appended to the application for the decision-in-principle concerning the final disposal of the spent nuclear fuel from the Olkiluoto 4 plant unit (TVO, 2008) (the original EIA already covered waste from six reactors). In 2008-2009, Posiva also carried out a new EIA procedure to include the spent nuclear fuel from the Loviisa 3 unit, so that the EIA procedures performed so far cover a total of 12000 uranium tons (Posiva, 2008). The application (Posiva, 2009) for the decision-in-principle for the expansion was rejected, because the decision-in-principle on the Loviisa 3 unit in 2009 was negative. The two companies that were granted a decision-in-principle were Fennovoima (Fact Box 2) and TVO. Fennovoima's unit will be located either in Simo or in Pyhäjoki on the shore of Gulf of Bothnia. An interesting battle over the disposal of waste from the Fennovoima unit is to be expected, because it has no agreements regarding cooperation with Posiva. Posiva has stated that there is no room for Fennovoima's waste in its repository, contradictory to its EIA report. The reason for this statement is that the extra room is still reserved for Loviisa-3 (Posiva, 2009b, p. 41).

Government Decree on the safety of disposal of nuclear waste

The basic principles of demonstrating the safety of the deep geological repository are expressed in the Government Decree on the safety of disposal of nuclear waste (MEE, 2008) (see Factbox 3). It gives quantified constraints on the accepted radiation levels for the operation of the waste facility and long-term impacts, as well as procedural guidelines (Fact Box 3), and states that the repository has to be based on the multi-barrier principle.

Perhaps the most difficult sections of the Decree to fulfil are those concerning the demonstration of the long-term safety and reliability in the safety case. It is stated there that long-term radiation safety, and the suitability of the disposal method and disposal site, shall be proven through a safety case. A safety case is a compilation of all the evidence and arguments to demonstrate the safety of the facility. It must include analyses of both expected evolution scenarios and unlikely events impairing long-term safety. It should also acknowledge all the relevant uncertainties. The structure of the safety case is guided in the Decision as follows:

Fact Box 3
Government Decree (736/2008) on the safety of disposal of nuclear waste defines guidelines
on
- **radiation safety**
- **design requirements**
- **long-term safety**
- **demonstration of compliance with safety requirements**
- **construction and operation**
- **organization personnel**

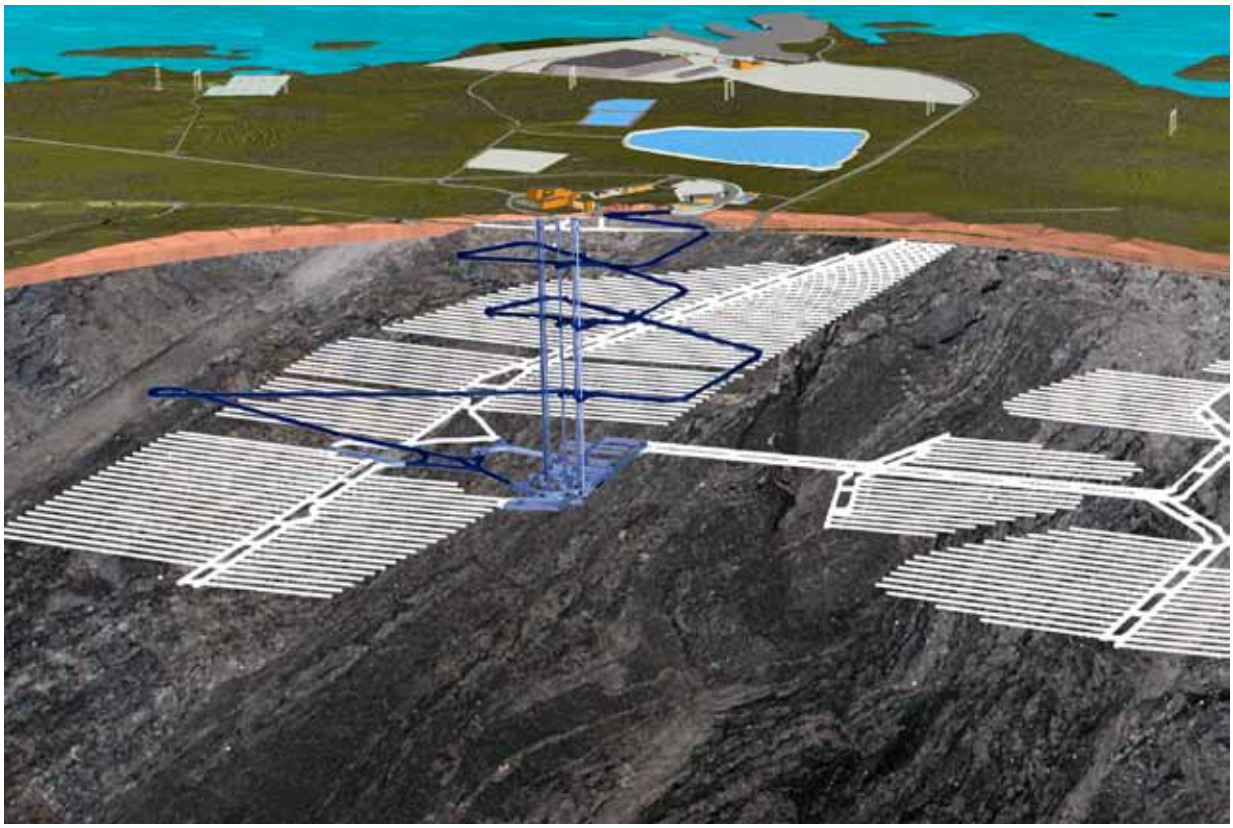
"The safety case comprises a numerical analysis based on experimental studies and complementary considerations insofar as quantitative analyses are not feasible or involve considerable uncertainties. [-] The input data and models utilised in the safety case shall be based on high-quality research data and expert judgement. Data and models shall be validated as far as possible, and correspond to the conditions likely to prevail at the disposal site during the assessment period. The basis for selecting the computational methods used shall be that the actual radiation exposure and quantities of radioactive materials released remain below the results of safety analyses, with a high degree of certainty. The uncertainties involved in the safety analysis, and their significance, shall be separately assessed."

Posiva's interpretation of safety case is described more in detail in Section 4.

From administrative point of view, the safety case, the EIA process and the decision-in-principle are intertwined as a complex toolset within: EIA reports of new power plants include references to EIA reports concerning the repository, the EIA report of the repository has references to the safety case plan, the DiPs of the new power plants rely on EIA reports regarding to waste management, and the safety case is confused with the EIA.

The formal procedures regarding nuclear facilities in Finland after 1994 are summarized in Appendix.

Multi-barrier system



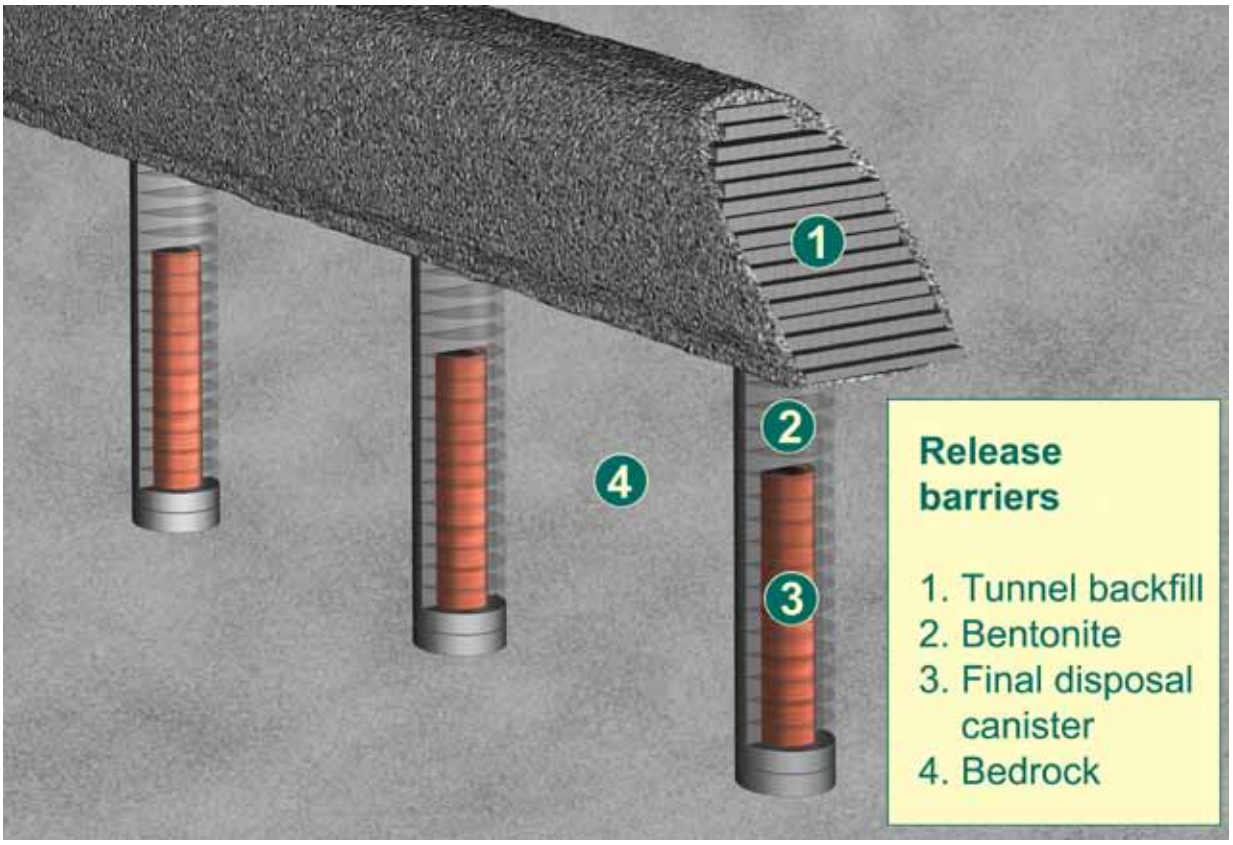
The planned repository in Olkiluoto. The underground rock characterisation facility ONKALO is painted in blue. (Illustration by Posiva Oy)

It is generally acknowleged that the most likely process that can lead to the release of radionuclides from a deep geological repository is transport by the groundwater. Practically the only other possibility is human intrusion – intentional or unintentional. Therefore, the main technical challenge of the system is to prevent the radionuclides from getting into contact with moving ground water.

The Finnish solution for the disposal of spent nuclear fuel is based on the KBS-3 method originally developed in Sweden. The idea of the disposal system is fairly simple. The waste will be put in copper canisters into the bedrock at a depth of several hundred meters (see Figure 1.). Since there is ground water in the bedrock, a buffer will be placed between the rock and each canister. The buffer material will reduce the movements of the ground water near the canister, so that corroding substances will not reach the canister surface, nor will the water transport the possible releases from the canisters to the bedrock. Therefore, the method is called a multi-barrier system with the four essential parts (see Figure 2.):

- the backfilling of the disposal tunnels
- the buffer between the canister and the rock
- the canister containing the fuel.
- the rock mass between the buffer and the biosphere

The third version of the concept, KBS-3, was published in 1983. Its technical core was essentially the same as in the original KBS-1 of 1977. Its main parts and how they are supposed to behave are described in the following.



The multi-barrier system of a KBS-3 repository for spent nuclear fuel (illustration by Posiva Oy)

The waste

The fuel of the nuclear reactors is uranium in form of ceramic pellets put in metal tubes called rods. The rods are joined together into fuel assemblies. The number of the rods in the assemblies depends on the type of the reactor, and it varies from 64 to 265. When a spent fuel assembly is removed from the reactor, it is put in a water basin in the reactor hall to cool down for a few years. The fuel assemblies are then transferred to the interim storage facility located in the power plant site – there is no central interim storage in Finland like CLAB in Sweden –, where they wait in water for about 40 years to be disposed.

More than 200 fuel assemblies are removed yearly from the currently operating reactors in Loviisa and Olkiluoto. Each assembly contains 120 to 180 kg of uranium, so the amount of uranium used there is about 40 tons a year in Olkiluoto and 20 tons a year in Loviisa.

The spent fuel consists mostly of uranium; only about 4% is transformed into other elements in the reactor in nuclear reactions. When the fuel is removed from the reactor, it is extremely radioactive. In the beginning, radioactivity of the fuel decreases very fast because of the rapid decay of the short-lived nuclides. After the cooling period of at least 20 years, the radioactivity of the fuel is about 1/1000 of that at the time of removal from the reactor, but it is still very dangerous to life if released in the biosphere.

Nuclear reactions in the reactor produce a wide range of different radioactive isotopes in the nuclear fuel. The processes are very complicated and the quantities of the radionuclides are not accurately known (Posiva, 2009b, p.330). If the canister is breached, there are two types of processes that can cause releases of safety-

relevant radionuclides. The fraction of the inventory that may be released instantaneously is called Instant Release Fraction (IRF) (Johnson et al, 2005). The other process is slow dissolution from the fuel matrix.

The canister

After the cooling period the spent nuclear fuel will be transported to the encapsulation facility at the repository site, and the fuel assemblies will be placed inside canisters consisting of a copper outer shell and a cast iron insert. The safety of the KBS-3 concept relies on the properties of the canisters. The other parts of the multi-barrier system should ensure stability of the conditions near the canisters and act as a back-up system. There are three main requirements for the canister properties:

- The canister must be air and gas tight and it must be able to isolate the fuel from the environment with a very high probability for at least 100,000 years.
- The canister must not endanger the performance of the other release barriers outside the canister.
- The fuel inside the canister must not become critical. At critical conditions, a nuclear chain reaction would be sustained.

The dimensions of the canisters vary depending on the origin of the fuel as described in Posiva's report on the canister design (Raiko, 2007, p.7). Both the canister for fuel from Olkiluoto boiling water reactors (BWR) and for fuel from VVER 40 type reactors in Loviisa will contain 12 assemblies. The canisters for the waste from the third plant under construction, referred to here as the European Pressurised Water Reactor (EPR), in Olkiluoto will contain four assemblies, since there are more fuel rods in each assembly. Diameter of all the canisters will be about one meter, but the length will be 3.6 m (VVER 40), 4.8 m (BWR) or 5.25 m (EPR). The total weight of one canister will be 18.6 (VVER 40), 24.3 (BWR) or 29.1 tons (EPR).

The decay of the radioactive nuclei in the waste produces radiation. The canister absorbs most of this radiation, which is thus transformed into heat. This heating power, called decay power, raises the temperature of the repository. The distance between the canisters should be sufficient to keep the temperature at the surface of the canister below 100 °C. In the reference case of these calculations, the decay power of one BWR canister is limited to 1700 watts. This is achieved by optimising the fuel composition in each canister. The optimisation is done with selecting fuel assemblies with different cooling times. The other types of fuel should produce an equal amount of heat per canister surface area, resulting in 1370 W for VVER 40 and 1830 W for EPR type canisters. The amount of radiation not absorbed by the canister will be limited with choice of materials to minimise the radiolysis of water outside the canister and to prevent alteration of the buffer material.

The mechanical load of the canister will mostly be caused by ground water and swelling of the bentonite buffer. These will add up to pressure of approximately 140 times atmospheric pressure (140 bar). During the glaciation, the supposedly 3 km thick ice sheet may triple the pressure on the surface of the canister. The weight of the ice sheet may also deform the disposal holes, so that the forces on the canister may vary depending on the direction.

The buffer

The canister should not be penetrated by corrosion in 100,000 years in the anticipated repository conditions. The main purpose of the bentonite buffer around the canister is to maintain these conditions and to protect the canister against chemical and mechanical damages. In the case of a damaged canister, the buffer should retard migration of radionuclides into the surrounding rock (Posiva, 2009b, p. 187).

Bentonites are types of clay that interact strongly with water. When bentonite is used as a buffer material, it is compacted to density of about 1.7 times the density of water. In this state, bentonite has voids that are filled with water and air. Width of most of the voids is in the range of 1 nanometer (1/1,000,000 mm), so there is not enough space for microbes. The volume of voids is about 40 % of the total volume of the material, and the voids will eventually be filled with water coming from the bedrock. Although ground water will be in contact with the canister, it is expected to be bound to the clay. Thus, ground water should not be able to transport harmful chemicals to the canister or possible radionuclide releases from the canister. (Miller and Marcos 2007, pp. 99-102).

When the bentonite buffer is placed in the deposition hole around the canister, it will take up water from the rock. Water replaces the air and expands the small voids so that the buffer swells and seals the openings in the buffer and in the deposition hole. This property is called

[4] Plastic means that certain kind of forces on the material are dampend by yielding of the material and the deformations are retained after the forces are no longer applied. Elastic materials transmit forces more directly and obtain the original shape after removal of fthe orces.

self-healing. Since the buffer is confined in the deposition hole, it cannot swell freely, and swelling pressure is generated. Most of the water is chemically bound to the bentonite. If the bentonite swells too much, the voids become so big that the water is not bound strongly enough and becomes mobile, i.e. the bentonite becomes more permeable to the water. Therefore, significant loss of buffer mass is not acceptable. (Miller and Marcos 2007, pp. 107-109)

Compacted bentonite is plastic material when it is saturated with water. Hence, it should also protect the canister from rock movements by yielding. However, the buffer should not let the canister sink to the bottom of the deposition hole.

In addition to these suitable properties, the choice of bentonite as the buffer material is based on the fact that it has been stable for millions of years in geological environments, which, on the other hand, do not have the elevated temperature of the repository environment. (Laine and Karttunen, 2010, .p. 109)

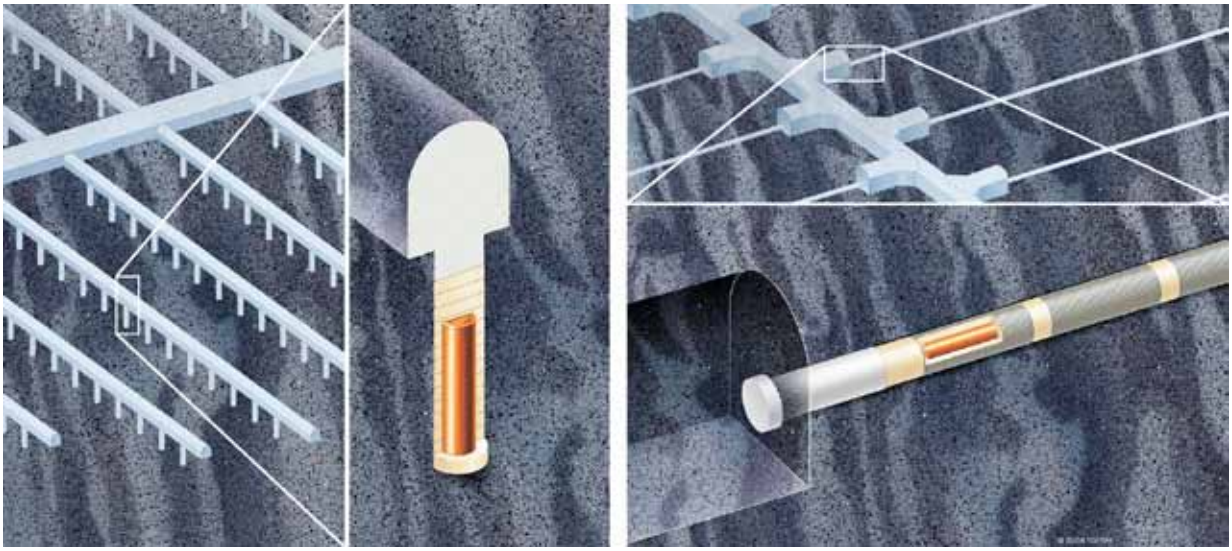
The buffer will be constructed of compacted bentonite blocks. In order to prevent the bentonite blocks and the canister from getting stuck during the installation, initial gaps have to be left between the canister and the buffer and between the rock and the buffer that will be filled due to the swelling of the bentonite. The gap at the canister side is designed to be 1 cm wide, while the width of gap at the rock side is not yet determined. Since the outer gap will be at least 25 mm wide, it has to be filled with bentonite in some form – pellets are currently the strongest candidate –, so that the total amount of bentonite in the deposition hole becomes adequately high. (Juvankoski, 2010)

The problem with bentonite is that the favourable properties – low water permeability, chemical stability, self healing properties and plasticity – can be lost in some conditions that has to be prevented from occurring.

Tunnel backfill

The tunnels in the repository must be filled so that they do not form pathways for groundwater flow that could damage the buffer and compromise the isolation of the canisters. The backfilling should also support performance of the bentonite buffer by restricting its swelling upwards. Design of backfilling is a difficult task, as can be seen from Posiva's most resent backfilling report (Keto et al, 2009).

The backfilling material has changed in the past decade. It was mentioned in Posiva's research and development plans for period 2004-2006 (Posiva, 2003), that there were indications that the reference backfilling design at that time, based on the use of crushed rock and bentonite, may not function properly in highly saline groundwater. For that reason, the current backfilling concept is based on the use of precompacted blocks and



The distinction between KBS-3V (vertical canisters, left) and KBS-3H (horizontal canisters, right) (Illustration by SKB)

pellets of clay. Partly because of these difficulties, SKV introduced an alternative repository concept without tunnel backfilling. In this alternative the waste canisters are not placed vertically in individual holes in the floor of deposition tunnels but several canisters are placed horizontally in the tunnel with the buffer material (Posiva, 2007). This alternative is called KBS-3H, and the original design is called KBS-3V to make a distinction. KBS-3V is the main candidate for the design in Finland, therefore the horizontal alternative is not discussed further in this report.

The rock

The official rejection of the first KBS concept in Sweden was mostly based on criticism of the requirements for the rock. It was argued that no rock with the specified properties could be found (Lidskog and Sundqvist, 2004). Later, the system relied more on the engineered buffers (National Research Council of the United States 1984). Those are the canister, the buffer and the backfill. The rock also gained most of the attention because the site selection has publicly been the most visible part of the repository project in Finland. Currently, the excavation of the underground rock characterisation facility ONKALO puts further emphasis on the rock properties.

The current requirements for the host rock of the repository are listed in Posiva's research and development plan for 2010-2012 (Posiva 2009b, p. 135):

- *"The characteristics of the host rock shall be favourable regarding the long-term performance of engineered barriers."*

- *"The location of the repository shall be favourable with respect to the groundwater flow regime at the disposal site."*

- *"The disposal depth shall be selected giving priority to long-term safety, taking into account the geological structures of the bedrock as well as the trends with depth in hydraulic conductivity, groundwater chemistry and rock stress."*

- *"The repository for spent fuel shall be located at the depth of several hundreds of meters in order to mitigate the impacts from aboveground natural phenomena, such as glaciation and human actions."*

- *"Such structures and characteristics of rock surrounding the waste emplacement rooms which may have importance regarding groundwater flow, rock movements or other factors affecting long-term safety, shall be defined and classified."*

Safety Case

The long-term safety of the repository concept should be demonstrated with a safety case. It is a collection of all the evidence and arguments to demonstrate the safety of the facility. According to the standards of IAEA (2008, p. 51), it shall also include an acknowledgement of all the existing unresolved uncertainties, of their relevance to the safety and approaches for their management. The safety case should be the main tool for the public and the authorities to make decisions regarding the disposal of spent nuclear fuel. Its compilation should be a continuous process with updates at each step of the development, construction and closure. Furthermore, it should be sufficiently detailed and comprehensive for regulatory authorities and other decision makers.

The information about the safety case of the repository is transmitted to the licensing procedure of new nuclear power plants through environmental impact assessment processes (see section 2). Since the statements of the coordinating authority do not assess the safety of the repository but the plans to demonstrate the safety, the problems of compiling the safety case are not mentioned in the statements. This reduces information in the public discussion.

According to the current timetable, Posiva should apply for the construction license by the end of 2012. The application cannot be postponed more than four years, because the DiP expires after that. A preliminary safety case should be attached to the application. The complete safety case should be included in the application for operation permit, which should be submitted by the end of 2018.

Posiva made the first plan for a safety case in 2005 (Vieno, 2005). It was preceded by safety assessments in a less organised manner. The Nuclear Safety Authority, STUK stated in its letter (STUK, 2007) that the plan was too general. Posiva rewrote the plan, and the currently implemented plan was published in 2008 (Posiva, 2008b).

According to the plan, the safety case will be presented in the following reports:

- Description of the disposal system
- Features, events and processes (FEPs) affecting the repository
- Formulation of scenarios
- Description of the models and the data used in analyses of the scenarios
- Analyses of the scenarios, expected and other
- Complementary considerations
- Summary of the safety case

Additional information to these is provided by the repository design and site investigations, and anticipated external conditions such as the climate.

Features, events and processes

In Posiva's Interim summary report of the Safety Case 2009 (Posiva, 2010b, p. 42) it is stated that

> *"Theoretical or conceptual understanding of relevant features, events and processes (FEPs) and their interactions forms the basis for assessing the long-term safety of the proposed repository and producing a safety case."*

The term "theoretical and conceptual understanding" deserves special attention here. In the literature the word "theory" can have two meanings. Strictly speaking, a scientific theory is a proven and accepted explanation of a related set of observations or events. Multiple verifications by various research groups are needed to ensure the acceptance. In a non-scientific context – and unfortunately also sometimes in a scientific one – a hypothesis is often called a theory. A hypothesis is an explanation of observations or events, with the support of reasoning and experimental data. Before it becomes a theory, the hypothesis has to be extensively tested and accepted by the scientific community. To prove a hypothesis beyond reasonable doubt, and to accept it as a theory is a long process.

In the case of nuclear waste management, the time scales are so long and effects of the failure of the safety of the repository would be so wide that special care should be taken when predictions are made: concepts of hypothesis and theory must not be confused. When any prediction is made, based upon a hypothesis, it should not be accepted until the hypothesis has become a theory. From this point of view, the term "conceptual understanding" becomes baffling. The conceptual model is a step in forming a hypothesis, with a long way ahead to understanding. Unfortunately, use of hypotheses in the safety case is legitimated by Section 15 of the Gov-

ernment Decree on the Safety of disposal of nuclear waste (MEE, 2008):

> *"The input data and models utilised in the safety case shall be based on high-quality research data and expert judgement. Data and models shall be validated as far as possible, and correspond to the conditions likely to prevail at the disposal site during the assessment period."*

Posiva's latest report concerning the FEPs was published in 2007 (Miller and Marcos, 2007). Posiva has not compiled its own database of FEPs, and the key sources of the report were the database of OECD Nuclear Energy Agency (NEA) (NEA, 2000) and SKB's process report from which Posiva has published a localized version (Rasilainen, 2004).

Formulation of the scenarios

Scenario analysis is the main tool used in Posiva's safety case (Posiva, 2008b). The system is analysed with different sets of possible external conditions and disturbing events. The cases defined by these sets are called scenarios. Formulation of the scenarios is a topic in Posiva's safety case that STUK commented in the following way (STUK, 2010, p.5):

> *"Instead of the whole repository, Posiva has insofar analysed behaviour of only one canister, there are shortcomings in justifications of chosen scenarios, and the mutual couplings of different safety functions are not taken into account in defining the scenarios."*

In other words, Posiva does not have a fully systematic way to choose the scenarios that are analysed, and performance of each part of the system is analysed assuming normal behaviour of other parts, thus omitting all cumulative effects. In view of this, Posiva should at least provide an explanation why it is sufficient to analyse only one canister. Omitting cumulative effects has also another important implication: it simplifies the dependence of the amount of the waste into a linear one (Posiva, 2009c, p.8).

One problem is that it is very difficult to quantify the effects of human errors. They can be reduced by proper quality assurance, but never completely eliminated. For example, there is a possibility of deliberate or accidental human intrusion. Posiva has not discussed it extensively, because there is no way to quantify it. Furthermore, the time-span of the disposal operation from installation of the first canister to closure of the repository is about a hundred years (Posiva, 2010). It means that several generations will take part in the project. There is no way to quantify the probability of severe errors in passing the knowledge and skills from one generation to another.

Research and development plans

In 2009, Posiva published its plans for research and development activities during the three-year period 2010-2012 (Posiva, 2009b). This document, TKS-2009, is an extensive presentation of the state of the repository project including an acknowledgement of open questions. TKS-2009 is the main part of the preliminary application material. STUK reviewed the material and gave out a press release (STUK, 2010) stating that Posiva's disposal project and the related preparation of material for construction license application is proceeding appropriately. The complete statement (STUK, 2010) seems to contradict this press release at a first glance. It points out several shortcomings in the material. For example:

> *"Posiva's preliminary application material or its background material do not present uniquely the initial state of the system or explain the evolution to the target state defined for the parts of the system."*
>
> *"In spite of the research and development work, there are several open safety issues in demonstrating the safety of the buffer and the canister, for example regarding corrosion of the canister and long-time performance of the buffer in the changing environmental conditions."*
>
> *"[-] Thus, relation between description of the properties of the disposal site and the long-time safety of the repository remains incomplete."*
>
> *"Posiva has below mentioned ongoing work that is schedule-critical with regard to construction licensing and of which handling and presentation of results need special attention from Posiva before submitting the license application.*
>
> - *Formulation of scenarios that describe the whole final disposal system and conform to the*
> - *requirements of STUK, and analysis of release and transport of radionuclides according to these scenarios.*
> - *Research, development and analysis needed for demonstration of performance of the engineered barriers, especially the buffer.*
> - *Development of the classification system for the host rock and demonstration of functionality of the system, as well as demonstration of*
> - *implementation of deposition tunnels and holes."*

However, one must bear in mind that this assessment of the progress is related to legislation. Submission of the application for the construction licence has to include a preliminary safety case. A preliminary version of a preliminary safety case is not expected to be complete, and as long as there are plans to fulfil the requirements, incomplete can be formally acceptable. Therefore, even critical uncertainties are formally allowed at present stage of development.

As an illustration, some of the important uncertainties of the engineered barriers are described in the following. The list is neither exhaustive – the properties of the rock are not included here at all –, nor are the examples necessarily the most important. The chosen examples show that none of the barriers is demonstrated yet to behave according to assumptions on which the safety case is built.

The numbers of open issues in the engineered barrier system in Posiva's research and development plans for periods 2004-2006 (Posiva, 2003), 2007-2009 (Posiva, 2006) and 2010-2012 (Posiva, 2009b) are shown in Table 1. The open issues are not presented in a unified manner in the R&D plans for different periods, so the compilation of this table could be done in several ways ending up to different figures. Furthermore, the issues here could be divided into bigger set of more exactly defined problems. Consistency between different periods is maintained here by using the definition of the issues similar to that of TKS-2009. However, it is more important to observe that the number of open issues has not decreased during the past decade than to try to find out the exact number of the open issues.

Table 1. The number of open issues in the R&D plans for the current and the past two three-year periods in Posiva's research programme.

Barrier	TKS-2003	TKS-2006	TKS-2009
Fuel	4	4	11
Canister	6	1	6
Buffer	7	10	7
Backfill	2	12	8
Whole EBS	19	27	32

Some further notions on the development of the number of open issues can be made:

- The fuel of the EPR plant under construction has increased the number of open issues.
- The canister design was considered to be nearly completed in 2006, but new issues have been acknowledged since then.
- The number of the open issues concerning the buffer has not changed much since 2003.
- The problems with the backfill became intolerably big in the period 2004-2006, and the design of it has changed very much since then. These problems were one of the reasons for introduction of the horizontal canister concept KBS-3H.

The initial state of the spent fuel

STUK commented already in its letter (STUK, 2007) on Posiva's R&D plan for the period 2007-2009 (TKS-2006) that there are uncertainties on the radionuclide inventory and instant release factor (IRF) values used in the safety case. TKS-2006 did not include this issue explicitly. Radionuclide inventory is the total amount of different radionuclei in the spent fuel, and the instant release factor is the fraction of them instantly accessible to water in the case of failure of the canister. In TKS-2009 Posiva still acknowledges that the activity inventory is currently based on expert judgement (Posiva, 2009b, p.329). Expert judgment, even if formal, used instead of measurements and theoretically based calculations is a method that is questionable in this context. Further, more information is needed about the spent fuel of EPR, the type of the power plant under construction, since the data is still based on extrapolations from other types of fuel (Posiva, 2009b, p.329). Extrapolation is a mathematical method where new data points are constructed outside the observation area, and it is generally unreliable.

Corrosion of the copper canister

Dr Peter Szakálos and Professor Gunnar Hultqvist from KTH (the Royal Institute of Technology in Stockholm) have argued that the copper canister may be corroded in pure water, and that 1 m thick copper canister would be needed instead of 5 cm for 100,000 years durability (Szakálos et al, 2007; Hultquist et al, 2009). Their research is based on results that Hultqvist first presented more than 20 years ago. The research team has now repeated the experiments and the results show that in water free of dissolved oxygen, copper corrodes, forming a hydrogen-containing corrosion product . Apparently, the hydrogen produced by corrosion in pure water is found in the metal, the corrosion product and the water as well as in the gas phase (Hultquist et al., 2008). The work of KTH team has been criticised by professor Lars Werme from Upsala University (Werme and Korzhavyi 2010), among others, and the KTH team has responded to the critics. Thus, there is a scientific debate going on about the issue.

The Swedish National Council for Nuclear Waste www.karnavfallsradet.se/en is an independent committee attached to the Swedish Ministry for the Environment. It took up the debate over copper corrosion in its State-of-the-Art Report 2010 (The Swedish National Council for Nuclear Waste, 2010). The Council states that the recent discussion of copper corrosion in oxygen-free water has created uncertainty concerning the copper canister as a credible long-term barrier. The Council urges SKB to actively work to investigate the issue in a scientifically correct manner to determine whether it is important or not. Furthermore, the Council thinks that the discussion has brought up a need for wider investigation of how copper behaves in the repository environment, and more research work with a focus

on corrosion of copper in the environment expected to exist in the repository is needed. The issue is also related to the choice of the buffer material. In the report the Council expresses the opinion that the composition of the bentonite should be studied in conjunction with copper corrosion under aerobic and anaerobic conditions at elevated temperature of the repository environment.

Posiva took the stand that the results are unreliable but acknowledges that the issue requires further investigations (Posiva, 2009b, p. 357). Together with VTT (Technical Research Centre of Finland), Posiva and SKB have initiated experimental work on the corrosion of copper in pure water in 2009. No results have been published yet.

Erosion of the buffer

According to current plans, the buffer is made from bentonite blocks. After their installation, they begin to take up water from the rock. Water causes bentonite to swell, and all the gaps between the blocks are sealed, as well as the gaps between the buffer and the canister and between the canister and the rock. This behaviour is understood relatively well, and it can be predicted with reasonable accuracy if the volume of the swelling is small compared to original volume of the buffer material. However, bentonite clay has turned out to be a very tricky material in some cases. One of the most problematic issues has turned out to be erosion of bentonite. It may occur in different ways and different time scales. Erosion of bentonite was not mentioned in research and development plans for either the three-year period 2004-2006 in TKS-2003 or the period 2007-2009 in TKS-2006.

The erosion mechanism related to water up-take after installation, but before sealing of the gaps, is called piping erosion. It occurs when water flows in the gaps faster than bentonite can take it up. In that case, clay particles can be bound to the flowing water and be transported away causing reduction of the buffer mass that compromises the performance of the buffer. This phenomenon is confirmed to exist with laboratory experiments (Börgesson and Sanden, 2006), but it is not understood well enough to make predictions of it. One difficulty at the moment is that the properties of bentonite cannot be calculated when the volume of the swelling is significant compared to the original density of the material. Furthermore, there are uncertainties on the effects of the water chemistry and gravitation (Posiva, 2009b, p.368). Posiva's plans for work concerning the issue in TKS-2009 include both mathematical and modelling work. Posiva has not published any results by the beginning of 2011. The problem has turned out to be very difficult to understand and model.

The other acknowledged possibility for bentonite erosion is chemical erosion by colloid formation. It occurs when bentonite swells into rock fractures and escapes from the buffer in form of colloids. This phenomenon is less probable than piping erosion, an it is likely to be prevented by salt in the ground water, so it may be an issue at the time of glacial melting, when dilute meltwater may infiltrate to the buffer. However, a number of uncertainties exist in predicting this complex phenomenon (Moreno and Neretnieks, 2010).

Posiva states in TKS-2009 (Posiva, 2009b, p. 369): "The occurrence of erosion will be minimised by buffer design". About the buffer design (Posiva, 2009, p. 191) it is stated that the control of buffer piping and mechanical erosion at the beginning of the disposal as well as potential chemical erosion due to post-glacial melt water is one of the essential issues in the design basis that have not been answered yet. This is an example of the incoherence of the Posiva's material that STUK mentions in its statement.

Alteration of the buffer material

Bentonite has been chosen as the buffer material partly because of its ability to swell when it takes up water. This property is based on electric charges in the mineral lattice, which are counterbalanced by ions attached to the clay mineral sheets (Odom, 1984). This structure is very stable at variable geochemical conditions, but it is also known that bentonite has a tendency to be transformed into illite at high temperatures, high meaning significantly higher than 100°C. This process is called illitisation (Posiva, 2009b, p. 370). Illite does not have the ability to swell, because the counter-ions are potassium that is poorly hydrated, so occurrence of illitisation would compromise the performance of the buffer. The results of current research work indicate that illitisation at the moderate temperatures of the repository environment is very slow. However, Posiva acknowledges in TKS-2009 that the process is still poorly understood (Posiva, 2009b, p. 370). Ilitisation at moderate temperatures has not been considered as an issue in TKS-2003 or TKS-2006, since earlier calculations indicated it to be negligible.

Piping in the backfill

The tunnels of the repository have to be backfilled with material that is stable, does not conduct water and pre-

vents the buffer from swelling too much. Currently, it is not known how these requirements are met. Especially, dealing with the piping effect where rapid flow of water erodes the backfill is challenging during the backfilling. The following key issues are taken from Posiva's latest assessment report about the backfilling (Keto et al. 2009, p. 150):

- Piping can develop in backfill and under high point inflow rates from the rock erosion of backfill can be substantial.

- In particular the pellet materials do not initially take up water uniformly and water can move rapidly from the point of inflow to the working face during the backfilling, particularly under high inflow conditions.

- Existing interfaces are the most likely pathways for piping, with preference to flow along the pellet-rock boundary. Moderate point inflow conditions do not result in extensive erosion of the backfill. Water tends to move rapidly along the piping feature to the downstream face of the backfill, meaning that it will be necessary to deal with the inflow almost as rapidly as it enters the tunnel.

- Due to the rapid movement of the water through the backfill it will be necessary to ensure that backfill operations do not cease for longer than a few days or up to one week in order to avoid problems with the installation process.

Conclusions

In co-operation with SKB and, to smaller extent, with other international actors in the field, Posiva has provided an impressive amount of research work. The construction of the underground rock characterisation facility ONKALO is a physical demonstration of that work. Posiva plans to work on finding solutions for the open questions and remaining challenges. Unfortunately, neither the amount of work done nor the existing plans guarantee that the safety of the deep geological repository concept will be demonstrated. In this report it is clearly shown that it is not yet known how Posiva will tackle the remaining challenges or envisage to provide an overall assessment of the whole repository project.

Although there is no proof so far that the planned repository is not safe and that the open problems cannot be solved, it is false to claim that a safe solution for every open problem exists just because it is looked for. Posiva seems to represent a belief in the omnipotence of technology. One example of this attitude is the piping erosion problem. It is acknowledged that there is a possibility that the flowing water fill could remove a substantial part of the buffer and tunnel backfill mass. This process could jeopardise the performance of the buffer and the backfill. However, at the current point of the timetable, it is sufficient for formal acceptance to say that the problem will be solved by technical design. This is a logical fallacy, because technical design is nothing more than description of technical solution: the sentence "the problem will be solved by its solution" has no information.

What happens if the timetable cannot be obeyed? Posiva writes in its news release in May 2010 (Posiva, 2010c):

> *"The timetable for the preparation of the construction licence application for repository in Olkiluoto is tight but possible. Posiva will not hold on the [the deadline in] year 2012 at any cost, if it turns out that sufficient level of safety cannot be demonstrated at that time. Eventually, STUK will decide the required level*
> *reporting and how much the application can be complemented after 2012."*

In other words, the timetable can be changed. However, there is a limit for the change: the decision-in-principle expires in 2016. The sufficient level does not mean, at the time of submitting an application for a construction licence, that the safety case should be completed, but there should be credible plans for finishing it. Credibility is a key question here.

Credibility should not be based on faith only. In the case of the safety case here, credibility should be gained by detailed description of the methods to acquire missing information, and the missing information should not concern crucial parts of the performance. At the moment, Posiva fails to meet these criteria.

As a justification for construction of new nuclear power plants, the nuclear waste management has been used in an untenable manner. It can be called reverse logic: Since the Finns need energy, the nation needs nuclear power. Since the nation needs nuclear power, a solution for the nuclear waste is needed. Since the solution for the nuclear waste is needed, science and technology will find the solution sooner or later. Since the solution will be found, the deep geological disposal method supports the justification of the nuclear power production. Unfortunately, this logic is simply false. The need for a solution does not mean that it will be found. A plan to solve the problem does not mean it can be solved. This reverse logic is also visible in the formal licensing procedures of nuclear power plants: the environmental impact assessment procedure describes the plans for nuclear waste management, the EIA procedures supported the DiPs regarding nuclear power plants that were mainly justified by economical aspects. The DiPs were granted before DiPs regarding expansions of the repository for the waste from the plant. Furthermore, the construction license for the Olkiluoto-3 power plant was granted before the safety case of the repository is completed and the operation license for the plant will not depend on the timetable of the repository project.

The spent nuclear fuel is an existing problem. It is undeniably dangerous to life. The issue is not the radiation emitted by the waste in intact canisters, but the radiation toxicity of the waste if it is released from the canisters into the biosphere. Therefore, the research has to go on and it has to be tried to find the best possible solution for the disposal of the spent nuclear fuel.

At the moment, a deep geological repository is widely considered as the best candidate for the final solution. However, its safety is currently a hypothesis. A wide discussion in the society is needed to assess, what the accepted level of uncertainty in the solution is. The task to estimate the level of that uncertainty is not for engineering and natural science only, since knowledge on the mechanisms of science and technological development need a wider perspective. The social and

human sciences should not be used merely as tools to keep up the faith in technology, but as active parts in the assessment of the solution including the mechanism that have led to it. For example, engineering methods cannot quantify the probability of severe errors in passing the knowledge and skills from one generation to another.

Obviously, minimizing the amount of the waste does decrease risks. At the moment, we do not know how much, because, for example, the cumulative effects of failures of different parts of the system have not been assessed. This has to be kept in the discourse about nuclear power production. If nuclear power plants are used, it has to be openly admitted that it involves currently uncontrolled risks that may have consequences for very long time. This is an especially important issue when nuclear energy is discussed on a global scale, since trends of a global scale usually originate and tend to accumulate from local decisions.

References

British Petroleum (2010). Statistical Review of World Energy 2010. www.bp.com/ReportsAndPublications. Accessed January 15th, 2011.
Börgesson, L. and Sandén, T. (2006). Piping and erosion in buffer and backfill materials. Current knowledge. SKB R-06-80. SKB.
Country Brand Delegation of Finland (2010). Mission for Finland. www.tehtavasuomelle.fi/documents/TS_Report_EN.pdf Accessed January 15th, 2011.
European Comission (2006). Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy. COM/2006/0105 final.
Finnish Government (2000). Decicsion-in-Principle (unofficial translation). www.stuk.fi/ydinturvallisuus/ydinjatteet/loppusijoitus_suomessa/en_GB/luvat/_files/12222632510023680/default/decision_in_principle.pdf"http://www.stuk.fi/ydinturvallisuus/ydinjatteet/loppusijoitus_suomessa/en_GB/luvat/_files/12222632510023680/default/decision_in_principle.pdf. Accessed February 2011.
Finnish Government (2010). Valtioneuvoston periaatepäätös 6. päivänä toukokuuta 2010 Fennovoima Oy:n hakemukseen ydinvoimalaitoksen rakentamisesta. Finnish Government.
Finnish Ministry of the Environment (1995). Act on Environmental Impact Assessment Procedure. Finnish statute 468/1994. Finnish Ministry of the Environment.
Finnish Ministry of the Environment (2006). Decree on Environmental Impact Assessment Procedure. Finnish statute 713/2006. Finnish Ministry of the Environment.
Henriksson, A. (2008). Käytettyä ydinpolttoainetta ei pidä loppusijoittaa pysyvästi Suomen kallioperään. Loviisan sanomat, 15th February 2008.
Hultquist, G., P,. Szakálos, M.J. Graham, G.I. Sproule, and G. Wikmark (2008). Detection of hydrogen in corrosion of copper in pure water. The International Corrosion Congress 2008. Paper No. 3384. NACE International, Houston, USA.
Hultquist, G., Szakalos, P., Graham, M. J., Belonoshko, A. B., and Rosengren, A. (2010). Reply to Lars O. Werme et al.: "Comments on 'Water Corrodes Copper'". Catalyst Letters , 135, 167-168.
Hultquist, G,. P. Szakálos, M. J. Graham, A. B. Belonoshko, G. Sproule, and L. Gråsjö (2009). Water corrodes copper. Catalysis Letters , 132, 311-316.
IAEA (2008). The Safety Case and Safety Assessment for Radioactive Waste Disposal. Draft Safey Guide. No. DS 355. International Atomic Energy Agency.
Juvankoski, M (2010). Description of Basic Design for Buffer. Posiva Working Report 2009-131. Posiva Oy.
KBS (1978). KBS 1 – Handling of spent nuclear fuel and final storage of vitrified high level reprocessing waste, I General. Report Art 722 1. Swedish Nuclear Fuel Supply Co/Division KBS.
KBS (1979). KBS 2 - Safe handling and storage of high level radioactive waste. A condensed version of the proposals of the Swedish KBS-project regarding reprocessing waste and spent fuel. Report Art 719. Swedish Nuclear Fuel Supply Co/Division KBS.
KBS (1983). KBS 3 - Final storage of spent nuclear fuel - KBS-3, Summary. Swedish Nuclear Fuel Supply Co/Division KBS.
Keto, P., D. Dixon, E. Jonsson, L. Börgesson, J. Hansen, and D. Gunnarsson (2009). Assessment of Backfill Design for KBS-3V Repository, Workreport 2009-115. Posiva Oy.
Kiljunen, P. (2010). Energy Attitudes 2009. Yhdyskuntatutkimus oy. URL http://www.sci.fi/~yhdys/eas_09/english/eas-eng_tied_09.htm. Accessed 4th April 2011.
Kojo, M. (2009), The Strategy of Site Selection for the Spent Nuclear Fuel Repository in Finland. In Kojo, M. And T. Litmanen (eds.): The Renewal of Nuclear Power in Finland, 161-190. Palgrave Macmillan, Houndmills.
Kärnavfallsrådet (2011). Nuclear Waste State-of-the-art Report 2011. The Swedish National Council for Nuclear Waste, Stockholm.
Laine, P. and H. Karttunen (2010). Long-Term Stability of Bentonite- A Literature Review. Posiva Working Report 2010-53. Posiva Oy.
Lampinen, A. (2009). An Analysis of the Justification Arguments in the Application for the New Nuclear Reactor in Finland. In Kojo, M. And T. Litmanen (eds.): The Renewal of Nuclear Power in Finland. Palgrave Macmillan, Houndmills.
Lindskog, R., and G Sundqvist. (2004). On the right track? Technology, geology and society in Swedish nuclear waste management. Journal of Risk Research, 7, 251-268.
MEE (1999). Yhteysviranomaisen lausunto ydinjätteen loppusijoituslaitosta koskevasta ympäristövaikutusten arvion-

tiselostuksesta. Ministry of Trade and Industry.
MEE (2008). Government Decree on the safety of disposal of nuclear waste. Finnish statute 2008/736. Finnish Ministry of Employment and the Economy.
MEE (2009). Käytetty ydinpolttoaine. Finnish Ministry of Employment and the Economy. 2009. www.tem.fi/. Accessed January the 15, 2011.
MEE (2009b). Nuclear Energy Act. Finnish Statute 990/1987. Finnish Ministry of Employment and the Economy.
Miller, B. and Marcos, N. (ed.s) (2007). Process Report – Feps and Scenarios for a Spent Nuclear Fuel Repository at Olkiluoto. Posiva Report 2007-12. Posiva Oy.
Moreno, L., I. Neretnieks, and L. Li (2010). Modelling of erosion of bentonite gel by gel/sol flow. SKB Technical Report 10-64. SKB.
National Research Council of the United States (1984). A review of the Swedish KBS-3 plan for final storage of spent nuclear fuel. Panel for the Review of the Swedish KBS-3 Plan. National Academy Press, Washington D.C.
NEA (2000). Features, Events and Processes (FEPs) forGeologic Disposal of Radioactive Waste. An International Database. Organisation for Economic Cooperation and Development, Paris.
Odom, I. E. (1984). Smectite clay minerals: properties and uses. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 311, 391-409
Patrakka, E (2007), "Ydinjätehuollon alkuvaiheet," ATS ydintekniikka, 36, n. 3, 28-30.
Posiva (1999). Käytetyn ydinpolttoaineen loppusijoitus - ympäristövaikutusten arviointiselostus. Posiva Oy.
Posiva (2003). TKS-2003 Nuclear Waste Management of the Olkiluoto and Loviisa Power Plants: Programme for Research, Development and Technical Design for 2004-2006. Posiva Oy.
Posiva (2006). TKS-2006 Nuclear Waste Management of the Olkiluoto and Loviisa Power Plants: Programme for Research, Development and Technical Design for 2007-2009. Posiva Oy.
Posiva (2007). Horizontal Deposition of Canisters for Spent Nuclear Fuel. Summary of the KBS-3H Project 2004-2007. Report 2008-3. Posiva Oy.
Posiva (2008). Environmental Impact Assessment Report 2008. Posiva Oy.
Posiva (2008b). Safety Case Plan 2008. Posiva Oy.
Posiva (2008c). Environmental Impact Assesment Report 2008. Posiva Oy.
Posiva (2009). Periaatepäätöshakemus käytetyn ydinpolttoaineen loppusijoituslaitoksen laajentamiseksi Loviisa 3 -yksikköä varten. Posiva Oy.
Posiva (2009b). TKS-2009 Nuclear Waste Management at Olkiluoto and Loviisa Power Plants: Review of Current Status and Future Plans for 2010-2012. Posiva Oy.
Posiva (2009c). YVA-selostuksen lisäselvitys. Posiva memorandum POS-005856. Posiva Oy.
Posiva (2010). Safe Final Disposal of Spent Nuclear Fuel. Brochure, Posiva oy.
Posiva (2010b). Interim Summary Report of the Safety Case 2009. Posiva Report 2010-2. Posiva Oy.
Posiva Oy (2010c). Loppusijoitushankkeessa edetään turvallisuuden ehdoilla. Press release 26th May 2010. www.posiva.fi/ajankohtaista/muita_ajankohtaisia_asioita/loppusijoitushankkeessa_edetaan_turvallisuuden_ehdoilla. Accessed 15th January 2011.
Raittila, P., P. Hokkanen, M. Litmanen, and T Kojo (2002). Ydinjäteihme suomalaisittain. Tampere University Press.
Raiko, H. (2007). Disposal Canister for Spent Nuclear Fuel - Design Report. Report 2005-2, Posiva Oy.
Rasilainen, K. (Ed.) (2004). Localisation of the SR97 Process report for Posiva's spent fuel repository at Olkiluoto. Posiva Report 2004-05. Posiva Oy.
SKI (1979). Statens Kärnkraftinspektion Skrivelse till Regeringen 79-03-27; Uppdrag att Bereda vissa Ärenden Enligt Lagen (1977:140) om Särskilt Tillstånd att Tillföra Kärnreaktor Kärnbränsle, m.m. Letter from the Nuclear inspectorate to the Cabinet 79-03-27. Swedish Nuclear Inspectorate.
Statistics Finland (2010). Energy supply, consumption and prices. www.stat.fi/til/ehkh/tau_en.html Accessed January 15th 2011.
STUK (2007). Olkiluodon ja Loviisan voimalaitosten ydinjätehuollon tutkimus- ja kehityssuunnitelm sekä teknisen suunnittelun ohjelma 2007–2009. Letter Y811/123. STUK.
STUK (2010). Käytetyn ydinpolttoaineen loppusijoituksen valmistelu - Posiva Oy:n alustavat selvitykset. Letter 6/H42212/2009, STUK.
STUK (2010b). Ydinjätteen loppusijoitusta valmisteleva Posva etenee asianmukaisesti. Press release,

www.stuk.fi/stuk/tiedotteet/2010/fi_FI/news_605/. Accessed 4th April, 2011.
Szakálos, P., G. Hultquist, and G. Wikmark (2007). Corrosion of Copper by Water. Electrochemical and Solid-State Letters , 10, 63-67.
Säynässalo, E (2009). Nuclear Energy Policy Process in Finland in a Comparative Perspective: Complex Mechanisms of a Strong Administrative State. In Kojo, M. And T. Litmanen (eds.): The Renewal of Nuclear Power in Finland. Palgrave Macmillan, Houndmills.
TVO (1999). Olkiluodon ydinvoimalan laajentaminen kolmannella laitosyksiköllä. Ympäristövaikutusten ariviontiselostus. Teollisuuden Voima Oy.
TVO (2008). Application for a Decision-in-Principle concerning the construction of a Nuclear Power Plant Unit – Olkiluoto 4. Teollisuuden Voima Oy.
USNRC (2009). Backgrounder on the Three Mile Island Accident. United States Nuclear Regulatory Comission. URL www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html. Accessed January 15th 2011.
Vieno, T. (2005). Plan for Safety Case of Spent Fuel Repository at Olkiluoto. Posiva Oy.

Werme, L. O. and P.A. Korzhavyi (2010). Comment on Hultquist et al. “Water Corrodes Copper”. Catalyst Letters , 135, 165-166.

Appendix

Summary of formal procedures

The following list is a summary of the formal procedures regarding nuclear facilities after the Act on Environmental Impact Assessment procedure came into force in 1994.

- Posiva carried out an EIA procedure in 1997 - 1999 covering waste from six nuclear power plants. The DiP report was delivered in May 1999, and the process end in November 1999 when the coordinating authority released its statement on the report.
- TVO initiated an EIA procedure regarding the third unit in Olkiluoto in June 1998.
- Posiva submitted an application for a DiP regarding final disposal in May 1999. The original application covered waste from six power plants.
- TVO delivered its EIA report regarding Olkiluoto-3 in August 1999. The statement by the coordinating authority closed the EIA procedure in February 2000.
- TVO submitted an application for a DiP regarding a nuclear power plant, Olkiluoto-3, in November 2000.
- Posiva sent a letter to the Government in November 2000 and specified that its application for a DiP covered the spent fuel from the existing four power plants and asked a separate DiP regarding the waste from Olkiluoto-3.
- The Government made a positive DiP regarding the final disposal of the waste from the four existing plants in December 2000.
- The Parliament ratified the Government DiP in May 2001.
- The Government made a positive DiP regarding the Olkiluoto-3 power plant and accepted Posiva's postponed application in February 2002.
- The Parliament ratified the decisions-in-principle regarding both Olkiluoto-3 and disposal of its waste in May 2002.
- TVO applied for a construction license regarding Olkiluoto-3 in January 2004.
- The Ministry of Trade and Industry (called the Ministry of Employment and the Economy from 2008) granted a construction license for Olkiluoto-3 February 2005.
- TVO initiated an EIA procedure concerning Olkiluoto-4 in May 2007.
- Fortum Power and Heat initiated an EIA procedure concerning Loviisa-3 in June 2007.
- Fennovoima initiated formally its EIA process regarding a new nuclear power plan either in Pyhäjoki, Ruotsinpyhtää or Simo in January 2008.
- TVO delivered the EIA report regarding Olkiluoto-4 in February 2008.
- Fortum Power and Heat delivered the EIA report regarding Loviisa-3 in April 2008.
- TVO asked the Government a DiP regarding a new power plant, Olkiluoto-4, in April 2008.
- Posiva started an EIA procedure for expansion of the repository for spent nuclear fuel in May 2008.
- The EIA procedure regarding Olkiluoto-4 was closed when the Ministry of Emplyment and the Economy released its statement on the EIA report in June 2008.
- The EIA procedure regarding Loviisa-3 was closed when the Ministry of Emplyment and the Economy released its statement on the EIA report in August 2008.
- Fennovoima delivered the EIA report regarding a new power plant in October 2008.
- Posiva delivered its EIA report concerning expansion of the repository in October 2008.
- Fennovoima applied for a DiP regarding a new nuclear power aither in Pyhäjoki or Simo in January 2009.
- Fortum Power and Heat oy and its owner Fortum oyj submitted an application for a DiP regarding a new nuclear power plant, Loviisa-3, in February 2009.
- The EIA procedure regarding Fennovoima's new power plant was closed when the Ministry of Emplyment and the Economy released its statement on the EIA report February 2009.
- Posiva applied for a DiP regarding expansion of its repository in March 2009.
- The Ministry for Employment and the Economy gave its statement on Posiva's EIA report in March 2009. The statement closed the EIA procedure.

The Government gave positive Decisions-in-Principle regarding TVO's and Fennovoima's power plants and negative DiPs regarding Loviisa-3 and Posiva's extension of the repository for wastes from Loviisa-3 in May 2010. The parliament ratified the positive decisions in July 2010.

IVO was merged with Neste Oy in 1997, forming Fortum Oyj. The Loviisa power plant is currently operated by Fortum Power and Heat Oy, a company completely owned by Fortum Oyj.

The somewhat obscure task of the Country Brand Delegation appointed by Minister of Foreign affairs Alexander Stubb in 2008 was to create a strategy for Finland that would convince the world to turn to Finland often and more effectively. The idea was to support exporting Finnish know-how in different fields of the eceonomy.

The DiP is valid for five years, and the condition has to be fulfilled within six years. If Fennovoima applies for a construction licence before the condition is fulfilled, the license, if granted, will be conditional.

Plastic means that certain kind of forces on the material are dampend by yielding of the material and the deformations are retained after the forces are no longer applied. Elastic materials transmit forces more directly and obtain the original shape after removal of fthe orces.

GREENPEACE