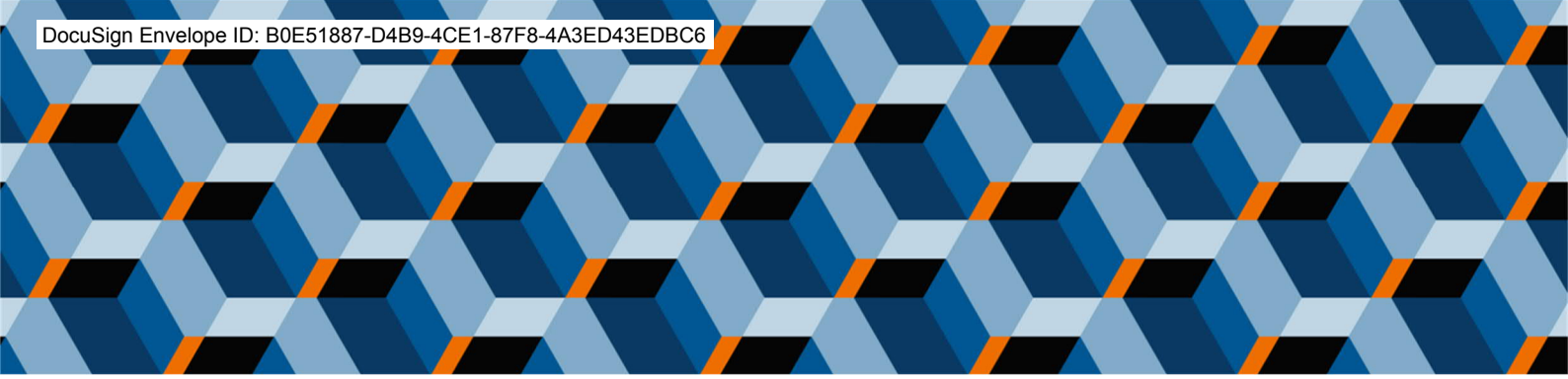

RESEARCH REPORT

VTT-R-00131-22

Examining Closure-Related Issues in Finnish Radioactive Waste Programs

Authors: Timothy Schatz & Sami Naumer

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beyond the obvious

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Summary

The final phases of radioactive waste repository programs are the closure and post-closure phases. It may take several decades or up to a century or more (in the case of a deep geologic disposal facility for spent nuclear fuel) to reach the closure phases after operations begin. The post-closure phases can continue on for far greater periods of time.

The radioactive waste management obligation of an operator responsible for radioactive waste disposal ends when it is confirmed that the final disposal has been implemented safely and in the planned and approved manner. When the operator's obligation has ended, the post-closure period for the repository begins and the responsibility for the radioactive waste is transferred to the Finnish State. Geologic repositories will not be directly observable after closure.

Presently in Finland, two low and intermediate-level waste radioactive waste repositories are in operation at depths of ~100 m and a high-level waste repository at a depth over 400 m for spent nuclear fuel is under construction with an operational license just submitted. In an effort to begin assessing the situation of Finnish radioactive waste repositories with respect to closure and post-closure, applicable Finnish legislative and regulatory requirements were reviewed. Additionally, relevant international guidance was considered as well. Overall, twenty-five closure-related requirements were identified. These requirements were divided into a set of nine categories including 1) closure performance, 2) closure planning, 3) closure implementation, 4) post-closure planning, 5) post-closure-actions, 6) post-closure resourcing, 7) post-closure responsibilities, 8) records preservation and 9) stakeholder engagement. The current handling of each identified closure-related obligation was explored and, in total, fourteen gap areas were found falling into four main domains: post-closure monitoring, knowledge preservation, transfer of ownership and post-closure responsibilities and stakeholder engagement.

In an effort to begin addressing these gaps/needs a set of actions are proposed. These actions are not described in terms of overall prioritisation. However, it is discussed, particularly in the case of post-closure monitoring, that strategic decisions should be made as early as possible.

Confidentiality	Public

Espoo 7.2.2022

Written by	**Reviewed by**	**Accepted by**
Timothy Schatz Project Manager	Paula Keto Senior Scientist	Heidi Krohns-Välimäki Project Owner

VTT's contact address

VTT Technical Research Centre of Finland Ltd., P.O. Box 1000, 02044 VTT, Finland

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VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD

Date:	16 February 2022
Signature:	DocuSigned by: Heidi Krohns-Välimäki C8D3A9772BFA41B...
Name:	Heidi Krohns-Välimäki
Title:	Research Manager

Preface

This report was prepared at VTT during 2021. The work performed was part of the Finnish Research Programme on Nuclear Waste Management 2019-2022 (KYT 2022) of the Ministry of Economic Affairs and Employment (TEM). The emphasis of the KYT programme is on nationally important research topics with the objective to ensure the authorities' access to competence and expertise in nuclear waste management in order to be able to compare and evaluate different approaches, methods and technologies.

The Mapping of Closure-Related Issues in Finnish Radioactive Waste Programs (CloMap) project was arranged as a small-scale project. The objective of the CloMap project during the first year was to explore and identify the most critical decisions, activities, uncertainties and readiness regarding closure-related activities (transitions from late operational to closure and immediate post-closure phases) of repository programs in Finland.

The CloMap project manager was Tim Schatz. Other VTT experts engaged in the CloMap project were Edgar Bohner, Arto Laikkari, Ville Rinta-Hiiro and Sami Naumer. The review of this report was performed by Paula Keto (VTT).

The project was initiated with an open seminar on closure-related topics held on 23 June 2021. Special thanks to our guest presenters Kai Hämäläinen (STUK), Jussi-Matti Mäki (Fortum), Johanna Hansen (Posiva), Johan Bertrand (ANDRA), Christian Rosnes (Interwell P&A) and Tommi Kauppila (GTK). The presentations are available online (http://kyt2022.vtt.fi/closure_workshop.htm).

A continuation project is envisioned for 2022-2023 which will focus on engagement with civil society regarding closure-related topics as well as knowledge preservation issues.

Espoo 7.2.2022

Timothy Schatz and Sami Naumer

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List of abbreviations

Engineered Barrier System	(EBS)
High Level Waste	(HLW)
International Atomic Energy Agency	(IAEA)
Low and Intermediate Level Waste	(LILW)
Ministry of Economic Affairs and Employment of Finland	(TEM)
Nuclear Energy Act	(NEA)
Nuclear Energy Decree	(NED)
Nuclear Power Plant	(NPP)
Säteilyturvakeskus	(STUK)
Spent Nuclear Fuel	(SNF)
Very-low-level waste	(VLLW)

1. Introduction

1.1 Background

Radioactive waste generated in nuclear power plants is classified as high, intermediate, low and very-low level wastes (STUK, 2019). High-level waste (HLW) typically consists of spent nuclear fuel (SNF), while the other categories are comprised of operational and decommissioning wastes. SNF and low- and intermediate-level waste in Finland is to be disposed in geologic repositories, where the waste is placed underground behind multiple protective barriers. Currently, a deep geological repository is being constructed in Olkiluoto, Finland for disposal of SNF and an operational license for this facility was recently submitted. Two low- and intermediate-level waste (LILW) repositories, near the Olkiluoto and Loviisa nuclear power plants (NPP), are currently in use. A very-low-level waste (VLLW) repository, where waste would be disposed in a near-surface, landfill-type structure, is being planned (TVO & Afry, 2021).

Closure is the final phase of actual radioactive waste repository operations and is intended to result in the repositories being permanently closed. The closing of these facilities entails constructing the final engineered barrier systems (EBSs) to shut remaining openings (tunnels, shafts, ramps, boreholes), dismantling and decommissioning the surface facilities and restoring the surfaces of the sites to more natural conditions.

Approval for closure implies that the disposed waste is not intended to be retrieved for future use and therefore must be safeguarded from external intrusion. Nevertheless, waste retrieval might be attempted after closure. Such circumstances could include, for example, correction of a previously unknown flaw in a repository or a future technological breakthrough that makes retreatment of radioactive wastes viable and desirable. The need for safeguards to maintain security and the desire for continued assurance of safety will influence decisions about post-closure monitoring and about whether to emplace and preserve surface markers at, and near, the sites to warn future generations of the presence of hazardous radioactive materials.

It is generally assumed that in an immediate post-closure period some form of maintenance or supervision of the site will occur (IAEA, 2006) which may include a monitoring program. Monitoring can be used to detect 1) any significant change in any property of the repository environment and components that might increase the probability of a safety failure, 2) an actual failure of a component or a release of radioactive contaminants to the near-field environment, 3) a process, parameter or interaction that affects radionuclide release or migration not earlier recognized and 4) an external intrusion event (human or animal). Such monitoring can continue as long as it is believed to be needed and for which the necessary resources are available.

In Finland, the radioactive waste management obligation of an operator responsible for radioactive waste disposal ends when STUK has confirmed that the final disposal has been implemented safely and in the approved manner (TEM, 2015). When the operator's obligation has ended, the post-closure period for the repository begins and the responsibility for the radioactive waste is transferred to the State (ibid). The State has the right to take any measures necessary for ensuring the radioactive wastes remain safely disposed or whether any disposed material is to be retrieved.

Given that radioactive waste repositories in Finland are not expected to start being closed for another 50 years or more (see Figure 1), detailed concepts and plans regarding the activities during the late operational, closure, and immediate post-closure phases have not yet been finalized. The transition between these phases of a repository program is displayed in Figure 2. This figure was designed with a high-level waste repository for spent fuel in mind, but in principle the decision points outlined therein are applicable to any repository type. Clearly, transitioning from the late operational to closure and post-closure

periods of a repository's lifecycle will require many serious considerations which will be of great interest to a wide assortment of stakeholders and should be made transparently. Insofar as late operational to closure and immediate post-closure phases of repository programs lie in the near, long-term future (decades from now), there is still time to evaluate what is needed and what possible knowledge gaps exist regarding not only concepts and plans for technical operations and related decision-making, but also whether and where (e.g., closure materials, designs and performance, monitoring technologies) further research & development activity should be directed.

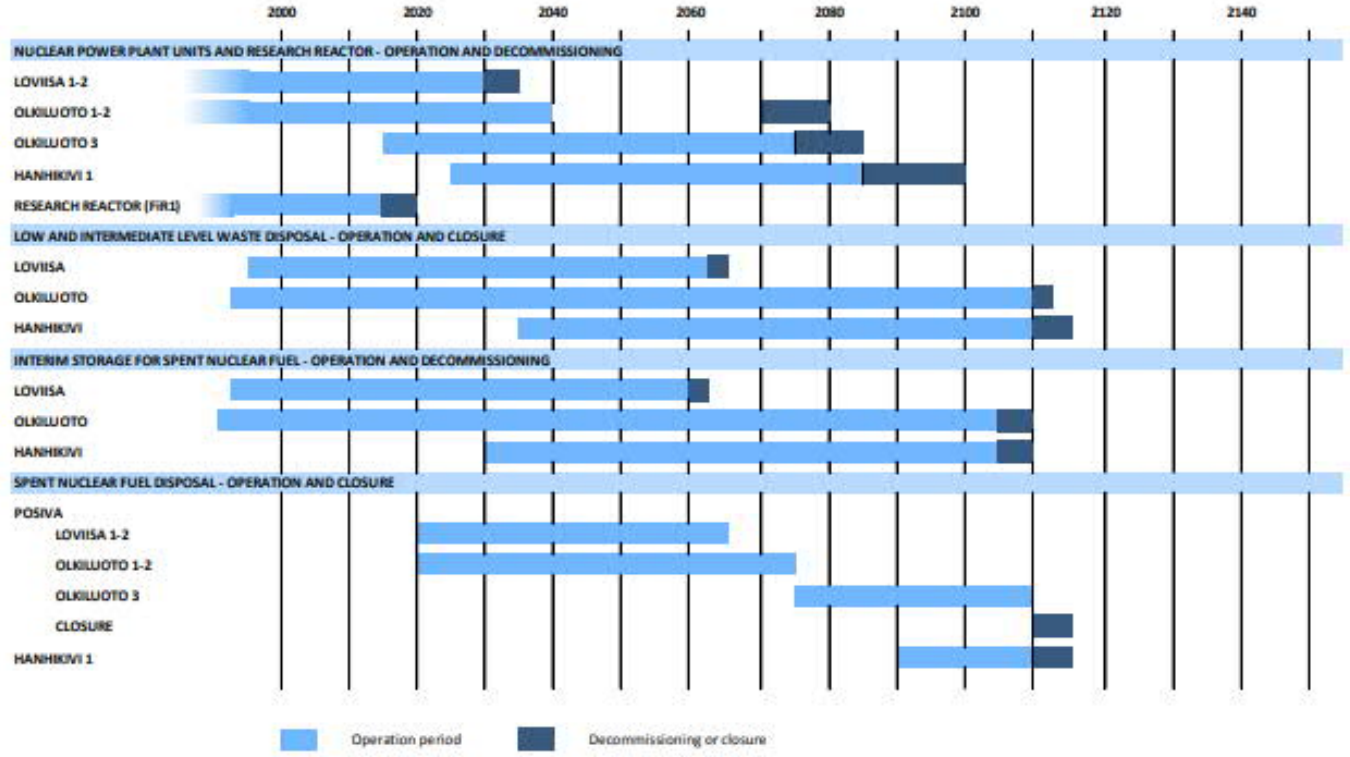

Figure 1. *Overall timeframe for nuclear activities in Finland (TEM, 2015).*

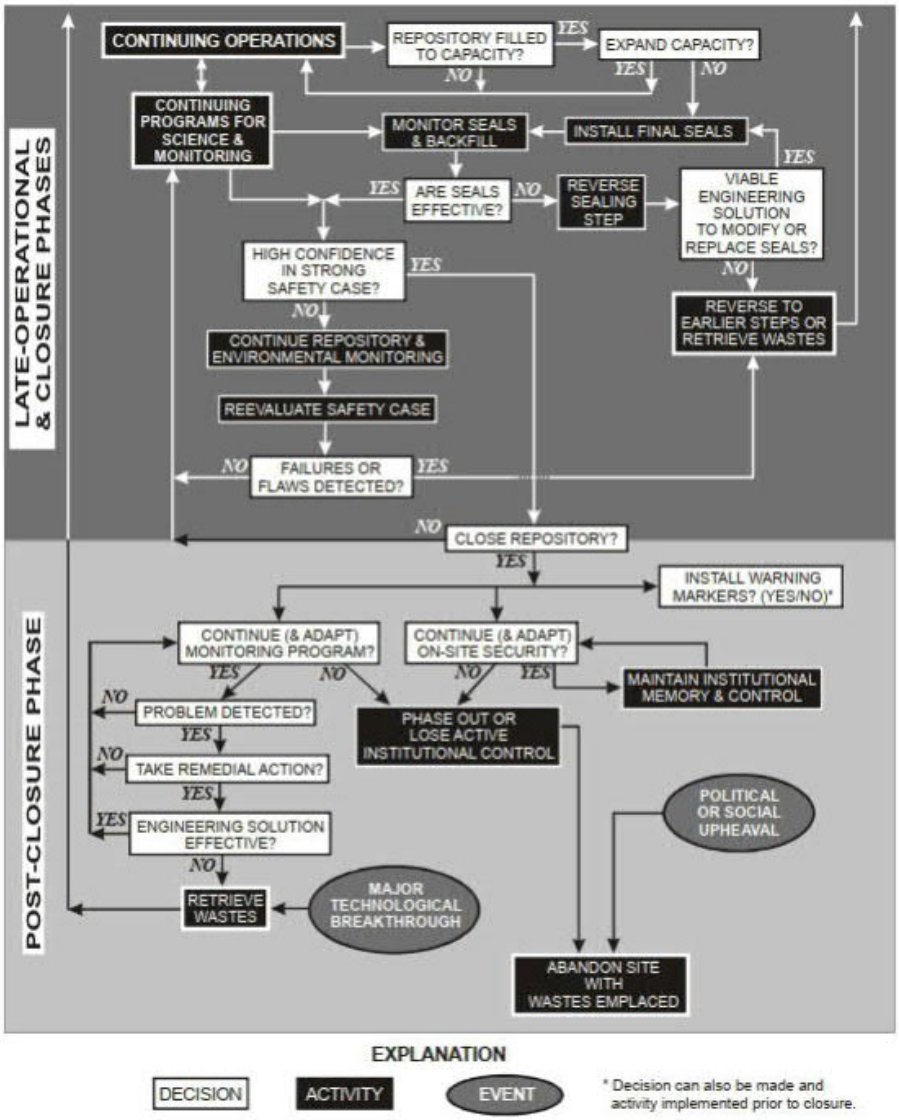

Figure 2. Examples of decision tree and activities during the late operational, closure, and post-closure phases of a repository program (National Research Council, 2003) Reproduced with permission from the National Academy of Sciences, Courtesy of the National Academies Press, Washington, D.C.

1.2 Objective and scope

The purpose of this report is to explore and identify the most critical decisions, activities, uncertainties and readiness regarding closure-related activities (transitions from late operational to closure and immediate post-closure phases) of repository programs in Finland. Key activities include:

- Analysis of existing Finnish and International closure-related regulations and guidance that express requirements for radioactive waste repository closure against available concepts, plans and actions proposed by license holders
- Identification of key gaps/needs in addressing or acknowledging the closure-related requirements
- Recommendation of procedures and actions to help prioritize and meet key gaps/needs

This report contains the results of the analysis a discussions of key gap findings and a set of recommendations and actions for consideration.

Applicable Finnish laws and regulations are evaluated to find radioactive waste repository closure-related requirements. Additionally, a limited number of international guidance documents (IAEA and EU) were examined with regard to closure-related issues. The primarily focus was on closing underground facilities.

Assessment of the key gaps/needs in the handling of closure-related requirements is based only on publicly available documents from license holders and other organizations responsible for closure and post-closure activities.

2. Identification of Requirements

In order to get an overview of the state of radioactive waste repository closure activities in Finland, it is necessary to first determine what these activities should achieve. This determination is made by identifying existing regulations and guidance that express requirements for repository closure. In this section, the existing legislative and regulatory requirements for closure and post-closure phases are presented and briefly reviewed. This section primarily addresses applicable legislation and regulations from a Finnish national perspective and secondarily from an international perspective.

2.1 Applicable Finnish Laws and Regulations

In Finland, the legislative requirements for nuclear waste management are prescribed in the *Nuclear Energy Act* (NEA) and the *Nuclear Energy Decree* (NED). In addition, the Radiation and Nuclear Safety Authority (Säteilyturvakeskus in Finnish, STUK) provides specific regulations in the *Radiation and Nuclear Safety Authority Regulation on the Safety of Disposal of Nuclear Waste* (Y/4) and the *Disposal of nuclear waste* (D.5). Initial design criteria for the deep geologic repository of Posiva have also been presented in the *Decision in Principle 2002 (DIP).* In this section, closure-related regulations are presented in roughly the order in which they were encountered in the above documents, where aspects regarding similar regulations are combined.

The purpose of the NEA is to ensure, that the use of nuclear energy contributes to the overall good of society (Valtioneuvosto, 1987). Therefore, it also applies to the safe disposal of spent nuclear fuel and other nuclear waste. The NED (Valtioneuvosto, 1988) provides more specific information on the use of nuclear power and also on nuclear waste management. Y/4 (STUK, 2018a) gives requirements for nuclear- and radiation safety, which are applied to nuclear waste management. D.5 (STUK, 2018b) provides guidance for nuclear waste disposal in geological repositories and the DIP includes a preliminary safety assessment of the SNF repository and some guidelines for ensuring long-term safety.

Under Finnish laws and regulations, the majority of closure-related responsibilities fall on the license holder. The holder of a license for nuclear energy activities and other activities involving radiation has the primary responsibility for maintaining safety and ensuring the safe handling and disposal of spent fuel and radioactive waste (see 8 and 9 § of the NEA, Valtioneuvosto, 1987). Ultimately, the license holder is responsible for defining and implementing the technical solutions by which nuclear waste is disposed of permanently and safely.

Once a licensee under a waste management obligation has closed the disposal facility, and STUK has confirmed that the final disposal of nuclear waste has been implemented safely and in the approved manner (i.e., in accord with an approved Closure Plan), the license holder can apply for a termination of liability of the nuclear waste management obligation (Valtioneuvosto, 1988). When the license holder's liability is terminated, ownership rights and responsibility for the disposed waste is transferred to the Finnish State. The State is thereby responsible for the nuclear waste management for the post-closure period. Termination of the license holder's liability also requires that a fee is paid to the State for any future monitoring and control of the waste. However, under the Nuclear Energy Act, final disposal must be designed and implemented in a manner that ensuring safety does not require post-closure control.

The set of identified closure and post-closure requirements (where, herein, the term requirements refers to all identified requirements, rules, regulations, instructions and guidance) for radioactive waste repositories derived from documents presented earlier in this section are listed below under nine categories (Closure Performance, Closure Planning, Closure Implementation, Post-Closure Planning, Post-Closure Actions, Post-Closure Resourcing, Post-Closure Responsibilities, Post-Closure Records and Preservation, and Stakeholder Engagement) which describe their nature. These categories are the same between Section 2.1 and Section 2.2. Requirement numbering is specific to this document.

Closure Performance

Requirement 1	Source: Y/4 10 § (STUK, 2018a)
The dose constraints of long-term radiation exposure caused by the disposal of nuclear waste and the threshold values of the emissions are enacted in the Nuclear Energy Decree. The disposal of nuclear waste shall be designed and implemented in a manner where the radiation exposure and emissions caused by nuclear waste as a result of expected evolution will not exceed the dose constraints and the threshold values of the emissions set in the Nuclear Energy Decree.	

Requirement 2	Source: NED 22 d § (Valtioneuvosto, 1988)
The annual dose constraint for an individual of the population arising from the normal operation and the planned decommissioning of a nuclear waste facility shall be 0.01 mSv. *During the reference period after closure of a disposal facility, when the radiation exposure to people can be estimated with sufficient reliability and which must be at least several thousand years long:* *1. the annual dose received by people with the highest exposure must be below the value of 0.1 millisieverts; and* 2. *the average annual doses received by other people must be negligible.*	

Requirement 3	Source: 508 c § of D.5 (STUK, 2018b)
The design of the closure shall aim to create closure structures that do not provide a flow path to the ground surface with better conductivity than that of the surrounding bedrock.	

Requirement 4	Source: NEA 7 h § (Valtioneuvosto, 1987)
Nuclear waste shall be managed so that after disposal of the waste no radiation exposure is caused which would exceed the level considered acceptable at the time the disposal is implemented. *The disposal of nuclear waste in a manner intended as permanent shall be planned in a way that gives priority to safety and so that ensuring long-term safety does not require the surveillance of the disposal site.*	

Closure Planning

Requirement 5	Source: D.5 815 § (STUK, 2018b)
A precondition for the permanent closure of a disposal facility is that STUK has approved the plan concerning the closure, which shall include: *a. a description of the technical implementation of the closure of the repository;* *b. an update of the safety case with due consideration given to the outcomes of the research and monitoring programmes referred to in paragraph 506 and the implementation of the closure; and* c. *a plan for the potential post-closure monitoring measures and a proposal for the restriction zone with prohibition on measures referred to in Section 85 of the NED.*	

Closure Implementation

Requirement 6	Source: 402 § of D.5 (STUK, 2018b)
The disposal of nuclear waste involves the following implementation stages: *……..* *h. backfilling and closure of emplacement rooms and other underground rooms;* *i. post-closure monitoring measures of the disposal facility where required*	

Requirement 7	Source DIP (Finnish Government, 2002)
The disposal of nuclear waste involves various stages, that are completed after the selection of the disposal area: *……* - *backfilling and closure of emplacement rooms and other underground rooms;* - *post-closure monitoring measures of the disposal facility where required* *These stages, some of which may overlap, should be scheduled so that they are beneficial for the long-term safety. In that case, the following aspects should be considered:* *……* - *possible post-closure measures required for ensuring long-term safety and nuclear non-proliferation;* - *the need for maintaining retrievability of SNF canisters from the repository;*	

Post-Closure Planning

Requirement 8	Source: NED 79 c § (Valtioneuvosto, 1988)
The National Nuclear Waste Management Programme referred to in section 27b of the Nuclear Energy Act shall include at least the following information: *……* *5) plans relating to the post-closure period of the disposal facility, the period during which the monitoring of the disposal shall be continued as well as the long-term measures through which the continuity of knowledge of the facility shall be assured*	

Post-Closure Actions

Requirement 9	Source: Y/4 34 § (STUK, 2018a)
An adequate protection zone shall be reserved around the disposal facility as a provision for the prohibitions on measures referred to in Section 63(1)(6)[1] of the NEA.	

[1] The Radiation and Nuclear Safety Authority shall, in order to carry out the oversight required in this Act and the provisions and regulations issued thereunder as well as by international treaties in the field of nuclear energy binding on Finland, be entitled to:
1) inspect and control operations referred to in section 2, subsection 1, paragraphs 1–6, and in section 2, subsection 2, paragraph 2, and for this purpose have access to any place where such an operation is being carried out, as well as to carry out measurements required for supervision, to take and to receive samples and to install equipment necessary for such supervision; (342/2008)

Post-Closure Resourcing

Requirement 10	Source: NEA 32 § (Valtioneuvosto, 1987)
The Ministry of Employment and the Economy, or the Radiation and Nuclear Safety Authority, having granted a license for operations that generate nuclear waste, shall order that the waste management obligation has expired when: *……* *3) the disposal of nuclear waste and the decommissioning of a nuclear facility have been carried out in accordance with Section 33, and the party with a waste management obligation has paid a lump sum to the State for the monitoring and control of the nuclear waste,*	

Post-Closure Responsibilities

Requirement 11	Source: NEA 34 § (Valtioneuvosto, 1987)
When the license holder's waste management obligation has ceased…, the ownership right to the nuclear waste is transferred to the State, which shall be responsible thereafter for the nuclear waste. *Should it become necessary after the disposal, the State has the right, at the disposal site, to take all measures required for the monitoring and control of the nuclear waste and for ensuring the safety of the repository.*	

Records and (Post-Closure) Preservation

Requirement 12	Source: Y/4 29 § (STUK, 2018a)
The licensee shall maintain a record of the disposed waste that includes waste package specific data on the waste type, radioactive substances, location within the emplacement rooms and other information deemed necessary by the authority. The waste records shall be submitted to the Radiation and Nuclear Safety Authority (STUK) in a format approved by it. The Radiation and Nuclear Safety Authority arranges the permanent keeping of records of information concerning the disposal facility and disposed waste.	

Requirement 13	Source: Source: D.5 603 § (STUK, 2018b)
The holder of an operating license of a disposal facility shall maintain records of the disposed waste, providing at least the following information to an accuracy of an individual waste package: *a. the waste type, its processing and packaging method and structural and material characteristics significant to safety;* *b. a waste package identifier and location in the emplacement room; and* *c. the upper limits for the activities of the significant nuclides, to an accuracy of an individual disposal canister in case of spent fuel and to an accuracy of an individual emplacement room in case of other waste*	

6) issue prohibitions on measures concerning real estate when this is necessary in order to secure safety, when that real estate includes premises referred to in section 3, paragraph 5, subparagraph b. (738/2000)

2.2 International Guidance

Directive 2011/70/EURATOM (EU, 2011) establishes a framework for the safe management of nuclear waste. Each European Union (EU) member state should implement the planning of a deep geological repository in their national programmes. Each member state is obligated to maintain policies on nuclear waste management and has the ultimate responsibly to manage their own generated nuclear waste. National policies should be updated based on any new experience gained.

In addition to the EU, Finland is a member state of the IAEA. Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards. The publications by means of which the IAEA establishes standards are issued in the IAEA Safety Standards Series. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are Safety Fundamentals, Safety Requirements and Safety Guides.

IAEA (2011) defines the beginning of the post-closure period to be when all waste has been disposed, the disposal facility is closed, and all surface facilities decommissioned. Post-closure safety should stem from long-term passive safety features. However, even in deep geological repositories, where passive systems should in theory ensure the long-term safety, some institutional controls may provide added benefit for safety. Such controls could include restrictions on land usage and monitoring of the site. Monitoring and surveillance can also be applied to increase safety and boost public acceptance. The aim of such measurement should thus not be on monitoring radiological parameters, but on ensuring that all safety functions operate as intended. These measurements might be more important for near-surface repositories and landfill-like structures. Nevertheless, repositories should be ultimately designed so, that no maintenance or repair is needed with respect to ensuring safety features.

IAEA (2011) states that responsibilities for nuclear waste management should be terminated after all such institutional control is ceased and all requirements fulfilled. They define the safety objectives of post-closure with respect to several design criteria. The main criterion is that dose limits are 1 mSv annually in all cases. The design of a disposal facility should ensure that this limit is not exceeded. Other criteria further specify dosage limits in various cases.

The set of identified closure and post-closure regulations, requirements and instructions for radioactive waste repositories derived from EU and IAEA guidance are tabulated in this section. Requirement numbering and categorization carry on from Section 2.1.

Closure Planning

Requirement 14	Source: 2011/70/EURATOM Article 12 (EU, 2011)
The national programmes shall set out how the Member States intend to implement their national policies referred to in Article 4 for the responsible and safe management of spent fuel and radioactive waste to secure the aims of this Directive, and shall include all of the following: *……* *(d) the concepts or plans and technical solutions for spent fuel and radioactive waste management from generation to disposal,*	

Requirement 15	Source: SSR-5 Requirement 1 (IAEA, 2011)
The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities shall be clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility. *1.7. Matters that have to be considered include:* *……* *d) Defining the overall process for the development, operation and closure of disposal facilities, including the legal and regulatory requirements (e.g., license conditions) at each step, and the processes for decision making and the involvement of interested parties*	

Requirement 16	Source: SSR-5 Requirement 19 (IAEA, 2011)
A disposal facility shall be closed in a way that provides for those safety functions that have been shown by the safety case to be important after closure. Plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.	

Post-Closure Planning

Requirement 17	Source: 2011/70/EURATOM Article 12 (EU, 2011)
The national programmes shall set out how the Member States intend to implement their national policies referred to in Article 4 for the responsible and safe management of spent fuel and radioactive waste to secure the aims of this Directive, and shall include all of the following: *……* *(e) the concepts or plans for the post-closure period of a disposal facility's lifetime, including the period during which appropriate controls are retained and the means to be employed to preserve knowledge of that facility in the longer term,*	

Requirement 18	Source: SSR-5 Requirement 1 (IAEA, 2011)
The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities shall be clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility. *1.7. Matters that have to be considered include:* *f) Defining legal, technical and financial responsibilities and, if necessary, providing for any institutional arrangements that are envisaged after closure, including monitoring and ensuring the nuclear security of different types of waste that have been disposed of.*	

Requirement 19	Source: SSR-5 Requirement 22 (IAEA, 2011)
Plans shall be prepared for the period after closure to address institutional control and the arrangements for maintaining the availability of information on the disposal facility. These plans shall be consistent with passive safety features and shall form part of the safety case on which authorization to close the facility is granted.	

Requirement 20	Source: SSR-5 Requirement 22, 5.7 (IAEA, 2011)
The risk of intrusion into a disposal facility for radioactive waste may be reduced over a longer timescale than that foreseen for active controls by the use of passive controls, such as the preservation of information by the use of markers and archives, including international archives.	

Requirement 21	Source: SSR-5 Requirement 22, 5.8 (IAEA, 2011)
Institutional controls over a disposal facility for radioactive waste have to provide additional assurance of the safety and nuclear security of the facility. Examples include provision for preventing access to the site by intruders and post-operational monitoring capable of providing early warning of the migration of radionuclides from the disposal facility before they reach the site boundary	

Requirement 22	Source: SSR-5 Requirement 22, 5.9 (IAEA, 2011)
Near surface disposal facilities are generally designed on the assumption that institutional control has to remain in force for a period of time. For short lived waste, the period will have to be several tens to hundreds of years following closure. Such controls will be either active or passive in nature…	

Requirement 23	Source: SSR-5 Requirement 22, 5.13 (IAEA, 2011)
Disposal facilities may not be closed for several tens of years or more after operations have commenced. Plans for possible future controls and the period over which they would be applied may initially be flexible and conceptual in nature, but plans have to be developed and refined as the facility approaches closure. Consideration has to be given to: local land use controls; site restrictions or surveillance and monitoring; local, national and international records; and the use of durable surface and/or subsurface markers. Arrangements have to be made to be able to pass on information about the disposal facility and its contents to future generations to enable any future decisions on the disposal facility and its safety to be made.	

Requirement 24	Source: SSR-5 Requirement 22, 5.12 (IAEA, 2011)
Geological disposal facilities have not to be dependent on long term institutional control after closure as a safety measure). Nevertheless, institutional controls may contribute to safety by preventing or reducing the likelihood of human actions that could inadvertently interfere with the waste or degrade the safety features of the geological disposal system. Institutional controls may also contribute to increasing public acceptance of geological disposal.	

Stakeholder Engagement

Requirement 25	Source: 2011/70/EURATOM Article 10 (EU, 2011)
1. *Member States shall ensure that necessary information on the management of spent fuel and radioactive waste be made available to workers and the general public. This obligation includes ensuring that the competent regulatory authority inform the public in the fields of its competence. Information shall be made available to the public in accordance with national legislation and international obligations, provided that this does not jeopardise other interests such as, inter alia, security, recognised in national legislation or international obligations.* 2. *Member States shall ensure that the public be given the necessary opportunities to participate effectively in the decision-making process regarding spent fuel and radioactive waste management in accordance with national legislation and international obligations.*	

2.3 Stakeholder Expectations

In addition to government entities, license holders and international bodies, other stakeholders have expressed expectations regarding nuclear waste management. For example, civil society actors such as municipalities, where nuclear waste disposal is carried out, are directly affected by the entire repository life cycle from development to release. In Finland, two municipalities, Eurajoki and Loviisa, currently host radioactive waste repositories (and nuclear power plants). Issues raised by members of these communities are presented below:

- The municipal board of Eurajoki (2021) stated their concerns about the Draft National Programme on Spent Fuel and Radioactive Waste Management and Report on its Environmental Impacts (Ramboll, 2021). They expressed a desire to be included in all discussions about changes in plans considering nuclear waste management within their municipality and that information about the nuclear waste repository, even information that everything is working as intended, is provided to them routinely and automatically. Additionally, it was noted that the repository has future implications on the municipality regarding land usage and attractiveness as any protective zones around a closed repository can have a very long-term effect. The municipality of Loviisa has not made any public statements recently on the low and intermediate level waste disposal they host.

- The Regional State Administrative Agency (AVI) (Tarhanen, 2021) stated in regard to the environmental impact assessment of the Loviisa NPP (Fortum, 2021) that during closure and decommissioning of the surface facilities, the environmental impact of such decommissioning in the form of noise and dust should be assessed.

- Porvoon Museo (2021) indicated, with respect to the Loviisa NPP environmental impact assessment, that the area has been in industrial use since the 1970s and that this profile is established in the scenery of the area. Therefore, decommissioning of surface facilities should be assessed also from a cultural-historical point of view.

3. Status assessment

The primary aim of this work is to determine to what extent the legislation, regulations, requirements, expectations and recommendations related to repository closure presented in Section 2 have been addressed by the responsible organizations. This determination involves an assessment of the current situation regarding closure-related obligations against the required/target state and includes discussion on what yet needs to be done and what is missing (i.e., a needs assessment/gap analysis). The current situation regarding the fulfilment of closure-related obligations is determined solely on the basis of publicly available information from organizations with waste management responsibilities.

Twenty-five requirements were identified by the evaluation activities described in Section 2. These requirements are discussed along with the described handling (where available) of the requirement by the responsible entities. The extent to which the described handling addresses the requirements is assessed. The clarity of the purpose and objectives of the requirements are also considered. Requirements with similar focus are presented together. The numbering of requirements in this section corresponds exactly to that used in Section 2.

It should be noted that the status assessment presented here is not a performance assessment; the ability of publicized concepts, plans or designs to meet objectives is not within the scope of this analysis. Rather, this work sets out to examine the state of the planning and design process for closure-related obligations. It is also acknowledged that meeting closure-related obligations is not required at this juncture and perhaps not even desirable given that future technology innovation and optimization may yet lead to improvements (or may even be necessary) in meeting the identified requirements.

3.1 Findings

Requirement 1, **Requirement 2** and **Requirement 4** are related to limiting radiation exposure to people and the environment from waste disposed in a repository. These requirements fall under the “closure performance” category. Repository closure systems must support the overall goal of long-term containment and isolation of disposed radioactive waste. **Requirement 3** describes a closure-specific performance target and finally **Requirement 5** gives a recommendation for retrievability of the disposed SNF after repository closure.

Technical closure system designs and requirements for the spent nuclear fuel repository at Olkilluoto, in terms of EBSs to shut remaining openings (outside of deposition tunnels), are described by Dixon et al. (2013), Sievänen et al. (2012) and Karvonen (2014). These Posiva reports serve as background documents to the safety case for the construction license application. Moreover, radionuclide transport assessments in support of this safety case were performed by Posiva. More recently, Posiva participated in the workshop that served as a kick-off to this project (see Appendix 1 for agenda) and gave a presentation on technical plans for the closure of the Onkalo repository (see Appendix 2).

In the very recent safety case for the operating license application, Posiva (2021a) provides information on closure performance and evolution over the repository life cycle.

Overall, it can be concluded that relatively detailed plans exist (regarding closure EBS designs) for the high-level waste repository in Finland relative to meetings **Requirements 1–4**.

In addition to the SNF-repository, TVO and Fortum gave a combined presentation at the project kick-off meeting (see Appendix 2) on closing the LILW repositories at Olkiluoto and Loviisa. Fortum has also published a safety case which includes information on technical closure system designs and requirements (Nummi, 2018). The main closure related safety functions are as follows: 1) the closure should protect concrete barriers from mechanical stresses, 2) the closure should limit groundwater flow, and 3) the closure should reduce the likelihood of inadvertent intrusion. In order to meet these aims, a set of performance targets were established, and basic technical closure system designs were provided.

In part, **Requirement 5** indicates that a precondition for permanent closure is that an approved closure plan includes a plan for potential post-closure monitoring and a proposal for the restriction zone. **Requirements 6 and 7** also refer, in part, to post-closure monitoring measures of the disposal facility where required, as an implementation stage. According to the STUK YVL Guide D.5 506 § (STUK, 2018b):

> During the construction and operation of the disposal facility, a research and monitoring programme shall be executed to ensure that the site and the rock to be excavated are suitable for disposal and to collect supplementary information about the safety-relevant characteristics of the host rock and the performance of the barriers. This programme shall at least include:
>
> a. the characterisation of the rock volumes intended to be excavated;
>
> b. the monitoring of rock stresses, movements and deformations in rock surrounding the emplacement rooms;
>
> c. the hydrogeological monitoring of the host rock surrounding the emplacement rooms;
>
> d. the monitoring of groundwater chemistry;
>
> e. the monitoring of the performance of engineered barriers; and
>
> f. the monitoring of surface environment.

Posiva has indicated that its monitoring programme will include the above elements (Pere, 2019). However, this monitoring programme will continue only until repository closure. Insofar as disposal operations at the Onkalo repository may begin in the second half of this decade, more detailed monitoring plans should be available in the near future.

In the safety assessment conducted for the construction license application, (Posiva, 2012a) briefly addressed the issue of post-closure monitoring and surveillance. It was indicated that such monitoring could include surface and borehole measurements of radioactivity, measurements of groundwater depth, chemistry and temperature. It was also mentioned that geophysical properties, such as measurements of micro earthquakes could be monitored from the surface. Lastly, it was claimed that any intended intrusions to the repository would result in surface damage that could be monitored with satellite imaging. Sievänen et al. (2012) also discussed the possibility of leaving some boreholes open for post-closure monitoring.

Post-closure monitoring is briefly addressed in the very recent operating license application for the SNF repository (Posiva (2021c). It is stated that a proposal for post-closure monitoring will be prepared in the closure phase of the repository. The application presents the same list of possible measurements as earlier (Posiva, 2012a) with no further updates.

Identified Gap: Detailed post-closure monitoring plans are not available for the Onkalo repository.

It is also not evident that Posiva should be solely responsible for developing and designing a post-closure monitoring strategy as its main interest would be in the estimated cost, not the outcomes.

As waste disposal is already ongoing in the LILW repositories at Olkiluto and Loviisa, so should testing and monitoring programmes as per STUK YVL Guide D.5 510 §, as well as post-closure monitoring planning. The safety case for the Loviisa repository (Nummi, 2018) states, that no post-closure surveillance period is planned, which seems to be somewhat contradictory with the expectations of **Requirement 6**, unless such monitoring was determined not to be required. The environmental impact assessment for the Loviisa NPP states that after closure, the repository is transferred for post-closure monitoring and surveillance to the government (Fortum, 2020).

Identified Gap: No information is available regarding the testing and monitoring programme (or post-closure monitoring planning) at the LILW repository at Olkiluoto.

Restriction-zone related requirements are discussed in more detail below.

The need for maintaining retrievability of SNF is also specified in **Requirement 7**. Retrieval should be possible for as long a period after repository closure as the canisters are sufficiently intact to separate nuclear material from the surrounding environment. Retrieval of SNF should be included in the repository design and should not come at the cost of long-term safety. Posiva (2012b) indicates that retrieval of SNF will be technically feasible even after closure as this condition is a performance target of the repository design.

An assessment of retrievability was made earlier by Saanio and Raiko (1999). It was stated, that in a case, where the canisters should be retrieved after the closure of the repository, the retrieval should be possible. Drifts and shafts would be re-excavated, and new vital systems, such as ventilation, would be constructed. Plugs at the entrances to deposition tunnels would be demolished and the tunnels re-excavated. One possibility for buffer removal would be dissolution with saline water. After removal of the buffer, it is envisioned that canisters would be retrieved with the same devices that were used in their emplacement.

According to Posiva (2012b), the canister design basis, which ensures long-term canister stability, is sufficient to meet the retrievability target.

Despite retrieval being technically feasible, questions remain as to post-closure responsibility. After closure, responsibility for the waste transfers from the license holder to the State. However, it is unknown under what conditions SNF retrieval would be authorized or which State actor would have authority over such actions. The possibility of authorized retrieval also raises the question of nuclear safeguards and implies that any authorized retriever would need to establish safeguards procedures and reporting systems to be verified by a State actor.

Moreover, although Saanio and Raiko (1999) envision that canisters would be retrieved with the same devices that were used in their emplacement, no mention is made of any plans to preserve these devices for possible future retrievability needs or, for that matter, repository layout and canister location information.

Identified gap: *It is not clear which State actor would have authority over SNF retrieval should it be petitioned for during post-closure or over what duration retrieval would be allowed. Information relevant for retrievability (i.e., repository layout, canister locations, EBS and disposal equipment designs) should also be preserved for the future.*

Requirement 8 defines some closure-related obligations of the KYT programme itself, indicating that it (the KYT programme) should include “plans relating to the post-closure period of the disposal facility, the period during which the monitoring of the disposal shall be continued as well as the long-term measures through which the continuity of knowledge of the facility shall be assured.”

Once a licensee under a waste management obligation has closed the disposal facility, and STUK has confirmed that the final disposal of nuclear waste has been implemented safely and in the approved manner (i.e., in accord with the approved Closure Plan), the license holder can apply for a termination of liability of the nuclear waste management obligation. When the license holder’s liability is terminated, ownership rights and responsibility for the disposed waste is transferred to the Finnish State. The State is therefore responsible for nuclear waste management in the post-closure period.

KYT (Kansallinen ydinjätehuollon tutkimusohjelma) is the Finnish national nuclear waste management programme which was established by the Ministry of Economic Affairs and Employment of Finland (TEM) and STUK. KYT’s mandate is to review and study the goals and principles of nuclear waste management (Valtioneuvosto 1987) and provide Finnish decision makers with independent information and knowledge to make nuclear waste management related decisions (TEM, 2018). Regarding plans for post-closure activities, KYT (2018) indicated that such plans have not yet been made and posited that it will be done in the following decades.

In addition to the period during which the monitoring of the disposal shall be continued as well as the long-term measures through which the continuity of knowledge of the facility shall be assured, plans relating to the post-closure period could include further aspects of monitoring strategy (i.e., what and how to measure), knowledge preservation strategy (i.e., what knowledge to preserve) and site control (i.e., active and passive measures).

Identified Gap: No post-closure plans, including post-closure monitoring and long-term information preservation have yet been established via KYT.

STUK has indicated it will be responsible for arranging the permanent archiving of information concerning the spent fuel destined for final disposal (TEM 2015). No detailed plans for the permanent archiving of information have yet been made because the closure of the first sections of the disposal facility is still many decades away. In fact, the arrangement of the permanent archiving of this information is currently estimated to begin in the 2060s (ibid). Final archiving of the information pertaining to disposed spent fuel can begin with emplacement of the last canister which will occur (possibly decades) prior to closure of the Onkalo repository.

Again, as waste disposal is already ongoing in the LILW repositories at Olkiluto and Loviisa, there should already be records of the location, type and packaging of the disposed wastes. However, no information on programmes or plans for the preservation of this information is available.

Requirement 9 calls for the reservation of a protective zone around the disposal facility. TEM (2013) states that a protective zone has been reserved around the spent fuel repository at Olkiluoto. The protective zone enables STUK to limit the usage of the area to ensure safety as stated in NEA 63 (6) § (Valtioneuvosto, 1987). The extent of the protective zone, which also includes the LILW repository, is presented in detail in the town planning report by AIRIX Ympäristö Oy (2009). Additionally, Afry (2021) are working on incorporating the VLLW-repository into the current land usage planning.

There is also a protective zone around the Loviisa NPP, which includes the LILW repository, as described in Huhtinen et al. (2008).

Identified Gap: The duration over which the protective zones should be maintained is not defined.

Entering final site area information to public registers may need to wait until repository closures are approved to ensure the most up to date information is recorded. Long-term plans for the preservation and administration of these records are not available. Arkistolaitos (2008) has stated that archiving is currently paper based but will be transitioned to electronic archiving. STUK will conduct data preservation plans in the 2100s (TEM, 2015). However, this planning may only apply to records pertaining to the spent fuel repository at Olkiluoto.

Identified Gap: It is not clear whether such planning will also be carried out for the zoning records from the LILW repositories (one of which is scheduled for closure in the 2060s) and also which specific records (for any repository) are to be preserved.

The environmental impact assessment for the Loviisa NPP (Fortum, 2021) describes two different possibilities for the post-decommissioning land usage at the site. In the first proposal the NPP area is open to further use as an industrial zone. All surface facilities that can be declared safe will be available for alternative uses. As the area is already connected to the Finnish electric grid, future siting of small modular reactors is a consideration. A second possibility is to allow a return of the area to its natural state by dismantling all surface facilities and fully restoring the landscape. It was considered that, in such a restored state, the area could be opened for normal land use with restrictions on the LILW repository (VLJ-cave) area. However, for this second possibility to occur, the restriction zone around the NPP area would need to be reassessed as the LILW repository lies within it.

Requirement 10 states, in part among other conditions, that parties with waste management obligations must pay a “lump sum to the State for the monitoring and control of the nuclear waste” in order to allow

such obligations to expire. Paying this lump sum implies that the monitoring and control strategies and methods were identified and agreed to in advance as well as the related costs. In principle, the permanent disposal of nuclear waste is to be performed in a way that does not require the surveillance of the disposal site. However, surveillance is not precluded either. Furthermore, **Requirement 11** expresses that, after disposal (which is taken here to mean after closure), the State has the right to take all measures required for the monitoring and control of the nuclear waste.

To the extent that the monitoring and control strategies and methods may involve elements of the monitoring programme described by STUK (YVL Guide D.5 510 §, STUK 2018b) or similar, their implementation may need to be started several decades before closure. Insofar as the implementation of a monitoring and control programme may need to begin decades before closure, its planning would need to be initiated well in advance of its implementation not to mention developing and acquiring the needed technology. It is also an open question as to which interested parties would be involved in choosing the monitoring and control strategies.

Posiva has acknowledged the need for paying upfront for a possible post-closure monitoring programme in Posiva (2021c).

Identified Gap: *As with the findings regarding **Requirements 5-7**, no information regarding aspects of the post-closure monitoring and control strategies are available for any radioactive waste repositories in Finland. Also, it is not clear which State actors (municipal, regional, or national) will be responsible for the disposed waste on a practical level after repository closure.*

Requirement 12 specifies that licensees should maintain records of the disposed waste to include data on the waste type, radioactive substances, location within the disposal facility and other information deemed necessary by the authority. These records are to be submitted to STUK in a preapproved format. STUK will then arrange for the permanent keeping of these records. **Requirement 13** gives further details on disposed waste data to be maintained by licensees.

Identified Gap: *These requirements do not indicate why the selected information was chosen for preservation or whether other information should be preserved as well. It is also unclear how the format of the data is decided and when, relative to repository operations, the data is to be submitted to STUK.*

Insofar as waste disposal is ongoing in the LILW repositories in Finland, data should be available regarding the disposed waste in these facilities. TEM (2015) reported some characteristics of the waste disposed at the Olkiluoto LILW repository as well as future estimates of inventories for both the Loviisa and Olkiluoto LILW repositories. However, complete lists of disposed LILWs are not available.

Identified Gap: *Only limited information could be found regarding the nature, format, submission or permanent archiving of this data.*

At present, no nuclear waste is yet disposed in the spent fuel repository at Olkiluoto and, therefore, no disposed waste data is available. Posiva (2021b) recently stated that waste data and properties must be collected during the operational phase of the repository. Furthermore, it is emphasized that the data should be stored and maintained so that it can be used for more than 100 years after the end of the operational period of the repository. No data collection, storage or preservation plans are presented; the 100-year data maintenance period is presumably discretionary.

The current locations and amounts of the spent fuel in interim storage is discussed by STUK (Kainulainen, 2015). Crude inventories for the low and intermediate level nuclear waste disposed in the Loviisa and Olkiluoto LILW repositories are also presented. It is further indicated that the disposal of low and intermediate level waste is being conducted as planned in both facilities.

Requirement 14 establishes that the radioactive waste management programmes of EU Member States should include concepts or plans and technical solutions from waste generation to disposal. Disposal ends with closure of repository facilities. As the assessments of **Requirements 1-4** above indicate, relatively detailed plans exist (regarding closure EBS designs) exist for the Onkalo spent fuel repository and the LILW repositories at Olkiluoto and Loviisa. To the extent that any post-closure monitoring strategies would need to be developed and implemented prior to repository closures, such concepts or plans and technical solutions might be needed in the relatively near future for the Onkalo spent fuel repository and as early as possible for the LILW repositories at Olkiluoto and Loviisa where waste disposal is already ongoing.

Identified Gap: No information regarding aspects of the post-closure monitoring and control strategies are available for any radioactive waste repositories in Finland.

Requirement 15 indicates, in part, that national government frameworks for radioactive waste management must consider defining the overall process for the development, operation and closure of disposal facilities, including the legal and regulatory requirements (e.g., license conditions) at each step, and the processes for decision making and the involvement of interested parties.

Based on the assessment of **Requirements 6-13** above, it can be concluded that the overall process for closure of disposal facilities in Finland is outlined in governmental and authority frameworks.

Requirement 16 states that plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.

Identified Gap: There is a lack of available, "defined and practicable" information regarding closure plans (including the transition from active management of the facilities) for any radioactive waste repositories in Finland.

Requirements 17 - 23 stress the need for concepts or plans for post-closure periods in radioactive waste management programmes and frameworks and what they should involve. It was also stated that such frameworks and programmes must consider defining the legal, technical and financial responsibilities and, if necessary, providing for any institutional arrangements that are envisaged after closure. Such arrangements were identified as:

- active site control measures (e.g., on-site security, surveillance)
- passive site control measures (e.g., durable surface and subsurface markers)
- monitoring (which is capable of providing early warning of radionuclide migration before reaching site boundaries)
- local land use rules
- knowledge preservation (at a local, national and international level, keeping in national archives)

Requirement 24 further specifies that concepts or plans for post-closure periods should be flexible and subject to refinement as disposal facilities approach closure (decades away in all cases) and that arrangements have to be made to be able to pass on information about the disposal facility and its contents to future generations in order to enable any future decisions on the disposal facility and its safety to be made.

Requirements 6-13, discussed above, express expectations for information contained in plans for post-closure periods from the National perspective. These expectations are largely in line with the post-closure arrangements discussed in **Requirements 17-23**, although it is not clear whether site control measures are covered by the former.

The findings pertaining to the earlier requirements can be consolidated and reiterated here, with respect to the latter requirements, as follows:

Identified Gap: *There is a lack of available, specific information (active and passive site control, monitoring, knowledge preservation, etc.) regarding concepts or plans for post-closure periods for any radioactive waste repositories in Finland.*

As a point of interest, bearing in mind that near surface repositories are not directly in the scope of this report, **Requirement 22** states that such facilities are generally designed on the assumption that (post-closure) institutional control (passive or active) has to remain in force for a period of time. Finnish legislation, as codified in 7 h of the NEA (Valtioneuvosto, 1987), states that long-term safety does not require active surveillance of the repository. Moreover, the environmental impact assessment for a very-low-activity surface repository at Olkiluoto (TVO & Afry, 2021) also states that no post-closure surveillance of the site is required, but the information and land restriction of the area are intended to be preserved. It is indicated that after the responsibility of the repository has been transferred to the government, any surveillance or other activities deemed necessary can be carried out.

The requirement for post-closure institutional control of surface repositories has not been included in Finnish legislation.

Requirement 24 establishes that geological disposal facilities must not be dependent on long term institutional control after closure as a safety measure. However, it is noted that institutional controls may contribute to safety by preventing or reducing the likelihood of human actions that could inadvertently interfere with the waste or degrade the safety features of the geological disposal system and, moreover, that institutional controls may also contribute to increasing the public acceptance of geological disposal.

Certainly, the principle that the safety of geological disposal facilities should not depend on post-closure institutional control is consistent with Finnish rules and regulations. On the other hand, the extent to which public acceptance has been sought on the basis of such control is not apparent.

Relatedly, **Requirement 25** addresses stakeholder engagement indicating that necessary information on the management of spent fuel and radioactive waste be made available to workers and the general public. In particular, this requirement states that it should be ensured that the public be given the necessary opportunities to participate effectively in the decision-making process regarding spent fuel and radioactive waste management in accordance with national legislation and international obligations.

Identified Gap: *The available outcomes of the dialogue with public stakeholders in terms of increased acceptance or decision-making relative to post-closure institutional control are limited to that presented in Section 2.3. It is not clear whether engagement on other aspects of post-closure planning has occurred.*

3.2 Recommendations

The gaps identified on the basis of the assessment of the current situation regarding closure-related obligations against the required/target state fall into four main categories: 1) post-closure monitoring 2) knowledge preservation 3) responsibility and 4) stakeholder engagement. In this section, recommendations are discussed relative to these gap categories.

Gaps related to post-closure monitoring

Assessments of **Requirements 6, 7, 8, 10** and **14** showed the presence of gaps regarding post-closure monitoring. Basically, plans for post-closure monitoring do not appear to exist even at a general strategic level (other than to say it will be done if needed) even though such obligations are defined in multiple requirements.

Post-closure monitoring can be beneficial in ensuring that repository closure has been conducted as planned. IAEA (2014) recommends that post closure monitoring periods and their durations should be determined depending on the disposed waste type. Durations for post-closure monitoring can also be influenced by confidence in the technical solution for the repository. For example, a deep geological repository should have higher confidence in containment than a near-surface, landfill-type repository. Post-closure monitoring may also be useful in boosting public confidence and acceptance. IAEA (2001) state that monitoring could potentially be sustained as long as society feels that there is a need for it. It will need to be determined who (i.e., which State actor) is to be responsible for any such monitoring programmes, but they could be folded into existing responsibilities. For example, STUK is already involved in various monitoring campaigns, e.g., measurements of radioactivity in the Baltic Sea (Mattila & Inkinen, 2020) and repository post-closure monitoring could fall into its purview as well, provided mechanisms exist to ensure the longevity of the institution (or at least transfer of responsibility and data) over monitoring programme durations.

Closure of the Onkalo spent fuel repository is estimated to start in the 2100s (Dixon et al., 2013), and thus detailed plans for post-closure monitoring are not yet urgently needed. However, if any monitoring with respect to access to the entirety of individual deposition hole positions is desired as part of a post-closure monitoring program, such measurement schemes may need to be installed already in the early stages of the operational phase as waste emplacement is estimated to start in the 2020s. Additionally, a partial closure approach will be employed by Posiva whereby some closure engineered barrier systems will be installed in sections where waste emplacement is complete. Specifically, the closure of the central tunnels in the first panel is presently planned to take place starting in the 2070s after the deposition tunnels in the North-East panel are backfilled (Dixon et al., 2013). Therefore, any monitoring with respect to these central tunnels would need to be installed at this time as well. Employing a partial closure approach which clearly includes installation of technical closure solutions also raises questions about when an approved closure license should be obtained.

In order to ensure the broadest possible coverage possible, creating a post-closure monitoring strategy now would allow for determining what should be measured, where it should be measured, how it will be measured and for how long against current technological availability and anticipated advances.

It is of course a challenge to implement such monitoring without comprising fundamental safety barriers. Therefore, it may be advantageous to focus on non-intrusive monitoring techniques, such as wireless sensor networks and wireless through-the-earth data transmission, fibre-optic technologies and geophysical techniques, monitoring of groundwater and chemistry, geotechnical monitoring, or air-based and satellite-based monitoring. Although some of these techniques look promising and are likely to be of relevance for repository monitoring, several of them (e.g., wireless data transmission, fibre-optics and geophysics) will require further research to adapt them to specific repository monitoring requirements (White et al., 2010).

Given that disposal operations are ongoing in the Finnish LILW repositories, post-closure monitoring plans should be reviewed and updated as deemed necessary without delay. Furthermore, the Loviisa LILW repository is estimated to be closed in the 2060s. Therefore, the urgency for review and update of any post-closure plans with respect to this facility is more acute, particularly in terms of public engagement.

Producing detailed post-closure monitoring plans, together with all other closure plans, earlier would also provide a safety margin in the event of unexpectedly early closure of any disposal facilities. The reasons why such early closures might occur are outside of the scope of this report, but, nevertheless, the earlier such plans are available the earlier closure could be implemented if need be.

Recommendation: - *Plans for post-closure monitoring for all radioactive waste repositories in Finland should be made (or reviewed if existing) as soon as possible for use in decision making. These plans should include provisions on transfer of monitoring programme oversight from current parties with waste management responsibilities to State actors upon repository closures.*

- *Keep current with the EU MODATS Project, which is focussed on repository monitoring strategies and technologies.*

Gaps related to knowledge preservation

Assessments of **Requirements 5, 8, 9, 12** and **13** showed gaps related to knowledge preservation. Relevant plans are still relatively undeveloped despite their necessity. Given that radioactive waste repositories in Finland are not scheduled for closure for many decades it could be surmised that there is no urgency in developing detailed knowledge preservation plans. However, waste disposal is already ongoing in the LILW repositories and is estimated to start in the spent fuel repository this decade. Presumably information and knowledge that could be preserved already exists and is currently stored somewhere in some format.

Perhaps the more urgent question is what data should be preserved for the future. Assessing which waste information should be preserved for future generations should be conducted as soon as possible, as waste is already being disposed in the LILW repositories. Pettersson and Bratt (2021) discuss different methods for preservation of information from geological disposal facilities for hazardous waste, including radioactive and non-radioactive waste. They state that we as a current generation cannot know what is important for future generations and, thus, it is wiser to preserve as much information as possible. However, preserving vast amounts of data may too expensive or complicated. Different levels of detail in preserved data based on priority could be made. For example, the most vital information should be saved as condensed as possible and saved redundantly to ensure long term preservation, while more general, less important, information can be stored more lightly.

Apart from information on disposed waste, land usage restrictions must be preserved. As it stands, some repository information is already in the land usage registers. However, it is not clearly defined how long the information should be preserved there. As land usage limits can have an effect on the long-term safety of the repository, i.e., in preventing human intrusion, it should be well defined how long the information should be preserved.

Finally, as discussed in relation to **Requirement 7**, information about repository layouts and designs as well as retrieval options should be preserved in the event that purposeful retrieval becomes desired or necessary by future generations.

Recommendation:
- *Knowledge preservation plans should be regularly reviewed and updated.*
- *As determining what information will be relevant to future generations is very complex, sufficient time should be spent determining what should be preserved. Only the most vital information should be preserved for the longest time, while less important information can be secured less stringently.*
- *Archivable spent fuel information will start being generated with emplacement of the first canister which is estimated to occur as early as this decade, therefore a plan for its preservation is needed in the near future.*
- *Information which may be needed for retrieval (e.g., repository layout, canister locations, waste data, EBS structures, disposal equipment) should be defined and a plan made for its preservation.*
- *Knowledge preservation plans should include processes by which transfer of custody of information from license holders to State actors occurs as well as agreement or understanding of the data formats, storage architecture and accessibility options to be used.*
- *Data formats, storage architecture, accessibility and maintenance need to be considered as well as changes in these factors over the input period and beyond.*
- *The durations the protection zones around the repositories are to be maintained should be defined.*

- *A knowledge preservation plan for the administrative records pertaining to the protective zones should be made.*

Gaps related to transfer of ownership and post-closure responsibilities

Assessments of **Requirements 5, 10, 11, 16** and **17-23** showed gaps related to transfer of ownership and post-closure responsibilities. As previously discussed, license holders can apply for termination of liability of the nuclear waste management obligations after closing disposal facilities and receiving approved confirmation from STUK. When the license holder's liability is terminated, ownership rights and responsibility for the disposed waste is transferred to the Finnish State and the State is thereby responsible for the nuclear waste management for the post-closure period.

Aside from the monitoring concerns discussed above under **Gaps related to post-closure monitoring**, several other open questions related to the transition from closure to post-closure phases remain:

- what aspects of the active and passive post-closure site control programme, if any, need to be established in closure plans?
- are licensees responsible for establishing active and passive post-closure site control programmes just prior to closure?
- how long should active post-closure site controls remain in place?
- are licensees required to pay fees to the State for the maintenance of post-closure site controls?
- If adaptations are made to site control and/or monitoring programmes during post-closure that increase or decrease costs relative to prescribed fee levels, are previous licensees required to pay additional fees or receive refunds?
- which State actor is responsible for adapting post-closure site control or monitoring programmes?
- which State actor is responsible for approving any such adaptations?

There is a lack of clearly defined and practicable information regarding the transition from closure to post-closure phases, particularly with respect to expectations for Closure Plans, for any radioactive waste repositories in Finland.

Additionally, there is a lack of information regarding waste retrieval in terms of authorizations or responsible State actors.

Recommendation:

- *Formal closure plans should include provisions on active and passive site controls, associated fee structures and the financial impact of adaptations to site control and monitoring programmes on licensees.*
- *State actors with site control and monitoring responsibilities should be identified.*
- *A preliminary plan should be made on how retrieval will be authorized, which State actor is responsible and over what applicable time period retrieval will be permitted.*

Gaps related to stakeholder engagement

Assessment of **Requirement 25** showed gaps related to stakeholder engagement. In the post-closure phase of radioactive waste repositories, planning land use practices, managing residual risk due to

containment failure and dealing with uncertainties over societal and technological developments are issues which directly affect host communities. In their roles as hosts to such facilities, it stands to reason that local communities should be involved in any decision making related to these issues.

The material presented in Section 2.3 shows that the local host communities in Finland are involved in discussions regarding land use practices. Additionally, the Municipal Board of Eurajoki expressed a desire to be included in all discussions about changes in plans considering nuclear waste management within their municipality and that information about the nuclear waste repository, even information that everything is working as intended, be provided to them routinely and automatically. The degree to which the local host communities in Finland have been specifically engaged in the risk and uncertainty post-closure issues is unknown

Addressing residual risks due to containment failure comes down to questions about monitoring. Issues regarding the how, what and where of post-closure monitoring were discussed above (under the gap of the same name). With respect to stakeholder engagement, the whether and why of post-closure monitoring is raised. Drawing on research on risk and trust and on analysis of published accounts on the relationship between stakeholders and monitoring activities focussed on the field of radioactive waste management, Bergmans et al. (2013) found that stakeholders do not necessarily expect monitoring to contribute to the safety of a repository but do expect it to check that safety is being ensured. There is a case to be made that monitoring has a role in public confidence building.

Apart from the general uncertainty over where societal and technological developments will lead in the future, there are examples of more specific uncertainties. One example is waste retrieval, and another is containment failure. The former is based on the possibility that future generations will want to retrieve wastes and process them with new technologies and the latter on the possibility that monitoring will detect radionuclide releases or other anomalies. Both situations could lead to profound impacts on local host communities.

Recommendation:

- *Review records of public stakeholder engagement on post-closure issues, if existing.*
- *Examine the information exchange to the Municipal Board of Eurajoki.*
- *Further (or initially) engage with public stakeholders on post-closure issues.*
- *Create and maintain records of public stakeholder engagement on post-closure issues.*

4. Conclusions

Overall, twenty-five closure-related requirements were identified from Finnish and International legislation, regulations, requirements, expectations and guidance. These requirements were divided into a set of nine categories as follows:

- closure performance
- closure planning
- closure implementation
- post-closure planning
- post-closure actions
- post-closure resourcing
- post-closure responsibilities
- records preservation
- stakeholder engagement

An exploratory assessment of the current handling of each identified closure-related obligation was performed against available information from Finnish nuclear waste license holders and other responsible organizations. In total, thirteen gap areas were found. These gap areas fall into four main domains:

- post-closure monitoring
- knowledge preservation
- transfer of ownership and post-closure responsibilities
- stakeholder engagement

There are also connections between the various gap domains; aspects of post-closure monitoring concern knowledge preservation, etc.

Gaps/needs related to post-closure monitoring arise from the lack of any available, substantive plans in this regard for the LILW and SNF repositories in Finland. It is naturally tempting to note that repository closures are many decades away and post-closure monitoring decisions can wait, and quite possibly should due to technological advancements. However, this position ignores that some strategic decisions on post-closure monitoring should probably be made prior to operations.

The purpose and scope of any post-closure monitoring programmes need to be specified relatively early, with respect to operations, as such strategic decisions will determine the monitoring resolution over the repository boundaries. Specifically, some sensors or schemes will need to be deployed with first waste emplacement activity (within this decade for the SNF repository and already now for the LILW repositories) if monitoring is desired at locations over the entirety of the repositories.

Aside from where and what to monitor, another important question to ask is how to monitor. It may well be that sufficient technology does not yet exist that will permit (on an immediate or delayed basis) monitoring of relevant parameters at boundary locations over operational time frames let alone into post-closure periods. If so, and if such monitoring is desired, investment in technology development will need to be

undertaken. If, on the other hand, the needed technology is unlikely to become available, this reality needs to be acknowledged and accepted.

Lastly, the why of the monitoring also needs to be addressed. Is the monitoring to serve primarily as a quality control check confirming repository performance or should it aim to register unlikely or unexpected events as well? And who decides, i.e., what level of stakeholder engagement is involved?

Similarly, gaps/needs related to knowledge preservation stem from the lack of clear plans in this area for the LILW and SNF repositories in Finland. Although the need for such plans is not urgent as closure is still many decades away for every facility, there are reasons to consider knowledge preservation plans more systematically. For example, waste disposal is already ongoing in the LILW repositories and is estimated to start in the spent fuel repository this decade. Information and knowledge that could be preserved already exists and is currently stored somewhere in some format. In order to devise the most efficient data collection and storage schemes, it should be specified what information and knowledge is to be preserved (and at what level of detail) for the future and, furthermore, who decides?

Gaps in transfer of ownership and post-closure responsibilities are primarily due to a lack of specificity in the requirements themselves. These gaps are concerned with active and passive site controls and waste retrieval authorization. Monitoring could of course be included in this gap domain as well but given how explicitly and frequently post-closure monitoring appears in the identified requirements it warranted its own category. To a lesser extent, the same reasoning applies to knowledge preservation.

The final gap domain is stakeholder engagement. These gaps pertain to a scarcity of information regarding the level of engagement with local stakeholders on post-closure issues. Specifically, planning land use practices, managing residual risk due to containment failure and dealing with uncertainties over societal and technological developments are issues which will or could directly affect repository host communities in post-closure periods. However, it is not evident that the voices of local stakeholders have been acknowledged.

A continuation of the KYT CloMap project is envisioned during 2022. A major part of the planned work will be dedicated to local stakeholder engagement in order to address the outstanding post-closure gaps in this area. It is also planned to 1) collaborate with the KYT YLYMU project on societal memory to further examine knowledge preservation possibilities, 2) interact with the international MODATS (Monitoring equipment and Data Treatment for Safe repository operation and staged closure) project and 3) pursue clarification on questions related to transfer of ownership and post-closure responsibilities.

References

AIRIX Ympäristö Oy. (2009). *Olkiluodon loppusijoitusalueen asemakaava ja asemakaavan muutos sekä asemakaavan ja ranta-asemakaavan osittainen kumoaminen*. http://www.ahiplan.airix.fi/tietopankki/tvo/poistettu/suunnitelma/vanhat/kaavaselostus-050109.pdf

Arkistolaitos. (2008). *Pysyvästi säilytettävät kunnalliset maankäytön, kaavoituksen ja maapolitiikan, kiinteistönmuodostuksen, mittaus- ja karttapalvelujen sekä asiamiespalvelujen ja rakennusvalvonnan asiakirjat* (AL 11665). https://arkisto.fi/uploads/normit/kunnallishallinto/seulontapaatokset/Kuntapaatos2008.pdf

Bergmans, A., Elam, M., Simmons, P., & Sundqvist, G. (2013). Different views on monitoring and the governance of repository development and staged closure. Presentation at the MoDeRn International Conference and Workshop, 19-21 March 2013, Luxembourg.

Dixon, D., Hansen, J., Korkiala-Tanttu, L., Karvonen, T. H., Marcos, N., & Sievänen, U. (2013). *Underground Disposal Facility Closure Design 2012* (Working Report 2012-09). https://inis.iaea.org/collection/NCLCollectionStore/_Public/46/094/46094981.pdf

EU. (2011). Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste. In (Vol. L 199).

Eurajoki. (2021). *Käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huollon kansallisen ohjelman luonnos ja ympäristöselostus* (VN/18944/2021). https://www.lausuntopalvelu.fi/FI/Proposal/Participation?proposalId=e01c4855-5b1f-4768-b41e-7e3392e07ad4&proposalLanguage=da4408c3-39e4-4f5a-84db-84481bafc744

Finnish Government. (2002). *Periaatepäätös 2002*. https://tem.fi/documents/1410877/2413079/PAP+2002.pdf/07e9e06d-9926-44ad-9095-caf24ed9a86b/PAP+2002.pdf?t=1465981168000

Fortum. (2020). *Loviisan ydinvoimalaitos Ympäristövaikutusten arviointiohjelma*. https://tem.fi/documents/1410877/32003546/YVA-ohjelma.pdf/6af48989-407d-dd08-723f-4df5553f899d/YVA-ohjelma.pdf?version=1.1&t=1598347751749

Fortum. (2021). *Loviisan ydinvoimalaitos Ympäristövaikutusten arviointiselostus*. https://tem.fi/documents/1410877/89823533/Ymp%C3%A4rist%C3%B6vaikutusten+arviointiselostus.pdf/a53dbc97-a920-fd1c-ea9d-e9eed4bfa51a/Ymp%C3%A4rist%C3%B6vaikutusten+arviointiselostus.pdf?version=1.1&t=1630928029549

Huhtinen, T., Rautiainen, J., & Meltaus, Y. (2008). *Loviisa Hästholmenin alueen asemakaava*. Loviisa, Loviisan kaupunki. https://www.loviisa.fi/wp-content/uploads/2017/04/7_LOV_hastholm.pdf

IAEA. (2001). *Monitoring of geological repositories for high level radioactive waste* (IAEA-TECDOC-1208). https://www-pub.iaea.org/MTCD/Publications/PDF/te_1208_web.pdf

IAEA. (2006). *Geological Disposal of Radioactive Waste Safety Requirements* (No. WS-R-4). (IAEA Safety Standards Series, Issue. https://www-pub.iaea.org/mtcd/publications/pdf/pub1231_web.pdf

IAEA. (2011). *Disposal of Radioactive Waste Specific Safety Requirements* (No. SSR-5). (IAEA Safety Standards Series, Issue. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1449_web.pdf

IAEA. (2014). *Monitoring and Surveillance of Radioactive Waste Disposal Facilities* (No. SSG-31). (IAEA Safety Standards Series Issue. https://www-pub.iaea.org/MTCD/publications/PDF/Pub1640_web.pdf

Kainulainen, E. (2015). *Ydinenergian käytön turvallisuusvalvonta Vuosiraportti 2014* (187). (STUK-B, Issue. http://urn.fi/URN:ISBN:978-952-309-262-4

Karvonen, T. (2014). *Closure of the Investigation Boreholes* (Posiva Working Report 2012-63). https://www.posiva.fi/en/index/media/reports.html

KYT. (2018). *Kansallinen ydinjätehuollon tutkimusohjelma KYT2022 Puiteohjelma tutkimuskaudelle 2019–2022*. http://kyt2022.vtt.fi/hankehaku/Puiteohjelma%20KYT2022.pdf

Mattila, A., & Inkinen, S. (2020). *Environmental Radiation Monitoring in Finland Annual Report 2019* (STUK-B 249). https://www.julkari.fi/bitstream/handle/10024/140198/Ymp%c3%a4rist%c3%b6n_s%c3%a4teilyvalvonta_vuosiraportti_2019.pdf?sequence=1&isAllowed=y

National Research Council. (2003). *One Step at a Time: The Staged Development of Geologic Repositories for High-Level Radioactive Waste*. T. N. A. Press.
Nummi, O. (2018). *Safety Case for Loviisa LILW Repository 2018 - Main Report*.
Pere, T. (2019). *Monitoring Programme for the Olkiluoto Repository, Finland* Modern2020, Paris. http://www.modern2020.eu/fileadmin/Final_Conference/Presentations/Day_1/Session_3/5_Presentation_Session_3_Pere_Modern2020_presentation-.pdf
Pettersson, C.-H., & Bratt, A. (2021). *Redovisning av regeringsuppdrag om metoder för säkerställande av information och kunskap över lång tid för slutförvaret för kärnbränsle* (SSM 2021:24). https://www.stralsakerhetsmyndigheten.se/contentassets/b1505bd7233d4980a1b6483e0153cb9b/202124-redovisning-av-regeringsuppdrag-om-metoder-for-sakerstallande-av-information-och-kunskap-over-lang-tid-for-slutforvaret-for-karnbransle
Porvoon Museo. (2021). *Loviisan ydinvoimalaitoksen ympäristövaikutusten arviointiselostus*. https://www.lausuntopalvelu.fi/FI/Proposal/Participation?proposalId=5cb5f2ac-2270-4a43-b607-c48cdbac0edf#
Posiva. (2012a). *RAKENTAMISLUPAHAKEMUS Olkiluodon kapselointi- ja loppusijoituslaitoksen rakentamiseksi käytetyn ydinpolttoaineen loppusijoitusta varten*. https://tem.fi/documents/1410877/2412863/Posivan_rakentamislupahakemus.pdf/3d8fae76-9866-3c3d-272e-8909b93111fe/Posivan_rakentamislupahakemus.pdf?t=1609153067984
Posiva. (2012b). *SAFETY CASE FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AT OLKILUOTO - DESIGN BASIS 2012* (POSIVA 2012-03).
Posiva. (2021a). *Buffer, Backfill and Closure Evolution* (WR 2021-08). https://www.posiva.fi/tietopankki.html
Posiva. (2021b). *Olkiluodon monitorointiohjelma -2022* (Posiva 2020-02). https://www.posiva.fi/media/raportitjajulkaisut.html
Posiva. (2021c). *Operating Licence Application for a Spent Nuclear Fuel Encapsulation Plant and Disposal Facility*. https://www.posiva.fi/tietopankki.html
Ramboll. (2021). *Käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huoltoa koskevan kansallisen ohjelman ympäristöselostus*. https://tem.fi/documents/1410877/82521802/Ymp%C3%A4rist%C3%B6selostus.pdf/03b7bd85-5e25-a98f-7df9-db951895defd/Ymp%C3%A4rist%C3%B6selostus.pdf?version=1.0&t=1628143740054
Saanio, T., & Raiko, H. (1999). *Käytetyn ydinpolttoaineen loppusijoituksapseleiden palautettavuus* (Työraportti 99-21). https://www.posiva.fi/media/raportitjajulkaisut.html
Sievänen, U., Karvonen, T., Dixon, D., Hansen, J., & Jalonen, T. (2012). *Design, Production and Initial State of the Underground Disposal Facility Closure* (POSIVA 2012-19). https://www.posiva.fi/media/raportitjajulkaisut.html
STUK. (2018a). Säteilyturvakeskuksen määräys ydinjätteiden loppusijoituksen turvallisuudesta. In.
STUK. (2018b). Ydinjätteiden loppusijoitus. In.
STUK. (2019). *Matala- ja keskiaktiivisten ydinjätteiden käsittely ja ydinlaitoksen käytöstäpoisto, 15.12.2019* (YVL D.4). https://www.stuklex.fi/fi/ohje/YVLD-4
Tarhanen, E.-R. (2021). *Loviisan ydinvoimalaitoksen ympäristövaikutusten arviointiselostus*. Retrieved from https://www.lausuntopalvelu.fi/FI/Proposal/Participation?proposalId=5cb5f2ac-2270-4a43-b607-c48cdbac0edf#
TEM. (2013). *Säteilyturvakeskuksen lausunto Olkiluodon käytetyn ydinpolttoaineen kapselointija loppusijoituslaitoksen rakentamisesta* (TEM/2955/08.05.01/2012). T.-j. Elinkeinoministeriö. https://www.stuk.fi/documents/12547/207522/stukin-lausunto-posivan-rl-hakemuksesta-temille.pdf/9b62b852-e80e-4a57-b01b-619f6d5c09c0
TEM. (2015). Käytetyn ydinpolttoaineen ja muun radioaktiivisen jätteen huolto Suomessa - Euroopan unionin neuvoston direktiivin 2011/70/Euratom 12 artiklan mukainen kansallinen ohjelma. In.
TEM. (2018). Kansallinen ydinjätehuollon tutkimusohjelma KYT2022 Puiteohjelma tutkimuskaudelle 2019–2022. In (Vol. 24).
TVO, & Afry. (2021). *Hyvin matala-aktiivisen jätteen maaperäloppusijoitus, Olkiluoto Ympäristövaikutusten arviointiselostus*. https://tem.fi/documents/1410877/74883740/YVA-selostus.pdf/7f252a08-4bc6-9d24-9ca0-37d51ffe6469/YVA-selostus.pdf?version=1.0&t=1620972184008

Valtioneuvosto. (1987). *Ydinenergialaki*. https://www.finlex.fi/fi/laki/ajantasa/1987/19870990
Valtioneuvosto. (1988). *Ydinenergia-asetus*. https://www.finlex.fi/fi/laki/ajantasa/1988/19880161
White, M., Morris, J., & Harvey, L. (2010). *Monitoring Technologies Workshop Report 7-8 June 2010 – Troyes (France)* (Deliverable 2.2.1. of the MoDeRn project - Euratom - FP7 (232598)). https://www.bge-technology.de/fileadmin/user_upload/MEDIATHEK/f_e_berichte/Modern/MODERN_D2.2.1_Monitoring-Technologies-Workshop_Report.pdf

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