Publications of the Ministry of Economic Affairs and Employment
Energy • 2022:20

Management of spent nuclear fuel and radioactive waste in Finland

Second national programme under Article 12 of Directive 2011/70/EURATOM of the Council of the European Union

Ministry of Economic Affairs
and Employment of Finland

Publications of the Ministry of Economic Affairs and Employment 2022:20

Management of spent nuclear fuel and radioactive waste in Finland

Second national programme under Article 12 of Directive 2011/70/EURATOM of the Council of the European Union

Linda Kumpula, Iida Huhtanen, Salla Palander, Mia Ylä-Mella,
Venla Kuhmonen

Ministry of Economic Affairs and Employment of Finland Helsinki 2022

Julkaisujen jakelu
Distribution av publikationer

Valtioneuvoston julkaisuarkisto Valto

Publikations-
arkivet Valto

julkaisut.valtioneuvosto.fi

Julkaisumyynti
Beställningar av publikationer

Valtioneuvoston verkkokirjakauppa

Statsrådets
nätbokhandel

vnjulkaisumyynti.fi

Publication sale

Online bookstore of the Finnish Government

vnjulkaisumyynti.fi

Publication distribution

Institutional Repository for the Government of Finland Valto

julkaisut.valtioneuvosto.fi

Ministry of Economic Affairs and Employment of Finland

ISBN pdf: 978-952-327-855-4
ISSN pdf: 1797-3562

Layout: Government Administration Department, Publications

Helsinki 2022

Description sheet

1 March 2022

Management of spent nuclear fuel and radioactive waste in Finland

Second national programme under Article 12 of Directive 2011/70/EURATOM of the Council of the European Union

Publications of the Ministry of Economic Affairs and Employment 2022:20		**Subject**	Energy
Publisher	Ministry of Economic Affairs and Employment of Finland		
Author(s)	Linda Kumpula, Iida Huhtanen, Salla Palander, Mia Ylä-Mella, Venla Kuhmonen		
Language	English	**Pages**	111

Abstract

The Ministry of Economic Affairs and Employment and the Ministry of Social Affairs and Health in cooperation with the Radiation and Nuclear Safety Authority have prepared a programme on the management of spent fuel and radioactive waste in Finland. The programme is a national programme required by Council Directive 2011/70/EURATOM. The current national programme is the second in its order. An environmental impact assessment of the programme was also carried out in connection with the preparation of the national programme.

The spent fuel and radioactive waste generated in Finland are mainly managed in Finland. The responsibility for the management of spent fuel and radioactive waste and its costs lies with the operator generating the waste. The Finnish State bears ultimate responsibility for the management of spent fuel and radioactive waste generated in Finland, and the State also have financial provision for the costs of waste management. The management of nuclear fuel and radioactive waste used in Finland is implemented responsibly. However, the national programme can be developed in coming decades, for example by reforming legislation, taking into consideration cooperation between operators in licence procedures and by further developing technical solutions related to waste management, waste recording, and national expertise.

Keywords	energy, nuclear energy, nuclear waste management, nuclear waste, radioactive waste, spent nuclear fuel, radioactivity		
ISBN PDF	978-952-327-855-4	**ISSN PDF**	1797-3562
URN address	https://urn.fi/URN:ISBN:978-952-327-855-4		

Kuvailulehti

1.3.2022

Käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huolto Suomessa
Toinen Euroopan unionin neuvoston direktiivin 2011/70/EURATOM 12 artiklan mukainen kansallinen ohjelma

Työ- ja elinkeinoministeriön julkaisuja 2022:20		**Teema**	Energia
Julkaisija	Työ- ja elinkeinoministeriö		
Tekijä/t	Linda Kumpula, Iida Huhtanen, Salla Palander, Mia Ylä-Mella, Venla Kuhmonen		
Kieli	englanti	**Sivumäärä**	111

Tiivistelmä

Työ- ja elinkeinoministeriö ja sosiaali- ja terveysministeriö ovat laatineet yhdessä Säteilyturvakeskuksen kanssa Suomessa toteutettavan käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huoltoa koskevan ohjelman. Ohjelma on Euroopan unionin neuvoston direktiivin 2011/70/Euratom edellyttämä kansallinen ohjelma. Nyt laadittu kansallinen ohjelma on järjestyksessään toinen. Kansallisen ohjelman laadinnan yhteydessä toteutettiin myös ohjelman ympäristövaikutusten arviointi.

Kansallinen ohjelma sisältää yhteenvedon merkittävimmistä ympäristövaikutusten arvioinnin tuloksista. Suomessa syntyneestä käytetystä ydinpolttoaineesta ja radioaktiivisesta jätteestä huolehditaan pääosin Suomessa. Vastuu käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huollosta ja sen kustannuksista on toiminnanharjoittajalla, jonka toiminnassa jäte syntyy. Suomen valtiolla on perimmäinen vastuu Suomessa syntyneen käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huollosta, ja valtio myös varautuu erikseen jätehuollon kustannuksiin. Suomessa käytetyn ydinpolttoaineen ja radioaktiivisen jätteen huoltoa toteutetaan vastuullisesti. Kansallista ohjelmaa voidaan kuitenkin kehittää tulevina vuosikymmeninä mm. uudistamalla lainsäädäntöä, huomioimalla toiminnanharjoittajien yhteistyötä lupamenettelyissä sekä kehittämällä edelleen jätehuollon teknisiä ratkaisuja, jätekirjanpitoa sekä kansallinen osaamista.

Asiasanat	energia, ydinenergia, ydinjätehuolto, ydinjätteet, radioaktiiviset jätteet, käytetty ydinpolttoaine, radioaktiivisuus
ISBN PDF	978-952-327-855-4
ISSN PDF	1797-3562
Julkaisun osoite	https://urn.fi/URN:ISBN:978-952-327-855-4

Presentationsblad

1.3.2022

Hanteringen av använt kärnbränsle och radioaktivt avfall i Finland

Det andra nationella programmet enligt artikel 12 i Europeiska unionens rådets direktiv 2011/70/EURATOM

Arbets- och näringsministeriets publikationer 2022:20		**Tema**	Energi
Utgivare	Arbets- och näringsministeriet		
Författare	Linda Kumpula, Iida Huhtanen, Salla Palander, Mia Ylä-Mella, Venla Kuhmonen		
Språk	engelska	**Sidantal**	111

Referat

Arbets- och näringsministeriet och social- och hälsovårdsministeriet har i samarbete med Strålsäkerhetscentralen utarbetat ett program för hanteringen av använt kärnbränsle och radioaktivt avfall i Finland. Programmet uppfyller kravet på nationella program enligt direktiv 2011/70/Euratom. Detta är Finlands andra nationella program. Vid beredningen av programmet utarbetades samtidigt ett program också för bedömning av miljökonsekvenserna.

Det använda kärnbränsle och radioaktiva avfall som härstammar från Finland hanteras huvudsakligen i Finland. De verksamhetsutövare som bedriver den verksamhet där avfallet uppkommer bär också ansvaret för hanteringen av det använda kärnbränslet och radioaktiva avfallet och kostnaderna för den. Det yttersta ansvaret för hanteringen av använt kärnbränsle och radioaktivt avfall som härstammar från Finland har den finska staten, och staten har även en särskild reserv för kostnaderna för avfallshanteringen. Hanteringen av använt kärnbränsle och radioaktivt avfall i Finland utförs på ett ansvarsfullt sätt. Det finns dock rum för att utveckla det nationella programmet under de kommande decennierna bland annat genom att revidera lagstiftningen och genom att bättre beakta verksamhetsutövarnas samarbete vid tillståndsförfarandena samt genom att ytterligare utveckla de tekniska lösningarna, avfallsbokföringen och den nationella kompetensen.

Nyckelord	energi, kärnenergi, kärnavfallshantering, kärnavfall, radioaktivt avfall, använt kärnbränsle, radioaktivitet		
ISBN PDF	978-952-327-855-4	**ISSN PDF**	1797-3562
URN-adress	https://urn.fi/URN:ISBN:978-952-327-855-4		

Contents

Preface 9

1 Introduction 11

2 Policy on the management of spent fuel and radioactive waste 14

3 Ensuring the safety of the general public, the environment and workers against the dangers arising from ionising radiation 23

4 National framework for the management of spent fuel and radioactive waste 27
4.1 Finnish legal environment 27
4.2 Authorities 30
4.2.1 Ministry of Economic Affairs and Employment 30
4.2.2 Ministry of Social Affairs and Health 31
4.2.3 Radiation and Nuclear Safety Authority 31
4.3 Licensing processes under the Nuclear Energy Act and the Radiation Act 32
4.4 Responsibility for spent fuel and radioactive waste 37
4.5 Classification of spent fuel and radioactive waste 38

5 Quantities of spent fuel and radioactive waste and estimates of future quantities 40

6 Principles for the implementation of the waste management obligation of spent fuel and radioactive waste 45
6.1 Decisions on the principles of implementation of waste management obligation in nuclear facilities 46
6.2 Principles for the treatment and storage of spent fuel and radioactive waste 49
6.2.1 Principles for the treatment and storage of spent fuel and radioactive waste resulting from the use of nuclear energy 49
6.2.2 Principles for the treatment and storage of radioactive waste from radiation practices 50
6.3 Principles for the disposal of spent fuel and radioactive waste 52
6.3.1 Principles for the disposal of spent fuel and radioactive waste resulting from the use of nuclear energy 52
6.3.2 Principles for the disposal of radioactive waste resulting from the use of radiation 53

7 Concepts, plans and technical solutions for the management of spent fuel and radioactive waste 54
7.1 Low and intermediate-level waste from the use of nuclear energy 55
7.2 Storage and disposal of spent fuel 59
7.2.1 Storage of spent fuel 59
7.2.2 Disposal of spent fuel 61
7.3 Radioactive waste from the decommissioning of nuclear facilities 63
7.4 Radioactive waste from radiation practices 65

8 Concepts and plans for the post-closure period of disposal facilities 67

9 Significant milestones and timeframes for the management of spent fuel and radioactive waste 70
9.1 Milestones and timeframes for spent fuel management 71
9.2 Milestones and timeframes of the management of radioactive waste generated in nuclear facilities 72
9.3 Overall timeframe for the management of spent fuel and radioactive waste from nuclear facilities subject to uncertainties 73
9.4 Milestones and timeframes for the management of radioactive waste from radiation practices 76

10 Research and development necessary for the implementation of solutions for spent fuel and radioactive waste management 77
10.1 Research and development carried out by operators of nuclear energy 77
10.2 Measures taken by the State to promote research and development 78
10.3 Finland's participation in international research and development 80
10.4 Maintaining and developing other expertise 81

11 Assessment of the costs of the national programme and the financing scheme in force 82
11.1 Costs for the management of spent fuel and radioactive waste from the use of nuclear energy 82
11.2 State´s financial provision for the costs for the management of spent fuel and radioactive waste from the use of nuclear energy 83
11.3 Costs of the management of radioactive waste not generated at nuclear facilities 86

12 Transparency and public acceptance in the management of spent fuel and radioactive waste 88
12.1 Transparency of the activities of the operator of the use of nuclear energy 88
12.2 Transparency of the authority's activities 89
12.2.1 Consultation on licensing procedures 90
12.2.2 Consultation on the national programme 91
12.3 Public acceptance 92

13 Environmental impact assessment of the national programme 94
13.1 Summary of the results of the environmental impact assessment 94
13.2 Monitoring of environmental impacts 95

14 Agreements with a Member State or a third country on the management of spent fuel or radioactive waste or on the use of a disposal facility 97

15 Maintenance and development of the national programme and responsibilities and performance indicators for its implementation 98
15.1 Responsibilities and performance indicators for the implementation of the national programme 98
15.2 Maintenance and development of the national programme 101
15.3 Objectives and methods for maintaining and developing the national programme 103

References 107

Appendix 1. Consideration of the environmental report, opinions and views 110

PREFACE

This document is the comprehensive plan for the management of spent fuel and radioactive waste, that is, the national programme required from the Finnish Government under Directive 2011/70/EURATOM of the Council of the European Union on the Responsible and Safe Management of Spent Fuel and Radioactive Waste. This programme provides information to the authorities, operators, communities and citizens on the situation and plans for the management of spent fuel and radioactive waste in Finland. The national programme is the second of its kind. The first national programme was drawn up in 2015.

The national programme fulfils the requirements set out in Article 12(1) of the Directive as regards the content of the national programme. However, the national programme also addresses other issues covered by the Directive so as to provide an overview of the issues related to the management of spent fuel and radioactive waste. In addition, the programme identifies the differences in the management of radioactive waste generated in nuclear facilities and elsewhere as a result of the heterogeneous development of national laws. One of the key objectives of the national programme is the development of radioactive waste management in Finland.

The national programme essentially follows the terminology used in the Directive which differs from the terminology used at the national level. The most significant difference is that the national legislation uses the term 'nuclear waste' for spent fuel and radioactive waste generated in nuclear facilities. This term is not used in the Directive. It is sometimes necessary to specify the origin of radioactive waste in the national programme using the terms 'radioactive waste generated in the use of nuclear energy' and 'radioactive waste generated in radiation practices'. The term 'spent fuel' is used in its own right, even if the spent fuel contains radioactive waste.

After the introduction, Chapter 2 deals with the national policy in respect of spent fuel and radioactive waste management (Article 12(1)(a)). Chapter 3 deals with the safety of the general public and workers in the management of spent fuel and radioactive waste as well as the national legislation related to the management of spent fuel and radioactive waste. Chapter 4 deals with other regulation and the main public authorities, namely the national framework referred to in the Directive. The quantities of spent fuel and radioactive waste

in Finland as well as the estimates of future quantities are discussed in Chapter 5 (Article 12(1)(c)).

Chapter 6 progresses from the national policy discussed in Chapter 2 towards the principles of spent fuel and radioactive waste management (Chapter 6) and further to the concepts, plans and technical solutions for spent fuel and radioactive waste management from generation to disposal developed on the basis of those principles (Chapter 7, Article 12(1)(d)). Chapter 8 deals with concepts and plans for the post-closure period of disposal facilities (Chapter 8, Article 12(1)(e)).

Chapter 9 focuses on the main objectives of spent fuel and radioactive waste management and the related timeframes (Article 12(1)(b)). Chapter 10 deals with the research and development activities needed in order to implement the abovementioned solutions for spent fuel and radioactive waste (Article 12(1)(f)). Chapter 11 gives an assessment of the costs of the national programme and the financing scheme in force (Article 12(1)(h) and (i)).

Chapter 12 deals with public acceptance and transparency in the management of spent fuel and radioactive waste (Article 12(1)(j)). Chapter 13 deals with the environmental impact assessment of the national programme for the management of spent fuel and radioactive waste. Chapter 14 deals with the agreements (if any) concluded with other Member States or third countries on the management of spent fuel or radioactive waste (Article 12(1)(k)).

Finally, Chapter 15 deals with the responsibility for the implementation of the national programme and the key performance indicators to monitor the progress of the national programme (Article 12(1)(g)). The maintenance and development of the national programme is also discussed.

The national programme for the management of spent fuel and radioactive waste used in Finland is prepared by the Ministry of Economic Affairs and Employment and the Ministry of Social Affairs and Health in cooperation with the Radiation and Nuclear Safety Authority. In practice, the national programme is drawn up in cooperation with the operators which also carry out the essential elements of the national programme in accordance with the legislation applicable to the activity.

Ministry of Economic Affairs and Employment
Ministry of Social Affairs and Health
Radiation and Nuclear Safety Authority

Helsinki, February 2022

1 Introduction

The national programme covers all the spent fuel and radioactive waste generated in Finland. Spent fuel and radioactive waste are mainly generated in Finland in normal operational states, but radioactive waste can also be generated in any incidental and accidental conditions. The primary objective of the national programme is to ensure that all the spent fuel and radioactive waste generated in Finland is safely disposed of and that all the waste management measures from the generation of waste to its disposal are carried out without undue delay.

The national programme for the management of spent fuel and radioactive waste is prepared and, where appropriate, updated by the Ministry of Economic Affairs and Employment and the Ministry of Social Affairs and Health in cooperation with the Radiation and Nuclear Safety Authority (STUK). The national programme describes the objectives of spent fuel and radioactive waste management, the safety objectives set by the authorities and the information, plans and reports on the implementation of waste management and on related solutions received mainly from the operators. The operators also, in practice, carry out the essence of the national programme, as each operator is legally responsible for the management of spent fuel and radioactive waste generated in the course of or as a result of their activities.

The management of spent fuel and radioactive waste from the use of nuclear energy in Finland was initially steered solely with the licence conditions set for operating licences for nuclear power plants, until the Government, in 1983, drew up a Government Policy Decision for the management of spent fuel and radioactive waste from the use of nuclear energy with a timetable (21/813/83 KTM, 28 November 1983) [1]. This Government Policy Decision has had a significant steering effect in the research and development of spent fuel and radioactive waste management. In 1991, the Ministry of Trade and Industry (now the Ministry of Economic Affairs and Employment) [2] specified the Government Policy Decision of 1983 to develop, for example, a domestic solution for the disposal of spent fuel, but retained in this respect the timetable of the 1983 decision.

The steering of the management of spent fuel and radioactive waste from the use of nuclear energy has also been influenced over the years by a number of legislative changes, the most significant of which was the change made in 1994, which ended the export of spent fuel from Finland after 1996, accelerating the development of a domestic

disposal solution for spent fuel. With Finland's accession to the EU and the entry into force of Directive 2011/70/EURATOM of the Council of the European Union (the Directive) in 2011, the first national programme [3] in its current form was completed in Finland in the summer of 2015.

This national programme continues the process of setting and implementing the objectives set out in the abovementioned decisions and programmes. The national programme includes all the measures described in previous decisions and programmes that have not yet been implemented. In practice, only the commencement of the disposal of spent fuel remains to be implemented. Furthermore, the decommissioning of nuclear power plants and the extension of disposal facilities to include radioactive waste from decommissioning and dismantling has not yet arisen. It is intended that all current objectives and principles related to spent fuel and radioactive waste management will be included in this programme and that there will be no need to refer to previous documents. In addition, the national programme sets new objectives for the future.

The national programme for the management of spent fuel and radioactive waste may change as the operating environment changes, which is why the national programme must be actively maintained. The national programme is mainly influenced by the development of spent fuel and radioactive waste management in Finland, but changes in other countries may also have an impact on Finland's national programme for the management of spent fuel and radioactive waste. The programme is also being developed to meet the obligations of international agreements and directives.

In Finland, the largest producers of nuclear energy are Fortum Power and Heat Oy (Fortum), which has an operating nuclear power plant in Hästholmen in Loviisa, and Teollisuuden Voima Oyj (TVO), which has an operating nuclear power plant in Olkiluoto, Eurajoki. Nuclear power plants also produce the majority of the spent fuel and radioactive waste generated in Finland. Olkiluoto is also home to Posiva Oy (Posiva), a company founded by TVO and Fortum in 1995 to plan and implement the disposal of the spent fuel of its owners.

A third nuclear power plant, planned by Fennovoima Ltd (Fennovoima) for Hanhikivenniemi in Pyhäjoki, is also envisaged in Finland. The research reactor of VTT Technical Research Centre of Finland Ltd (VTT), located in Otaniemi, Espoo, was for a long time mainly used for research and training purposes, but the reactor has been permanently closed, its spent fuel has already been removed and VTT is moving to the dismantling of the research reactor.

VTT has also significant radiation practices in Finland. VTT has a VTT Centre for Nuclear Safety in Otaniemi, Espoo, where VTT has centralised its radioactive materials research

laboratory. Radiation practices are also found in industry, research institutes, universities and health care. Approximately 6,000 sealed radioactive sources are being used by industrial operators. A sealed source means a radiation source containing a radioactive substance whose structure or properties prevent the release of radioactive substance into the environment under planned conditions of use. Sealed sources become radioactive waste after the termination of their use.

Other operators that use radiation extensively and whose activities, especially at the end of their activities, may result in radioactive waste, include the University of Jyväskylä Accelerator Laboratory, the University of Helsinki Accelerator Laboratory and the facilities used by the radiochemistry research groups of the University of Helsinki's Department of Chemistry, especially the facilities of the particle accelerator. Åbo Akademi University in Turku has a particle accelerator, the use of which is about to end. Radionuclides used in the manufacture of radiopharmaceuticals are being produced with cyclotrons at the national Turku PET Centre, Kuopio University Hospital of the Kuopio University Hospital District Municipal Federation, the Cyclotron Unit of the Hospital District of Helsinki and Uusimaa (HUS) in Helsinki and MAP Medical Technologies Oy (Curium Pharma) in Helsinki. HUS has a neutron accelerator in Helsinki suitable for boron neutron capture treatment and the facilities used for such treatments. The North Ostrobothnia Hospital District previously used high-activity cobalt sources for radiotherapy, which are awaiting decommissioning. Over the years, the steelworks of Outokumpu Stainless Oy in Tornio have accidentally melted sealed sources that were among recycled metal. As a result, radioactive contaminated slag has been produced.

2 Policy on the management of spent fuel and radioactive waste

In Finland, spent fuel is generated in connection with or as a result of the operation of nuclear power plants. Radioactive waste is generated by the operation of nuclear power plants and other nuclear facilities and smaller quantities by the use of radiation sources containing radioactive material in industry, health care and research facilities. For the purposes of the national programme, **radioactive waste** means waste generated by the use of nuclear energy, use of radiation or any other radiation practices, which contains a quantity of radioactive material exceeding the specified clearance level and which has not been released from regulatory control. Furthermore, the term 'spent fuel' is used in its own right, even if the spent fuel contains radioactive waste.

Spent fuel and radioactive waste are mainly generated under **normal operational states**. The national programme also covers any radioactive waste arising from various **incidental and accidental conditions**. In the case of this waste, it is essential that at least general plans are in place for radioactive waste generated in different situations in Finland and for its treatment, storage and disposal.

The amount of radioactive waste generated can be influenced. According to the leading principle of waste management, **the amount of spent fuel and radioactive waste shall be kept as small as reasonably possible**. The principle applies to the amount of spent fuel and radioactive waste as well as to its radioactivity. However, minimising the amount of waste must not compromise the safety of operations.

Spent fuel and radioactive waste generated in Finland **shall be managed in Finland**. However, in some specific cases, the State has the possibility to differ from this principle in cases where the amount of spent fuel or radioactive waste is small and can be managed abroad in a way that is assessed acceptable. No spent fuel or radioactive waste may be imported to Finland from abroad for treatment, storage or disposal. However, a disused radiation source may be exported from Finland (for example, to return a sealed source to the manufacturer), but a radiation source manufactured outside Finland may not be imported to Finland as radioactive waste.

The **ultimate objective** of spent fuel and radioactive waste management is to protect the general public and the environment from the dangers of ionising radiation. To this end,

spent fuel and radioactive waste are isolated from human living environments for a period sufficiently long that they no longer pose a risk. The impact of waste management on the general public and environment is regularly assessed, and significant environmental impacts are prevented and mitigated. Waste management measures are implemented in such a way that the general public and workers are protected from ionising radiation in accordance with the general principles of radiation protection as set out in Chapter 3.

Isolation of spent fuel and radioactive waste from the living environment is carried out by means of disposal of spent fuel and radioactive waste. Prior to disposal, spent fuel and radioactive waste are treated and stored on site. Storage and different treatment methods of radioactive waste can reduce the volume and radioactivity of waste before disposal. Radioactive waste is disposed of as soon as possible. The disposal is planned and implemented in such a way that the safety of the spent fuel and radioactive waste after the disposal is achieved without active measures, that is, passively.

The development and implementation of methods for the management of spent fuel and radioactive waste in Finland have been decided to be implemented mainly **during the generations that produce the waste**. The disposal of radioactive waste has been carried out in Finland for decades, and Finland also has a solution for the disposal of spent fuel. Therefore, no undue burden will be left to future generations, although disposal will continue for several generations due to the continued use of nuclear energy and the long interim storage periods required for spent fuel cooling.

Responsibilities for the management and financing of spent fuel and radioactive waste from the use of nuclear energy were already laid down in the Government decision of 1978 [4]. The State has the **ultimate responsibility** for the management of spent fuel and radioactive waste generated in Finland. However, the State does not have a waste management organisation – the **primary responsibility** for the management of spent fuel and radioactive waste lies with the one whose activities generate spent fuel or radioactive waste. The disposal of spent fuel and radioactive waste is carried out by each operator independently or in cooperation with other operators. In the case of radioactive waste generated by the use of radiation, the State and TVO have agreed, within the specified limits, on the disposal of radioactive waste in a disposal facility for low and intermediate-level waste located in the nuclear power plant site of the nuclear power company (LILW disposal facility in Olkiluoto). Cooperation between Fortum and TVO is also on the background of the spent fuel disposal project.

Because of the ultimate responsibility of the State, the State directs and controls the activities and management of spent fuel and radioactive waste throughout their life cycle. The State, that is, the Finnish Government or other authorities, grants **licences** for activities that produce spent fuel and radioactive waste, and for their possession,

treatment, storage and disposal. The State also decides on the principles for the management of spent fuel and radioactive waste. The State requires the nuclear energy operator to draw up **plans** in accordance with the principles at regular intervals. The State supervises the activities and the implementation of the plans.

The operator is responsible for all measures of spent fuel and radioactive waste management and their appropriate preparation. In addition, the operator is responsible for the disposal of radioactive waste from the use of nuclear energy until the closure of the disposal facility. After the closure of the disposal facility, responsibility for the disposed spent fuel and radioactive waste will be transferred to the State.

An operator generating spent fuel and radioactive waste in connection with its operations is fully responsible for the **costs** of waste management measures. It is the responsibility of the State to ensure that adequate funding is available for the management of spent fuel and radioactive waste. The State ensures this by collecting funds in the National Nuclear Waste Management Fund (Fund) for spent fuel and radioactive waste generated in the use of nuclear energy. In the case of other radioactive waste, the operator must, where appropriate, lodge a security.

The **licensing system for nuclear facilities in Finland is phased**, and project plans are required to evolve as the licensing phases progress. At each licensing phase, the licence applicant must submit a plan for the management of spent fuel and radioactive waste generated in the use of nuclear energy. A licence may only be granted if the preconditions for granting a licence laid down by law are met.

If the licence is for the construction of a nuclear facility of considerable general significance, such as a disposal facility, the necessity of the facility is decided in the first phase based on the overall good of society (**decision-in-principle**). A favourable opinion from the municipality in which the facility is planned to be located is an essential requirement for a decision-in-principle. Furthermore, no decision-in-principle can be adopted if facts proving that the facility cannot be built safe have been presented. A decision-in-principle by the Government considering the project to be in the overall good of society is submitted to the Parliament, which may accept the decision or reverse it as such.

If the construction of the facility has been found to be in the overall good of society, the prerequisites for construction activities and the possibilities for constructing the facility as safe (**construction licence**) are assessed in the next phase. After this, the operating conditions of the facility and the safety of the operation of the facility are assessed (**operating licence**). In the final years of operation, the conditions and safety of

decommissioning or closure **(decommissioning licence or closure under an operating licence)** are assessed.

Procedures for the licensing of nuclear facilities are carried out using an **evidence-based and documented decision-making process**. Licensing decisions are taken on the basis of the licence applicant's application and the opinions received on the application. As regards the treatment, storage and disposal of spent fuel and radioactive waste generated in the use of nuclear energy, the scope of the decision-making process is decided and the safety assessed consistent with a graded approach in relation to the level of risk of the waste. The decisions and opinions of the regulatory safety authority are based on the results of the safety assessment, information on the robustness and reliability of the assessment and the findings of the continuous regulatory control.

In Finland, the management of spent fuel and radioactive waste generated in the use of nuclear energy has been guided by adding **licence conditions** to the operating licences of nuclear power plants. Already in the first operating licences for nuclear power plants in 1978, the State imposed conditions on the planning of radioactive waste management [4]. The requirements of the Government Policy Decision of 1983 on the objectives and timeframes of the research and development of spent fuel and radioactive waste management was also included in the operating licences issued in the same year. At first, the operating licences for nuclear power plants were only a few years long because the State considered it important to develop the management of spent fuel and radioactive waste from the very first decades of the operation.

The Government Policy Decision of 1983 on the objectives and timeframes of the research, and development of spent fuel and radioactive waste management has had a significant steering effect on the development of spent fuel and radioactive waste management in Finland. The timeframe for the decision has been adhered to well while, at the same time, there have been more nuclear power plant projects and new types of spent fuel and radioactive waste to manage.

The Government Policy Decision of 1983 set out two alternatives for spent fuel management. The first option was to make use of international, centralised disposal solutions and contractual arrangements that would have allowed disposal abroad of reprocessing waste or spent fuel in an irreversible manner. If this could not be done, the nuclear power companies were to prepare for the disposal of spent fuel in Finland, in a way that meets the safety and environmental protection requirements, from around 2020 onwards.

The **export of spent fuel** from Finland was banned by an amendment to the Nuclear Energy Act in 1994 and it ended in 1996. These events led to the establishment of the

nuclear power companies' joint spent fuel disposal company in 1995. The company was assigned the task of developing and implementing a domestic disposal solution. Regarding the domestic disposal solution, the Government Policy Decision of 1983 required nuclear power companies to identify and select a disposal site for spent fuel in Finland by the end of 2000. In addition, they had to be prepared to present the necessary plans for an encapsulation plant and a repository for their construction. The timeframe for the submission of the necessary studies and plans for the construction licence was clarified in 2003 such that they had to be submitted by the end of 2012 [5].

The Government Policy decision of 1983 established as the premise of the management of radioactive waste from the use of nuclear energy that the waste would be treated, stored and **disposed of in Finland**. The aim was to be able to have disposal facilities for operational waste in operation by the end of 1992, if necessary. Disposal of the radioactive waste resulting from the decommissioning and dismantling of nuclear facilities in the disposal facilities to be constructed was also to be provided for.

Some **national choices, made possible by international directives and agreements**, were made in the management of spent fuel and radioactive waste in Finland. One of the most significant choices is the fuel cycle approach: spent fuel used in Finland is considered radioactive waste, which is directly disposed of in Finland. Finnish legislation prohibits the export and import of spent fuel, which means that it is not possible to send spent fuel abroad for reprocessing, for example. The only exception is spent fuel for research purposes, the quantity of which has been minimal.

In Finland, it will later be considered whether more than one spent fuel disposal facility is needed in the overall good of society. However, Finland has a **disposal method** that can be utilised in any spent fuel disposal facilities that may be constructed in the future.

The management of spent fuel and radioactive waste in Finland emphasises the **priority of safety**. The safety of nuclear facilities, including waste management, is assessed when applying for construction and operating licences, in connection with plant changes and in connection with periodic safety reviews. The safety assessment must demonstrate that the nuclear facility has been designed and implemented in accordance with the safety requirements. Regarding the disposal of spent fuel and radioactive waste, its long-term safety is also assessed. The assessment of long-term safety is presented in the safety case, which assesses the developments in the disposal system after the closure of the disposal facility and the related releases of radioactive materials by means of computational analyses and other complementary reviews. The regulatory authority carries out continuous safety monitoring.

At the end of the operation of nuclear facilities, the radioactive structures, systems and components of the facility are dismantled, and the resulting radioactive waste is disposed of. **Provision must be made for the decommissioning of the plant already in the planning of the plant** so that the design solutions can take account of the effects of the operating phase on the systems, structures and components, for example by avoiding materials that become highly radioactive, and thus reduce the amount or activity of the radioactive waste generated.

The decommissioning of a nuclear facility in Finland can be based on either an **immediate or a deferred decommissioning strategy**. In the case of immediate decommissioning, the decommissioning of the nuclear facility commences as soon as possible after its final closure. In the case of deferred decommissioning, the nuclear facility is maintained in a permanent shutdown state for long periods, even decades, before the dismantling starts. In Finland, from the point of view of the nuclear energy legislation, decommissioning is aimed only at the dismantling of the radioactive structures, systems and components of a nuclear facility, in which case the decommissioning will leave buildings on the site of the nuclear facility ('brownfield' option). After the decommissioning, the buildings can be used for other activities, such as industry and storage. Another option is to dismantle all the buildings and structures of the site and thus bring the site in line with the natural state ('greenfield' option).

The operator selects for its nuclear facilities the decommissioning strategy best suited to its activities. Since measures to manage spent fuel and radioactive waste must not be unduly deferred, there must be grounds for choosing a **deferred decommissioning strategy**. These may include, for example, reducing the radiation dose caused by dismantling, the use of common waste management solutions, or the benefits of successive dismantling projects in utilising knowledge and experience.

In Finland, it has been chosen to dispose of radioactive waste resulting from the dismantling of nuclear facilities in the **same disposal facility** as radioactive waste generated during operation. This implies an extension of the disposal facility late in the operating phase, as it is only expedient to excavate the necessary repository at any given time.

In Finland, the legislation also allows for the disposal of very low-level radioactive waste in a **near-surface** disposal facility. Such a near-surface disposal solution could, if implemented, reduce the amount of radioactive waste disposed in bedrock and thus significantly reduce the volume of the deep geological disposal facility.

In Finland, radioactive waste may also be **released from regulatory control** if its activity or activity concentration is below the clearance level set by legislation. In this case, the

waste is treated in the same way as other non-hazardous waste and is subject to the order of priority defined in the Waste Act: Where possible, waste is reused, recycled or recovered by other means, such as energy by incineration or, as a last resort, landfilled or, alternatively, incinerated without energy recovery or disposed of by other means. The procedure for release from regulatory control is important because proportionate treatment solutions and waste classification save resources for the safe treatment, storage and disposal of radioactive waste.

The management of spent fuel and radioactive waste requires substantial expertise. **Maintaining and developing expertise** is an essential part of ensuring a high level of safety. The key expertise for the management of spent fuel and radioactive waste must be retained in Finland. The identification of key areas of expertise and the mapping of existing ones are the responsibility of the authorities. However, the responsibility for maintaining and developing the expertise of the personnel of nuclear facilities rests with the operator.

Expertise in spent fuel and radioactive waste management is also widely found in technical support organisations, universities, other institutes of higher education and companies carrying out planning and development tasks. The means of maintaining and developing expertise can be different, for example, participation in research and development projects at the national or international level, productisation and marketing of national expertise as well as participation in various cooperation projects. It is also important to maintain and develop the expertise of the authorities.

The prerequisite for the implementation of spent fuel and radioactive waste management is **public acceptance** of the activities. Public acceptance is a multifaceted concept, one of the key themes of which is the safety of the activities. Public acceptance also involves the transparency of the activities of the operator and the authorities. Transparency includes, for example, effective communication with the public. Transparency in the activities of public authorities also includes opportunities for all the relevant stakeholders, local authorities and citizens to participate in decision-making processes in accordance with the national and international regulations.

There are also **challenges** in the management of spent fuel and radioactive waste in Finland. While the abovementioned 1983 Government Policy Decision guided the research and development done by operators of the nuclear power plants, it also separated the nuclear power plant projects from the entity of management of radioactive waste generated in Finland. However, there was no corresponding decision on the research and development of management of radioactive waste from health care, research institutes and industry.

Radioactive waste generated in radiation practices, which cannot be released from regulatory control, is stored in an interim storage cavern attached to the LILW disposal facility at Olkiluoto and disposed of in the LILW disposal facility. Most of the sealed sources delivered to the storage can be disposed of in Olkiluoto. However, there are some high-level sealed sources, waste containing certain radionuclides or waste with otherwise challenging properties that cannot be disposed of in Olkiluoto. Waste is stored until a suitable disposal solution is in place.

Although the responsibility for the management including disposal of this radioactive waste rests primarily with the operator generating the waste, the establishment of each operator's own disposal facility is neither expedient nor cost-effective, as the quantities of such radioactive waste are limited. The development and disposal of radioactive waste disposal solutions in cooperation with operators using nuclear energy can therefore be considered as a priority.

The management of radioactive waste should in the future allow for better cooperation between operators in the sector: it is appropriate that the treatment, storage and disposal of radioactive waste from radiation practices should mainly be carried out at the nuclear facilities already in existence or planned to be constructed.

In addition, the management of radioactive waste must be able to reasonably prepare for new situations that may occur despite long-term planning and the radioactive waste that they generate. The management of radioactive waste streams resulting from various incidents, deviations and accidents presents challenges, as the potentially different properties of the waste or a significant increase in the amount of waste challenge the chosen waste management solutions or their capacity.

The new Radiation Act, which entered into force in 2018, also took into account waste that is not classified as radioactive waste in Finland but must be managed with consideration of radiation safety. Such waste may be generated, for example, in environmental clear-up after a large-scale fallout. Waste may also be generated, for example, in mining and ore enrichment activities where ore, waste rock or tailings contain higher amounts of naturally occurring radioactive material. Waste containing naturally occurring radioactive material is also traditionally referred to as NORM.

Non-radioactive waste is disposed of primarily on the basis of the requirements of waste and environmental legislation, that is, the classification and basic definition of the waste, the method of pre-treatment and disposal, and the category of the waste facility are determined primarily on the basis of these requirements. Waste that is not radioactive waste according to the Radiation Act, but whose waste management must take into account radiation safety (waste generated in activities that expose to natural radiation

and in the implementation of protective measures, the activity concentration of which is higher than the clearance level referred to in the Radiation Act), must also be approved by STUK. The disposal method is accepted if the calculated radiation exposure resulting from it is low, that is, the exposure is lower than the reference values.

The body that generates such waste must carry out a radiation exposure assessment before the waste is disposed of. The exposure assessment is used to demonstrate that the selected disposal method is radiation safe. The exposure assessment for the disposal of waste must take into account the necessary waste pre-treatment and transport, the exposure of the workers of the waste facility during the disposal and the potential exposure of the general public after the closure of the waste facility. If the exposure assessment indicates that the waste may give rise to a higher exposure than the reference values, the properties of the waste or the way it is disposed of should primarily be changed so that the exposure remains below the reference values. This could include, for example, landfilling of the waste in hazardous waste landfills instead of landfills for inert or non-hazardous waste, pre-treatment of the waste affecting the chemical form of the radioactive material of the waste or modification of the industrial process to alter the properties of the waste.

3 Ensuring the safety of the general public, the environment and workers against the dangers arising from ionising radiation

The general public, the environment and workers are protected from the dangers of ionising radiation. The general principles of radiation protection apply to the protection of workers of nuclear facilities and personnel involved in the use of radiation and to the assessment of the safety of radiation practices. The use of radiation and other radiation practices are assessed through the overall benefit achieved. Radiation practices are justified when the overall benefit is greater than the detriment caused (justification principle). The exposure of workers and the general public to ionising radiation must be optimised by means of radiation protection to be as low as reasonably achievable (optimisation principle). The radiation dose to workers and the general public must not exceed the specified dose limits (individual dose limitation principle).

In the use of radiation and in nuclear facilities, workers must be classified as radiation workers on the basis of the radiation exposure arising from the work and the potential exposure arising from any abnormal situations. Radiation workers are classified in category A or B, of which the radiation exposure in category A may be higher. If the radiation exposure caused by the work falls below the dose limit for the general public, the worker does not need to be classified as a radiation worker. The classification is to be made before starting radiation work, and exposure conditions at work are to be monitored regularly. Class A radiation workers must have individual monitoring based on the measurements made by a dose measurement service.

In order to ensure the safety of workers of nuclear facilities and the general public, a constraint for the annual dose of an individual in the population has been imposed on the operation of encapsulation plant of spent fuel, nuclear facilities for the management of radioactive waste and disposal facilities. The constraint for the annual dose of an individual in the population from the normal operation and planned decommissioning and dismantling of the abovementioned plants and the decommissioning of a nuclear power plant is 0.01 millisieverts (mSv). The constraint for the annual dose of an individual in the population due to an anticipated operational occurrence is 0.1 mSv.

In addition, in the reference period following the closure of a disposal facility, which must be at least several thousand years in length, the annual dose to the most exposed people must be below the value of 0.1 mSv and the average annual dose to other people must be negligible. In the reference periods after the abovementioned period of several thousand years, the long-term averages of the quantities of radioactive materials released into the environment from spent fuel and radioactive waste from the use of nuclear energy disposed of must be below the constraints specified by STUK for each radionuclide. The constraints are set in such a way that the radiation effects resulting from the disposal may be at most equivalent to those resulting from the presence of naturalradioactive substances in the ground and the wide-ranging radiation effects are negligible.

According to Finnish legislation, the safety of the operation of nuclear facilities must be maintained at as high a level as practically possible. The safety of nuclear facilities must be developed on the basis of operating experience and safety research, and as a result of scientific and technological progress. When applying for a construction and operating licence, the operator must demonstrate in the safety assessment that the requirements concerning the safety of nuclear facilities are met reliably. The operator must then periodically assess the safety of the nuclear facility.

A periodic safety review of spent fuel and radioactive waste disposal facilities generated by nuclear facilities must be carried out at least every 15 years and submitted to STUK for approval. The periodic safety review must include an assessment of the safety status of the nuclear facility, possible developments and the preservation of safety. In addition, the long-term safety of the disposal of spent fuel and radioactive waste generated in nuclear facilities must be assessed in connection with the selection of the disposal site, the application for a decision-in-principle, all licensing phases in accordance with the Nuclear Energy Act and in connection with the periodic safety review.

The post-closure safety assessment is presented in the safety case. The safety case must cover the entire period after the closure of the facility required to ensure the safety of the disposal. The safety case for the spent fuel disposal facility extends over a period of approximately one million years, while for the disposal facilities for low and intermediate-level waste, the typical assessment period is approximately one hundred thousand years.

When designing a nuclear facility, the operator must prepare for the possibility of operational occurrences and accidents. The primary goal is to prevent accidents. The secondary goal is to manage accidents, in which case the necessary practical measures must be taken to mitigate the consequences. In the event of operational occurrences and accidents, constraint for the annual dose of an individual in the population have been set separately. The operator must estimate the radioactive releases and radiation doses on a computational basis, taking into account normal operational states, any operational

occurrences and accident situations. Releases and radiological effects caused by any operational occurrences and accident situations must be fully investigated. On the basis of these, the necessary emergency arrangements must be planned. Emergency response must be practised regularly.

The safety of disposal facilities must be based on a combination of natural and engineered barriers (multi-barrier principle) and primarily on passive systems. According to the multi-barrier principle, the deficiency of one of the barriers must not jeopardise the safety of the disposal solution. The more radioactive the waste to be disposed of is, the higher the performance of the barriers is required. In addition, the number of barriers required increases with the radioactivity of the waste, so the number of barriers is highest in the spent fuel disposal facility.

In the spent fuel disposal concept, successive independent engineered barriers (waste matrix, waste container, buffer surrounding the containers, repository backfill and closure structures) together with the bedrock ensure the safety of the disposal solution. The design of the engineered barriers must take into account the characteristics of the waste to be disposed of and must be such that they effectively prevent the entry of radioactive materials into the bedrock or living environment surrounding the repository. The bedrock serves as a natural barrier. Beneficial host rock properties for safety are rock stability and water tightness, low groundwater flow, favourable groundwater chemistry, retardation of radioactive materials in the rock and protection against human actions and natural phenomena. If one barrier is damaged or fails completely, safety is guaranteed by the characteristics and performance of the remaining barriers.

Spent fuel encapsulation plant, nuclear facilities for the management of radioactive waste and disposal facilities must be protected against potential threats to them by means of security arrangements. These must be based on up-to-date threat scenarios and analyses of the need for security of nuclear facilities. Security arrangements ensure that no one can intentionally damage nuclear facilities in such a way as to create a radiological hazard to the environment or to humans.

A responsible manager approved by STUK must be appointed for the spent fuel encapsulation plant, the nuclear facilities for the management of radioactive waste and the disposal facilities. It is the responsible manager's task to ensure that the provisions, licence conditions and regulations issued by STUK concerning the safe use of nuclear energy, security arrangements, emergency arrangements and the safeguards of nuclear material are complied with.

In addition, the operator must have a sufficient number of qualified personnel suitable for the related tasks. The operator must separately appoint the persons responsible for

the security arrangements, emergency arrangements and nuclear safeguards and their deputies. The persons concerned must be approved by STUK. The operator must provide adequate training to maintain and develop the expertise of its personnel in the field of nuclear safety. In addition, the nuclear facility must have a management system describing systematic practices and their periodic evaluation and development.

Finland also takes into account international agreements on the safety of spent fuel and radioactive waste. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Finnish Treaty Series 36/2001) is a convention under the International Atomic Energy Agency (IAEA). The aim of the Convention is to achieve and maintain a high level of safety worldwide in spent fuel and radioactive waste management, through the enhancement of national measures and international cooperation (including technical cooperation). The Convention contains provisions on the safety of both spent fuel and radioactive waste management. The Convention requires a national report to be drawn up every three years on the fulfilment of the obligations of the convention. The most recent report for Finland was prepared in 2020 [6]. The reports are discussed in review meetings, where the other contracting parties have the opportunity to present their assessments of the conformity of Finland's spent fuel and radioactive waste management. The review also provides information on possible development targets in spent fuel and radioactive waste management.

The use of radiation is aimed at ensuring that radiation sources requiring a safety licence remain under the control of a regulatory authority throughout the lifespan of the radiation source. An operator that has a safety authorisation for the use of radiation is responsible for the safe use and storage of the radiation sources in its possession, taking into account the safety of the personnel and the general public. The use of radiation sources must be limited to workers who are properly inducted or trained for the tasks.

4 National framework for the management of spent fuel and radioactive waste

Directive 2011/70/EURATOM requires Member States to establish and maintain a national framework for the management of spent fuel and radioactive waste, including a national legislative, regulatory and organisational framework. This national framework distributes responsibility for the management of spent fuel and radioactive waste and ensures coordination between the competent authorities concerned.

4.1 Finnish legal environment

In Finland, the Nuclear Energy Act (990/1987) and Radiation Act (859/2018) as well as the Nuclear Energy Decree (161/1988), Government Decree on Ionizing Radiation (1034/2018) and Ministry of Social Affairs and Health Decree on Ionising radiation (1044/2018) issued on their basis are considered to be part of the national framework. In addition, the Waste Act (646/2011) is considered to belong to the framework. The decrees specify the requirements set by the acts.

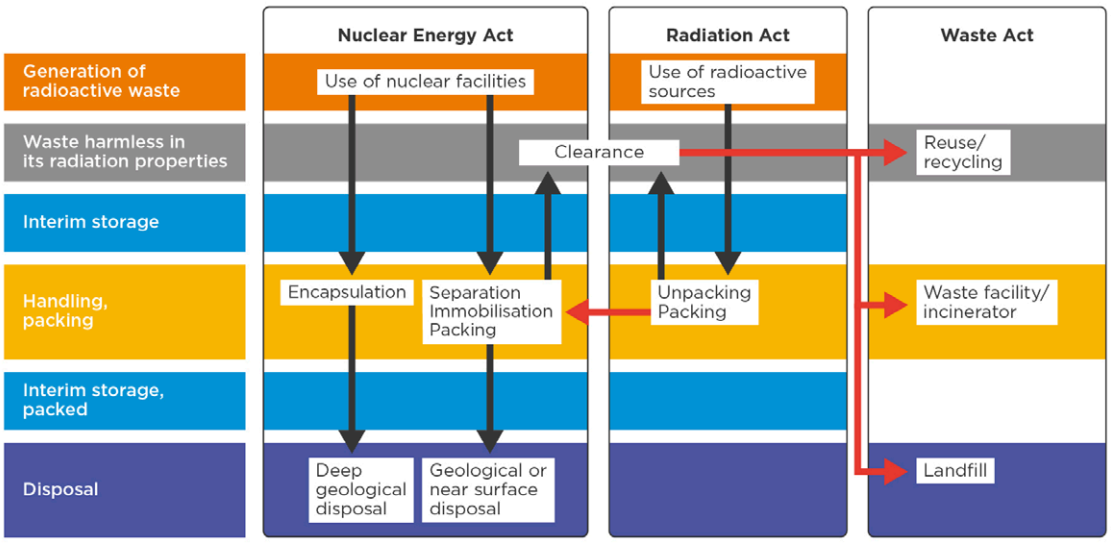
More detailed requirements for the management of spent fuel and radioactive waste are laid down in the STUK regulations and guides. Thus, the national framework also includes the STUK regulations on the safety of a nuclear power plant (Y/1/2018), the emergency arrangements of a nuclear power plant (Y/2/2018), the security in the use of nuclear energy (Y/3/2020), the safety of disposal of nuclear waste (Y/4/2018) and the safety of mining and milling operations aimed at producing uranium or thorium (Y/5/2016) under the Nuclear Energy Act as well as the regulation on exemption values and clearance levels (SY/1/2018) under the Radiation Act and the Nuclear Energy Act.

In addition, the framework includes the regulations issued by STUK pursuant to the Radiation Act on the investigation, assessment and monitoring of occupational exposure (S/1/2018), a plan for radiation safety deviations and actions during and after radiation safety deviation (S/2/2018), radioactive waste and discharge of radioactive substances in the use of unsealed sources (S/2/2019), practices causing exposure to natural radiation (S/3/2019), the in-service radiation safety of radiation sources (S/5/2019), radiation practices subject to a safety licence (S/6/2019), measurements of ionizing radiation (S/7/2021) and the security arrangements of radiation sources subject to a safety licence (S/9/2021). The requirements presented in the STUK regulations are mandatory.

STUK's Regulatory Guides on nuclear safety and security (YVL), the Act on the Radiation and Nuclear Safety Authority (1069/1983) and the Decree on the Radiation and Nuclear Safety Authority (618/1997), as well as the Administrative Procedure Act (434/2003), the Act on the Environmental Impact Assessment Procedure (252/2017), the Decree on the Environmental Impact Assessment Procedure (277/2017) and the Act on the Openness of Government Activities (621/1999), where applicable, are also considered to be part of the framework. STUK's regulatory guides may be reasonably deviated from if the proposed solution achieves a level of safety equivalent to that indicated in the guides.

The requirements for the management of spent fuel and radioactive waste resulting from the use of nuclear energy are included in the Nuclear Energy Act and the requirements for the management of radioactive waste resulting from the use of radiation are included in the Radiation Act (Figure 1). The requirements of the Directive (2011/70/EURATOM) have been implemented by the Nuclear Energy Act and the Radiation Act. In addition, the Radiation Act has transposed requirements of the Directive on basic safety standards for protection against the dangers arising from exposure to ionising radiation (BSS Directive, 2013/59/EURATOM). The requirements of the Radiation Act also apply to activities in accordance with the Nuclear Energy Act, for example with regard to radiation work.

Figure 1. Radioactive waste is generated, for example, as a result of the use of nuclear energy (in the figure, the use of nuclear facilities) and the use of radiation (in the figure, the use of radiation sources). There is no separate disposal facility for the radioactive waste referred to in the Radiation Act in Finland, but waste can be treated, stored temporarily and disposed of at nuclear facilities within the limits allowed by their licences. The red arrows illustrate the transfer of waste from the scope of one law to another. The image uses the terminology of the source [8], which is slightly different from that of the national programme.



The Nuclear Energy Act refers to spent fuel and radioactive waste generated in connection with or as a result of the use of nuclear energy as nuclear waste. The Radiation Act uses the definition of radioactive waste for waste generated as a result of radiation practices. The definition of nuclear waste poses challenges between the Nuclear Energy Act and the Radiation Act. At the international level, there is no clear distinction between nuclear waste and other radioactive waste. Spent fuel is treated internationally as a separate entity that does not fall within the definition of radioactive waste. The Finnish definition does not contradict international definitions, but in practice it makes legislation inconsistent and may lead to difficulties in the interpretation. Legislation, therefore, needs to be reformed in such a way that the management of radioactive waste is regulated in a comprehensive and harmonised manner, regardless of where the waste is generated.

The management of spent fuel and radioactive waste is also dealt with by other Finnish and EU legislation. Examples of other legislation include the Directive on the assessment of the effects of certain public and private projects on the environment (2011/92/EU, as amended by Directive 2014/52/EU, known as the EIA Directive) and the Council Directive establishing a Community framework for the nuclear safety of nuclear installations (2009/71/EURATOM, as amended by Directive 2014/87/EURATOM).

Finland follows international recommendations on nuclear and radiation safety, and takes changes in legislation, regulations and guidelines into account in an appropriate manner. Nuclear and radiation safety requirements and measures are dimensioned and allocated to the risks of the use of nuclear energy and use of radiation in accordance with the graded approach, taking into account normal operation and possible occurrences and accidents. Nuclear safety requirements are based, inter alia, on the recommendations of the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators' Association (WENRA).

Radiation safety requirements are based on the EU's radiation protection directives and the IAEA's recommendations. They take into account the principles of radiation protection adopted by the International Commission on Radiological Protection (ICRP).

The management of spent fuel must also take into account international and national obligations relating to safeguards. Safeguards, that is, non-proliferation controls, ensure that nuclear materials and other nuclear products remain in peaceful use, as licensed and declared, and that nuclear facilities and technology are used only for peaceful purposes.

Nuclear safeguards are based on the Treaty for the Non-Proliferation of Nuclear Weapons of 1970 (Finnish Treaty Series 10/1970). The general requirements set for nuclear safeguards in order to comply with international obligations and national targets are set out in the Nuclear Energy Act and the Nuclear Energy Decree as well as in a STUK

guide. In addition, Finland concluded a safeguards agreement with the IAEA under the Non-Proliferation Treaty in 1971. The Treaty establishing the European Atomic Energy Community (EURATOM) and the Commission's Regulation on the application of EURATOM safeguards (EURATOM/302/2005) also provide for safeguards.

4.2 Authorities

4.2.1 Ministry of Economic Affairs and Employment

The Ministry of Economic Affairs and Employment is responsible for the supreme management and regulation of the nuclear energy field, creating the general legislative and administrative framework for nuclear energy activities. Thus, the Ministry is also responsible for the administrative tasks related to the management of spent fuel and radioactive waste generated in nuclear facilities. The Ministry prepares the licence decisions required for the construction and operation of nuclear facilities according to the Nuclear Energy Act for decision by the Finnish Government. The Ministry directs and supervises the planning and implementation of waste management measures and ensures the implementation of the national needs and international regulations in the field. The Ministry is also responsible for the timeliness and development of legislation related to nuclear energy. Figure 2 presents the responsibilities of the Ministry of Economic Affairs and Employment in relation to other ministries and STUK.

The Fund operates under the Ministry of Economic Affairs and Employment. The Fund collects, stores and securely invests funds that will, if necessary, cover the costs of the management of spent fuel and radioactive waste generated from the use of nuclear energy in the future. The Ministry of Economic Affairs and Employment also coordinates statutory research programme in the field of nuclear energy to ensure that the authorities have at their disposal adequate and comprehensive nuclear engineering expertise and other capabilities needed to assess the different practices and methods of spent fuel and radioactive waste management.

The national programme for the management of spent fuel and radioactive waste in Finland will be drawn up as a joint entity. The drafting of the national programme is based on section 27b of the Nuclear Energy Act in the case of spent fuel and radioactive waste from the use of nuclear energy and section 87 of the Radiation Act in the case of radioactive waste from the use of radiation practises. The programme is prepared by the Ministry of Economic Affairs and Employment and the Ministry of Social Affairs and Health in cooperation with STUK.

The Ministry of Economic Affairs and Employment is responsible for organising the self-assessment of the national programme and requests an international peer review of the national programme and the competent regulatory authority.

4.2.2 Ministry of Social Affairs and Health

The Ministry of Social Affairs and Health is responsible for the supreme authority and highest directing power in supervising compliance with the Radiation Act. The Ministry prepares legislation and other guidelines related to radiation safety, give opinions on radiation protection issues as well as monitors and guides the development and implementation of radiation issues. Figure 2 presents the responsibilities of the Ministry in relation to other ministries and STUK.

As stated hereinabove, the national programme for the management of spent fuel and radioactive waste in Finland is drawn up as a joint entity. The drafting of the national programme is based on section 87 of the Radiation Act in the case of radioactive waste from radiation practices and section 27b of the Nuclear Energy Act in the case of spent fuel and radioactive waste from the use of nuclear energy. The programme is prepared by the Ministry of Social Affairs and Health and the Ministry of Economic Affairs and Employment in cooperation with STUK.

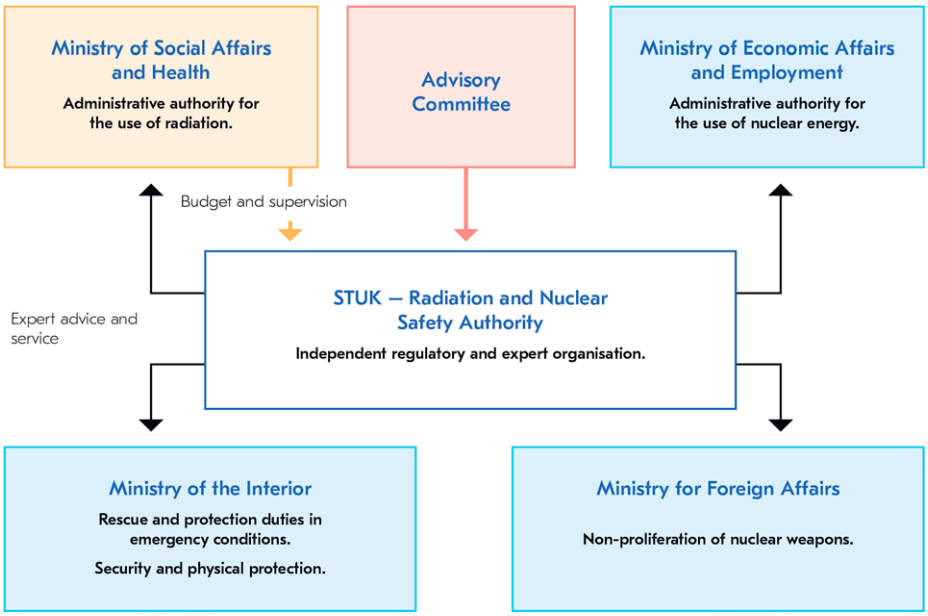
4.2.3 Radiation and Nuclear Safety Authority

STUK is an independent authority in the administrative branch of the Ministry of Social Affairs and Health, which aims to protect people, society, the environment and future generations from the harmful effects of radiation. Figure 2 presents the responsibilities of STUK vis-à-vis the ministries.

STUK controls the use of nuclear energy and radiation and other radiation practices with the powers specified in the Nuclear Energy Act and Radiation Act. STUK also monitors the radioactivity in the environment of nuclear facilities. In addition, STUK supervises the implementation of the security and emergency arrangements for nuclear facilities and nuclear materials and is the competent authority in matters related to the transport of nuclear materials and radioactive waste. STUK inspects the insurance certificates of operators in accordance with the Nuclear Liability Act (484/1972) and the securities of the activities in accordance with the Radiation Act. STUK's regulatory control is based on radiation and nuclear safety legislation, safety regulations and regulatory guides. STUK participates in the preparation of regulations with the ministries responsible and is responsible for the preparation of safety regulations and regulatory guides.

STUK monitors the occurrence of external radiation in the whole of Finland around the clock. STUK has a continuous standby service in case of a emergency exposure situations. In emergency exposure situations, STUK acts as a radiation expert in cooperation with other authorities. STUK also takes care of a large part of Finland's international cooperation related to radiation safety and nuclear safety. In international cooperation, STUK aims to influence and develop guidelines so that safety also improves globally.

Figure 2. Division of responsibilities of the Ministry of Social Affairs and Health, the Ministry of Economic Affairs and Employment, the Ministry of the Interior, the Ministry for Foreign Affairs and STUK in the supervision of spent fuel and radioactive waste management. (Source: STUK)



4.3 Licensing processes under the Nuclear Energy Act and the Radiation Act

The licensing procedures for nuclear facilities follow the successive licensing phases defined in the Nuclear Energy Act. The licensing process for nuclear facilities starts with the Government's decision-in-principle and continues with the Government's construction, operating and decommissioning licences. The operator applies for the **decision-in-principle and licences** of the nuclear facility. The Ministry of Economic Affairs and Employment acts as the authority responsible for the licensing process of nuclear facilities. The decisions-in-principle and the licences of nuclear facilities are issued by the Government. In addition, a positive decision-in-principle must be submitted to the

Parliament for approval. The licensing phases are also accompanied by an environmental impact assessment, which must be carried out at least before applying for a decision-in-principle and a decommissioning licence. In other situations, its implementation is assessed on a case-by-case basis. Figure 3 illustrates the licensing process for nuclear facilities.

The preconditions for granting licences include, for example, fulfilling the safety requirements provided for by law and taking due account of the safety of workers and the general public as well as environmental protection. The principle of successive decision-making and licensing is that the safety assessment is continuous and that the assessments are refined as the projects progress. The mission of STUK is to supervise all activities from the planning of facilities to the cessation of activities. STUK participates in the processing of licence applications for nuclear facilities, gives opinions on them, prepares safety assessments for projects and monitors compliance with the licence conditions. Also other public authorities, municipalities, communities and citizens are given an adequate opportunity to express their views on projects.

The construction of a nuclear facility of considerable general significance requires the Government's decision-in-principle to the effect that the construction of the nuclear facility is in line with the overall good of society. Furthermore, no decision-in-principle can be adopted if facts proving that the nuclear facility cannot be built safe have been presented. Before the Government's decision-in-principle, the Ministry of Economic Affairs and Employment obtains a preliminary safety assessment from STUK for the application. In its safety assessment, STUK assesses the project's possibilities to meet the requirements set out in the Nuclear Energy Act and Decree. When preparing the safety assessment, STUK requests the opinion of the Advisory Committee on Nuclear Safety and, if necessary, other expert organisations. The Ministry of Economic Affairs and Employment also requests opinions from the Ministry of the Environment, the municipal council of the planned location of the facility and neighbouring municipalities on the application for a decision-in-principle. In addition, the Ministry must organise a public consultation on the project to ensure that the public can participate in the decision-making process.

In its consideration of the decision-in-principle, the Government weighs in particular the necessity of the facility for the country's energy supply, the suitability of the intended siteof the facility, the environmental impact of the nuclear facility and the arrangements of spent fuel and radioactive waste management. The Parliament may accept or reverse the decision. In the decision-in-principle phase, the technical issues and safety of the facility are not yet assessed in detail, and the decision is also partly political in nature.

After receiving the decision-in-principle, the operator must apply for and obtain from the Government a licence for the construction of the nuclear facility before starting the

construction. For the construction licence, the applicant must demonstrate that the project fulfils the preconditions for the granting of the licence set out in the law.

STUK gives an opinion on the application for a construction licence, which must be accompanied by a safety assessment. When preparing the safety assessment, STUK requests the opinion of the Advisory Committee on Nuclear Safety and, if necessary, other expert organisations. In its safety assessment, STUK comments on whether the requirements set out in legislation have been met with regard to matters falling within the mandate of STUK.

Prior to the start of the operation of a nuclear facility, a licence for its operation must be applied for from the Government. The preconditions for granting an operating licence are laid down in the Nuclear Energy Act. STUK gives an opinion on the operating licence application and, in a safety assessment attached to the opinion, STUK comments on whether the requirements set out in the legislation have been met with regard to matters falling within the mandate of STUK. When preparing its opinion, STUK requests the opinion of the Advisory Committee on Nuclear Safety and, if necessary, other expert organisations.

In Finland, the operating licence for a nuclear facility is always granted for a fixed term. When considering the duration of the licence, particular attention is paid to ensuring safety and to the estimated duration of operations. STUK may suspend the operation of a nuclear power plant if it is necessary to ensure safety.

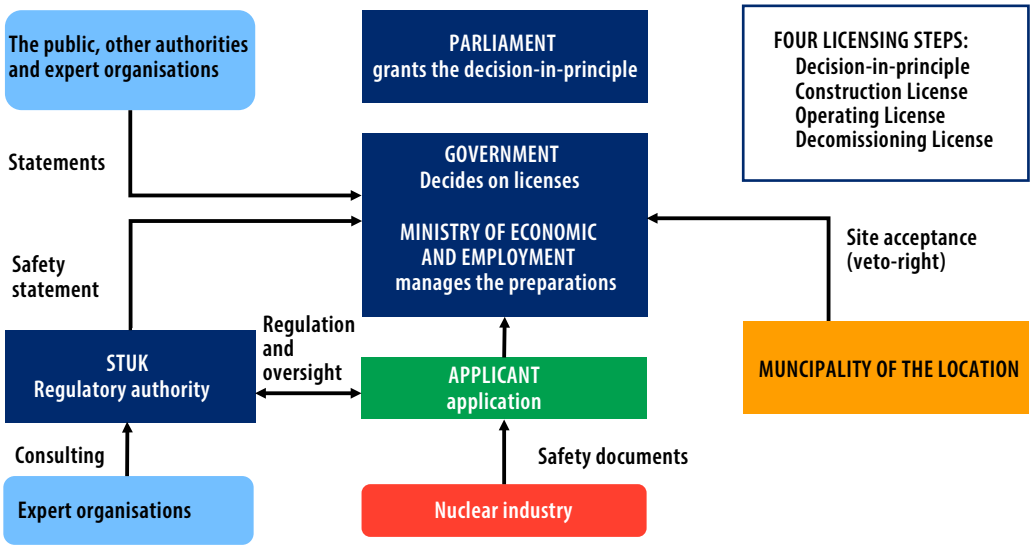
Prior to the decommissioning of a nuclear facility, a decommissioning licence must be applied for from the Government. The preconditions for granting a decommissioning licence are laid down in the Nuclear Energy Act. STUK gives an opinion on the decommissioning licence application and, in a safety assessment attached to the opinion, STUK comments on whether the requirements set out in legislation have been met with regard to matters falling within the mandate of STUK. When preparing its opinion, STUK requests the opinion of the Advisory Committee on Nuclear Safety and, if necessary, other expert organisations.

In addition, the implementation of a nuclear facility requires several permits, such as a building permit issued by the municipality, an environmental permit in accordance with the Environmental Protection Act and permits in accordance with the Water Act. In addition to the licence granted under the Nuclear Energy Act, the transport of nuclear materials, spent nuclear fuel and radioactive waste requires compliance with the regulations governing the transport of dangerous goods.

Upon application, STUK grants **licences for operations** related to, for example, the treatment, storage and disposal of radioactive waste when the total activity of the waste is low (< 1 TBq). In addition, STUK grants **transport licences** in accordance with the Nuclear Energy Act. The preconditions for granting licences are recorded in the Nuclear Energy Act and must be fulfilled in order for a licence to be granted. Consequently, the licence process guides the planned activities.

The regulation of nuclear facilities was assessed in a working group established by the Ministry of Economic Affairs and Employment in 2019. According to the final report of the working group [7], the regulation of nuclear facilities is fragmented, in some places difficult to interpret and written in an environment no longer commensurate with the current situation. Numerous changes to the legislation over the decades have undermined the coherence of the provisions. The need for amendments to the nuclear energy legislation has also been examined in several other working groups, for example from the perspective of spent fuel and radioactive waste management [8], the Fund [9], new technologies as well as the aforementioned regulation of the life cycle of nuclear facilities [7], led by the Ministry of Economic Affairs and Employment. The conclusion has been that the nuclear energy legislation as a whole should be reformed. The Parliament's Constitutional Law Committee and the Commerce Committee have also drawn attention to the need to reform the legislation. The overall reform of the Nuclear Energy Act is being prepared at the Ministry of Economic Affairs and Employment.

Figure 3. Licensing process for nuclear facilities. (Source: STUK)



The use of radiation requires a **safety licence** granted by STUK. The use of radiation includes all activities related to radiation sources, such as their manufacture, use, possession, trade, installation, maintenance, remediation, import and export. Radiation sources include X-ray equipment and radioactive materials or radiation sources and equipment containing them. Possession, safekeeping, storage, rendering harmless and transport of radioactive waste are also uses of radiation. Definitions of the use of radiation are provided in the Radiation Act. The Radiation Act specifically lists activities that do not require a safety licence. A safety licence is also required for practices involving exposure to natural radiation and existing exposure situations (such as cleaning of the environment after a radiation safety deviation) if the occupational or public exposure exceeds the reference level.

The safety licence is valid until further notice; for a special reason, it can be granted for a fixed term. The safety licence is amended as necessary as operations change. An application for changes to a safety licence must be made in advance for changes that are more significant from the radiation safety point of view, and other changes must be notified within two weeks of the change occurring. A radiation safety expert must be used in the design and implementation of radiation protection for workers and the general public, and the operator must designate a radiation safety officer to assist the operator in the implementation of the radiation protection. The qualifications of the radiation safety expert and the radiation safety officer depend on the operation. The operator to whom the safety licence has been granted is responsible for the safety of the operation. The responsibility cannot be transferred to another party, and the appointment of a radiation safety officer does not remove the responsibility of the operator.

The safety licence is withdrawn upon notification by the operator of the discontinuation of radiation practices. At the discontinuation of radiation practices, the radiation sources must be returned to the manufacturer, delivered to another operator, rendered harmless or sent to another operator to be handled as radioactive waste. Radiation sources must be accompanied by handover certificates or an account of how they have been rendered harmless. Where unsealed sources have been handled, it is possible that the premises have become contaminated with radioactive material. At the end of the use of unsealed sources, information must be provided on how the cleanliness of the premises and the treatment or ageing of radioactive waste has been ensured.

The licensing procedures under the Nuclear Energy Act and the Radiation Act differ from each other. The licensing procedures for nuclear facilities in accordance with the Nuclear Energy Act are based on decision-making at the level of the Government, while in the licensing procedures in accordance with the Radiation Act, the licence is issued by STUK. For spent fuel and radioactive waste management procedures, it is important that the interface between the Nuclear Energy Act and the Radiation Act is clear and that similar matters are regulated in both Acts according to the same principles and procedures, while taking into account the graded approach in relation to the level of risk of the waste.

4.4 Responsibility for spent fuel and radioactive waste

The operator has a waste management and financial provision obligations for spent fuel and radioactive waste generated from the use of nuclear energy. With certain exceptions, radioactive waste generated in connection with or as a result of the use of nuclear energy in Finland must be treated, stored and disposed of in Finland in a manner that is intended to be permanent. The waste management obligation covers the treatment, storage, transport and disposal measures required for the management of spent fuel and radioactive waste.

The disposal of spent fuel and radioactive waste generated from the use of nuclear energy must be carried out fully in a way that does not require post closure control to ensure safety. The costs of waste management are borne by the operator of the nuclear facility. When the operator of a nuclear facility has successfully closed the disposal facility and paid the State for the future monitoring and control of the spent fuel and radioactive waste, the ownership of and responsibility for the waste is transferred to the State.

It is the responsibility of the State to ensure that adequate funding is available for the management of spent fuel and radioactive waste. The State ensures this by collecting funds for the Fund (Section 11.2) for spent fuel and radioactive waste generated from the use of nuclear energy, and by requiring a security for other radioactive waste.

Similarly, an operator that generates radioactive waste as a result of the use of radiation must ensure that the radioactive waste does not cause harm to health or the environment and that the radioactive waste generated in the activity is rendered harmless (Radiation Act 859/2018).

In order to render radioactive waste harmless, decommissioned radiation sources may be returned to the manufacturer, transferred to another operator for recovery or, in the case of short-lived radionuclides, aged under controlled conditions until the amount of radioactive material is reduced to a sufficiently low level by radioactive decay, or disposed of.

In the case of radioactive waste, the State has a subsidiary waste management obligation if the operator does not, or cannot be expected to, fulfil its obligations within a reasonable time or if there is no operator whose business is to render radioactive waste harmless and the source cannot be returned to the manufacturer. In this case, the State is responsible for rendering the waste harmless.

However, the operator must reimburse the State for the costs incurred in rendering the waste harmless. According to the Government Decree on Ionizing Radiation, STUK is responsible for the tasks assigned to the State. The responsibility for waste is transferred

to the State when the waste is handed over to STUK. Within STUK, different departments are responsible for receiving and rendering radioactive waste harmless and for regulatory oversight of the management of radioactive waste.

4.5 Classification of spent fuel and radioactive waste

In Finland, radioactive waste generated as a result of the use of nuclear energy is classified as very low, low or intermediate-level waste in accordance with the Nuclear Energy Act. In addition, spent fuel is classified as high-level waste.

Radioactive waste resulting from the use of nuclear energy is to be classified in accordance with the following principles:

- Very low-level waste (VLLW) refers to radioactive waste whose average activity concentration of significant radionuclides does not exceed 100 kBq/kg and whose total activity per licensed disposal facility does not exceed 1 TBq and α activity does not exceed 10 GBq.
- Low-level waste (LLW) refers to radioactive waste whose activity is so low that it can be treated without any special radiation protection arrangements. The activity concentration of the waste is normally not more than 1 MBq/kg.
- Intermediate-level (ILW) waste refers to radioactive waste whose activity is so high that effective radiation protection arrangements are needed when handling it. The activity concentration of the waste is usually between 1 MBq/kg and 10 GBq/kg.
- High-level waste (HLW) refers to radioactive waste whose activity is so high that very effective radiation protection arrangements and, in most cases, cooling are needed when handling it. The activity concentration of the waste is normally over 10 GBq/kg.

In addition, radioactive waste resulting from the use of nuclear energy must be sorted and classified in a manner that is appropriate in terms of further processing, release from regulatory control, storage and disposal.

Radioactive waste from the use of radiation is classified according to the routes of disposal. Spent sealed sources and other solid radioactive waste must be returned to the supplier or handed over for delivery to the State's interim storage cavern attached to the LILW disposal facility at Olkiluoto, unless they can be managed by ageing. The waste may be disposed of as normal municipal waste in a waste incineration plant or in a landfill

if the quantities of radioactive materials are below the clearance levels laid down for that purpose. The total activity of the waste container to be disposed of must be below the nuclide-specific exemption values, and the maximum number of waste containers to be disposed of from one radiation application site per month is limited. Similarly, at specified activity levels, discharges into sewers or air are permitted. At the monthly level, a maximum amount of discharge has been set for each radiation application site. The operator must have a waste accounting system that shows, for example, the radionuclides contained in the waste, their activity and other necessary information for the treatment of the waste as well as information on its disposal.

In Finland, radioactive waste can be released from regulatory control under the general clearance procedure. In addition to the general clearance procedure, both the Radiation Act and the Nuclear Energy Act define a case-specific clearance procedure. The limits of the general clearance procedure for solid radioactive waste are laid down in the Radiation and Nuclear Safety Authority Regulation on Exemption Values and Clearance Levels (STUK SY/1/2018). Release from regulatory control on a case-by-case basis complies with the activity limits separately approved by STUK. Waste released from regulatory control is not subject to the Nuclear Energy Act or the Radiation Act and can be treated in accordance with the Waste Act as conventional municipal or industrial waste.

The processing of soil, stone or other materials of natural origin may result in higher concentrations of naturally occurring radioactive material in the final products, process fractions or waste from industrial processes. Such activities may include, for example, mining and ore enrichment activities, metal processing and groundwater treatment. Waste resulting from activities involving exposure to natural radiation is not radioactive waste in accordance with the Radiation Act, but in the management of such waste, the exposure of workers and the general public to natural radiation must be determined if the activity levels of naturally occurring radioactive material are higher than the clearance levels. If the results show that the exposure may be higher than the reference value, the radiation safety of workers and the general public must be taken into account in waste management.

Protective measures following emergency exposure situations may produce relatively large quantities of waste with activity levels higher than the clearance levels. Moreover, waste resulting from protective actions is generally not radioactive waste under the Radiation Act. The operator responsible for waste management must determine the radiation exposure of workers and the general public caused by the waste. If the results show that the exposure may be higher than the reference value, the radiation safety of workers and the general public must be taken into account in waste management.

5 Quantities of spent fuel and radioactive waste and estimates of future quantities

In Finland, spent fuel is generated at the nuclear power plants operating in Olkiluoto and Loviisa. At the end of 2019, there was a total of 2,261 tons of heavy metal (tHM) of spent fuel in pool storages at the plant locations. According to current estimates, the quantities of spent fuel in storage will be about 3,200 tHM in 2030 and about 4,200 tHM in 2050. The estimate is based on the operating licences of the Olkiluoto and Loviisa nuclear power plant units (OL1–2 and LO1–2) and on the estimates of the start-up dates of the OL3 and Hanhikivi 1 plant units. This estimate does not yet take into account the start of disposal in the 2020s, as the exact start date and rate of disposal are not yet known. In addition to the above, approximately 21 kgHM of spent fuel from the research reactor was stored in Otaniemi at the end of 2019. This fuel was returned to the TRIGA reactor in the United States for further use in 2020.

Most of the radioactive waste generated in Finland comes from the use of nuclear energy. The amount of radioactive waste stored at the power plant sites and in Otaniemi at the research reactor and the amount of radioactive waste to be disposed of in the repositories for low and intermediate-level waste at the power plant sites at the end of 2019 is presented in Table 1. The figures in Table 1 also include radioactive waste from radiation practices that has been disposed of at the LILW disposal facility in Olkiluoto. Radiation practices generate radioactive waste requiring disposal at a rate of approximately 1 m^3 per year.

At the end of 2019, the filling rate of LILW disposal facility´s low-level waste disposal silo (MAJ silo) in Olkiluoto was 65% and that of the intermediate-level waste silo (KAJ silo) was 57%. In Loviisa, LILW disposal facility´s the low-level maintenance waste facility 1 (HJT 1) is full. At the end of 2019, filling rates for maintenance waste facilities 2 (HJT 2) and 3 (HJT 3) were 61% and 16%, respectively. The operation of the repository for intermediate-level waste in Loviisa (KJT) was starting, with a filling rate of 0.1% at the end of 2019. Both LILW disposal facilities will have sufficient capacity for a long time to come. The need for the extension of LILW disposal facilities will become topical before the power plant units are decommissioned and dismantled.

Table 1. The amount of radioactive waste stored and disposed of in Finland on 31 December 2019.[1)]

Waste type	Quantity stored m³	Quantity disposed of m³
Very low-level	204	[2)]
Low-level	1,691	6,541
Intermediate-level	1,970	2,117
High-level	0	0

1) The programme presents the latest information on waste inventories submitted to the European Commission and the IAEA (as of 31 December 2019). STUK monitors the waste quantities annually as part of the regulatory oversight.
2) The very low-level waste fraction includes maintenance waste previously released from regulatory control that has been deposited at TVO's landfill and part of the low-level waste that, according to previous practice, has been disposed of in the MAJ silo of the LILW disposal facility. Since 2018, very low-level waste has not been disposed of, but it has been collected proactively for possible near-surface disposal.

In Finland, only small quantities of radioactive waste awaiting release from regulatory control or disposal are usually stored for short periods of time. For this reason, Finland has not prepared any estimates for future quantities of radioactive waste stored. The estimates for future quantities of waste disposed of in 2030 and 2050 are presented in Table 2 (Table 2).

Table 2. Estimates for future quantities of radioactive waste disposed of in 2030 and 2050.

Waste type	Disposed of in 2030 m³	Disposed of in 2050 m³
Very low-level	2,300	6,900
Low-level	8,761	10,661
Intermediate-level	8,278	9,078
High-level	not assessed	not assessed

The amounts of waste generated from the decommissioning of nuclear power plants have been estimated in the decommissioning plans updated six-yearly by licence holders. The decommissioning of the Loviisa and Olkiluoto nuclear power plants will generate approximately 57,000 m³ of radioactive waste. The decommissioning of the research reactor will generate approximately 40 m³ of radioactive waste.

At the end of 2019, there were roughly 12,100 sealed sources in the State's interim storage cavern attached to the LILW disposal facility in Olkiluoto, equivalent to a total activity of 11.7 TBq. If the number of sealed sources keeps increasing steadily, there will be 13,000 in

storage in 2030 and 15,500 in 2050. The impact of the Radiation Act, which entered into force in 2018 and requires that spent sealed sources must primarily be returned to their country of origin, has not been taken into account in the estimate.

The Spent Fuel and Radioactive Waste Information System (SRIS) database developed by the IAEA was adopted in Finland in spring 2020. The database was developed by the IAEA in cooperation with the European Commission and is intended to enable Member States to submit quantitative data and estimates for future quantities on radioactive waste and spent fuel electronically to both the IAEA and the European Commission in the future.

The database includes data on radioactive waste and spent fuel in storage and disposal. In addition, estimates of the amounts of radioactive waste and spent fuel in the coming years are stored in the database. Finland's goal is to export waste amount data to the SRIS database annually and publish them every three years in connection with reporting under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Finnish Treaty Series 36/2001). In 2020, data on waste amounts at the end of 2019 (31 December 2019) and estimates for 2030 and 2050 were published [6].

With regard to waste records, the objective for the next few years is to further develop and consolidate national procedures for waste recording. The consolidation of procedures requires a more precise definition of what information should be stored in the national database. The recently introduced SRIS database sets requirements for internationally required information, but the national debate on what is to be included in the database is still ongoing.

Requirements concerning waste recording have been set for operators in the Radiation Act and the Regulation STUK S/2/2019 issued on the basis thereof. Requirements concerning waste recording in relation to nuclear facilities are presented in Regulation STUK Y/4/2018 and Guide YVL D.4. Operators are obliged to keep up-to-date records of the radioactive waste and spent fuel in their possession. Practices in this respect are well established and no immediate development needs have been identified. Operators also maintain and update future waste estimates to provide background information on their waste management planning and to estimate costs.

The precise quantities of radioactive waste and spent fuel in storage and disposed are known. In particular, predicting the amount of radioactive waste decades from now poses a challenge to waste recording. For nuclear power plants, waste estimates are based on operating experience from plant units. However, there are uncertainties, as it is impossible to predict, for example, possible future operational events (e.g. fuel leaks, major

unforeseen maintenance needs, additional outages) affecting the amount of radioactive waste generated in a nuclear facility.

Estimates are also made more difficult by the fact that the operating licences of facilities are always for a fixed term, and the length of the future lifespan is unknown. The exact date of commissioning of new nuclear power plants is not known either. In the case of new facilities, the data becomes more accurate when the facilities start operating and data on the accumulation of waste in the first years are available. Estimates of the amount of radioactive waste generated from decommissioning will become more accurate as decommissioning planning progresses closer to the decommissioning date.

The quantities of radioactive waste generated as a result of radiation practices are low and the estimates are very general at this stage. As more experience is gained after the return of sources to the country of origin begins, the projections for waste quantities can be refined.

It is necessary to develop common guidelines for the calculation of waste estimates in order to have harmonised estimates, in particular, for nuclear facilities. After all, they produce most of the radioactive waste generated in Finland. Currently, the compilation of data is cumbersome because the waste data produced by different parties is not commensurate. In addition, waste volume data as regards the use of radiation has not been collected centrally. STUK is responsible for compiling reporting data for international treaty obligations and maintains data on the amount of radioactive waste disposed of. By contrast, an up-to-date database of all radioactive waste stored in Finland is not maintained.

In Finland, the largest quantities of waste, according to the Radiation Act, in activities exposing to natural radiation, are generated in the enrichment of metal ores and metal processing. Some of the waste deposited in Finland comes from foreign raw materials. Similarly, in some cases, the naturally occurring radioactive materials that accompany product fractions manufactured in Finland end up as waste containing natural radiation or as radioactive waste abroad. The total amount of waste going abroad has not been estimated.

Terrafame Ltd (formerly Talvivaara Sotkamo Ltd) accounts for approximately 300,000 tonnes of residue from iron removal per year, which is further disposed of in a hazardous waste landfill in the mine area.

Umicore Finland Oy's cobalt plant in Kokkola produces approximately 30,000 tonnes of iron residue per year, which is landfilled with hazardous waste.

The dismantling of Venator P&A Finland Oy's pigment factory in Pori is planned and it is known that some of the waste contains naturally occurring radioactive material in concentrations higher than the clearance levels. The total amount of this waste is not yet known, as the waste characterisation work is still ongoing.

The steelworks of Outokumpu Stainless Oy in Tornio have by 2021, resulting from accidental smelting of sealed sources at the steelworks, just over 36 000 tonnes and more than 41 000 MBq of slag, mainly rich in americium-241, dumped at the company's industrial landfill.

Groundwater treatment plants producing domestic water are only starting the process of investigation in Finland, but on the basis of the preliminary study carried out in STUK's FINNORM project, some of these will generate waste with higher levels of naturally occurring radioactive material than the clearance levels. Data on the total amount of waste from groundwater treatment plants will only be available on the basis of future reports.

Small batches of a few tonnes of waste have resulted, for example, from metal recycling and ore-enrichment experiments, and these have been deposited in industrial landfills or are still in storage awaiting any further studies or disposal.

Some industrial landfills and old extractive waste sites contain historical waste from the period before or during the previous Radiation Act, which in current radiation legislation would be considered to have been generated by activities involving exposure to natural radiation. The total quantities of these wastes can be estimated better when the database of NORM materials developed by STUK in the FINNORM project is completed.

6 Principles for the implementation of the waste management obligation of spent fuel and radioactive waste

Any operator whose operations generates spent fuel or radioactive waste must take all the measures necessary for the management of this waste, its appropriate preparation and the cost thereof. However, the principles for the implementation of waste management obligation of spent fuel and radioactive waste, such as implementation solutions and timeframes, are decided by the State on the basis of the waste management plan submitted by the operator. The Radiation Act and the Nuclear Energy Act use different procedures to decide on the principles.

Deciding on the principles for implementation of the waste management obligation of spent fuel and radioactive waste resulting from the use of nuclear energy

According to the Nuclear Energy Act, the Ministry of Economic Affairs and Employment or STUK, having granted a licence for the use of nuclear energy, must determine the principles on the basis of which the spent fuel or radioactive waste generated in operations is to be managed. Decisions on the principles for the management of spent fuel and radioactive waste must specify the timeframe and implementation to be followed at the key waste management stages. The decision must also indicate when the spent fuel and radioactive waste management measures are to be carried out at the latest. The decision does not examine in detail the fulfilment of the various policy objectives, but the operator must nevertheless plan and implement the management of spent fuel and radioactive waste in accordance with the principles of the policy. Their implementation is monitored as part of STUK's continuous monitoring.

The principles for the implementation of spent fuel and radioactive waste management may be changed later, where appropriate. The State may also, upon application, transfer responsibility for the implementation of spent fuel and radioactive waste management to another operator. The transfer of responsibility is subject to the condition that the transfer does not jeopardise the implementation of spent fuel and radioactive waste management. In this context, the State must consider whether the transferee can be granted the licence required by the Nuclear Energy Act for the possession of spent fuel and radioactive waste and other activities required for waste management. If this cannot be done, responsibility cannot be transferred. In addition, the transferee must submit acceptable plans for the

implementation of spent fuel and radioactive waste management and for financial provision for the costs of waste management. In practice, this possibility of transferring responsibility has never yet been used.

The operator's responsibility for spent fuel and radioactive waste will continue until waste management for each waste has been completed and a decision on the termination of the responsibility has been taken by the State. In practice, this means, for most operators, the phase of decommissioning and dismantling of the nuclear facilities, the disposal of all spent fuel and radioactive waste and the closure of the disposal facilities. End of responsibility may also occur by transferring responsibility of all spent fuel and radioactive waste to another operator for disposal. In Finland, no decision on the termination of an operator's responsibility has yet been made.

Main principles of the management of radioactive waste resulting from the use of radiation

There are three main principles for the management of radioactive waste resulting from the use of radiation: (1) the aim is to return the disused sealed sources to the importer or manufacturer; (2) short-lived nuclides and waste containing them are aged and (3) small quantities are released from regulatory control. Finally, radioactive waste that cannot be treated in accordance with points 1 to 3 is disposed of.

Operators must submit plans for the management of radioactive waste generated during the operation and its closure to STUK for approval as part of the application for a safety licence or apply for a change to the safety licence during its period of validity.

6.1 Decisions on the principles of implementation of waste management obligation in nuclear facilities

The management of spent fuel and radioactive waste from the use of nuclear energy in Finland was initially directed by the licence conditions set for operating licences of limited duration issued for nuclear power plants. In 1983, the Government drew up a Government Policy Decision for the management of spent fuel and radioactive waste from the use of nuclear energy (see Chapter 2). Decisions on the principles for the implementation of the waste management obligations of spent fuel and radioactive waste required by the Nuclear Energy Act were taken for the operating nuclear power plant units of Loviisa and Olkiluoto in 1989 (62/814/87, 63/814/87 and 11/815/88) [10], 1991 (7/815/91 KTM) [11] and 1995 (9/815/95 KTM) [12], and for Olkiluoto 3 in 2011 (TEM/1592/08.05.01/2011) [13]. A similar decision was taken for the FiR 1 research reactor in 1985 (25/816/84) [14].

The decision on the Posiva´s encapsulation plant and disposal facility was taken in 2021 (VN/11149/2021) [15].

Decisions [10] taken in 1989 approved the return of spent fuel to the Soviet Union as a management option for the Loviisa power plant. In connection with the return of the fuel, the spent fuel was transferred entirely outside the jurisdiction of Finland. The return was based on agreements concluded between Imatran Voima Oy (now Fortum) and V/O Atomenergoexport in 1986 and 1987. For this reason, Imatran Voima Oy was not required to plan the disposal of the spent fuel in Finland. Low and intermediate-level waste was required to be treated, stored and disposed of in Finland. According to the decision, the disposal of low and intermediate-level waste was to start in Loviisa between 1997 and 2000. In addition, the power plant's decommissioning plan was to be updated every five years.

In accordance with the 1989 decision [10], the TVO's management of the spent fuel had to pursue international centralised disposal solutions through contractual arrangements allowing the disposal of the spent fuel abroad. Preparation for disposal in Finland was required to be continued unless such contractual arrangements were reached. TVO was set a target timetable for the promotion of domestic disposal, according to which the disposal site was to be selected by the end of 2000. The plans necessary for the authorisation of the construction of the encapsulation plant and disposal facility had to be submitted to the authorities by the end of 2010. According to the decision, the disposal of spent fuel should start around 2020. The management principles set for low and intermediate-level waste were the same as those set for Imatran Voima Oy. However, TVO was required to put in place a disposal facility for low and intermediate-level waste by the end of 1992. The nuclear power plant's decommissioning plans were to be updated every five years.

In 1991, the Ministry of Trade and Industry adopted a new decision for operating nuclear power plants on the principles of the implementation of waste management obligations of radioactive waste and spent fuel [11]. The decision specified that the Loviisa disposal facility for low and intermediate-level waste (LILW disposal facility in Loviisa) should be in place by the year 2000. In the case of TVO, the decision stated that since TVO has not submitted to the Ministry any agreements for arranging spent fuel management abroad, it should prepare for the development of a domestic disposal solution. The target timeframe for the disposal of spent fuel remained unchanged. For the rest, the principles for the management of radioactive waste and spent fuel by operators, as set out in the Government Policy Decision of 1983, remained unchanged.

As a result of the Parliament's amendment to the Nuclear Energy Act in 1994, the export of spent fuel from the Loviisa nuclear power plant to Russia was no longer an acceptable principle for the management of spent fuel after the end of 1996. The amendment banned the export and import of radioactive waste and spent fuel to Finland. As a result, in 1995,

TVO and Imatran Voima Oy notified the Ministry of Trade and Industry of an agreement between the two companies concerning cooperation in the management of spent fuel and the construction of a joint disposal facility. The Ministry approved the joint plan of TVO and Imatran Voima Oy for a spent fuel disposal facility [12]. In its decision, the Ministry states that the timetable targets set for TVO in the previous decisions on the disposal of spent fuel remain unchanged. At the same time, the Ministry decided that the export of spent fuel from the Loviisa power plant to Russia was no longer possible after 1996. Other principles for the management of radioactive waste remained unchanged.

For the Olkiluoto 3 plant unit, a decision on waste management principles was taken in 2011 (TEM/1592/08.05.01/2011) [13]. According to the decision, the low and intermediate-level waste from the operation and decommissioning phases of Olkiluoto 3 was to be stored in the interim storage facility for low and intermediate-level waste in Olkiluoto and disposed of in the LILW disposal facility in Olkiluoto. The spent fuel was to be disposed of in Olkiluoto at Posiva Oy's disposal facility that was then in the planning phase.

The principles of waste management of VTT's FiR 1 research reactor were approved by a decision of the Ministry of Trade and Industry in 1985 (KTM 11 July 1985) [14] as the return of spent fuel to the United States and the treatment and disposal of waste from the operation and dismantling phase of the research reactor in Finland. Regarding the disposal of radioactive waste, it was agreed that VTT would agree on its disposal in the disposal facilities for low and intermediate-level radioactive waste, which were envisaged at the time of the decision by the power companies.

The principles for waste management at Posiva's spent fuel encapsulation plant and disposal facility have been approved by a decision of the Ministry of Economic Affairs and Employment (VN/11149/2021) [15] concerning the treatment and storage at the Olkiluoto nuclear power plant of waste generated during the operation of the facility. According to the decision, the radioactive waste can be disposed of in accordance with its activity and other characteristics (1) in the LILW disposal facility in Olkiluoto, (2) in the near-surface disposal facility for very low-level waste planned for TVO's Olkiluoto nuclear power plant area, or (3) in Posiva's repository for low and intermediate-level waste, provided that the licences for the operation of the facilities allow their disposal.

However, according to the decision, Posiva must prepare for the management of radioactive waste generated during the operation on their own if it turns out that the infrastructure of the Olkiluoto nuclear power plant is not available to Posiva until the end of the period of operation of the encapsulation plant and the disposal facility. Posiva must also be prepared to manage the radioactive waste generated during the decommissioning of the encapsulation plant and the disposal facility. The decision also states that, on the basis of the available plans, the closure of the disposal facility must be completed by the end of the 2130s at the latest.

6.2 Principles for the treatment and storage of spent fuel and radioactive waste

6.2.1 Principles for the treatment and storage of spent fuel and radioactive waste resulting from the use of nuclear energy

According to the principles of implementation of spent fuel and radioactive waste management, spent fuel and radioactive waste generated in connection with or as a result of the use of nuclear energy in Finland are treated and stored in Finland. In the case of spent fuel, this principle means in practice that reprocessing of spent fuel generated in Finland is not possible. The Nuclear Energy Act does not prohibit the reprocessing of spent fuel, but in order for it to be possible, the reprocessing plant would have to be located in Finland. In Finland, spent fuel is stored for several decades before encapsulation, so that the decay heat power of the fuel becomes suitable for disposal.

The Nuclear Energy Act allows the export of small quantities of spent fuel and radioactive waste for research purposes. Spent fuel and radioactive waste may be disposed of in the host state after the end of the research activity if Finland has an agreement between Member States within the meaning of Directive 2011/70/EURATOM in force at the time of transfer. The Nuclear Energy Act also allows radioactive waste to be delivered abroad for appropriate treatment. However, the radioactive end-products of the treated radioactive waste must be returned to Finland for disposal.

Radioactive waste is treated mainly in Finland. The radioactive waste generated is treated and disposed of as quickly as possible. The treatment and packing of radioactive waste in disposal containers are carried out in waste disposal facilities located at power plants. Similarly, waste is stored in storage facilities located in power plant sites.

In the management of radioactive waste, it is essential that the amount of radioactive waste is kept as small as reasonably achievable. In practice, this principle means that even in the design and operation of a nuclear facility, priority is given to solutions that minimise as much as is reasonably achievable the amount of waste generated at different stages of the lifespan of the facility.

In nuclear facilities, measures to reduce the amount of waste apply to the entire operation of the plant. The amount of excess goods brought to the controlled area is kept small (for example, packaging materials are not in principle brought to the controlled area) and plant modifications are planned such as to generate no excess waste. The classification of waste on the basis of radioactivity and waste properties is done at the source of the waste. These, combined with efficient methods of waste treatment and packing at nuclear

facilities, have led to an effective reduction in the amount of radioactive waste and, as a result, a reduction in the amount of waste destined for disposal in recent years.

Nowadays, nuclear power companies also occasionally send large components abroad to be melted down in order to reduce the volume of waste. In this case, the radioactive end-products are returned to Finland to be disposed of. In addition, radioactive waste can be released from regulatory control and then be sent for reuse or recycling in the same way as non-hazardous waste. All recoverable materials are delivered for recycling.

By sorting waste at source, waste eligible for release from regulatory control has been separated more effectively from other radioactive waste. In addition, nuclear power plants have invested in the development of procedures for releasing waste from regulatory control. This has led to an increase in the amount of waste released from regulatory control.

The quantities of waste released from regulatory control vary quite considerably from year to year, for example, due to the maintenance work carried out at the power plants. In 2019, the Loviisa power plant released approximately 240,500 kg of waste from regulatory control and the Olkiluoto power plant approximately 112,700 kg. The waste released from regulatory control includes, for example, concrete, metal, mixed dry waste and hazardous waste, such as waste oils and fluorescent tubes. The largest quantity of metals, a total of around 298,000 kg, was released from regulatory control in nuclear power plants in 2019. The metal is delivered for recycling. In 2019, approximately 37,000 kg of waste was landfilled. The majority of these are mixed dry waste, which could be incinerated in a waste incineration plant.

It is planned to examine whether it would be possible to incinerate maintenance waste released from regulatory control in a Finnish waste incineration plant in the future. This would reduce the amount of landfilled waste, and it would be in line with the order of priority under the Waste Act, assuming that the energy generated from incineration is recovered. So far, waste incineration plants have not received waste released from regulatory control from nuclear power plants into their incineration process.

6.2.2 Principles for the treatment and storage of radioactive waste from radiation practices

In Finland, an operator may hand over a decommissioned sealed source containing radioactive material to an operator whose operation includes receiving, treating and storing radioactive waste. The preferred option for the decommissioning of sealed sources is to return them to the manufacturer in the country of origin, but this will not

always be the case, especially for older sealed sources. The Radiation Act, which entered into force in 2018, defines a maximum service life of 40 years for sealed sources, beyond which sealed sources must be decommissioned. There is a transitional period of five years for decommissioning, which will end in December 2023. Several hundred old sealed sources will be decommissioned. Subsequently, smaller quantities of sealed sources will be decommissioned each year. In the future, there must be effective procedures for the decommissioning of sealed sources, either for their export or for their disposal in Finland.

Radioactive waste, waste resulting from practices involving exposure to natural radiation or waste resulting from protective measures following emergency exposure situations may be released from regulatory control if its activity levels are below the clearance levels, or in individual cases, if the conditions for releasing laid down in the Radiation Act are met. Such waste is no longer treated as waste under the Radiation Act, but it is covered by the Waste Act.

If the activity concentrations of waste resulting from activities involving exposure to natural radiation or from protective measures following an emergency are higher than the clearance levels, the radiation exposure from the waste must be investigated and taken into account in the management of this waste, if the exposure of workers and the general public is higher than the reference values. Methods of treatment and disposal are chosen primarily on the basis of waste and environmental legislation. Typically, the waste is disposed of at a landfill or at an extractive waste facility. If, on the basis of studies, it is shown that the radiation exposure is low in that mode of operation, the treatment and disposal may take place without any additional requirements being set under the radiation legislation. If the exposure is higher than the reference values, the measures limiting the exposure must be increased and, if necessary, a safety licence must be applied for in accordance with the Radiation Act. If the waste is reused, recycled or recovered, the purpose of use must be taken into account in the exposure assessment. The regulations concerning the transfer, export and import of radioactive waste do not apply to waste causing exposure to natural radiation in Finland.

Radioactive waste from radiation practices under the Radiation Act that cannot be released from regulatory control is stored in the interim storage cavern attached to the LILW disposal facility in Olkiluoto. The State also holds high-activity sealed sources (HASS) in the storage. Similar sources are also stored by operators all over Finland. The sources are quite old, dating back to the 1960s and 1970s, and cannot be returned to the manufacturer. These sources will be stored until they can be disposed of. Responsibility for the radioactive waste in the storage facility lies with the State.

6.3 Principles for the disposal of spent fuel and radioactive waste

6.3.1 Principles for the disposal of spent fuel and radioactive waste resulting from the use of nuclear energy

Spent fuel and radioactive waste from of the use of nuclear energy must be permanently disposed of in Finland in the manner intended and must not cause any harm to the environment or to people now or in the future. Radioactive end-product generated abroad as a result of the treatment of radioactive waste generated in Finland is also to be returned to Finland for disposal.

There are a few exceptions to this principle provided for in the Nuclear Energy Act. However, in these exceptional cases, the amount of spent fuel or radioactive waste is small enough to be irrelevant when deciding on the principles for implementation of the management obligations of spent fuel and radioactive waste. The State imposes conditions on these wastes as well. The condition for the approval of the transfer of spent fuel and radioactive waste outside the jurisdiction of Finland is that the transfer has been the subject of a binding agreement between at least the operators and the agreement can be considered feasible for the management of spent fuel and radioactive waste, taking into account the timeframe for the implementation of the agreement and other conditions.

The safety of the disposal facility must be based on passive safety features. The disposal facility must be designed to not require maintenance or monitoring after closure. Typically, the construction of a disposal facility proceeds in stages. The room that are necessary for the operation are built first. Provision is made for the extension of the disposal facility already at the planning stage, but the implementation of the extension will be decided separately, if necessary. For example, the size of the facilities for the disposal of low and intermediate-level waste may be reduced during the operation of the nuclear power plant due to the introduction of more efficient procedures for waste sorting, treatment and release form regulatory control or a completely new disposal concept (e.g. near-surface disposal), as determined by the original waste quantities. Staged construction also reduces the adverse effects of construction on the natural characteristics of the bedrock.

Low and intermediate-level waste generated from the use of nuclear energy is disposed of in a disposal facility located in the bedrock of Finland. The disposal facility has been designed taking into account the characteristics of the bedrock. In LILW disposal facility in Olkiluoto, waste is disposed of in silos, and in LILW disposal facility at Loviisa, it is disposed of in tunnels. According to preliminary plans, the disposal facility to be built in Pyhäjoki will be of the tunnel type. In the case of the disposal facility to be built in Pyhäjoki, the

plans will be further specified as the site of the disposal facility is examined and as the planning of the plant proceeds in the coming years. Waste from the decommissioning of power plants will also be disposed of in future extensions to existing disposal facilities.

The Nuclear Energy Act also allows for the disposal of very low-level waste in a near-surface disposal facility. Currently, very low-level waste is disposed of in LILW disposal facilities in Olkiluoto and Loviisa. TVO is planning to build a near-surface disposal facility in Olkiluoto and has carried out an assessment of its environmental impact [16], [17]. However, a decision on the construction of a near-surface disposal facility has not yet been taken and a licence has not been applied for. The introduction of a near-surface disposal facility would reduce the amount of waste going to the LILW disposal facility in Olkiluoto. Fennovoima is also planning to build a near-surface disposal facility in Pyhäjoki.

Spent fuel is to be disposed of in a disposal facility to be built in bedrock in Finland. The disposal of spent fuel is to be carried out using the KBS-3 method developed by the Swedish company SKB. There are two options for the method: In KBS-3V, canisters are deposited vertically (vertical deposition) and in KBS-3H, horizontally (horizontal deposition). Of these options, KBS-3V has been chosen as the preferred solution in Finland.

Spent fuel will be encapsulated before disposal. In the encapsulation plant, the spent fuel will be packed in disposal canisters and sealed by welding. The quality of the weld will be ensured by a variety of non-destructive methods. The sealed and inspected disposal canister will be transferred from the encapsulation plant to the repository for disposal.

6.3.2 Principles for the disposal of radioactive waste resulting from the use of radiation

Radioactive waste from the use of radiation is disposed of in the LILW disposal facility in Olkiluoto within the specified limits. However, the State and the operators are in possession of high-activity sealed sources, which cannot be disposed of in the LILW disposal facility in Olkiluoto due to their high activity. Certain sealed sources and other radioactive waste also contain radionuclides that cannot currently be disposed of in the LILW disposal facility in Olkiluoto. In addition, other characteristics of the waste, such as its chemical form, may prevent disposal in existing facilities. These are kept in storage until a suitable disposal solution is in place. For these, the possibility of disposing of them in LILW disposal facilities in Olkiluoto or in Loviisa or disposal facility of spent fuel should be explored. The responsibility for the radioactive waste disposed of in the LILW disposal facilities in Olkiluoto lies with the State after its disposal.

7 Concepts, plans and technical solutions for the management of spent fuel and radioactive waste

As part of the preparation of the waste management, an operator using nuclear energy and whose operation generate spent fuel or radioactive waste is to submit a plan for the implementation of the management of spent fuel and radioactive waste to the Ministry of Economic Affairs and Employment for evaluation every three years. These plans include up-to-date plans and technical solutions for the management of spent fuel and radioactive waste, and thus constitute an important starting point for this programme. The Ministry of Economic Affairs and Employment asks STUK for an opinion on the plans.

The plan must include an overall plan for the management of the waste, with a timeframe and specification, including the necessary preparations and research measures, the administrative arrangements for the waste management obligation. The plan must also include an estimate of the current state of research, development and design work, and a detailed plan of the measures to be taken over the next three years. Also a general outline of the planned measures to be taken over the next six years must be provided.

In addition, a description must be provided for any agreements or other arrangements for the management of spent fuel and radioactive waste concluded by the operator. The plan may also include a brief overview of the measures taken in the previous period for the management of spent fuel and radioactive waste, unless otherwise implemented. On the basis of the plan, the progress of the plans for the management of spent fuel and radioactive waste can be monitored and the adequacy and timeliness of the measures taken by the operator can be assessed.

The plan for the Olkiluoto and Loviisa nuclear power plants for 2022–2024 was published in September 2021 [18]. The plan will next be updated by the end of September 2024. The plan for VTT's research reactor [19] was published in September 2021. The progress of the measures for the management of Fennovoima's spent fuel and radioactive waste will be assessed as part of the processing of the construction licence application [20] and the regulatory control during construction, until the principles for the implementation of the waste management obligation of spent fuel and radioactive waste have been decided.

In addition to the plans drawn up by the operators for the management of spent fuel and radioactive waste, the measures taken are reported in the annual reports drawn up by the operators [21]. In addition, the overall situation of spent fuel and radioactive waste management in Finland is reported in the three-yearly assessment reports under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [6] and in the reports pursuant to Directive 2011/70/EURATOM [22]. They contain detailed information on the planning and development of Finland's spent fuel and radioactive waste management.

In the case of radioactive waste resulting from the use of radiation, the operator must, when applying for a safety licence, present the procedures for the treatment of the radioactive waste. In the case of new sealed sources containing radioactive materials to be added to the safety licence, the manufacturer or importer is required to commit to receive the source at the end of its use. Where appropriate, the importer will deliver the radiation sources to the manufacturer once they have been decommissioned.

Sealed sources, which cannot be returned to the manufacturer, are delivered through Suomen Nukliditekniikka Oy for disposal in LILW disposal facility in Olkiluoto. Suomen Nukliditekniikka Oy is the only company currently receiving and treating radioactive waste from other operators in Finland. In the case of other radioactive waste, procedures for the delivery of the waste to incineration or landfill in the quantities permitted by the clearance levels must be set out.

In addition, an estimate of the amount of emissions to sewers or air generated by the operation must be presented. If the amount or treatment of waste changes during the operation, it must be submitted to STUK in advance. The use of radiation may also result in liquid waste exceeding the clearance levels and in waste problematic due to other characteristics, for which there is currently no disposal solution. It would be practical if the potential of facilities for treating waste generated from the use of nuclear energy could be exploited in the treatment of this waste.

7.1 Low and intermediate-level waste from the use of nuclear energy

The operation and decommissioning of the Olkiluoto and Loviisa nuclear power plants and the VTT's FiR 1 research reactor generate low and intermediate-level waste. Posiva's encapsulation plant and disposal facility and the Hanhikivi nuclear power plant will also generate low and intermediate-level waste once the facilities are operational. Low-level waste includes, for example, various packaging, scaffolding, protective equipment,

insulation and cleaning materials accumulated during the operation of nuclear plants, as well as during service and repair work.

At the Olkiluoto and Loviisa nuclear power plants, low-level waste is packed in steel drums. Compressible waste is compressed to fit more waste in the disposal containers. In Olkiluoto, the drums are also packed in concrete containers before disposal. In 2018, the collection and treatment of very low-level waste started in Olkiluoto for planned near-surface disposal. Very low-level waste is baled for disposal. The treatment of low-level waste does not require any special radiation protection arrangements.

Intermediate-level waste requiring the use of radiation protection during treatment includes ion exchange resins used to clean process water in nuclear power plants. Intermediate-level waste is mainly wet or liquid, so it is dried and/or solidified before disposal. Storage of liquid waste at plants prior to solidification is carried out in dedicated storage tanks.

In the Olkiluoto plant units OL1 and OL2, wet or liquid intermediate-level waste is solidified with bitumen in steel drums. In the OL3 plant unit, the intermediate-level ion exchange resin is dried together with low-level evaporator concentrates by means of vacuum drying directly into a 200-litre drum. Drums containing dried resin waste are stored on site until the disposal concept is confirmed. TVO is considering solidifying the wet or liquid waste of all the plant units with cement in the future, but it has not yet made a decision to implement the change.

In Loviisa, liquid waste has been stored in storage tanks since the start of operation. In 2016, the Loviisa power plant started solidifying liquid intermediate-level waste with cement. The concrete solidification vessel serves as the radiation shield. In addition, part of the liquid waste has been purified at the Loviisa power plant using the selective ion exchange method (NURES) developed by Fortum. The treatment method has significantly reduced the amount of waste to be solidified.

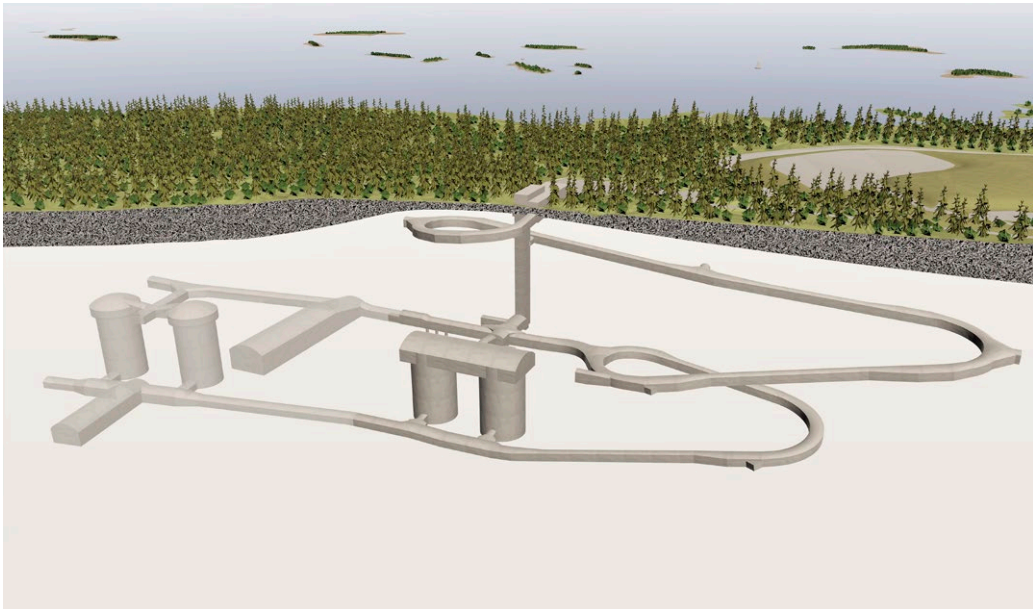
In Olkiluoto, waste is temporarily stored in the power plant units, in the storage of the radioactive waste buildings and in the interim storage facility for low and intermediate-level waste. In Loviisa, operational waste is stored in storages located in the power plant area and in an intermediate storage locating in connection with the repository. Waste is typically stored for a short period of time, as waste is transferred to a disposal facility on an annual basis. In Loviisa, only waste awaiting release from regulatory control is stored for a longer period of time, about 5 years.

The Nuclear Energy Act allows for the disposal of very low-level waste in near-surface facilities. TVO is considering the construction of a near-surface disposal facility and

performed an environmental impact assessment procedure for it in 2020 and 2021 [16], [17].

Low and intermediate-level waste is disposed of in disposal facilities built in the bedrock of the plant sites at a depth of about 100 metres. They were opened in the 1990s. In Olkiluoto, the disposal facility consists of two silos, one for low-level and one for intermediate-level waste (Figure 4). The LILW disposal facility in Olkiluoto include an interim storage for radioactive waste, mainly from health care and industry. The disposal of waste held by the state in the LILW disposal facility in Olkiluoto started in 2016.

Figure 4. LILW disposal facility in Olkiluoto. The available rooms are marked in dark grey and the planned extension is marked in light grey. (Source: TVO)



The LILW disposal facility in Loviisa consists of three tunnels for maintenance waste and one repository for solidified waste (Figure 5). Low-level waste from power plant operation is disposed of in maintenance waste tunnels 1 and 2. For the time being, maintenance waste tunnel 3 is used for interim storage of low-level waste prior to its release from regulatory control. The maximum storage period is five years. Maintenance waste tunnel 3 is to be used for disposal at a later date. Since the end of 2019, liquid waste solidified in cement has been disposed of in the solid waste repository.

Figure 5. LILW disposal facility in Loviisa. The rooms in use are marked in dark grey and the planned extension is marked in green. (Source: Fortum).

Both LILW disposal facilities are planned to be expanded for the disposal of radioactive waste generated during decommissioning. The need to expand the disposal facilities for low and intermediate-level waste has increasingly moved into the future, as improved waste treatment has succeeded in significantly reducing the volume of waste to be disposed of compared to the waste quantities estimated at the time of planning and construction of the disposal facilities. Examples of practices that have reduced waste volumes include denser waste packing, more effective releasing from regulatory control, development of waste sorting and shipment of large components abroad for smelting.

According to the current plans, the LILW disposal facilities will be closed when the decommissioning of spent fuel storage facilities is completed. During the closure phase, the LILW disposal facilities will be partly backfilled and the necessary concrete closing structures will be built in the tunnels and shafts. The closure plans will be specified closer to the closure of the LILW disposal facilities. After the closure of a LILW disposal facility, it does not need to be monitored for radiation safety reasons.

Low and intermediate-level waste generated in the Posiva encapsulation plant during the encapsulation of spent fuel is to be treated and stored at the Olkiluoto nuclear power plant. Posiva's liquid waste is designed to be vacuum-dried in drums or similar containers.

According to the current plan, the operating and decommissioning waste from the encapsulation plant will be disposed of depending on its activity and other characteristics in the LILW disposal facility in Olkiluoto, in the near-surface disposal facility planned for Olkiluoto or in Posiva's repository for low and intermediate-level nuclear waste.

Low and intermediate-level waste generated by the use of the VTT's FiR 1 research reactor is treated and packed in the research reactor. The waste will be stored in the Loviisa nuclear power plant site, and later it is planned to be disposed of in the LILW disposal facility in Loviisa in accordance with the agreement concluded by VTT and Fortum in spring 2020. Launching the abovementioned activities in Loviisa will require licences in accordance with the Nuclear Energy Act.

According to the current plans, the low and intermediate-level waste from Fennovoima's nuclear power plant will be treated at the power plant and stored in storage facilities at the power plant site. In addition, Fennovoima is planning a disposal facility for low and intermediate-level waste in the bedrock of the power plant site. Low and intermediate-level waste generated during both operation and decommissioning is to be disposed of in the disposal facility. Fennovoima has also planned to build a near-surface disposal facility for very low-level waste.

7.2 Storage and disposal of spent fuel

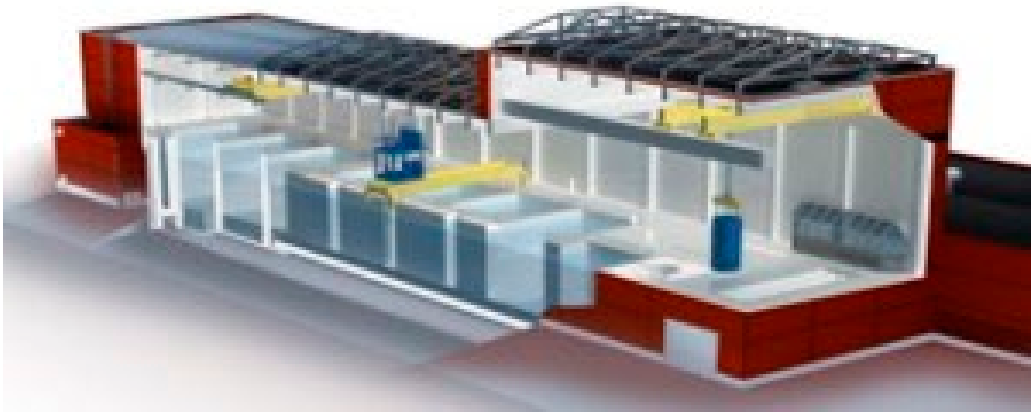
7.2.1 Storage of spent fuel

The operation of the Olkiluoto and Loviisa nuclear power plants generates spent fuel, which are stored temporarily in interim storage pools located in the Olkiluoto and Loviisa power plant areas. Olkiluoto's storage facility stores all spent fuel generated by Olkiluoto's plant units during their more than 40 years of operation. In accordance with the original delivery contract, Loviisa's spent fuel was returned to the Soviet Union/Russian Federation after a storage period of about five years. Following the amendment to the Nuclear Energy Act in 1994, all spent nuclear fuel generated in Finland must be stored and disposed of in Finland. Transport of spent fuel to Russia ceased in 1996. Thus, all spent fuel generated in Loviisa nuclear power plant since the beginning of the 1990s is in interim storage in Loviisa.

Spent fuel assemblies from Loviisa and Olkiluoto are cooled for a few years in storage pools in the reactor hall or fuel building of the nuclear power plant unit. From there, the fuel assemblies are transferred in a transfer cask to the storage pools of the interim storage for spent fuel (KPA storage) at the power plant site. In the storage pools of the KPA storage, fuel assemblies are cooled underwater for decades before the start of disposal. During this

period, the radioactivity and heat output of the spent fuel decrease to the level required for disposal.

Figure 6. Underwater storage pool for spent fuel in Olkiluoto (Source: TVO).



The Olkiluoto KPA storage (Figure 6) has been expanded to meet the needs of the third (OL3) reactor unit. The extension was commissioned in 2015. The capacity of the Loviisa KPA storage has been increased by the introduction of denser fuel racks, which means that the storage capacity will be sufficient until the end of the currently expected operating lifetime of the power plant. If necessary, the capacity of the KPA storage in Loviisa can be further increased by introducing more of the dense racks or by building more storage space. The cooling capacity of the interim storage facility is also increased as necessary. Interim storage in Loviisa will continue until all spent fuel has been transported to Olkiluoto for disposal.

Fennovoima is also planning to build an interim storage for spent fuel at its plant site. According to Fennovoima's preliminary plans, spent fuel will be stored in pools in the interim storage for several decades before disposal.

The spent fuel generated during the operation of the FiR 1 research reactor was returned to the United States in 2020. Since the fuel was returned to the United States, the planning of its interim storage and disposal in Finland has ended.

7.2.2 Disposal of spent fuel

Posiva is building a spent fuel encapsulation plant and disposal facility in Olkiluoto, Eurajoki. The encapsulation plant and disposal facility form a complex of two nuclear facilities. The encapsulation plant is designed to serve the encapsulation needs throughout the disposal period. On the other hand, the underground disposal facility will be progressively expanded according to the progress of the disposal such as to optimise the disposal in terms of the time, space and resources used.

The spent fuel generated by the owners of Posiva (Fortum and TVO) during the operation of their nuclear facilities will be disposed of in the disposal facility. Spent fuel will be transferred from Olkiluoto's and transported from Loviisa's interim storage to the encapsulation plant. Spent fuel is to be disposed of in bedrock at a depth of approximately 400 metres.

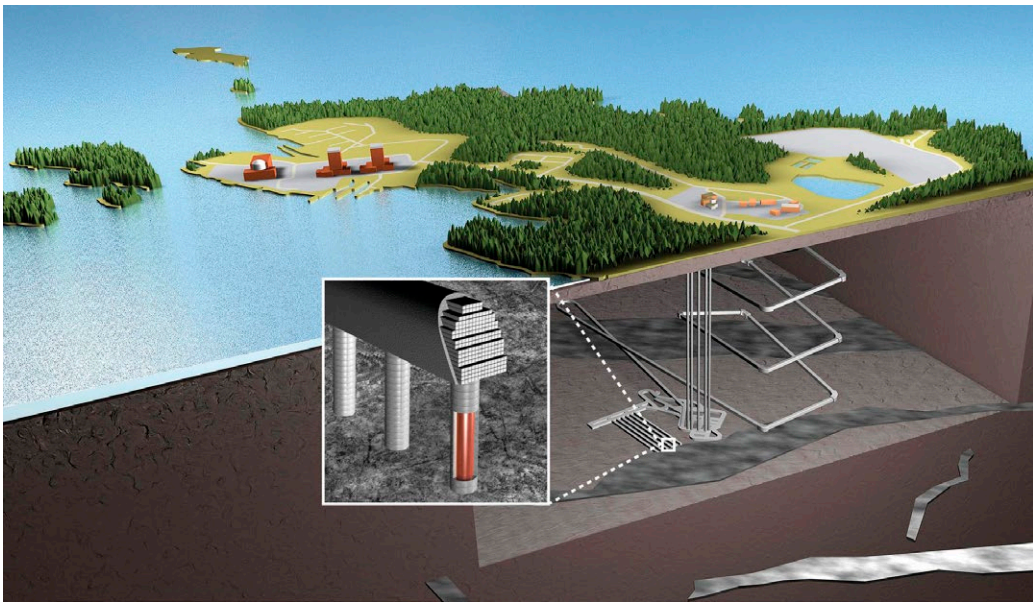
In the KBS-3 disposal concept (Figure 7) developed by the Swedish company SKB, approved for use in Finland, fuel assemblies are enclosed in sealed metal containers (canisters) with a cast-iron insert and a surrounding copper shell. The heat output of each disposal canister is limited to an acceptable level by always selecting sufficiently cooled fuel assemblies with a suitable heat output for each disposal canister. Once fuel assemblies have been transferred inside the canister, it is filled with inert gas and sealed tightly with the inner steel lid of the canister. The top copper lid of the canister is sealed by welding. The tightness of the weld is ensured visually and by non-destructive methods.

The sealed and inspected disposal canister is transferred via a vertical shaft to the disposal facility's reception station at a depth of about 420 m and from there by vehicle to the repository and a deposition hole. The strong, corrosion-resistant canister is designed to contain spent fuel and to prevent radioactive material from entering the bedrock where it could enter the living environment with groundwater.

In the repository, the canisters are isolated from the bedrock by means of a layer of bentonite clay. The purpose of bentonite is to maintain favourable conditions for disposal and isolation of the canister and to prevent as much as possible the effects of groundwater on the canister. It is also intended to prevent and slow down the transport of radionuclides within the bedrock in possible exceptional situations, for example in the event of leakage or breakage of a copper canister.

The bedrock properties of the disposal site must be favourable for the containment of radioactive materials from the living environment. The planned disposal site must have sufficient and intact rock volumes for the construction of the disposal facility. The disposal site and its immediate vicinity must not contain significant amounts of recoverable natural resources. Other technical and economic requirements of the operator, as well as factors related to public acceptance, are also involved in the selection of the disposal site.

Figure 7. Illustration of KBS-3V disposal solution (Source: Posiva).



Posiva chose Olkiluoto, Eurajoki as the disposal site of spent fuel. The disposal site was approved by a decision-in-principle in 2000 [23], which was confirmed by the Parliament in 2001. The progress of Posiva's project is described in more detail in Section 9.1. Based on the decision-in-principle, Posiva started the construction of the ONKALO® underground rock characterisation facility in Olkiluoto in 2004. The rock characterisation facility consists of an access tunnel built to the disposal depth and vertical shafts drilled in connection with it.

The underground rock characterisation facility enabled detailed investigations of the bedrock of the disposal site at the depth of the disposal, testing of disposal solutions under real bedrock conditions and the development of the necessary methods and procedures for the construction of the disposal facility. In the rock characterisation facility, installation tests of the disposal system will be carried out and the operation will be demonstrated in full scale before the start of disposal. Since the rock characterisation facility will be incorporated into the disposal facility, STUK supervised its construction on the basis of a decision-in-principle as if it were a nuclear facility under construction.

The decision-in-principle on Posiva's disposal facility requires the ability to retrieve the fuel after the closure of the disposal facility. In addition, it must be possible to retrieve the spent fuel at any stage of disposal, if required for safety reasons. However, the long-term safety of disposal must not be impaired as a result of the re-opening and retrievability.

According to current plans, Fennovoima's spent fuel will be disposed of using the KBS-3 method in the crystalline bedrock of Finland. Fennovoima has launched an environmental impact assessment procedure for its own disposal site [24]. Fennovoima plans to dispose of spent fuel in Eurajoki or Pyhäjoki (Sydänneva area). In June 2016, Fennovoima entered into an agreement with Posiva Solutions Oy, a subsidiary of Posiva, regarding development work on the disposal of spent fuel.

7.3 Radioactive waste from the decommissioning of nuclear facilities

The decommissioning and dismantling of the Loviisa and Olkiluoto nuclear power plants and the FiR 1 research reactor will generate radioactive waste. The commissioning of the Hanhikivi nuclear power plant will also later result in radioactive waste from its decommissioning and dismantling. The operator must take the decommissioning of the nuclear facility must into account already at the planning stage of the facility. At this point, the operator must also submit the first preliminary decommissioning plan to the authorities for approval as part of the application for the facility's construction licence. Preliminary decommissioning plan must be submitted to the authorities for approval also in accordance of the operating licence application.

During the operating phase of facilities, the operator is to draw up decommissioning plans every six years for evaluation by the Ministry of Economic Affairs and Employment. During the operation according to the operating licence, the Ministry of Economic Affairs and Employment ensures the technical feasibility of the decommissioning plan, compliance with the safety principles and reliability of the cost estimates. The Ministry of Economic Affairs and Employment asks STUK for an opinion on the plan, and the latter assesses the technical feasibility of the plan and the adequacy of the measures for radiation protection and radioactive waste management. As regards the reliability of cost estimates, the Ministry of Economic Affairs and Employment requests an evaluation from an independent expert or entity specialised in the evaluation of technical economic calculations.

The radioactive waste generated as a result of the decommissioning has been planned to be disposed of in subsequently constructed and licensed extensions of the power plants' disposal facilities for operational waste at both the Loviisa and Olkiluoto nuclear power plants (LILW disposal facilities). The treatment of radioactive waste is to be carried out using methods used during the operation of the nuclear power plants. If necessary, new waste treatment premises are to be planned for the power plants in order to deal with the large volume of waste during the decommissioning period. Large quantities of waste, and

possibly also new types of waste with new characteristics, also require the development of treatment methods.

In Finland, according to the nuclear energy legislation, decommissioning covers only the dismantling of structures and systems that are activated and/or contaminated. Buildings released from regulatory control remaining in nuclear power plant sites can be used for other industrial activities (brownfield), for example, or they can be demolished in the same way as conventional industrial buildings.

The decommissioning plans for the OL1 and OL2 units of the Olkiluoto power plant are based on deferred dismantling [25]. Deferred dismantling is justified because it reduces the radiation doses for dismantling personnel and the amount of waste to be disposed of and allows the use of the same waste management arrangements during the dismantling of all plant units. It is also reasonably feasible because, since during the safe storage of the OL1 and OL2 units, the OL3 unit of the Olkiluoto power plant and the interim storage for spent fuel are in operation, and thus the operator has the necessary organisation and expertise to operate. The OL3 unit is planned to be dismantled immediately after use. After the decommissioning of the nuclear power plant units and the disposal of all the spent fuel, the interim storage for the spent fuel will be dismantled. Once all the radioactive waste has been disposed of, the LILW disposal facility will be closed.

The decommissioning plans for the LO1 and LO2 units of the Loviisa power plant are based on immediate dismantling after permanent shutdown [26]. The decommissioning will start with a preparation period of a few years before the dismantling starts. During the decommissioning of the plant units, the spent fuel storage, liquid waste storage and solidification plant will operate independently until the spent fuel from the Loviisa power plant has been transported to Posiva's encapsulation plant and disposal facility in Olkiluoto. After that, the interim storage for spent fuel, the storage of liquid waste and the solidification plant can also be decommissioned and dismantled. The LILW disposal facility will be closed when all radioactive waste has been disposed of.

The initial decommissioning strategy of Fennovoima is based on immediate dismantling [20]. The decommissioning plan for Fennovoima's nuclear power plant also includes a preparation period of a few years before the dismantling of the plant starts. After the dismantling of the plant unit, and once all spent fuel has been disposed of, the independent interim storage facility for spent fuel will be dismantled. The radioactive waste generated during the decommissioning phase will be disposed of in an extension of the on-site operational waste disposal facility, which will be closed last when all the waste has been disposed of.

In June 2021, the Government granted VTT a licence to decommission and dismantle the FiR 1 research reactor [27]. VTT may begin dismantling of the research reactor once STUK has approved the detailed dismantling plans and the resulting radioactive waste has a storage approved in accordance with the Nuclear Energy Act. Decommissioning includes the decontamination of the premises and the treatment of the resulting radioactive waste. The radioactive waste generated in the decommissioning of the research reactor will be treated and packed in the premises of research reactor, stored in the Loviisa power plant site, and later disposed of in the LILW disposal facility in Loviisa in accordance with the agreement concluded by VTT and Fortum in spring 2020. Launching the abovementioned activities in Loviisa will require licences for the Loviisa facility in accordance with the Nuclear Energy Act.

7.4 Radioactive waste from radiation practices

Approximately 6,000 sealed sources containing radioactive materials are used by operators in the monitoring of various processes and in quality control as radiometric measuring devices and calibration sources. The Radiation Act, which entered into force in 2018, defines a maximum service life of 40 years for sealed sources, beyond which sealed sources must be decommissioned. The law provides for a five-year transitional period until the end of 2023, during which hundreds of sealed sources will be decommissioned. The reception of decommissioned sealed sources and the management of radioactive waste are currently managed by Suomen Nukliditekniikka Oy as the only operator in Finland.

Radioactive materials are also handled as unsealed sources in research and health care, for example. Waste from the handling of unsealed sources may be disposed of under conventional waste management in accordance with the specifiedclearance levels. Waste containing short-lived radionuclides can be aged and then disposed of as non-hazardous waste. The treatment of unsealed sources can also result in solid or liquid waste requiring disposal. Solid or solidified waste may be sent for disposal or handed over to an operator holding a safety licence for the treatment of radioactive waste and for its receipt from other operators. Not all operators have the capacity to treat or solidify liquid waste, which may make it more difficult to deliver to disposal. At the moment, there is also no operator capable of receiving liquid waste for transport to the interim storage cavern attached to the LILW disposal facility in Olkiluoto.

Disposal of radioactive waste resulting from radiation practices is carried out using the procedures for low and intermediate-level waste from nuclear facilities. The radioactive waste is packed in steel drums just as waste from nuclear power plants. Solid radioactive waste is received and stored before disposal in the interim storage cavern attached to the LILW disposal facility in Olkiluoto.

The treatment or disposal of radioactive waste generated merely in radiation practices (pursued under the Radiation Act) may be authorised under the Radiation Act. However, no such application for a safety licence for disposal has ever been received and no such project is known.

The decommissioning of the laboratory facilities used for material research locating in connection with VTT's FiR 1 research reactor has already been started in accordance with the safety licence issued by STUK [28]. Decommissioning includes the decontamination of the premises and the treatment of the resulting radioactive waste. The radioactive waste generated in the decommissioning of the laboratory facilities used for material research will be treated and packed in the premises of VTT, stored in the Loviisa nuclear power plant site, and later disposed of in the LILW disposal facility in Loviisa in accordance with the agreement concluded by VTT and Fortum in spring 2020. Launching the abovementioned activities in Loviisa will require licences for the Loviisa facility in accordance with the Nuclear Energy Act.

8 Concepts and plans for the post-closure period of disposal facilities

Closure means the closure of the rooms of a disposal facility in a manner that is intended to be permanent. The closure of the disposal facility must be carried out in such a way that the bedrock retains, as far as possible, the characteristics essential for long-term safety.

Fortum and TVO have prepared preliminary plans for the closure of the LILW disposal facilities in Loviisa and Olkiluoto, respectively. The facilities are to be closed permanently once all nuclear facilities in the nuclear power plant sites have been dismantled and the radioactive waste has been disposed of. According to the preliminary plans, the LILW disposal facility in Loviisa will be closed first in the 2060s at the earliest.

The closure of the ONKALO spent fuel disposal facility will be carried out in stages according to Posiva's plans. The deposition tunnels will be closed as soon as the planned number of canisters have been disposed in them, and the closure of the central tunnels will begin decades from now upon transition to the next disposal panel. The other rooms will be closed only at the end of the operating phase of the facility. Detailed closure planning will continue based on experience from disposal. According to current estimates, the permanent closure of ONKALO will not take place until the 22nd century at the earliest.

The permanent closure of the disposal facility is subject to the approval of the closure plan by STUK. The plan must include a description of the technical implementation of the closure of the repository, an update of the safety case, a plan for the potential post-closure monitoring measures and a proposal for the restriction zone with a prohibition on measures. It is therefore the responsibility of the operator to define the post-closure monitoring measures that it considers necessary for its disposal concept and to propose restrictions on the use of the site, which may be supplemented by measures that the authorities consider necessary. According to the Nuclear Energy Act, disposal must be carried out in full in such a way that post-closure monitoring is not needed to guarantee the safety of the concept, but post-closure monitoring may be necessary from the point of view of environmental impacts, nuclear safeguards or security arrangements, for example.

The main functional requirement for closure is to isolate the disposal facility from changes above ground and human activities. The aim is to restore the conditions to correspond as closely as possible to those that, according to scientific data, prevailed in the bedrock before the construction and use of the repository and have a beneficial effect on the long-term performance and safety of the disposal system. The above-ground parts of the disposal site will be landscaped according to the surrounding nature. The monitoring measurements of the disposal facility will be continued by the operator until the facility is closed in a manner approved by STUK.

When the operator has successfully closed the disposal facility and paid the State a lump sum for the future monitoring and control of the spent fuel and radioactive waste, the operator's waste management obligation ends. The ownership and responsibility for the disposed spent fuel and radioactive waste is transferred to the State.

In addition to safety, the need for monitoring after the closure of disposal facilities is significantly affected by the nuclear safeguards of spent fuel. Detailed discussions on safeguards following the closure of ONKALO are ongoing with the Commission and the IAEA and will be taken into account in future legislative updates.

If it is necessary after closure of disposal facility, the State is obliged to take all necessary measures to monitor, control and ensure the safety of disposal. STUK's task is to arrange the permanent keeping of records of information concerning the disposal.

Information on the location of the disposal facility is provided in local detailed plans. In this respect, it must be ensured that the plan symbols are preserved in the future. In addition, land use registers may, if necessary, specify information about restrictions on the further use of the site. The plans for the permanent keeping of records of information on the period after the closure of a disposal facility are to be further specified before the closure of the first disposal facility. It is the responsibility of STUK to enter the information concerning the location of the disposal facility and any prohibitions of measures in the necessary registers.

Licensing procedures for the closure of disposal facilities must be examined in prospective amendments of Nuclear Energy Act. Under current legislation, closure of disposal facility is subject to an operating licence. STUK will approve the closure of the disposal facility on the basis of the closure plan prepared by the operator. In future, it will have to be considered whether this is an adequate procedure, or whether the permanent closure of a disposal facility would be a matter for a licence issued by the Government, as responsibility for the waste disposed of there and for any post-closure monitoring measures related to the facility will be transferred to the State. The substantive requirements for the closure plan are likely to need further clarification in the future.

Similarly, the regulatory requirements for the technical implementation of the closure phase itself need to be further developed based on experience from disposal operations.

It is not appropriate to start the abovementioned measures decades before the closure of disposal facilities has become topical, as the operating environment may change substantially over the decades. Legislation and regulatory guidance will be reviewed at regular intervals, and the necessary amendments can be made gradually. Permanent keeping of records of information concerning the disposal should be the subject of preliminary policy discussions, and the most appropriate procedures should be considered in view of the need to keep of records for up to centuries. In addition, it is good to define in good time what information needs to be kept. The national objective can be considered to be that the detailed licensing procedures for closure, technical requirements and appropriate responsibilities, including the transfer of responsibilities, be defined about a decade before the closure of the first disposal facility is scheduled to take place.

9 Significant milestones and timeframes for the management of spent fuel and radioactive waste

The use of radiation in Finland began already in the early part of the last century and increased strongly from the 1970s onwards in industry and research. Currently, Finland has a large number of well-established uses of radioactive materials and sources that cannot be replaced by other existing technologies. Thus, the use of radioactive materials and the need to take care of disused radiation sources will continue long into the future.

The use of nuclear energy in Finland began with the introduction of sub-critical pile at the end of the 1950s and more widely in the early 1960s with the introduction of FiR 1 research reactor. Finland's first four nuclear power plant units were commissioned at the turn of the 1970s and 1980s. The construction of the fifth nuclear power plant unit (OL3) began in the early 2000s, and the plant unit is expected to start the regular electricity production in 2022.

The sixth nuclear power plant unit (Fennovoima's Hanhikivi 1) was granted a decision-in-principle in 2010 [29] which was supplemented in 2014 [30]. The Finnish Government is expected to consider the construction licence for the plant in the early 2020s.

The lifespan of nuclear power plants has been increased in Finland by modernising them. Valid operating licences for nuclear power plants currently in operation extend until 2030 (LO2) for the Loviisa plant [31] and towards the end of the 2030s for OL1 and OL2 plant units in Olkiluoto [32]. The planned technical operating lifetime of new nuclear power plant units is approximately 60 years. The first operating licence of the OL3 plant unit extends to the late 2030s [33].

The overall timeframe for the management of spent fuel and radioactive waste from nuclear facilities, as currently planned, is shown in Figure 8. The overall timeframe will be specified, where appropriate, in national reports to be drawn up every three years in accordance with Article 14(1) of Directive 2011/70/EURATOM.

9.1 Milestones and timeframes for spent fuel management

The environmental impact assessment of the construction and operation of Posiva's encapsulation plant and disposal facility was for the first time assessed in 1999 [34]. The decision-in-principle concerning the construction of the spent fuel encapsulation plant and disposal facility was taken by the Government in 2000 [23]. In the process, in accordance with the timeframe set by the Government Policy Decision of 1983 and Posiva's application, the site of the facility was approved as Olkiluoto, Eurajoki. The decision-in-principle to construct an extended encapsulation plant and disposal facility was taken by the Government in 2002 [35]. The Parliament approved the decisions-in-principle in 2001 and 2002.

The decisions-in-principle concern spent fuel generated by the operation of five nuclear power plants (LO1–2 and OL1–3), the total quantity of which will not exceed approximately 6,500 tonnes of uranium. The decision-in-principle started several years of detailed studies of the bedrock in Olkiluoto. The construction of ONKALO, meaning the underground rock characterisation facility at the time, started in 2004. At the same time, the development of the disposal concept was continued to achieve readiness for a construction licence. Posiva applied for a construction licence at the end of 2012 in accordance with the timeframe set out in the Government Policy Decision of 1983 [1] and the specified decision of 2003 [5]. For the application for a construction licence, the environmental impact assessment was updated. The Government granted Posiva a construction licence for the encapsulation plant and disposal facility in 2015 [36], and Posiva started the construction in 2016.

The operation of the encapsulation plant and disposal facility is subject to an operating licence granted by the Government. Posiva submitted an application for the first operating licence to the Government in the end of 2021. Posiva applied for the operating licence for a period from March 2024 to the end of 2070. For the purpose of the operating licence application, Posiva updated the environmental impact assessment according to construction licence conditions. The processing of the operating licence application for the spent fuel encapsulation plant and disposal facility will be topical in the coming years. The operation of the plant would continue until the disposal of all spent fuel from the five abovementioned units, estimated to last until the 2120s. The encapsulation plant would then be decommissioned and dismantled and the disposal facility permanently closed. The closure of the disposal facility will be completed by the end of the 2130s at the latest, in the light of current plans.

According to Fennovoima's estimate, the disposal of spent fuel from the sixth nuclear power plant unit in Finland, which is in the contraction licensing phase, would start at the earliest in the 2090s and would last until the disposal of all spent fuel from the plant unit,

estimated to last until the 2130s. The plans of Fennovoima will be specified in the coming years, once the processing of the application for the construction licence for the nuclear power plant [20] has been completed.

9.2 Milestones and timeframes of the management of radioactive waste generated in nuclear facilities

Disposal facilities for low and intermediate-level waste were commissioned in Olkiluoto, Eurajoki, and in Hästholmen, Loviisa, in the 1990s. Low and intermediate-level waste generated during the operation and decommissioning of nuclear power plant units, interim spent fuel storage facilities and radioactive waste treatment and storage facilities will be disposed of in the disposal facilities. In addition, the components resulting from the dismantling of the reactors, with the exception of spent fuel, will be disposed of in the LILW disposal facilities. The LILW disposal facilities will be closed after all nuclear facilities in the nuclear power plant site have been dismantled and the radioactive waste resulting from the dismantling has been disposed of.

The decommissioning of the Olkiluoto power plant units is scheduled for the 2070s and 2080s. The decommissioning of the interim spent fuel storage facility will take place last in the early 2100s, as currently planned [25]. The closure of the LILW disposal facility would then occur in the 2120s. The operation of the Loviisa power plant units will end in 2027 and 2030 in accordance with the currently valid operating licence [31]. The nuclear power plant units are to be dismantled immediately after permanent shutdown [26]. The dismantling of the interim storage for spent fuel, the storage for liquid waste and the solidification plant in Loviisa would take place after this stage and would be topical in the 2060s, when all spent fuel has been transported to Olkiluoto for disposal. The LILW disposal facility would then be closed in the late 2060s.

Fennovoima plans to build a disposal facility for low and intermediate-level waste in the bedrock of its plant site. Low and intermediate-level waste generated during the decommissioning of the plant unit is also to be disposed of in the disposal facility. According to current plans, the operation of the disposal facility will start at the earliest in the late the 2030s. The operation of the disposal facility is to continue until all low and intermediate-level waste from Fennovoima's power plant has been disposed of in the 2130s.

In spring 2020, VTT and Fortum agreed to store the low and intermediate-level waste generated during the decommissioning of VTT's FiR 1 research reactor and laboratory facilities used for material research in the Loviisa power plant and disposed of them in

the LILW disposal facility in Loviisa. The solution requires new operating licence for the LILW disposal facility in Loviisa [37]. According to the current plan, the dismantling of the research reactor will take place in the early 2020s.

In Finland, progress has also been made in the design of a near-surface disposal facility for very low-level waste. At the moment, TVO is at the most advanced stage of planning., the TVO performed an environmental impact assessment of the near-surface disposal facility in 2020 and 2021 [16][17]. According to TVO's assessment, the facility will be operational in the early 2020s. Most of the very low-level waste generated in the Olkiluoto power plant area would be disposed of in the near-surface disposal facility. It is estimated that the operation of the facility would continue until the 2090s. In 2019, TVO started the collection and packing of very low-level waste for planned near-surface disposal. Fennovoima is also planning to build a near-surface disposal facility for very low-level waste.

9.3 Overall timeframe for the management of spent fuel and radioactive waste from nuclear facilities subject to uncertainties

The plans for the management of spent fuel and radioactive waste go far into the future and are, therefore, subject to uncertainty. Uncertainties are managed by the three-yearly plans required from operators (see Chapter 7), in which the operator has to report on the planned measures for the management of spent nuclear fuel and radioactive waste for a period of up to six years.

The valid operating licences of Fortum's nuclear power plant units will expire in 2027 and 2030 [31], and it is currently unknown whether Fortum will apply for new operating licences for the plant units or whether the decommissioning of the plant units will begin after the end of the valid operating licence periods. If Fortum decides to apply for new operating licences, the measures required for decommissioning, such as the expansion, operation and closure of the LILW disposal facility, will be postponed to a later date. For example, if the operation of the Loviisa nuclear power plant units is continued for 20 years after the currently valid operating licences, the expansion of the repository would not be topical until the 2040s, and the operation of the repository could continue until the closure in the 2090s.

The delay in the start of the regular electricity production of Olkiluoto 3 plant unit will have little impact on the waste management plans for the coming decades in Olkiluoto, as the necessary infrastructure for the implementation of spent fuel and radioactive waste

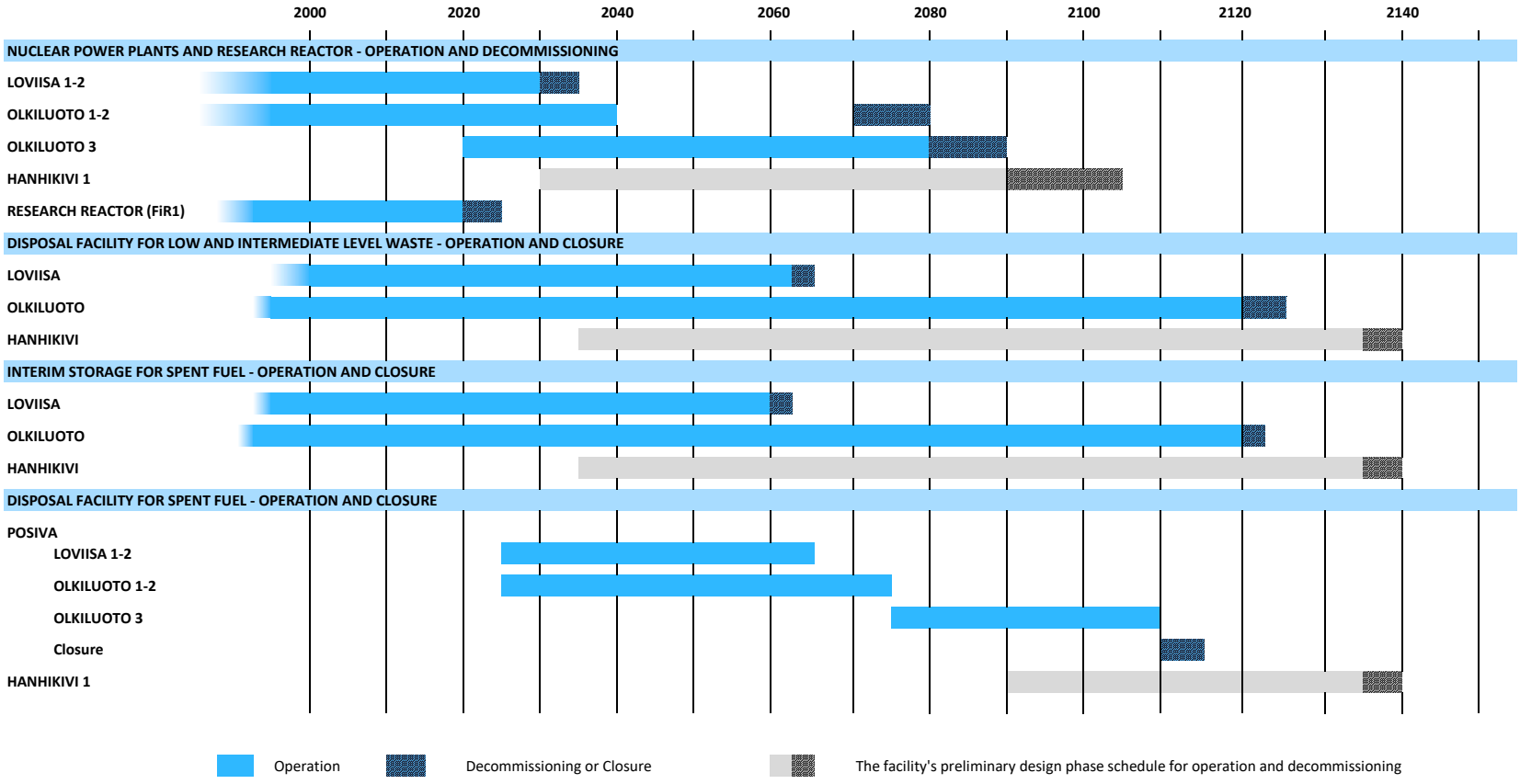
management already exists or is under construction. However, the operating lifetime of the plant unit has a direct impact on the long-term development of the management of spent fuel and radioactive waste in Olkiluoto, both in TVO's and Posiva's nuclear facilities.

Posiva submitted an application for an operating licence to the Government in the end of 2021. Delay in the start of disposal would not prevent the operation of nuclear power plants, as the spent fuel storage capacity can be further increased in both nuclear power plant sites.

The timeframe for the decommissioning of the FiR 1 research reactor was specified with the radioactive waste management agreement concluded by VTT and Fortum. VTT may begin dismantling of the research reactor in accordance with the licence issued by the Government in June 2021 [27] once STUK has approved the detailed dismantling plans and the resulting radioactive waste has a storage approved in accordance with the Nuclear Energy Act. According to the current plan, the dismantling of the facility will start in the early 2020s. The timeframe is, however, dependent on the licencing process of Loviisa nuclear power plant.

The processing of the application for the construction licence for Fennovoima's nuclear power plant [20] has progressed slowly in recent years due to missing design documentation. The delay of the nuclear power plant from the original schedule will delay the need for the implementation of measures for the management of spent fuel and radioactive waste. It is essential that Fennovoima has at its disposal the necessary treatment and storage facilities for the implementation of spent fuel and radioactive waste management at the time the plant becomes operational and adequate plans for the arrangement of disposal of spent nuclear fuel and radioactive waste.

Figure 8. Overall timeframe for the management of spent fuel and radioactive waste from nuclear facilities (Source: STUK).



9.4 Milestones and timeframes for the management of radioactive waste from radiation practices

Until 2010, STUK received disused radiation sources containing radioactive nuclides from radiation users. The received radiation sources were initially stored in the Defence Forces' area in Santahamina, Helsinki, until in 1996 the State leased the interim storage cavern attached to the LILW disposal facility in Olkiluoto. the State has agreed with TVO on the storage and disposal of the radioactive waste received in the LILW disposal facility within separately specified limits.

In 2005, the role of a 'recognised installation' in the management of radioactive waste was added to the Radiation Act valid at the time. The addition was based on the then Directive and aimed at ensuring the proper waste management of radiation sources under all circumstances. However, the aim was to find possible other solutions for arranging the reception of sources so that STUK, as the authority, would not be involved in the paid waste management offered to operators. In 2010, STUK stopped receiving radioactive waste when a private company, Suomen Nukliditekniikka, took over this activity. The Radiation Act which entered into force in 2018 no longer uses the term 'recognised installation', as the term was also disappeared from the radiation protection directives as unnecessary. Where radiation sources are decommissioned, they are to be returned to the manufacturer or handed over to an operator holding a safety licence for the receipt and treatment of radioactive waste.

According to the licence conditions updated in 2012 [38] for the LILW disposal facility in Olkiluoto , the majority of the waste in the storage cavern facility can be disposed of as low and intermediate-level waste in LILW disposal facility in Olkiluoto. The disposal of radioactive waste held by the State started in 2016.

10 Research and development necessary for the implementation of solutions for spent fuel and radioactive waste management

In Finland, the operators using nuclear energy carry out the research and development activities necessary for the implementation of the solutions for the management of spent fuel and radioactive waste, either independently or by participating in national and international joint projects. The state has responsibilities and obligations for the supreme management, regulation and control of the management of spent fuel and radioactive waste, which requires the development of expertise. In addition, the State organises various national projects related to expertise and infrastructure development. The State is also responsible for research and development activities related to the post-closure period of disposal facilities.

10.1 Research and development carried out by operators of nuclear energy

Operators using nuclear energy plan and carry out the research and development necessary for the management of spent fuel and radioactive waste, either in the form of the company's own research projects or various joint projects. The research and development activities planned by the operators are aimed at those areas of the management of spent fuel and radioactive waste which they have identified as the most important for their activities.

For decades, Posiva's research and development has focused on the development of spent fuel disposal and the disposal concept. As the project progresses, the research and development perspective is changing or has already partly changed to the product development of the disposal solution as well as the topics related to the operation of the overall facility. Research and development projects at the Loviisa and Olkiluoto nuclear power plants have included research and development projects on low and intermediate-level waste, such as projects related to the development of solidification of liquid waste

and near-surface disposal as well as repository monitoring projects. VTT has investigated topics that are important for the decommissioning of the research reactor, such as the nuclide inventory of the research reactor and the treatment of graphite waste. In recent years, Fennovoima has conducted research and development in the management of spent fuel and radioactive waste in cooperation with Posiva Solutions Oy.

Every three years, the operators report to the Ministry of Economic Affairs and Employment their plans for the implementation of the management of spent fuel and radioactive waste for the whole life cycle of the management of spent fuel and radioactive waste (see Chapter 7). The plans also include descriptions of the main research and development activities for the next six years. Operators also report to the Ministry of Economic Affairs and Employment (see Chapter 7) on the decommissioning plans of nuclear power plants every six years, focusing on research and development measures related to the decommissioning of nuclear power plants.

Operators receive an assessment of the abovementioned plans from the authorities. The authorities may use the assessments of independent experts or research institutes as a basis for their assessment. Research and development are also directly or indirectly assessed at the various licensing phases. The state of research and development can also be examined in various international evaluations. Licence conditions and various assessments may extend the research and development activities planned by operators or bring new research and development tasks.

10.2 Measures taken by the State to promote research and development

The Fund finances the Finnish Research Programme on Nuclear Waste Management (KYT). The current research programme is KYT2022 [39], which will end in 2022. The aim of the research programme is to ensure the availability of expertise independent of the operators in the management of spent fuel and radioactive waste for the needs of the authorities. The scope of the research currently covers spent fuel and radioactive waste generated by operation and decommissioning of nuclear facilities as well as all measures for the safe treatment, storage and disposal of such wastes.

The content of the KYT2022 research programme is divided into main interacting themes: safety, feasibility and acceptability of spent fuel and radioactive waste management. When evaluating safety, the acceptability must be taken into consideration as well as the boundary conditions arising from technical feasibility. The assessment of feasibility is based on safe solutions and their public acceptability. The public acceptability of disposal

depends on its safety and feasibility. The planning of the disposal of radioactive waste resulting from the use of radiation makes use of the information obtained in the study on the disposal of radioactive waste from the use of nuclear energy.

The State has also started preparing for the closure of disposal facilities and the permanent keeping of records of information concerning disposal as part of the KYT2022 research programme. The purpose of the preliminary survey on closure is to identify the main research and development needs related to closure. The purpose of the preliminary survey on permanent keeping of records is to define what data needs to be kept and what appropriate procedures might be available.

Since 2016, the KYT research programme has also provided extensive funding for the development of research infrastructure. The funding is currently mainly used for the costs of the facilities of the laboratories at the VTT Centre for Nuclear Safety in Otaniemi, Espoo, in 2016–2025, and was used for the purchase of research equipment in 2016–2020. The VTT Centre for Nuclear Safety offers research services for both private and public operators.

The Fund collects funds from nuclear energy operators for research purposes in proportion to the scope of their spent fuel and radioactive waste management measures. Operators are also involved in the management of the research programme in different steering, support and follow-up groups, and thus have the possibility to influence the content of the research programme. Authorities also need expertise on issues that are relevant to operators. In addition to high-quality research and development of expertise, the research programme offers a meaningful community of authorities, operators and researchers.

The Ministry of Economic Affairs and Employment has decided to combine the research programme on the management of spent fuel and radioactive waste arising from the use of nuclear energy with the Finnish Research Programme on Nuclear Power Plant Safety, SAFIR [40] from the beginning of 2023. At the same time, number of dedicated assets for research in the Fund decreases from two to one: the Nuclear Waste Research Fund will merge with the Nuclear Safety Research Fund, which is intended to finance the SAFIR research programme.

The merging of the research programmes is based, inter alia, on the goal of managing larger research entities. The joint SAFER programme can also take better account of research and development projects at the interface with existing research programmes, technological developments throughout the life cycle of the use of nuclear energy as well as aspects related to the management of expertise. The joint programme will also be able to take better account of the operational phase of Posiva's encapsulation plant

and disposal facility and will also bring administrative benefits. At the same time, the programme will change from four to six years. The planning group on the new research programme started work at the beginning of 2021.

In addition to the KYT research programme, STUK uses external experts as required for supervision of safety and, if necessary, commissions research or analysis directly related to regulatory oversight, which is excluded from the KYT research programme. STUK's supervision support programme has focused mainly on the disposal of spent fuel, and its purpose has been to produce assessments and analyses of issues related to the safety of disposal.

STUK's FINNORM research and development project (2019–2020) developed methods for exposure assessment and monitoring as one of the areas related to the management of waste resulting from activities involving exposure to natural radiation. The results of the project will be used in the form of guidelines for the waste concerned. The FINNORM project has also developed a database on practices involving exposure to natural radiation, including information on quantities of substances, potential releases and the resulting exposures. In the future, the database can be used for research purposes when comparing the impact of different disposal methods. In order to ensure the long-term safety of waste, more detailed research should be carried out in the future on changes in the mobility of naturally occurring radioactive materials in the presence of physical, chemical and, in particular, (micro)biological agents in waste disposed of near surface. Research in this area is already under way in cooperation with universities.

10.3 Finland's participation in international research and development

Finland also participates extensively in international research cooperation. The most important research activity for the management of spent fuel and radioactive waste is the fission programme under the EURATOM Treaty. One of the three main areas of the programme is research into the management of radioactive waste and, in particular, the disposal of spent fuel. Other areas, namely the safety of nuclear facilities and radiation protection, have also involved projects that have benefited spent fuel and radioactive waste management.

As regards global research, the research activities carried out by the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA) cover all aspects of nuclear energy use and thus also the management of spent fuel and radioactive waste. Finland also participates in separate, large international projects, such as the Jules

Horowitz research reactor project in France. Nordic Nuclear Safety Research (NKS) has also covered, for example, decommissioning research projects.

International cooperation in the whole field of nuclear energy has been developed through the Nuclear Energy Research Strategy published by the Ministry of Economic Affairs and Employment in 2014 [41]. The recommendations made at the time for strong participation in international cooperation or the development of national infrastructure solutions have also served the research into the management of spent fuel and radioactive waste.

10.4 Maintaining and developing other expertise

Since 2010, courses have been organised on the management of spent fuel and radioactive waste resulting from the use of nuclear energy. Approximately thirty people annually attended the course focusing on the spent fuel disposal concept and long-term safety. The course was combined in 2015 with the national nuclear safety course, which also included a section focused on the management of spent fuel and radioactive waste.

The combined course was named the Nuclear Safety and Nuclear Waste Management Course (YJK). Currently, the course is implemented in cooperation with operators and has been attended annually by about 100 experts in the field. The course covers the entire life cycle of the use of nuclear energy.

The Ministry of Economic Affairs and Employment also establishes various national working groups for the development of the thematic areas related to the management of spent fuel and radioactive waste generated in the use of nuclear energy. Operators in the sector have also been widely represented in the working groups. In recent years, such working groups have included the National Nuclear Waste Management Cooperation Group (YETI) in 2017–2019 [8], the VYR working group on the development of the investment activities of the Fund in 2018–2019 [9] and the REILA working group on the development of the life cycle regulation of nuclear facilities in 2019–2020 [7].

The number of persons carrying out research, development and planning work in the management of spent fuel and radioactive waste from the use of nuclear energy, their years of work experience and educational background were surveyed as part of the entire nuclear energy sector in 2010 [42] and 2017 [43].

11 Assessment of the costs of the national programme and the financing scheme in force

An operator generating spent fuel and radioactive waste in connection with its operations is fully responsible for the costs of waste management measures. It is the responsibility of the State to ensure that appropriate funding is available for waste management in case the operator is unable to bear the costs. In the case of spent fuel and radioactive waste arising from the use of nuclear energy, the funds will be collected by the Fund, which is subordinate to the Ministry of Economic Affairs and Employment. In the case of radioactive waste resulting from the use of radiation, the operator must, where appropriate, lodge a security.

11.1 Costs for the management of spent fuel and radioactive waste from the use of nuclear energy

The total costs of the spent fuel and radioactive waste management of the Loviisa and Olkiluoto nuclear power plant units (OL1–3, LO1–2) are estimated at approximately EUR 7 billion for the entire lifetime of the power plants (at the 2020 price level). Of this, the costs of spent fuel disposal are approximately EUR 5 billion. The figure includes the disposal of spent fuel, the construction, operation and closure of the overall facility, as well as Posiva's research and development expenses, property taxes and the costs of regulatory control. The costs for the management of operational waste from nuclear power plants are approximately EUR 150 million. The costs of decommissioning the plants are approximately EUR 1.1 billion. The remainder of the costs consist, inter alia, of TVO's and Fortum's research and development costs, interim storage costs, regulatory control costs and taxes.

The total decommissioning cost estimates cover the costs of dismantling the radioactive parts of the facilities and the disposal of the dismantling waste in the on-site disposal facilities. The most significant investment required for decommissioning is the extension of the disposal facilities for dismantling waste. The costs of dismantling the parts of

the power plant released from regulatory control are not included in the provision in accordance with the Nuclear Energy Act.

The total costs of the management of the spent fuel and radioactive waste of the nuclear power plant in Pyhäjoki, excluding the disposal of the spent fuel and the decommissioning of the plant, will be approximately EUR 600 million. As the plans for the disposal of spent fuel are still incomplete, it is not appropriate to publish an overall cost estimate for them at this stage. The total cost of decommissioning the nuclear power plant and the interim spent fuel storage facility is estimated at approximately EUR 250 million.

The total cost of decommissioning VTT's research reactor was estimated at approximately EUR 30 million in autumn 2020. The cost estimate made a provision for the storage and disposal of spent fuel in Finland. However, as the return of spent fuel to the United States was achieved at the turn of the year 2020–2021, the cost estimate will be reduced by several million euros. The cost of decommissioning the laboratory facilities used for material research in connection with the research reactor is approximately EUR 10 million.

Detailed information on the costs of the management of spent fuel and radioactive waste is subject to commercial confidentiality and cannot be published.

11.2 State´s financial provision for the costs for the management of spent fuel and radioactive waste from the use of nuclear energy

It is the responsibility of the State to ensure that appropriate funding is available for the management of spent fuel and radioactive waste from the use of nuclear energy. The State ensures this by raising funds for the Fund. The Fund is subordinate to the Ministry of Economic Affairs and Employment, but it is not included in the state budget. The Fund helps to ensure that sufficient funds are available for the management of spent fuel and radioactive waste generated in nuclear facilities if the operator is unable, for any reason, to fulfil the obligations imposed on it for the arrangement of waste management.

The Fund was established by the Nuclear Energy Act (990/1987), which entered into force in 1988, and the Decree of the President of the Republic on the National Nuclear Waste Management Fund (162/1988), which was subsequently replaced by the Government Decree on the National Nuclear Waste Management Fund (161/2004). The activities of the Fund will be reformed in the coming years in accordance with the transitional provisions of the Act (269/2021), which was adopted in 2021. The Act has a significant impact on, for

example, the management of the Fund, the number of dedicated assets in the Fund and the Fund's investment and research activities.

The Fund currently consists of three dedicated assets: the Financial Provision Fund, the Nuclear Safety Research Fund and the Nuclear Waste Research Fund. Funds collected in the dedicated assets may be used only for the purposes indicated in the relevant provisions of the Nuclear Energy Act and may not be transferred between the dedicated assets. The Fund is managed by a board of directors and a director appointed by the Government. Decisions regarding the Fund are taken by the board of the Fund.

Among the dedicated assets, the Financial Provision Fund is important for the provision of the management of spent fuel and radioactive waste. The Board collects funds from nuclear energy operators for the Financial Provision Fund on an annual basis. Currently, the operators from which the funds are collected are TVO, Fortum and VTT. These operators have spent fuel and/or radioactive waste which has not yet been disposed of. Fundraising from Posiva and Fennovoima will start when their operations have resulted in spent fuel or radioactive waste.

Fundraising will be carried out in accordance with the procedure defined in the Nuclear Energy Act and Decree. Every three years, the operators submit their estimates of the costs of the management of spent fuel and radioactive waste for evaluation by the Ministry of Economic Affairs and Employment. In addition, operators may refine their cost estimates on an annual basis.

The estimate is made on the assumption that the operator's operation generating spent fuel and radioactive waste ends at the end of each current year and that the existing spent fuel and radioactive waste is managed in accordance with the approved management plans (Chapter 7). The estimate is therefore not an annual update of the total cost of spent fuel and radioactive waste management, but an estimate of the residual cost if the operation generating spent fuel and radioactive waste was discontinued.

The costs presented in the estimate are estimated at the current price and cost level. The estimate uses price and cost information that can be considered reliable. The uncertainty of the available price and cost information must also be taken into account as a cost-increasing factor.

The cost estimates submitted are assessed by independent bodies specialised in the evaluation of technical economic calculations. The Ministry of Economic Affairs and Employment then confirms each year the estimated costs of each of the aforementioned operators for the current year and provisionally decides the estimated costs for the next two years. In addition, the Ministry of Economic Affairs and Employment establishes for

each operator the amount of assets which, based on the estimated costs, the operator must have in the Financial Provision Fund during the following year.

On the basis of the decision of the Ministry of Economic Affairs and Employment and the assets already held by the operator in the Fund, the board of the Fund collects a contribution that the operator must also pay to the Fund on an annual basis. If the operator has an excessively large amount of assets in the Financial Provision Fund, the operator will receive a refund.

Funds are returned to the operators as spent fuel and radioactive waste management is implemented, thus reducing the overall costs of the management measures still to be implemented. However, the returns are made in such a way that the operator must first carry out the measure in question with their own funding, after which the assets allocated to the Financial Provision Fund for the measure are returned to the operator.

At the end of 2020, the Fund's Financial Provision Fund held EUR 2.6 billion. The majority of the funds of the Fund are due to the provision for the disposal of spent fuel and the decommissioning of nuclear facilities. After the decommissioning of nuclear facilities, the disposal of spent fuel and radioactive waste, the closure of the disposal facilities in an approved manner and the expiry of the operator's obligation to manage spent fuel and radioactive waste, operators will still be charged a fee to cover the post-closure monitoring and control of spent fuel and radioactive waste disposal facilities transferred to the State. However, the fee or the principles for determining it have not yet been defined.

In addition to the collection, the Fund is responsible for preserving and safely investing the funds collected from the operators in the Financial Provision Fund that might be required in the future for the management of spent fuel and radioactive waste. The Fund ensures that the funds will definitely exist and be available, if needed, when measures for the management of spent fuel and radioactive waste have to be taken. The funds will be used for the management of spent fuel and radioactive waste only if the operator fails to fulfil its statutory waste management obligation. It is possible to develop the investment activities of the assets in the Financial Provision Fund in the future. The final report of the VYR working group on the development of the investment activities of the Fund was completed in 2019 [9].

The Nuclear Waste Research Fund and the Nuclear Safety Research Fund provide funding for research on the management of spent fuel and radioactive waste generated in connection with the use of nuclear energy as well as for nuclear safety research, respectively, in the manner set out in Chapter 10.

11.3 Costs of the management of radioactive waste not generated at nuclear facilities

The operator bears the costs of the management of radioactive waste resulting from the use of the radiation and other radiation practices. The costs of returning the radiation sources to the manufacturer are borne by the operator, unless otherwise agreed at the time of purchase. The cost of the treatment, packing for disposal and disposal of radioactive waste is borne by each operator when they hand over the waste to another operator that handles the delivery of the waste for disposal. An operator that delivers radioactive waste for disposal to the interim storage cavern attached to the LILW disposal facility in Olkiluoto pays STUK for the disposal. The disposal fee for radioactive waste is based on the volume to be disposed of.

In the use of radiation, the operator must, according to the Radiation Act, provide a financial security for the rendering radioactive waste harmless or any environmental clean-up measures, if the practices is considered to result in significant waste management costs. This security is required if the operator has a high-activity sealed source (HASS) or if the combined nuclide-specific activity of the radioactive material or radiation sources held by the operator at any time is higher than the activity of an equivalent HASS. A security is also required for practices where radiation appliance containing sealed sources is maintained or rendered harmless if the sealed sources are removed from their fixed container and the combined nuclide-specific activity on an annual basis is higher than that of an equivalent HASS.

A security in accordance with the Radiation Act is also required for practices that generate or may generate radioactive waste or waste whose treatment must take radioactivity into account, if the costs of rendering the waste harmless are significant. Short-lived radioactive materials with a half-life of less than 150 days do not require the lodging of a security.

The basic amount of the security to be lodged on the basis of the value of the HASS, the activity held or the combined nuclide-specific activity of the radiation sources to be removed each year from their containers is EUR 10,000. In addition to the basic amount, there is an amount of EUR 75 per payment unit. The number of payment units is calculated by dividing the value of the activity of the HASS concerned, the value of the activity of the radioactive material held at one time or the value of the the combined nuclide-specific activity of the sealed sources to be removed each year by the value of the activity of the HASS.

In the case of practices that generate or may generate radioactive waste, a security must be lodged if the costs of rendering the radioactive waste harmless, of managing the

waste generated or of carrying out the necessary environmental clean-up measures are estimated to exceed EUR 100,000. The security lodged by the operator is a guarantee, insurance or pledged deposit. No security is required from a municipality, joint municipal authority or the State.

In the case of radioactive waste, the State has a subsidiary waste management obligation if the operator cannot fulfil its obligations or if there is no operator whose business is to render radioactive waste harmless. In this case, the State is responsible for rendering the waste harmless, and STUK is responsible for the tasks assigned to the State. The costs of rendering waste harmless will be reimbursed by the operator to the State. In STUK, different departments are are responsible for receiving and rendering radioactive waste harmless and for regulatory oversight of the management of radioactive waste.

12 Transparency and public acceptance in the management of spent fuel and radioactive waste

The prerequisite for the implementation of spent fuel and radioactive waste management is public acceptance of the activities. Public acceptance is a complex concept, and it is also one of the main themes of the research of the Finnish Research Programme on Nuclear Waste Management KYT2022, together with the safety and feasibility of the management of spent fuel and radioactive waste.

Public acceptance of the management of spent fuel and radioactive waste is based on confidence. Confidence in the operator requires that the implementation of spent fuel and radioactive waste management is based on existing scientific knowledge, technical progress and a high level of expertise. Confidence is also based on the fact that the authorities control the activities of the operator in accordance with the legal requirements and independently assesses the safety of the management of spent fuel and radioactive waste.

12.1 Transparency of the activities of the operator of the use of nuclear energy

Operators provide up-to-date and factual information on their activities and projects. Communication is often done at several levels: local, national and international. Communication is typically proactive and multiformat, taking into account the different information needs of different stakeholders.

From the point of view of communication and public relations, the most important stakeholders are employees, shareholders, the plant supplier and the residents of the municipality having nuclear power plant and its surrounding areas, in particular local decision-makers and authorities. Depending on the subject to be communicated, other stakeholders or audiences may also be important or even the primary target group for communication. Communication is also influenced by the stage of the operator's project or activity. For example, at the beginning of the project, communication and dialogue will

be more active, whereas for facilities in the operational phase, communication will focus more on the actual operational events of the facility.

Operators make extensive use of a variety of communication channels. Operators publish a range of periodic reports on the results of the work and may include information on plans for the near future. Up-to-date information is published in news, press releases and various media events. In addition, basic information on operators, as well as up-to-date information on their activities, is typically available on the operators' websites. Operators also actively use other electronic channels for communication purposes.

At the moment, a stakeholder magazine is published in all municipalities having nuclear power plant for residents in the vicinity of the nuclear power plant. Various stakeholder events and meetings organised by operators from time to time are also very important. Operators also arrange visitor activities to their sites whenever possible, and Olkiluoto, for example, has a visitor centre, which presents Olkiluoto's nuclear power plants and Posiva's encapsulation plant and disposal facility to approximately 13,000 visitors annually. A nuclear-themed visitor centre will also be built in Pyhäjoki.

Operators typically maintain close contact with decision-makers in their municipality and in the nearest neighbouring municipalities, and contacts are organised with various cooperation and discussion groups.

12.2 Transparency of the authority's activities

The activities of authorities are guided, for example, by the Administrative Procedure Act (434/2003) and the Act on the Openness of Government Activities (621/1999). The purpose of the Administrative Procedure Act is to implement and promote good administration and legal protection in administrative matters. The information rights and duties of authorities provided for in the Act on the Openness of Government Activities are intended to ensure transparency in the activities of authorities and to enable individuals and entities to monitor the use of public authority and public funds, freely form their opinions, influence the use of public authority and to supervise their rights and interests.

According to the principle of openness, official documents are in the public domain unless specifically provided otherwise in the Act on the Openness of Government Activities or another Act. Everyone has the right of access to official documents in the public domain. The authorities must also promote the openness of their activities. In this context, an official document is defined as a document in the possession of an authority and prepared by an authority or a person in the service of an authority, or a document delivered to an authority for the consideration of a matter or otherwise in connection with a matter

within the competence or duties of the authority. In addition, a document is deemed to be prepared by an authority if it has been commissioned by the authority, and a document is deemed to have been delivered to an authority if it has been given to a person commissioned by the authority or otherwise acting on its behalf for the performance of the commission.

However, an official document must be kept secret if it has been so provided in the Act on the Openness of Government Activities or another Act, if it has been declared secret by an authority on the basis of an Act, or if it contains information covered by the duty of non-disclosure, as provided in an Act. Secret official documents are provided for in section 24 of the Act on the Openness of Government Activities. Such documents may include, for example, documents concerning the security arrangements of spent fuel and radioactive waste management and documents affecting their implementation. In addition, documents containing information on a trade secret or other comparable business information of a private business are secret if disclosure of the information would cause economic loss to the private business.

An official document will not be kept secret after the expiry of the period provided in an Act or ordered on the basis of an Act or after the order for secrecy has been revoked by the authority which ordered the document to be kept secret. The period of secrecy of official documents is 25 years, unless otherwise provided or ordered on the basis of an Act.

12.2.1 Consultation on licensing procedures

The Nuclear Energy Act also provides for the openness of government activities. For example, before taking a decision-in-principle, the Ministry of Economic Affairs and Employment must reserve the opportunity for the residents and municipalities of the vicinity of the nuclear facility, the authorities and the public to present an opinion or views on the project in writing. The Ministry will also arrange a public event in the municipality of the intended site of the facility for oral or written statement of views on the issue. The opinions and views presented will be taken into account in the preparation of the decision-in-principle, and they will also be communicated to the Government before the decision-in-principle is taken.

The Ministry of Economic Affairs and Employment also communicates the licence applications for a nuclear facility by means of a public notice. Provisions on a public notice are laid down in the Administrative Procedure Act. In practice, a public notice means the publication of the licence application and a related announcement on the website of the Ministry of Economic Affairs and Employment at www.tem.fi/. If necessary, the notice can

also be published in the newspaper of the affected area or in another way decided by the authority.

In addition, the Ministry of Economic Affairs and Employment must reserve the opportunity for the public to state their views in writing on the issue of the licence before granting the licence for the construction and operation of a nuclear facility and the licence for the decommissioning of a nuclear facility. In addition, the licence applicant must be given the opportunity to give an explanation of the views stated on the application and of the opinions requested in accordance with the Act. The opinions and views presented will be taken into account in the preparation of the licence decision.

The Ministry of Economic Affairs and Employment also acts as the coordinating authority referred to in the Act on the Environmental Impact Assessment Procedure for projects concerning the nuclear facilities referred to in the Nuclear Energy Act. The coordinating authority must ensure that the necessary opinions are requested on the environmental impact assessment programme and report of the project and that an opportunity to state views is reserved. The coordinating authority must also give the municipalities in the area affected by the project the opportunity to give their opinion on the evaluation programme and report.

The coordinating authority must communicate the environmental impact assessment programme and report by means of a public notice without delay. The coordinating authority and the project promoter may also agree to organise other forms of participation, such as a public event. The environmental impact assessment procedure concludes with a reasoned conclusion by the coordinating authority on the significant environmental effects of the project. The opinions and views presented will be taken into account in the preparation of the opinion and the reasoned conclusion of the coordinating authority. The coordinating authority must communicate the reasoned conclusion by means of a public notice without delay.

12.2.2 Consultation on the national programme

This national programme for the management of spent fuel and radioactive waste is an authority's programme whose environmental impact assessment is carried out in accordance with the Act on the Assessment of the Effects of Certain Plans and Programmes on the Environment (SEA Act). The communication and consultation provisions of the Nuclear Energy Act of the national programme are broadly in line with the requirements of the SEA Act and are fulfilled when the national programme is consulted about and communicated in accordance with the SEA Act.

The preparation of the national programme and its environmental impact assessment was organised in such a way as to provide the public with information on the starting points, objectives and preparation of the programme and its environmental report as well as to state their views on the programme. The plan for the national programme and its environmental impact assessment, as well as the public notice concerning the plan, were published on the websites of the Ministry of Economic Affairs and Employment, the Ministry of Social Affairs and Health and STUK.

Opinions were also sought from other authorities on the planned scope and level of detail of the information to be provided on the national programme and its environmental impact assessment. The opinions and views were taken into account in the preparation of the national programme and its environmental impact assessment report.

The Ministry of Economic Affairs and Employment, the Ministry of Social Affairs and Health and STUK also reserved the opportunity for the public to familiarise themselves with drafts of the national programme and its environmental impact assessment report and to state their views on them. The drafts were communicated by means of a public notice. Opinions were also sought from other authorities on the drafts of the national programme and its environmental impact assessment report. The opinions and views were taken into account when finalising the national programme and its environmental impact assessment report.

Finally, a reasoned opinion was written on how the opinions and views on the national programme and its environmental impact assessment report have been taken into account (Appendix 1). In Appendix 1, it was also written how the views, opinions, the environmental impact assessment report and environmental considerations have influenced the content of the national programme and the choice of alternatives.

The national programme and the decision approving it will be communicated by means of a public notice. The approval decision, the national programme and the environmental impact assessment report will be submitted to the authorities for information.

12.3 Public acceptance

Since 1983, Finnish Energy has regularly surveyed the views and attitudes of Finns regarding energy issues. The most recent survey was carried out in 2020 [44]. According to the survey, 42% of Finns thought that the use of nuclear power in energy production should be increased, while 24% of Finns were in favour of reducing nuclear power. Over the past three years, the number of people in favour of more nuclear power has remained fairly constant.

According to the results of the 2020 survey, a good one-third (36%) of Finns have confidence in the safe disposal of spent fuel and radioactive waste from the use of nuclear energy in the bedrock of Finland. The share of Finns who disagree with this claim is almost the same (38%). Around a quarter (26%) did not know what to say about the safety of disposal. The figures have remained almost unchanged for the last three years, but over the longer term, confidence in the safety of disposal has increased.

Women have a more negative attitude towards both nuclear power and the disposal of spent fuel and radioactive waste from the use of nuclear energy than men. However, on the basis of the results of the surveys, it can be stated that public acceptance of the use of nuclear energy is reasonably good.

The public acceptance of the spent fuel disposal project has been studied several times over the course of the project. In the disposal facility's decision-in-principle phase at the end of the 2000s, around 60% of the population in Loviisa and Eurajoki supported the construction of the disposal facility [34]. Some 30% were opposed to it. The situation was almost exactly the opposite in the alternative locations inland, with around 60% opposed and 30% in favour. In recent years, such acceptance-related surveys have no longer been conducted by Posiva in Eurajoki or its neighbouring municipalities. However, Posiva continues to study the visibility of its project and conduct surveys that have been more specifically targeted at the key stakeholders of the project.

13 Environmental impact assessment of the national programme

13.1 Summary of the results of the environmental impact assessment

In connection with the preparation of the national programme for the management of spent fuel and radioactive waste, an environmental impact assessment of the programme was carried out in accordance with the Act on the Assessment of the Effects of Certain Plans and Programmes on the Environment (200/2005).

The environmental impact assessment focused in particular on the environmental impact of the objectives and development targets of the national programme. The focus of the impact assessment was on the impact of achieving or not achieving the objectives, particularly at the societal level. For some impacts, the scope of the assessment extends to impacts on the environment of operators.

The reform of the Nuclear Energy Act proposed in the national programme has no direct impact on the living environment, natural environment, community structure or natural resources. The impact of the reform is mainly administrative. However, the predictability brought to operators by the legislative reform will create an opportunity to develop operations in a proactive manner to be more efficient and safer, which is likely to have a positive impact on the environmental impact of the operations in the long term.

Similarly, the clarification of the requirements and responsibilities for the closure of disposal facilities proposed in the national programme will allow the operator to better prepare for the future and thus design the necessary measures to prevent or reduce impacts on the natural and living environment. Similarly, the proposed development of the accounting procedure for waste management has no direct impact on the living environment, natural environment, community structure or natural resources, but has an administrative impact.

The impact assessment considered the utilisation of existing or planned nuclear facilities to be a socially sustainable, safe and cost-effective solution for the treatment and disposal of radioactive waste generated elsewhere in Finland. The amount of radioactive waste received by nuclear facilities from other sources is small in relation to the amount of

waste generated by the nuclear facility itself. Therefore, the reception of waste does not significantly increase the impact on the natural or living environment of the sites.

A more detailed environmental impact assessment of the proposed treatment of waste released from regulatory control in waste incineration plants is required. In particular, consideration must be given to the behaviour of waste released from regulatory control in the incineration process and to the technical and radiation protection solutions to be taken into account. The treatment of waste released from regulatory control in incineration plants would support the principle of the Waste Act that the recovery of waste as energy is preferable to its disposal in landfills. This would also reduce the amount of waste going to landfills and thus reduce the environmental impact of landfills on, for example, the natural environment and groundwater. In the course of the assessment, it was therefore recommended that a report be drawn up on the suitability of the waste to be released from regulatory control for treatment at an incineration plant, its possible environmental impact and the means of mitigating any harm. It was also suggested that the licensing procedure for incineration plants should be examined in more detail with regard to the treatment of waste released from regulatory control.

The maintenance of national expertise and training were not found to have a direct impact on the living environment, natural environment, community structure or natural resources. However, training can be used to improve the skills of operators and authorities. Increasing expertise may lead to technological developments, which may further create the conditions to prevent or reduce environmental impacts.

The identified environmental impact of the national programme will be further examined in the context of the implementation of the objectives of the national programme and in any separate environmental impact assessment procedures of the operators.

13.2 Monitoring of environmental impacts

The possible environmental impacts of the achievement or non-achievement of the objectives of the national programme for the management of spent fuel and radioactive waste are monitored, for example, by national self-assessment and international peer review.

A national self-assessment must be carried out and an international peer review must be requested every ten years. According to the Nuclear Energy Act, the national programme must be updated based on the results of the self-assessments and peer reviews. The first international peer review and the related national self-assessment are planned for late 2022. The peer review will take the form of an ARTEMIS review of the IAEA. The results of

the peer reviews will be communicated to the Commission and the other Member States and made available to the public, in so far as they do not involve classified information.

The next review of the policy, the national framework and the national programme will be based on the results of the abovementioned ARTEMIS evaluation. On the basis of the review, it can be identified whether the national programme for the management of spent fuel and radioactive waste is in need of immediate updates. If the needs for immediate updates are not identified on the basis of the results of the peer review, the programme will next be updated before the next peer review, which will take place in the 2030s. The update will be made earlier if there are significant changes in the operating environment that need to be taken into account in the national policy, national framework and national programme for the management of radioactive waste and spent fuel.

The identified environmental impact of the national programme will be further examined in the context of the implementation of the objectives of the national programme and in any separate environmental impact assessment procedures of the operators. The environmental impact assessment reports for operators' sites for environmental impact assessment procedures set out a range of impact monitoring measures to be implemented by operators in accordance with their plans and licence conditions.

14 Agreements with a Member State or a third country on the management of spent fuel or radioactive waste or on the use of a disposal facility

The legislation is based on the premise that spent fuel and radioactive waste generated in connection with or as a result of use of nuclear energy in Finland will be treated, stored and permanently disposed of in Finland.

A small quantity of spent fuel and radioactive waste, which is or has been supplied abroad for research purposes, may be disposed of in the Member State of the European Union or in a third State that is the country of destination, if Finland has an agreement with the country of destination within the meaning of Directive 2011/70/EURATOM in force at the time of transfer.

An agreement with a third country must be notified to the European Commission and, prior to the transfer, sufficient assurance must be given as to the safety of the spent fuel and radioactive waste management procedures of the country of destination. The measures to be taken to ensure the safety of the management procedures for spent fuel and radioactive waste in the third country of destination have been specified at regulation level.

At the moment, Finland has no contractual arrangements for the management of spent fuel or radioactive waste with a Member State or a third country.

15 Maintenance and development of the national programme and responsibilities and performance indicators for its implementation

15.1 Responsibilities and performance indicators for the implementation of the national programme

In Finland, the responsibility for the management of spent fuel and radioactive waste lies with those who generate spent fuel or radioactive waste in connection with or as a result of their activities. Operators under the Nuclear Energy Act submit plans for the management of spent fuel and radioactive waste to the Ministry of Economic Affairs and Employment for regular assessment and approval every three years as described in Chapter 7. In addition, the use of radiation by industry, research institutes and health care results in radioactive waste, the management of which has to be carried out by these operators. The radioactive waste management plans of these operators are dealt with in connection with the processing of the safety licence or by a separately requested change in the amount or quality of the waste, if the amount or quality of the waste changes from that approved in the safety licence. The implementation of waste management is monitored by STUK's control measures.

The costs of the management of spent fuel and radioactive waste are borne by the operators whose activities generated the spent fuel or radioactive waste. Operators make their own cost estimates for the implementation of the management of spent fuel and radioactive waste. In addition, operators under the Nuclear Energy Act are obliged to submit estimates of the costs for spent fuel and radioactive waste management to the Ministry of Economic Affairs and Employment for assessment and approval for financial provisions every three years as described in Chapter 11. Based on the abovementioned plans and their assessment, the following key figures can be considered performance indicators.

1. Implementation of technical solutions and timeframes for the management of spent fuel and radioactive waste, and adequacy and timeliness of planned measures

The plans for the management of spent fuel and radioactive waste for nuclear facilities set out detailed plans for the research, development and implementation of waste management over the next three years. In addition, they present general plans for the following three years. Overall, the plan covers waste management plans for the next six years. The plans present the technical solutions for waste management that are in the planning stage and in the implementation stage as well as the timetables for the implementation of the solutions. In addition, they describe ongoing and planned research projects. The operator is responsible for the implementation of the measures, the timetable for implementation and any changes.

The progress of the measures of the plans is monitored on the basis of regulatory oversight. At the same time, the adequacy of the measures in relation to the amount of spent fuel and radioactive waste generated and the consideration of the interdependencies between the different measures are assessed. With its decisions, the authority can address deficiencies in the plans or implementation and steer the activities through the decisions it makes. The authority may also require issues to be resolved within a specified timeframe, if it deems it necessary.

When applying for a safety licence for the use of radiation, the operator must present the procedures for the disposal of the radioactive waste generated in the operation and the remaining waste at the end of the operation. If the amount or quality of the waste changes during the operation, an application for changes to the safety licence must be submitted in advance in this regard.

2. Functioning of the financial provisions for the management of spent fuel and radioactive waste

An independent evaluation of the cost estimates for spent fuel and radioactive waste management are carried out every three years, on the basis of which the accuracy of the cost estimates for waste management and the adequacy of the provisions is assessed. The amount of assets in the Fund must be sufficient to cover the costs of the future management of spent fuel and radioactive waste. The authority may require the cost estimates to be specified if it sees a need to do so. The lodging of the financial security required under the Radiation Act is monitored as part of the oversight of the operations of operators by STUK.

3. Implementation of the principle of continuous improvement in the management of spent fuel and radioactive waste

The management of spent fuel and radioactive waste should be based on the principle of continuous improvement. Plans and regulatory oversight are used as a basis to assess compliance with the principle of continuous improvement. The introduction of more effective procedures and methods improves the efficiency and decreases cost of the management of spent fuel and radioactive waste. As part of the assessment, attention is paid to how operators react to identified areas for development in their waste management and how effectively corrective measures are taken. If the operator is not sufficiently active in addressing the identified areas for development, the authorities may require the development measures to be initiated on the basis of the decisions they have taken.

4. Amount of radioactive waste generated, and amount of radioactive waste disposed of and waste released from regulatory control with respect to the amount of radioactive waste generated

The main objective of the management of radioactive waste, in addition to protection from the dangers of ionising radiation, is to reduce the amount of radioactive waste generated by the activity. In addition, the measures of the management of radioactive waste should aim at reducing the amount of radioactive waste that needs to be disposed of with respect to the amount of waste that is generated. Reducing the amount of waste is not possible for all types of waste. For example, the amount of ion exchange resins used in the purification of radioactive water is hardly affected by the plant's operating procedures. Instead, the amount of maintenance waste generated as a result of operation can be influenced by measures taken at the facility.

The sorting of radioactive waste based on radioactivity and other properties at the source, as well as efficient waste treatment and packing methods, can significantly reduce the amount of waste to be disposed of. In addition, the release of radioactive waste from regulatory control enables it to be recycled in the same way as non-hazardous waste. The increase in the amount of waste released from regulatory control with respect to the amount of waste generated is indicative of effective waste sorting and measurement procedures.

Operators under the Nuclear Energy Act submit information on waste quantities to STUK every year by 1 March. There is no corresponding obligation in the Radiation Act. Waste quantities and estimates of waste quantities to be generated in the coming years are reported every three years in both the assessment reports of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Finnish Treaty Series 36/2001) and Directive 2011/70/EURATOM.

The achievement of the performance indicators for spent fuel and radioactive waste is reported every three years in the context of the preparation of the evaluation report under Directive 2011/70/EURATOM.

5. Expertise development and maintenance

One of the key objectives of the planned SAFER research programme is to develop and maintain expertise in the management of spent fuel and radioactive waste for the needs of the authorities. Following the launch of the new programme in 2023, the amount and distribution of research funding in the different areas of spent fuel and radioactive waste management will be monitored. Steering activities contribute to the development of research projects in key areas related to the information needs of the authorities. In addition, the Ministry of Economic Affairs and Employment is able to monitor the development and maintenance of expertise based on the development of other public research funding. Traditional indicators include the number of people working in the sector or the number of qualifications over a given period. The Ministry of Economic Affairs and Employment is still developing the monitoring of these indicators in the management of spent fuel and radioactive waste generated from the use of nuclear energy, but they have been monitored for a longer period in the whole nuclear energy sector.

15.2 Maintenance and development of the national programme

The national programme for the management of spent fuel and radioactive waste in Finland is prepared and, if necessary, updated by the Ministry of Economic Affairs and Employment and the Ministry of Social Affairs and Health in cooperation with STUK. The national programme has been drawn up in accordance with national legislation and in accordance with the obligations laid down in international agreements and directives. The plans drawn up by the operators for the management of spent fuel and radioactive waste provide important input for the national programme. The Ministry of Economic Affairs and Employment is responsible for organising the self-assessment of the national framework and the national programme on spent fuel and radioactive waste and for requesting the international peer review of the national framework, the competent regulatory authority and the national programme.

The Ministry of Economic Affairs and Employment, together with the Ministry of Social Affairs and Health, decides on the updating of the national programme for the management of spent fuel and radioactive waste on the basis of changes in national

legislation, international agreements, directives or the national and international operating environment or other development needs that have emerged in the operations.

The national programme for spent fuel and radioactive waste will be amended and developed over time. These changes may be due to a number of reasons. Progress in the management of spent fuel and radioactive waste, changes in the commissioning plans of nuclear facilities or the entry of new operators into the sector may affect the amount of spent fuel and radioactive waste being managed and, therefore, the scope of the national programme. Significant changes in the activities of operators or in the extent of cooperation, expertise or public acceptance may also necessitate changes to the national programme. Changes may also be attributed to shortcomings in the programme.

The national programme is also developed in the light of technical and scientific progress, operating experience gained, the results of the self-assessments and the recommendations, proposals and good practices of the peer reviews. In addition, the national programme is developed in accordance with the obligations laid down in international agreements and directives, should they change. Changes in other countries may also have an impact on Finland's national programme for the management of spent fuel and radioactive waste.

A national self-assessment must be carried out and an international peer review must be requested every ten years. According to the Nuclear Energy Act, the national programme must be updated based on the results of the self-assessments and peer reviews. To date, no international peer review has been carried out for the management of spent fuel and radioactive waste. The first international peer review and the related national self-assessment are planned for late 2022. The peer review will take the form of an ARTEMIS review of the IAEA. The results of the peer reviews will be communicated to the Commission and the other Member States and made available to the public, in so far as they do not involve classified information.

The next review of the national programme will be based on the results of the abovementioned ARTEMIS evaluation. On the basis of the review, it can be identified whether the national programme for the management of spent fuel and radioactive waste is in need of immediate updates. If the needs for immediate updates are not identified on the basis of the results of the peer review, the programme will next be updated before the next peer review, which will take place in the 2030s. The update will be made earlier if there are significant changes in the operating environment that need to be taken into account in the national programme for the management of radioactive waste and spent fuel. Such a change could, for example, be the introduction of small modular reactors (SMR) in Finland.

15.3 Objectives and methods for maintaining and developing the national programme

The national programme is based on existing legislation which sets the framework conditions for the planning and implementation of waste management. In the event of changes in the operating environment, the national programme and the legislation governing it will need to be changed. The comprehensive reform of the Nuclear Energy Act has been found necessary in order to better meet the requirements of the current operating environment [7].

The Ministry of Economic Affairs and Employment has launched background studies aimed at reforming the Nuclear Energy Act. The work will be carried out under the leadership of the Ministry of Economic Affairs and Employment over the next five years. A similar comprehensive reform of the Radiation Act was carried out in connection with the implementation of the Basic Safety Standards Directive in 2018.

The main objective of the national programme is to ensure a safe and cost-effective disposal solution for all spent fuel and radioactive waste generated in Finland that cannot be otherwise taken care **of.** In the future, the management of spent fuel and radioactive waste and the related licences should allow for better cooperation between the operators in the sector on market terms. In addition, the achievement of the objective requires the development of disposal methods for radioactive waste which, owing to its activity, the presence of radionuclides or other characteristics, such as chemical properties, cannot currently be treated or disposed of in existing facilities. The disposal of new types of waste in existing or planned disposal facilities for low and intermediate-level waste requires the updating of safety assessments for new wastes to be disposed of and may require the identification of new packing methods and types.

The State at the interim storage cavern attached to the LILW disposal facility in Olkiluoto, as well as licence holders throughout the country have in their possession HASS for which no disposal site can yet be identified. It is appropriate that the treatment, storage and disposal of radioactive waste should mainly take place at existing nuclear facilities or those under construction. The Ministry responsible for the management of waste taken over by the State will ensure that the development of a solution enabling the disposal of HASS is initiated in cooperation with the operators in the sector.

It is important to promote the development of a solution for the disposal of HASS, as the Radiation Act requires operators to decommission 40-year-old sources by the end of 2023. The aim of the development work is that the technical conditions for the disposal of these sources are clarified and the effects on the long-term safety of existing and planned disposal facilities are assessed by the end of 2030. Clarification of the issue will be raised

as one of the research themes of the new research programme, in which it is hoped that it will contribute to and accelerate the development of a national disposal solution for these sealed sources.

In addition, the management of radioactive waste must take reasonable care to prepare for new situations that may occur despite long-term planning and the radioactive waste that they generate. In the event of unexpected situations, free storage space must be maintained in the interim storage cavern attached to the LILW disposal facility in Olkiluoto , and it must be determined in advance how and with what funding the necessary surveys for the disposal of waste are carried out. The generation of this type of waste is not regular and the quantities of waste generated are not expected to be large. In the context of the environmental impact assessment of the objectives and development targets of the national programme, it was also recommended that general guidance and guidelines be drawn up in the framework of the national programme in the event of unforeseen events.

The objective for the next decade is to start the disposal of spent fuel in Olkiluoto, Eurajoki. The start of operations will require an operating licence, which Posiva applied for in the end of 2021.

The authorities will monitor the progress of future nuclear power plant projects, and their future decisions will require the promotion of spent fuel disposal planning so that a disposal solution or a credible plan for the implementation of a disposal solution is in place. Disposal can take place in cooperation with other organisations familiar with disposal or in an on-site disposal facility. The processing of the licence for the construction of the sixth nuclear power plant planned for Finland is proceeding. So far, decisions have not been taken on the disposal of spent fuel from the nuclear power plant. The matter will not be topical until the Government has taken a decision on the construction licence for Fennovoima's nuclear power plant.

There are still a number of outstanding issues relating to the closure of disposal facilities. The closure of a disposal facility must be carried out in such a way that active control measures are not required in order to ensure safety. In addition to safety, the need for supervision after the closure of disposal facilities is also significantly affected by the nuclear safeguards of spent fuel. The licensing procedures related to closure are specified in the event of an amendment to the Nuclear Energy Act and in any subsequent legal updates.

In addition, the substantive requirements for the closure plan will be further specified once experience has been gained with the disposal operation. Similarly, the regulatory requirements for the technical implementation of the closure phase itself will be further developed based on experience from disposal. The transfer of responsibility to the State

after the closure of the disposal facility also requires further clarification. So far, there is no need for urgent action, but the legislation and the guidelines of the authorities are to be updated gradually to clarify the issues related to closure.

Permanent record keeping of disposal information is the subject of preliminary policy discussions, and the most appropriate procedures are being considered in view of the need to keep data for up to centuries. The preliminary studies initiated by the state concerning the research and development needs related to the closure and the record keeping related to the disposal of spent fuel will provide the necessary starting material for the development work. The national objective can be considered to be that the licensing procedures for closure, technical requirements and operational responsibilities, including the transfer of responsibilities, be defined about a decade before the closure of the first disposal facility.

The treatment methods for low and intermediate-level waste are fairly well established and the waste requiring disposal has been significantly reduced in recent years. Nuclear power plants have improved the sorting of waste at source and are able to release significant amounts of waste from regulatory control. Waste released from regulatory control can be treated like conventional municipal waste and is subject to the Waste Act. In Finland, waste incineration plants have so far not received waste released from regulatory control into their incineration process. The aim is to find out how the incineration of waste released from regulatory control in waste incineration plants in Finland can be smoothly carried out in the future. Incineration of this waste would eliminate the need to take maintenance waste suitable for incineration to landfills.

In the context of the environmental impact assessment of the objectives and development targets of the national programme, it was recommended that a report be drawn up on the suitability of waste released from regulatory control for treatment at an incineration plant, its possible environmental impact and possible means of mitigating harm. The licensing procedure for incineration plants should also be examined in more detail with regard to the treatment of waste released from regulatory control. If the incineration of maintenance waste released from regulatory control is not possible, the exemption practice must continue to be possible in order to maintain a cost-effective and environmentally sound waste management route for the waste released from regulatory control.

The implementation of the recommendation can take into account the work done in the final report of the National Nuclear Waste Management Cooperation Group [8] on the implementation of the recommendation and proposal on the subject as well as focus on the possible environmental impacts of the radioactivity and further use of the ash and slag

generated in the incineration of waste released from regulatory control and the mitigation of possible harm.

With regard to waste records, the objective for the next few years is to develop and consolidate the national procedures for waste recording maintained by STUK. The consolidation of procedures requires a more precise definition of what information should be stored in the national database. Currently, the quantities of radioactive waste and spent fuel in storage and disposal at nuclear facilities are known very precisely.

Operators subject to the Nuclear Energy Act are obliged to keep their own waste accounting up to date and to submit the data annually to STUK. On the other hand, less precise data is available on the quantities of radioactive waste held by operators subject to the Radiation Act. In the future, efforts will be made to improve the preparation and reliability of forecasts of the quantities of radioactive waste, for example by agreeing on common principles for the calculation of forecast data.

Maintaining expertise in the management of spent fuel and radioactive waste is primarily the responsibility of each operator for its own needs. Given the long duration of the tasks related to the management of radioactive waste and spent fuel, it is necessary to ensure that new professionals in the field are also trained for the needs of operators and authorities. Skills are developed through national research programmes (KYT and SAFIR, which will be merged into the SAFER programme in 2023) and through national training in the management of spent fuel and radioactive waste. Initial national training, jointly organised by all actors, is arranged as necessary.

References

[1] VN 1983, Valtioneuvoston periaatepäätös ydinjätehuollon tutkimus-, selvitys- ja suunnittelutyön tavoitteista, Kauppa- ja teollisuusministeriö [Government Policy Decision of 10 November 1983 on the objectives of nuclear waste management research, studies and planning], Ministry of Trade and Industry, 21/813/83 KTM, 28 November 1983.
[2] KTM 1991, Kauppa- ja teollisuusministeriön päätös ydinvoimalaitosten ydinjätehuollossa noudatettavista periaatteista [Decision of the Ministry of Trade and Industry on the principles governing the management of nuclear waste in nuclear power plants], 7/815/91 KTM, 19 March 1991.
[3] TEM 2015, Management of spent fuel and other radioactive waste in Finland – national programme in accordance with Article 12 of the Council Directive 2011/70/EURATOM. 14 July 2015.
VN 1978. Valtioneuvoston päätös 21. päivänä maaliskuuta 1977 päivättyyn hakemukseen, jossa Helsingin kaupungista oleva Teollisuuden Voima Oy – Industrins Kraft Ab on pyytänyt atomienergialaissa tarkoitettua lupaa Eurajoen kunnassa sijaitsevan, omistamansa ja hallitsemansa voimalaitoksen (jäljempänä Olkiluodon voimalaitos) ensimmäisen ydinvoimalaitosyksikön TVO I käyttöön ja, jota hakija on myöhemmin täydentänyt 20 päivänä kesäkuuta 1977, 12 päivänä joulukuuta 1977, 5 päivänä huhtikuuta 1978 ja 14 päivänä huhtikuuta 1978 päivätyillä selvityksillään [Government decision on an application dated 21 March 1977 in which Helsinki-based company Teollisuuden Voima Oy – Industrins Kraft Ab applied for a licence pursuant to the Atomic Energy Act for the operation of the first power plant unit, TVO I, of the power plant it owns and controls located in the Municipality of Eurajoki (hereinafter Olkiluoto power plant), and which the applicant has subsequently supplemented with reports dated 20 June 1977, 12 December 1977, 5 April 1978 and 14 April 1978]. 21 August 1978.
[5] KTM 2003, Käytetyn ydinpolttoaineen loppusijoituksen valmistelu [Preparation for the disposal of spent fuel], 9/815/2003, 23 October 2003.
[6] STUK, 2020, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. 7th Finnish National Report as referred to in Article 32 of the Convention. STUK-B 259, Helsinki 2020, 157 p.
[7] TEM 2020, Developing regulation to cover the life cycle of nuclear facilities – Final report, Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 2020:43.
[8] TEM 2019, Final Report of the National Cooperation Group on Nuclear Waste Management, Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 2019:45.
[9] TEM 2019, The development of investment activities by the National Nuclear Waste Management Fund – Final report. Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 2019:47.
[10] KTM 1989, Voimayhtiöiden A. Ydinjätehuollossa noudatettavat periaatteet, B. ydinjätehuollon ohjelma vuodelle 1989 ja alustava ohjelma vuosille 1990-1993 sekä C. voimalaitosten käytöstäpoistosuunnitelmat [Power companies' A) principles for the management of nuclear waste, B) nuclear waste management programme for 1989 and preliminary programme for 1990–1993, and C) plans for the decommissioning of power plants]. 62/814/87 KTM, 63/814/87 KTM, 11/815/88 KTM, 6 April 1989.
[11] KTM 1991, Kauppa- ja teollisuusministeriön päätös ydinvoimalaitosten ydinjätehuollossa noudatettavista periaatteista [Decision of the Ministry of Trade and Industry on the principles governing the management of nuclear waste in nuclear power plants], 7/815/91 KTM, 19 March 1991.
[12] KTM 1995, Teollisuuden Voima Oy:n ja Imatran Voima Oy:n yhteistyö käytetyn ydinpolttoaineen huollossa [Cooperation between Teollisuuden Voima Oy and Imatran Voima Oy in the management of spent fuel], 9/815/95, 5 September 1995.
[13] TEM 2011, Ydinvoimalaitosyksikön OL3 ydinjätehuollon periaatteet ja liittyminen käytetyn polttoaineen yhteistyöjärjestelyihin [Principles of nuclear waste management at nuclear power plant unit OL3 and accession to spent fuel cooperation arrangements], TEM/1592/08.05.01/2011, 9 December 2011
[14] KTM 1985, Valtion teknillisen tutkimuskeskuksen (VTT) FiR 1-reaktorin ydinjätehuollon tutkimus- ja selvitystyö [Nuclear waste management research and analysis of the FiR 1 reactor of the VTT Technical Research Centre of Finland], KTM/25/816/84, 11 July 1985.
[15] TEM 2021, Työ- ja elinkeinoministeriön päätös Posiva Oy:n ydinjätehuollon periaatteista [Decision of the Ministry of Economic Affairs and Employment on principles for the management of nuclear waste of Posiva Oy], VN/11149/2021, 7 September 2021.
[16] TVO 2020, Hyvin matala-aktiivisen jätteen maaperäloppusijoitus, Olkiluoto [Near-surface disposal of very low-level waste, Olkiluoto]. Environmental impact assessment programme, TVO-11718, 11 August 2020.
[17] TVO 2021, Hyvin matala-aktiivisen jätteen maaperäloppusijoitus, Olkiluoto [Near-surface disposal of very low-level waste, Olkiluoto]. Environmental impact assessment report, TVO-11971, 11 May 2021.

[18] Posiva 2021, YJH-2021 Olkiluodon ja Loviisan laitosten ydinjätehuollon ohjelma vuosille 2022–2024 [YJH-2021 Nuclear waste management programme for Olkiluoto and Loviisa for 2022–2024].
[19] VTT 2021, Teknologian tutkimuskeskus VTT Oy:n ydinjätehuolto [Nuclear waste management of VTT Technical Research Centre of Finland], 986/0720/2015, 30 September 2021.
[20] Fennovoima, 2015, Ydinenergialain (990/1987) 18 §:n mukaisen rakentamislupahakemus Hanhikivi 1-ydinvoimalaitoksen rakentamiseksi, 30.6.2015, ja hakemuksen päivitykset ja lisäselvitykset [Application for a construction licence under section 18 of the Nuclear Energy Act (990/1987) for the construction of the Hanhikivi 1 nuclear power plant, 30 June 2015, and updates and further clarifications to the application].
[21] Posiva 2021. Olkiluodon ja Loviisan voimalaitosten ydinjätehuolto – Yhteenveto vuoden 2020 toiminnasta [Nuclear waste management at Olkiluoto and Loviisa power plants – Summary of 2020 activities].
[22] STUK, 2018, Member State Report of Finland as required under Article 14(1) of Council Directive 2011/70/EURATOM. 22 August 2018.
[23] VN 2000, Valtioneuvoston periaatepäätös 21 päivänä joulukuuta 2000 Posiva Oy:n hakemukseen Suomessa tuotetun käytetyn ydinpolttoaineen loppusijoituslaitoksen rakentamisesta [Government decision-in-principle of 21 December 2000 on the application of Posiva Oy for the construction of a spent fuel disposal facility for spent fuel generated in Finland]. 21 December 2000.
[24] Fennovoima 2016, Käytetyn ydinpolttoaineen kapselointi- ja loppusijoituslaitoksen ympäristövaikutusten arviointiohjelma [Environmental impact assessment programme for the spent fuel encapsulation plant and disposal facility].
[25] TVO 2020. Olkiluodon ydinvoimalaitoksen käytöstäpoistosuunnitelma [Olkiluoto nuclear power plant decommissioning plan], TVO-11843, 22 December 2020.
[26] Fortum Power and Heat Oy, 2018. Decommissioning plan of Loviisa NPP. 18 December 2018.
[27] VN 2021, Valtioneuvoston päätös Teknologian tutkimuskeskus VTT Oy:n hakemukseen saada ydinenergialain (990/1087) 20 §:ssa tarkoitettu lupa vuoden 2030 loppuun saakka poistaakseen käytöstä Espoon Otaniemessä sijaitseva FiR 1 –tutkimusreaktori [Government decision on the application by VTT Technical Research Centre of Finland to obtain the licence referred to in section 20 of the Nuclear Energy Act (990/1087) until the end of 2030 for the decommissioning of the FiR 1 research reactor in Otaniemi, Espoo], 17 June 2021.
[28] STUK 2019, Säteilyturvakeskuksen päätös 8444/L1/19 ja turvallisuuslupa 8444, 4.12.2019 [STUK Decision 8444/L1/19 and safety licence 8444], 4 December 2019.
[29] VN 2010, Valtioneuvoston periaatepäätös 6. päivänä toukokuuta 2010 Fennovoima Oy:n hakemukseen uuden ydinvoimalaitoksen ja voimalaitoksen toimintaan samalla laitospaikalla tarvittavien ydinlaitoksien rakentamisesta [Government decision-in-principle of 6 May 2010 on the application of Fennovoima Ltd for the construction of a new nuclear power plant and the construction of nuclear facilities necessary for the operation of the power plant on the same site].
[30] VN 2014, Valtioneuvoston periaatepäätös 18 päivänä syyskuuta 2014 Fennovoima Oy:n hakemukseen uuden ydinvoimalaitoksen ja voimalaitoksen toimintaan samalla laitospaikalla tarvittavien ydinlaitoksien rakentamisesta [Government decision-in-principle of 18 September 2014 on Fennovoima Ltd's application for the construction of a new nuclear power plant and the construction of nuclear facilities necessary for the operation of the power plant on the same site].
[31] VN 2007, Valtioneuvoston päätös Fortum Power and Heat Oy:n hakemukseen saada ydinenergialain 20 §:ssä tarkoitettu lupa käyttää ydinvoimalaitosyksiköitä Loviisa 1 ja Loviisa 2 ja niihin kuuluvia ydinpolttoaine- ja ydinjätehuollon kannalta tarpeellisia rakennuksia ja varastoja [Government decision on Fortum Power and Heat Oy's application for a licence referred to in section 20 of the Nuclear Energy Act to use the nuclear power plant units Loviisa 1 and Loviisa 2 and the buildings and storage facilities necessary for the management of nuclear fuel and nuclear waste], 26 July 2007.
[32] VN 2018, Valtioneuvoston päätös Teollisuuden Voima Oyj:n hakemukseen saada ydinenergialain (990/1987) 20 §:ssä tarkoitettu lupa käyttää Olkiluoto 1 ja Olkiluoto 2 ydinvoimalaitosyksiköitä sekä niiden toimintaan kuuluvia Eurajoen Olkiluodossa sijaitsevia käytetyn ydinpolttoaineen välivarastoa, keskiaktiivisen jätteen välivarastoa, matala-aktiivisen jätteen välivarastoa mukaan lukien komponenttivarastoa vuoden 2038 loppuun saakka [Government decision on Teollisuuden Voima Oyj's application for a licence referred to in section 20 of the Nuclear Energy Act (990/1987) to use the Olkiluoto 1 and Olkiluoto 2 nuclear power plant units and the intermediate storage of spent fuel, intermediate storage of medium-level waste, intermediate storage of low-level waste, including component storage, located in Olkiluoto, Eurajoki, until the end of 2038]. TEM/2555/08.04.01/2016, 20 September 2018.
[33] VN 2016, Valtioneuvoston päätös Teollisuuden Voima Oyj:n hakemukseen saada ydinenergialain (990/1987) 20 §:ssä tarkoitettu lupa käyttää Eurajoen Olkiluodolla Olkiluoto 3 –ydinvoimalaitosyksikköä vuoden 2038 loppuun saakka [Government decision on Teollisuuden Voima Oyj's application for a licence to operate the Olkiluoto 3 nuclear power plant at the Eurajoki Olkiluoto in accordance with section 20 of the Nuclear Energy Act (990/1987) until the end of 2038]. TEM/573/08.04.01/2016, 7 March 2019.

[34] Posiva, 1999. Käytetyn ydinpolttoaineen loppusijoitus – ympäristövaikutusten arviointiselostus [Disposal of spent fuel – environmental impact assessment report]. 26 May 1999.
[35] VN 2002. Valtioneuvoston periaatepäätös 17 päivänä tammikuuta 2002 Posiva Oy:n hakemukseen Suomessa tuotetun käytetyn ydinpolttoaineen loppusijoituslaitoksen rakentamisesta hakemuksen ratkaisemattomalta osalta, jonka valtioneuvosto on siirtänyt ratkaistavaksi samassa yhteydessä kuin käsitellään Teollisuuden Voima Oyj:n 15 päivänä marraskuuta 2000 valtioneuvostolle jättämä periaatepäätöshakemus uuden voimalaitosyksikön rakentamisesta [Government decision-in-principle of 17 January 2002 on the application of Posiva Oy for the construction of an unresolved application for the construction of a spent fuel disposal facility in Finland, which the Government transferred to the Government for resolution in connection with the examination of Teollisuuden Voima Oyj's application for a decision-in-principle of 15 November 2000 to the Government on the construction of a new power plant unit]. 17 January 2002.
[36] VN 2015, Valtioneuvoston päätös Posiva Oy:n hakemukseen saada ydinenergialain 18 §:ssä tarkoitettu lupa rakentaa kapselointi- ja loppusijoituslaitos Eurajoen Olkiluotoon [Government decision concerning Posiva Oy's application to receive a licence referred to in Section 18 of the Nuclear Energy Act for the construction of an encapsulation and disposal facility at Olkiluoto in Eurajoki]. 12 November 2015.
[37] VN 1998, Valtioneuvoston päätös Imatran Voima Oy:n hakemukseen saada ydinenergialain 20 §:ssä tarkoitettu lupa käyttää ydinvoimalaitosyksiköitä Loviisa 1 ja Loviisa 2 ja niihin kuuluvia ydinpolttoaine- ja ydinjätehuollon kannalta tarpeellisia rakennuksia ja varastoja kymmenen vuoden ajan sekä voimalaitosjätteiden loppusijoituslaitosta vuoden 2055 loppuun saakka [Government decision on Imatran Voima Oy's application for a licence referred to in section 20 of the Nuclear Energy Act to use the nuclear power plant units Loviisa 1 and Loviisa 2 and the related buildings and warehouses necessary for the management of spent fuel and nuclear waste for ten years and the power plant waste disposal facility until the end of 2055]. 2 April 1998.
[38] VN 2012, Valtioneuvoston päätös Teollisuuden Voima Oyj:n hakemukseen Eurajoen Olkiluodossa sijaitsevan VLJ-luolan käyttölupaehtojen muuttamiseksi [Government decision on Teollisuuden Voima Oyj's application to amend the conditions of the repository for low and intermediate-level radioactive waste in Olkiluoto], 15 November 2012.
[39] TEM 2018, Finnish Research Programme on Nuclear Waste Management KYT2022 Framework Programme for the Research Period 2019–2022, Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 24/2018.
[40] TEM 2018, National Nuclear Power Plant Safety Research 2019–2022, SAFIR2022 Framework Plan, Publications of the Ministry of Economic Affairs and Employment, Energy, 22/2018.
[41] TEM 2014, Nuclear Energy Research Strategy, Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 17:2014.
[42] TEM 2012, Kansallisen ydinenergia-alan osaamistyöryhmän raportti [Report of the National Nuclear Expertise Group], Publications of the Ministry of Economic Affairs and Employment, Energy and Climate 2:2012.
[43] VTT 2018, Ydinenergia-alan osaamisselvitys 2017–2018 [Survey of expertise in the nuclear energy sector 2017–2018], VTT Technology 344.
[44] Finnish Energy 2020, Suomalaisten energia-asenteet 2020 [Finnish energy attitudes 2020].

Appendix 1. Consideration of the environmental report, opinions and views

Section 11 of the Act on the Assessment of the Effects of Certain Plans and Programmes on the Environment (200/2005) requires that the environmental report be taken into account when preparing the national programme for the management of spent fuel and radioactive waste as well as the opinions and views referred to in sections 8 and 9 of the Act, and the results of negotiations between states in accordance with section 10 of the Act.

The abovementioned opinions and views referred to in section 8 of the Act are the opinions and views obtained in the first consultation phase, and the opinions and views referred to in section 9 of the Act are the opinions and views obtained in the second consultation phase for the national programmes discussed in Chapter 12. No transboundary environmental impact assessment within the meaning of section 10 of the Act was carried out for the national programme, as the objectives of the national programme were not assessed to have environmental effects that could extend beyond the borders of Finland.

In addition, section 11 of the Act requires that the national programme or the decision approving it must indicate how the environmental report and the opinions and views referred to above have been taken into account and, further, how these and environmental considerations have influenced the content of the national programme and the choice of options. In addition, the national programme or the decision approving it must state how the monitoring of the environmental effects referred to in section 12 of the Act is to be carried out. When preparing the national programme, it was decided to include the above information in the national programme instead of the approval decision.

The abovementioned opinions and view referred to in sections 8 and 9 of the Act were taken into account in the preparation of the national programme and the environmental impact assessment report. On the basis of the opinions and views, the role of the national programme, for example, was clarified in relation to previous programmes and decisions. In addition, the content of the programme was revised and in some places specified in terms of the priority of operations under the Waste Act, the procedures in use and the quantities of waste released from regulatory control. The opinions and views also underlined the importance of the development objectives of the national programme. Several opinions highlighted the need to improve legislation and to specify and present more clearly the quantities of radioactive waste for further planning and monitoring of waste management. In addition, the opinions and views largely supported the plans for the management of spent fuel and radioactive waste discussed in the programme. On the basis of the opinions and views, a number of minor corrections and clarifications were also made.

The environmental impact results of the national programme and monitoring of environmental impact are discussed in Chapter 13 of the national programme. The environmental impact assessment focused in particular on the environmental impact of the objectives and development targets of the national programme. The focus of the impact assessment was on the impact of achieving or not achieving the objectives, particularly at the societal level. For some impacts, the scope of the assessment extends to impacts on the environment of operators.

The environmental impact of the implementation of the objectives for the development of the national programme was assessed as positive. The environmental impact assessment also made recommendations for the development of the national programme. The environmental impact assessment report recommended that provision be made for the management of radioactive waste generated in possible unexpected situations by drawing up general guidance and guidelines on the measures to be taken. The recommendation was included in the development objectives of the national programme.

The environmental impact assessment also concluded that a more detailed environmental impact assessment of the proposed treatment of waste released from regulatory control in waste incineration plants is required. The environmental impact assessment report therefore recommended that a report be drawn up on the suitability of the waste to be released from regulatory control for treatment at an incineration plant, its possible environmental impact and the means of mitigating any possible harm. It was also suggested that the licensing procedure for incineration plants should be examined in more detail with regard to the treatment of waste released from regulatory control. The recommendation was included in the development objectives of the national programme.

The results of the environmental impact assessment support the achievement of the main objective of the national programme. The main objective of the national programme is to ensure a safe and cost-effective disposal solution for all spent fuel and radioactive waste generated in Finland that cannot be otherwise taken care of. It is appropriate that the treatment, storage and disposal of radioactive waste in Finland should mainly take place at existing nuclear facilities or those under construction.

The environmental impact assessment considered the utilisation of existing or planned nuclear facilities to be a socially sustainable, safe and cost-effective solution for the treatment and disposal of radioactive waste generated elsewhere in Finland than through own activities. The amount of radioactive waste received by nuclear facilities from other sources is small in relation to the amount of waste generated by the nuclear facility itself. Therefore, the reception of waste does not significantly increase the impact on the natural or living environment of the sites.

Electronic publications
ISSN 1797-3562
ISBN 978-952-327-855-4

Electronic version: julkaisut.valtioneuvosto.fi
Publication sales: vnjulkaisumyynti.fi