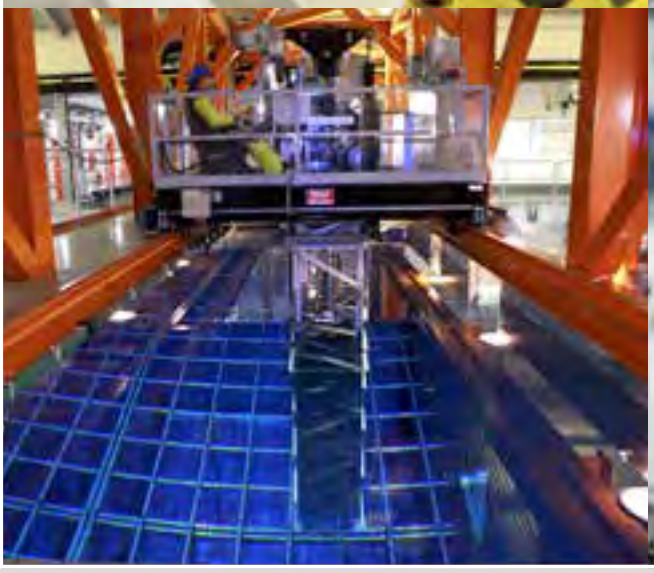
Ds 2020:21

Sweden's seventh national report under the

Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management

Sweden's implementation of the obligations of the Joint Convention



Government Offices of Sweden
Ministry of the Environment

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Cover: SSM
Upper left: Disassembly of Co-60 source holder at Cyclife Sweden AB, Non-Nuclear Department.
Upper right: Sweden's spent fuel will be disposed of in a geological repository at approximately 470 metres depth, and the licensing process is ongoing.
Lower left: Spent fuel is stored in underground pools in the central interim storage facility, Clab, for at least 30 years before encapsulation and eventual disposal.
Lower right: Responsibility of the licence holder.

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Foreword

The requirements of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management have for a long time been incorporated in the Swedish system for spent fuel and radioactive waste management. The Swedish Government judged at the time of signing the Joint Convention in 1997 that national policy and legislation as well as the safety work conducted by the licensees and the authorities in Sweden were in compliance with the obligations of the Convention.

The Swedish nuclear programme is in a phase of change with regard to new requirements on safety improvements for the continued operation of nuclear reactors and the shutdown and immediate decommissioning of other reactors. Of Sweden's thirteen nuclear reactors, six reactors at the Forsmark, Ringhals and Oskarshamn sites have plans for long-term operation beyond 2020. The Ågesta reactor has been shut down since 1974, the two reactors in Barsebäck since 1999/2005, while in 2015 the utilities decided also to permanently shut down the four oldest electricity-producing reactors at Oskarshamn and Ringhals before the end of 2020. Following the development of new regulatory conditions for decommissioning, the review and approval of licensees' safety reporting and issued environmental permits, actual large-scale dismantling activities will commence at the Ågesta, Barsebäck and Oskarshamn sites in 2020.

Since Sweden's sixth national report under the Joint Convention, progress has also been made in the licensing of final disposal facilities. The applications for an encapsulation plant and a deep geological repository for spent nuclear fuel from Swedish reactors, as well as for an extension of the existing repository for low- and intermediate level waste (SFR) to receive reactor decommissioning waste, have been reviewed and statements and recommendations have been forwarded to the Swedish Government for licensing decisions.

Remediation activities at the former Ranstad uranium mine and treatment facility were completed in 2019 with a decision to release the site from regulatory requirements. Financing has been secured through the nuclear waste fund for the continued monitoring of a legacy mine tailings deposit.

A new Radiation Protection Act (2018:396) was decided by the Swedish Parliament on 26 April 2018 and entered into force on 1 June 2018. The new Act transposes several key provisions of Council Directive 2013/59/ Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.

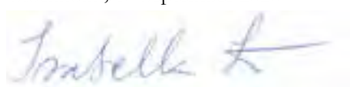
Sweden has completed a first round of international peer reviews, with a full scope IAEA IRRS in 2012 and a follow-up mission in 2016. The Swedish Government has officially requested the IAEA to carry out a new IRRS to Sweden in autumn 2022, followed by an ARTEMIS mission on Sweden's waste management programme in spring 2023.

This report has been produced by a working group of representatives from the Swedish Radiation Safety Authority (SSM) and with the support of the Swedish Nuclear Fuel and Waste Management Company (SKB), see section L3. Other fuel cycle facilities and waste management organisations have also been consulted with and have provided information.

The report is designed for good screen readability. This increases its accessibility, while also reducing the need to make a printout. This is beneficial from an environmental aspect.

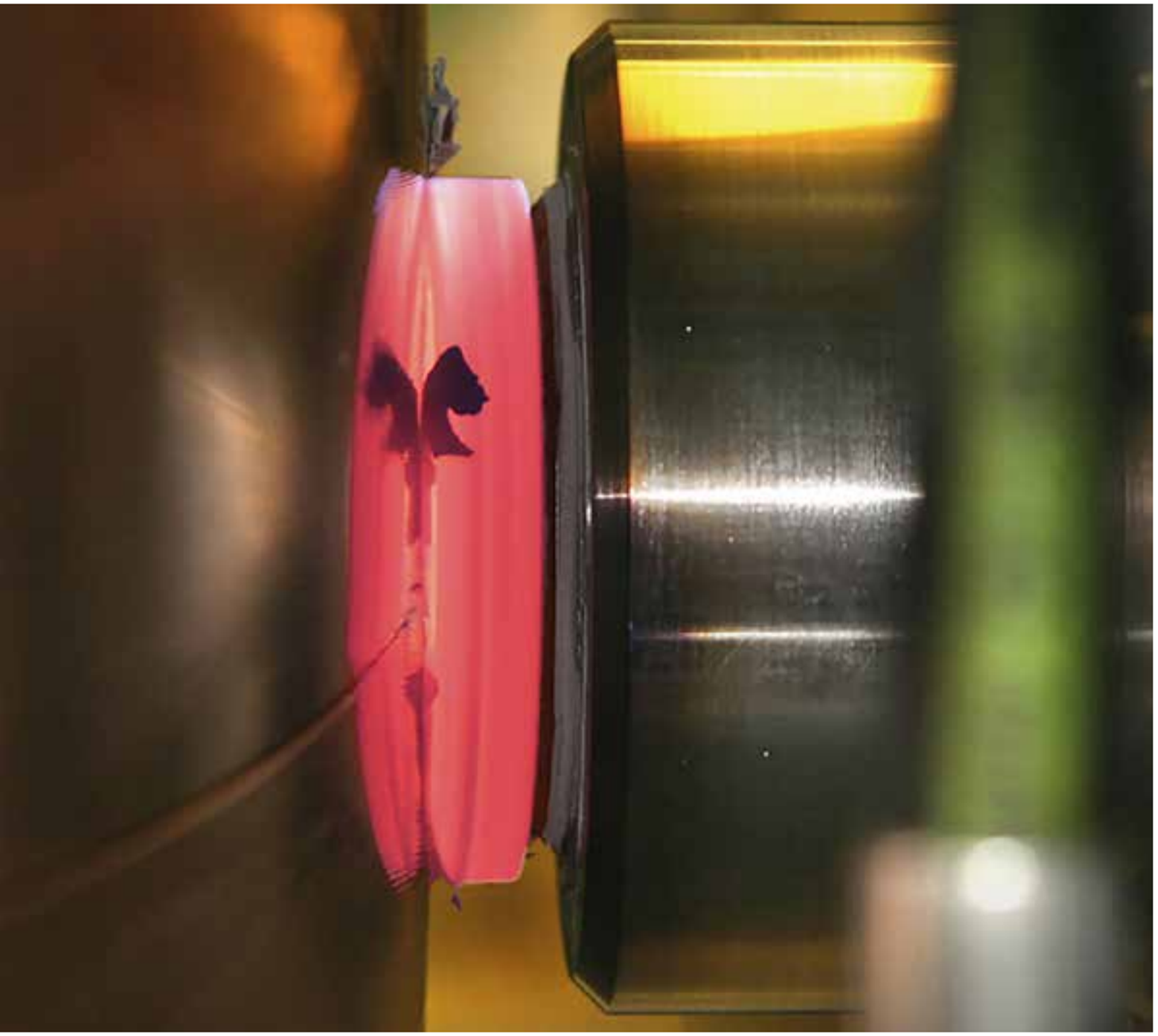
Pursuant to the requirements of the Joint Convention, Sweden submits its Seventh National Report on the fulfilment of obligations under the Convention and accounts for developments since the Sixth Review Meeting. Sweden reaffirms its commitment and continues to comply with the Joint Convention.

Stockholm, 10 September 2020



Isabella Lövin

Minister for Environment and Climate



Section A – Introduction

A.1 Purpose and structure of this report

Sweden signed the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (hereinafter 'Joint Convention') on 29 September 1997. Sweden ratified the Joint Convention approximately two years later and has been a Contracting Party to the Joint Convention since 29 July 1999. The Joint Convention entered into force on 18 June 2001.

Each member state that has ratified the Joint Convention (Contracting Party) is obligated to prepare a national report covering the scope of the Joint Convention and to subject the report to review by other Contracting Parties at review meetings held in Vienna, Austria. Sweden has participated in all review meetings since the First Review Meeting was held in November 2003. The present report is the seventh Swedish National Report under the Joint Convention.

This report meets the requirements of the Joint Convention for reporting on the status of safety at spent fuel and radioactive waste management facilities within the borders of Sweden. It constitutes an updated document with the same basic structure as the previous national reports under the terms of the Joint Convention, and reflects developments in Sweden up to 31 December 2019 unless stated otherwise. The report will be subject to review in May 2021 at the Seventh Review Meeting of the Contracting Parties in Vienna.

The report's format and content follow the guidelines for structure and content of national reports, as agreed at the Second Review Meeting of Contracting Parties to the Joint Convention, held in May 2005 (taking into account subsequent revisions). The sections in this report have the same titles as in these guidelines, thus facilitating review by other Contracting Parties. Table A1 provides cross reference between the sections in this report and the specific reporting provisions of the Joint Convention.

Section A provides a broad overview of the Swedish waste management system, including a brief account of important developments since the last national report.

Table A1 Joint Convention Reporting Provisions.

National Report Section	Joint Convention Section
A. Introduction	–
B. Policies and Practices	Article 32, Paragraph 1
C. Scope of Application	Article 3
D. Inventories and Lists	Article 32, Paragraph 2
E. Legislative and Regulatory Systems	Articles 18–20
F. General Safety Provisions	Articles 4–9, 11–16 and 21–26
G. Safety of Spent Fuel Management	Articles 4–10
H. Safety of Radioactive Waste Management	Articles 11–17
I. Transboundary Movement	Article 27
J. Disused Sealed Sources	Article 28
K. General Measures to Improve Safety	Multiple Articles
L. Annexes	Multiple Articles

Section A also includes a summary of highlights and issues raised with regard to the Swedish report and presentation during the Sixth Review Meeting, held 21 May to 1 June 2018, and a list of issues Sweden was asked to report on in its seventh national report.

At the Sixth Review Meeting it was agreed to address four topics in the National Reports for the next Review Meeting. These topics are discussed as follows in the current report:

- Implementation of national strategies for spent fuel and radioactive waste management, see sections A.8, B.1.2, D.1.1, G.1.2, G.5.2, G.5.3.2 and K.1.1 (spent fuel) and A.9.3.2, A.9.4, B.1.2, D.1.3, H, K.1.2 and K.3.2.1 (nuclear fuel cycle wastes).
- Safety implications of long-term management of spent fuel, see section K.2.4.
- Linking long-term management and disposal of disused sealed radioactive sources, see sections A.4, A.5.3, D.1.4, B.1.2.2, J and K.3.2.1.
- Remediation of legacy sites and facilities, see sections A.4, D.1.5.6, E.2.1.4, F.4.2.2, F.6 and K.3.1.6.

A.2 Overview matrix

In order to provide continuity from the second review meeting, the rapporteur's overview matrix has been revised and supplemented with references to explanatory sections of the report in Table A2 below.

Table A2 Revised overview of the Swedish programme for management and disposal of spent nuclear fuel and radioactive waste.

Type of liability	Long-term management policy	Funding of liabilities	Current practice/ facilities	Planned facilities
Spent fuel	NPP licensees responsible. Shared obligations for cost calculations and development of disposal solutions. Strategy in place for disposal.	Funded by fees on nuclear energy production, accumulated in segregated funds (the Nuclear Waste Fund).	Stored on site initially, then transferred to the central interim storage facility (Clab) pending disposal. Reviews of the adequacy of funding every three years.	Licence application for an encapsulation plant and a spent nuclear fuel repository pending Government decision.
See section	A.5, A.8.2, B.1.1, E, K.3.1.3	A.6.4, E.2.1.4	A.8.2.1, B.1.2, D.1.1, G.1.2	A.8.2.2, G.5.2, G.5.3.2, K.1.1
Nuclear fuel cycle wastes	NPP licensees responsible. Shared obligations for cost calculations and development of disposal solutions. Strategy in place for disposal.	Mainly funded by fees on nuclear energy production, accumulated in the Nuclear Waste Fund. Disposal of short-lived operational LILW (SFR) from NPPs, paid for directly by owners.	Short-lived LILW disposal at existing repository (SFR); shallow land burial for short-lived VLLW are present at NPP sites. Reviews of the adequacy of funding every three years.	Licence application for extension of the existing repository for short-lived LILW (SFR) pending Government decision. Long-lived LILW to be disposed of in the planned repository for long-lived LILW (SFL). Licence application expected in 2031.
See section	A.5, A.8.3, B.1.1, E.2.7	A.6.4, E.2.1.4, F.2.1.2	A.8.3.1, B.1.2, D.1.3, D.1.4, H.1, H.2	A.8.3.2, H, K.1.2
Non-power wastes	Disposal at fuel cycle waste facilities when appropriate.	Financed by producers/ owners of waste. Government funding available for legacy wastes.	Disposal at fuel cycle waste repository (SFR) or interim storage pending disposal in the planned repository for long-lived LILW and nuclear fuel cycle waste (SFL).	Licence application for extension of the existing repository for short-lived LILW (SFR) pending Government decision. Long-lived LILW to be disposed of in the planned repository for long-lived LILW (SFL). Licence application expected in 2031.
See section	A.5, B.1.2.2, E.2.1.2, K.3.2.1	A.6.4, E.2.1.4, K.3.2.1	A.8.3.1, D.1.4.1, K.3.2.1	A.5.3, H, K.3.2.1
Decommissioning	Licensee is responsible.	Mainly funded by fees on nuclear energy production (NPPs) or other fees (FCF), accumulated in the Nuclear Waste Fund.	Preliminary plans for decommissioning exist for all nuclear facilities, with more detailed plans for those approaching or undergoing decommissioning. Reviews of the adequacy of funding every three years.	Licence application for extension of the existing repository for short-lived LILW (SFR) to accommodate radioactive waste from decommissioning of nuclear facilities pending Government decision. Long-lived LILW to be disposed of in the planned repository for long-lived LILW (SFL). Licence application expected in 2031.
See section	A.4, A.6., E.2.1.1, F.6, G.4	A.6.4, E.2.1.4, F.2.1.2, F.6	A.4, D.1.5, D.1.6, F.6, G.6.1.7, G.6.2.7, K.2.1	A.8.3.2, H, K.1.2
Disused sealed sources	Returned to manufacturer.	Financed by producers/ owners of waste. Government funding available for orphan sources.	Returned to manufacturer or disposed of in SFR or in interim storage pending disposal in the planned repository for long-lived LILW (SFL).	To be disposed of in repositories for nuclear fuel cycle wastes, SFR or SFL (if not returned to the manufacturer).
See section	J.1	J.1	J.1	J.1

A.3 Summary of results from the previous review

In the period prior to the sixth review meeting, Sweden received 114 questions on the report from 21 countries. The questions touched upon several articles of the Joint Convention. Key areas addressed included the consequences of decommissioning for storage and disposal, ongoing licensing processes for disposal facilities, plans for disposal of long-lived waste and operational experiences related to the repository for low- and intermediate level waste (SFR) at Forsmark. All the questions were answered on the Joint Convention website and commented on at the review meeting.

During the discussion at the review meeting, it was agreed that Sweden seems to comply well with the obligations of the Joint Convention. The Good Practice on Sweden's progress towards a fully-operational deep geological repository for spent fuel, first identified at the fifth review meeting, was reiterated.

The review further acknowledged several Areas of Good Performance including:

- provisions for stakeholder involvement,
- the funding system for radioactive waste and spent fuel management,
- the development of an upgraded safety culture and facility ageing management programme, and
- development of a national strategy for management in the event of a nuclear or radiological emergency.

A number of Challenges were discussed for future development as regards management of spent fuel and radioactive waste, including:

- completing the licensing for construction and operation of the encapsulation plant and the spent fuel disposal facility and for the extension of the SFR repository for low- and intermediate level waste,
- addressing issues related to decommissioning of nuclear reactors,
- management of regulatory competences, and
- handling of non-conformities at the SFR facility.

The rapporteur's report also included a specific Suggestion to complete the implementation of actions arisen from the IRRS follow-up mission in 2016, specifically:

- provision to maintain competence for nuclear safety and radiation protection on a national level, and
- the systematic evaluation of operational experience from non-nuclear facilities and radiation protection events and activities, including dissemination of all significant experience.

These challenges and suggestions are discussed in section K.1 in this report.

A.4 Summary of developments since the previous report

This section briefly summarises key developments in Sweden's waste management programme since the Sixth Review Meeting under the Joint Convention.

Reactor decommissioning
In October 2015, the nuclear power plant licensees decided to permanently shut down the four oldest reactors at Oskarshamn (BWR units 1 and 2) and Ringhals (BWR unit 1 and PWR unit 2) before the end of 2020. The Oskarshamn units were permanently shut down in 2017, Ringhals unit 2 in 2019 and unit 1 is in preparation for shutdown before the end of 2020. Preparatory decommissioning activities have been carried out at the two shut down Oskarshamn units, the two BWR units at Barsebäck that were shut down in 1999 and 2005 and at the Ågesta PHWR shut down in 1974. These include the segmentation of reactor internals and radiological characterisation work. An interim storage facility for reactor internals was established on the Barsebäck site in 2015.

In late 2019, the Oskarshamn, Barsebäck and Ågesta reactors had all received environmental licences for decommissioning and the regulatory approval of safety reports and radiological monitoring programmes. The large scale dismantling work that will commence in 2020 has to follow a work breakdown structure with required notifications to the regulatory authority before the start of each work package.

The dismantling of Studsvik's R2 materials testing reactors started in February 2015 and is, after some delay, planned to be finalised in 2020, aiming for the free release of the facility. See also sections D.1.1, D.1.5.5 and F.6.

Ranstad legacy site remediation
The decommissioning and site remediation of the Ranstad uranium mining and milling facility that started in 2010 has been completed after the dismantling of the processing plant in 2017 and the subsequent radiological controls and preparations for site release. The regulator, the Swedish Radiation Safety Authority (SSM), decided in 2019 on the free release of the industrial site from regulatory requirements. See sections A.5.1 and D.1.5.6.

Licence applications for spent fuel disposal facilities
In 2011, the Swedish Nuclear Fuel and Waste Management Company (SKB) submitted its licence applications for an encapsulation plant in Oskarshamn and a deep geological repository for spent fuel in Forsmark. The Land and Environment Court has examined SKB's application under the Environmental Code, with a systems approach that cover both facilities. The regulatory authority, SSM, has reviewed SKB's applications under the Act on Nuclear Activities. In June 2016, SSM submitted a statement to the Court based on the outcome of the Authority's review, stating the conclusion that the proposed sites and facilities have the potential to comply with radiation safety requirements and regulations. SSM also participated in the Court's

consultation process which included giving independent testimony in a five-week public court hearing in October 2017.

In January 2018, both SSM and the Court submitted final review statements to the Government for licensing decisions. SSM recommended the approval of SKB's application for a licence to possess, construct and operate an encapsulation plant and a final repository under the nuclear activities act. The Court on the other hand stated that SKB should present further documentation clarifying the long-term integrity of the copper canisters, for the repository to be considered permissible according to the environmental legislation.

In April 2019, SKB submitted supplementary information requested by the Government, including results from further experimental and theoretical studies. In a public consultation, stakeholders were given the possibility to state their opinions. SSM, after a thorough technical review of the new material, reiterated its earlier statement to the Government that SKB's preferred site is suitable, the disposal concept is feasible and the safety case fulfils strict regulatory requirements. See also sections A.9.4.1, A.10.2 and K.1.1.

Licence application for an extension of the SFR disposal facility
In 2014, SSM received a licence application for an extension of the final repository for short-lived low and intermediate level waste at Forsmark (SFR) so that it can also accommodate decommissioning waste. SSM in 2019 finalised its review and participated in the Land and Environment Court's public hearing and consultation process. In October of the same year, SSM submitted its final statement to the Government recommending the approval of SKB's proposed extension and continued operation of the facility. In November also the Land and Environment Court recommended the Government to approve the license applications. See sections A.9.4.2, H.5.2 and K.1.2.

Review of SKB's twelfth RD&D programme
In September 2019, SKB, on behalf of the nuclear power plant licence holders, submitted its twelfth tri-annual research, development and demonstration (RD&D) programme for the management of spent nuclear fuel and nuclear waste to SSM for evaluation. Based on its review, including a public consultation process, SSM concluded that the 2019 programme fulfils the statutory requirements. In its statement of March 2020, the Authority recommended the Government's approval, with certain proposed conditions that SKB take into account SSM's review comments in the continued development of the programme. See sections A.8.2, G.1.2.1, G.1.3.1, H.1.2.1, H.1.3.1, and K.2.2.

Changes in the financing system for decommissioning, nuclear waste management and disposal
A revision of the Act (2006:647) and Ordinance (2017:1179) on Financing of Management of Residual Products from Nuclear Activities came into force on 1 December 2017 in order to further reduce the state's financial risk. Based on the changed legislation and SSM's review of SKB's revised cost estimates (Plan 2016), the Government in December 2017 decided on the financial guarantees and nuclear waste fees (that are set per delivered kilowatt-hour of electricity generated) to be provided by the nuclear power plant licensees to the Nuclear Waste Fund for the years 2018 through 2020.

On 1 September 2018, the regulatory responsibility for the review of cost estimates changed from SSM to the National Debt Office. The Debt Office is currently reviewing SKB's latest cost estimates (Plan 2019), that will serve as a basis for the Government's decision on financial guarantees and nuclear waste fees for the nuclear power plants for the period 2021 through 2023. In December 2019, the Debt Office decided on the nuclear waste fees and financial guarantees for other nuclear licensees, such as nuclear fuel cycle and waste management facilities, for the period 2020 through 2022. See also sections A.8.3 and E.2.1.4.

Orphan sources control
During the years 2016 through 2018, SSM was allocated SEK 11 million to conduct a campaign relating to the treatment and storage of radiation sources from disused smoke detectors for industrial use that have been incorrectly delivered to recycling centres. In total, more than a hundred thousand sources were taken care of by SSM's contracted waste treatment company, Cyclife. SSM's funding for enabling control and safe management of orphan sources and certain legacy waste from non-nuclear activities continues from 2019 with an annual budget of SEK 3.0 million. See also sections E.2.1.4 and J.

Legislative changes
On 1 June 2018, a new Radiation Protection Act with Ordinance and eleven new SSM regulations came into force. These implement the European Council Directive 2013/59/Euratom (BSS) on radiation protection. See section E.2.3.

Amendments to the Act on Nuclear Activities entered into force on 1 August 2017. These changes, implementing the EU's revised nuclear safety directive, 2009/71/Euratom, clarify the licensee's responsibility for safety and that safety must be continuously evaluated and verified. New provisions are also introduced to give the regulatory authority insight into how the licensee ensures that contractors and suppliers meet the safety requirements.

In March 2019, a Government-appointed inquiry reported on a review of the national nuclear legislation. The inquiry proposes that the current Act on Nuclear Activities be repealed and replaced by a new act based upon the structure of the new Radiation Protection Act. Certain new provisions are proposed on clarifying the responsibilities of nuclear licence holders and operators with regard to waste management, decommissioning and the stepwise licensing process for new facilities. A specific proposal is to formalise the state's subsidiary responsibility for nuclear activities and ultimate responsibility for a closed geological repository. This proposal was taken into a special consideration by the Government and sent to the Parliament. The Government bill was adopted on 10 June 2020 and will enter into force 1 November 2020. The rest of the proposals from the inquiry will be taken into consideration in the coming years. See section E.2.7.

Major revision of SSM regulations
The Swedish Radiation Safety Authority in 2013 initiated a major multi-objective revision of its regulations promulgated in the SSM Regulatory Code, SSMFS. The revision addresses recommendations from the 2012 IRRS review regarding consistency of the Swedish regulatory framework with IAEA Safety Standards. It also takes into account the implementation of the European Union nuclear safety, waste management and BSS directives, as well as WENRA's applicable safety reference levels. An important goal of the revision is to clarify and broaden the regulations in order to create more predictability for the licensees and to improve the regulatory support.

The first of the new regulations in the established structure entered into force in June 2018. Key regulations governing nuclear power reactors are expected to come into force in 2021, followed by corresponding regulations on fuel cycle and waste management facilities, while applying a graded approach. New regulations on nuclear waste management, currently subject to consultations, are expected to come into force in 2021. See section K.2.5.

Euratom directives' reporting
In December 2017, Sweden submitted its third report to the European Commission under Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel.

In August 2018, Sweden submitted its second report to the European Commission on the implementation of Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste. A revision of the Swedish National Programme under the Directive, first notified to the Commission in 2015 and kept up-to-date by SSM, is planned for 2020. See also section A.7.

Peer review missions
Sweden has completed a first round of international peer reviews, with a full scope IAEA IRRS (Integrated Regulatory Review Service) review in 2012 and a follow-up mission in 2016. The follow-up mission concluded that the Swedish system for nuclear safety and radiation protection is solid and continues to show good progress. The Swedish Government has officially requested the IAEA to carry out a new IRRS to Sweden in autumn 2022, followed by an ARTEMIS mission in spring 2023 on Sweden's waste management programme. See sections A.11.4 and K.4.

European Spallation Source
The European Spallation Source ERIC (ESS) has during the period 30 June 2017 to 15 July 2019 prepared an application for trial operation of the normal conducting linear accelerator part of the ESS facility. For the moment there is an ongoing review at the Swedish Radiation Safety Authority (SSM) of this application, see section A.8.1.8.

A.5 Overall context of Sweden's programme for nuclear and radioactive waste management

A.5.1 Generation of spent nuclear fuel and radioactive waste

Spent nuclear fuel and nuclear waste emanates mainly from the twelve electricity-producing nuclear power reactors located at four sites in southern Sweden: Barsebäck, Forsmark, Oskarshamn and Ringhals. Nine of these reactors are of BWR type (ASEA-ATOM design), three are of PWR type (Westinghouse design). All of these reactors were taken into commercial operation between 1972 and 1985. The two BWR units B1 and B2 at the Barsebäck site were shut down permanently in 1999 and 2005, respectively. The two oldest BWR units O1 and O2 at the Oskarshamn site were permanently shut down in 2015 and 2016. Of the two oldest units at the Ringhals site, R1 (BWR) was permanently shut down in 2019 and a decision has been taken to permanently shut down R2 (PWR) in 2020.

Other fuel cycle facilities include the Westinghouse fuel fabrication plant in Västerås and the former uranium mining and milling facility in Ranstad. The Ranstad facility was constructed and operated in the 1960s. The uranium open-cast mine and the mill tailings deposits were restored and covered in the 1990s. The industrial facility has been free-released from regulatory requirements since 2019.

Spent fuel from the nuclear power reactors is shipped to the centralised storage facility, Clab, close to the Oskarshamn nuclear power plant, which has been in operation since 1985.

Short-lived low- and intermediate level operational waste is disposed of in the repository for low and intermediate level short-lived waste, SFR, in Forsmark, Östhammar municipality. SFR was commissioned in 1988 and is situated close to the Forsmark nuclear power plant.

Long-lived low- and intermediate level waste is stored at the nuclear power plants, in Clab or at the Studsvik site.

Spent fuel and nuclear waste emanates also from three research reactors and the first prototype nuclear power reactor (PHWR) in Ågesta, which was in operation between 1963 and 1974 and mainly used for district heating in a suburb of Stockholm. The oldest research reactor R1, situated in Stockholm, was in operation between 1954 and 1970. Two additional research reactors R2 and R2-0, situated in Studsvik, were in operation between 1960 and 2005. Studsvik is the centre for nuclear research activities and hosts facilities for nuclear fuel and materials testing as well as facilities for waste treatment and storage.

Radioactive waste originates also from medical use, industry, research and consumer products. There are thousands of activities outside the nuclear fuel cycle where ionising radiation is used for different purposes; at hospitals, educational and research facilities, non-nuclear industries and so forth. These activities generate relatively

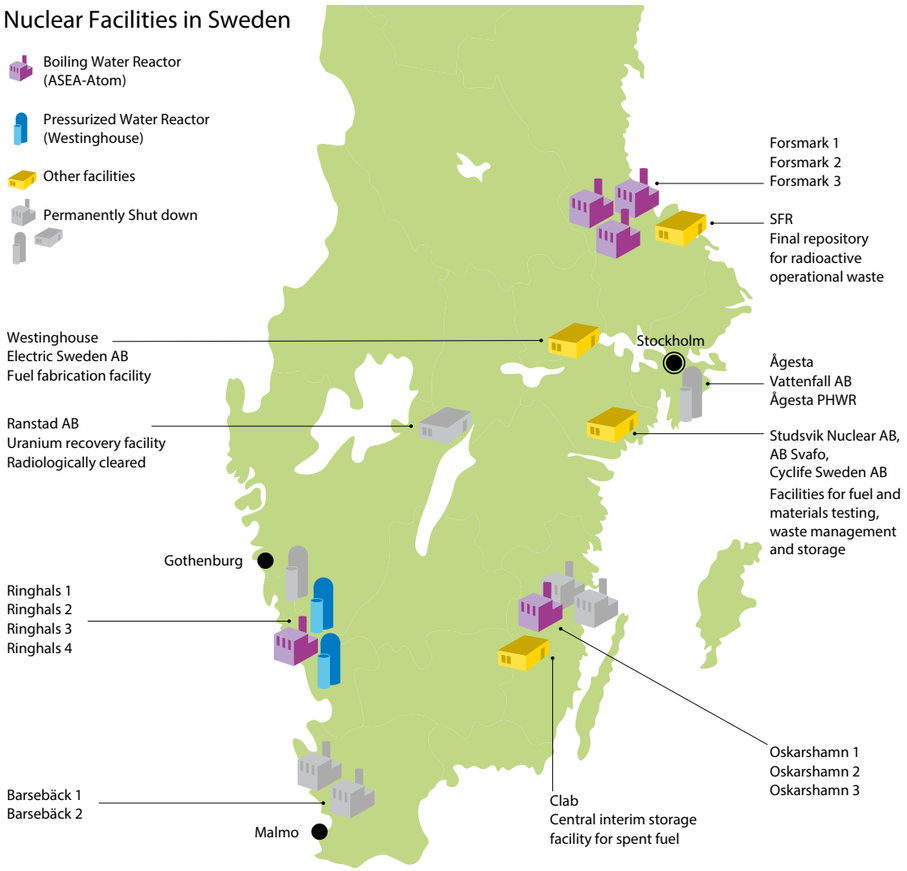


Figure A1 Nuclear facilities in Sweden.

small volumes of radioactive waste compared to the volumes generated within the nuclear fuel cycle. Arrangements are in place, based on commercial contracts, to allow for radioactive waste from medical use, industry, research and consumer products to be managed within the management solutions developed for nuclear fuel cycle wastes. See also section K.3.2.1.

Radioactive waste will also arise from the European Spallation Source (ESS) accelerator facility in southern Sweden. Current plans envisage the facility to become operational in 2025 and that the facility will be in operation for about 40 years. The ESS facility is not a nuclear facility, but it will house considerable quantities of radioactive material and significant volumes of radioactive waste will be generated at the facility. A letter of intent has been signed by the ESS consortium and SKB with the understanding that SKB will provides services as regards the future management of the radioactive waste from the facility.

Figure A1 shows the location of the nuclear facilities in Sweden.

A.5.2 National policy and fundamental principles

Fundamental principles for the management of spent fuel and radioactive waste have evolved in stages since the 1970s through public debate and a number of policy decisions taken by both the Government and Parliament. These principles are reflected in the Swedish legislation, which is further described in sections B.1.1 and E.2.1.

The most important fundamental principles of the national policy are:

- Costs for the management and disposal of spent fuel and radioactive waste from nuclear activities shall be covered by fees that licensees are required to pay.
- The licensees are to safely dispose of spent nuclear fuel and radioactive waste from nuclear activities.
- The state has the ultimate responsibility for final management of spent nuclear fuel and radioactive waste from nuclear activities.
- Each country is to be responsible for the spent nuclear fuel and radioactive waste generated by nuclear activities in that country.

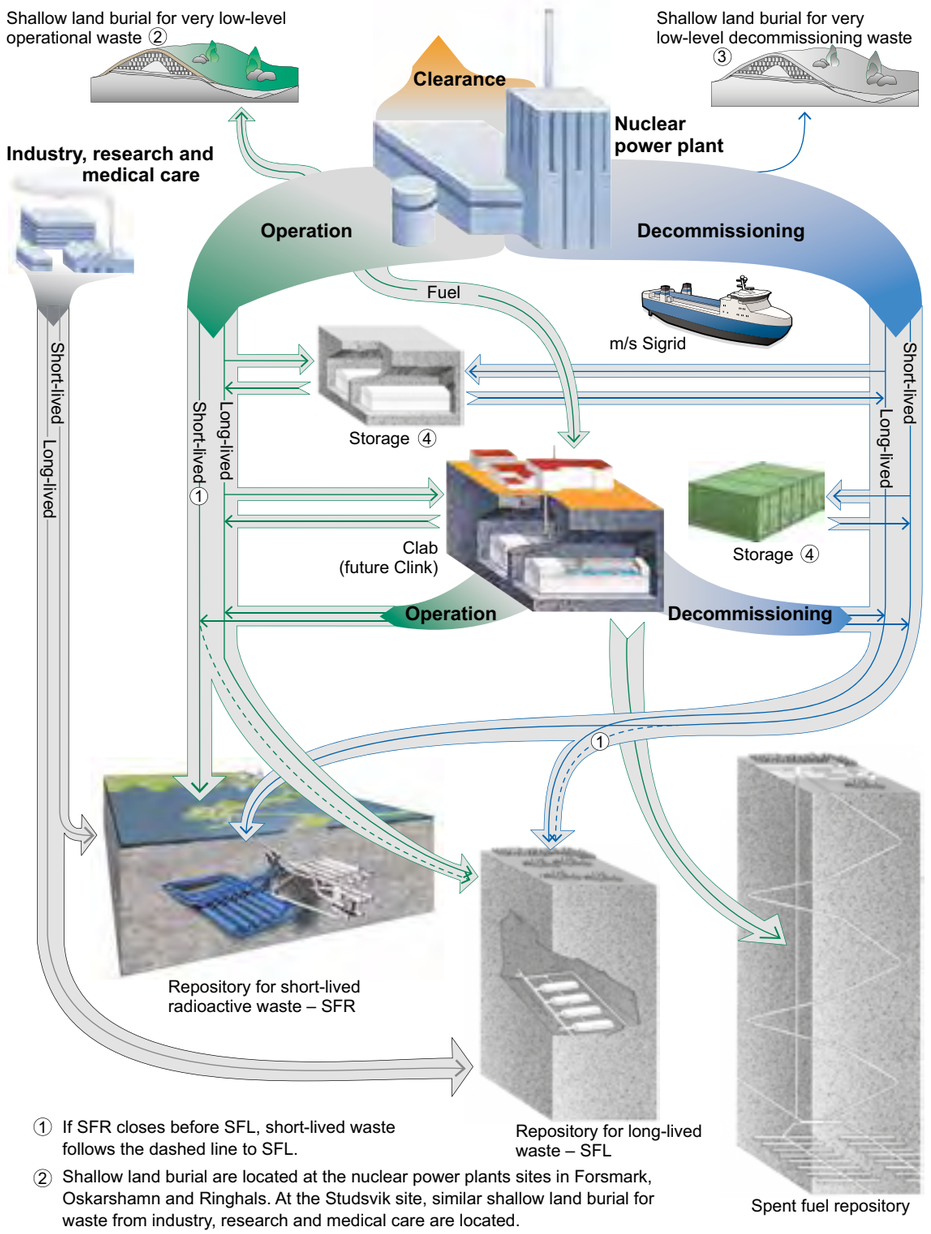


Figure A2 The system for managing spent nuclear fuel and radioactive waste.

The implementation of these principles in Swedish legislation in practice constitutes the implementation of the producer pays principle.

A.5.3 Basic preconditions

A.5.3.1 Management of spent nuclear fuel and nuclear waste

The responsibility for managing spent fuel and nuclear or radioactive operational and decommissioning waste that arises in an activity rests with the licence holder for the activity in question (see sections A.6.2 and E.2.1.1). The four utilities operating nuclear power reactors in Sweden have formed a special company, the Swedish Nuclear Fuel and Waste Management Co. (SKB), to assist them in executing their responsibilities regarding all handling, transportation and storage of spent fuel and radioactive waste outside the nuclear power plants. SKB is also responsible for the planning and construction of facilities required for the management of spent nuclear fuel and radioactive wastes, and for the research and development work required in order to provide such facilities (R&D programmes). Thus, management solutions for spent fuel and nuclear fuel cycle wastes are developed and implemented by the nuclear reactor utilities in cooperation, through SKB.

Figure A2 provides an overview of the existing and planned facilities associated with the relevant waste streams in the overall system to manage spent nuclear fuel and nuclear waste. A more detailed description of the figure is given in section A.8.1.

A.5.3.2 Management of non-nuclear fuel cycle wastes

As accounted for above, arrangements have been set up to allow for radioactive waste from non-nuclear fuel cycle applications, i.e. medical use, industry, research activities and consumer products, to be managed within the management solutions developed for nuclear fuel cycle wastes, as appropriate. It should however be emphasised that there is no legal requirement on the utilities operating nuclear reactors to accept radioactive waste from non-nuclear activities to be disposed of in facilities developed for nuclear waste. More information in this regard is provided in section K.3.2.1.

A.6 The legislative and regulatory framework

A.6.1 Implementation of national policy in legislation

The legal framework provides a consistent system involving clear allocations of responsibilities, licensing, prohibitions, institutional control, regulatory inspections, documentation and reporting. The framework also enables the enforcement of applicable regulations and terms of the licences. The competent regulatory body (SSM) has the mandate, qualified staff and financial resources necessary for its activities. The legislation clearly points out the operator as being primarily responsible for the safety of spent fuel and radioactive waste management. The state, however, has the ultimate responsibility for safety aspects of spent fuel and radioactive waste.

The legal framework corresponds well to the objectives of the Joint Convention. An overview is given in sections A.7 and E.

The following main legislative instruments regulate the management of spent fuel and nuclear waste:

- The Act on Nuclear Activities
- The Radiation Protection Act
- The Environmental Code
- The Act on Financing of Management of Residual Products from Nuclear Activities

Under the Act on Nuclear Activities, the holder of a licence for nuclear activities is primarily responsible for the safe handling and disposal of spent fuel and radioactive waste produced. In addition, under the Radiation Protection Act, the licensee must take all the measures and precautions necessary to prevent or counteract harmful effects to human health and the environment due to radiation.

The Environmental Code specifies basic environmental principles such as the precautionary principle, the principle of best available technology, the polluter pays principle, the principle of conservation of natural resources, and the principle of selecting the most appropriate location where the purpose of the activity can be achieved with a minimum of damage and detriment to human health and the environment. The Code also contains provisions relating to the conduct of environmental impact assessments.

The Act on Financing of Management of Residual Products from Nuclear Activities lays down the principles for the financing of expenses for decommissioning and the management and disposal of spent fuel and decommissioning waste.

Sweden has implemented the European Union's radioactive waste and spent fuel management directive (2011/70/Euratom) in its legislative framework. The directive requires that EU countries:

- have a national policy for spent fuel and radioactive waste management;
- draw up and implement national programmes for the management and disposal of all spent nuclear fuel and radioactive waste generated on their territory;
- have in place a comprehensive and robust framework and competent and independent regulatory body, as well as financing mechanisms to ensure that adequate funds are available; and
- provide public information on radioactive waste and spent fuel and ensure that opportunities for public participation are available.

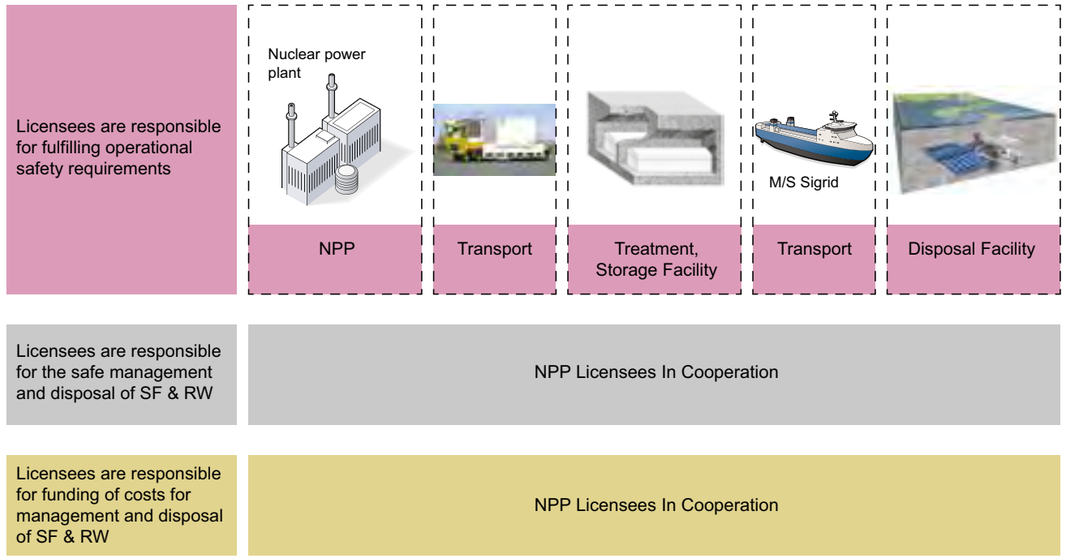


Figure A3 Basic requirements and general obligations of licensees.

A.6.2 Licence holder responsibilities

A.6.2.1 General obligations on licensees for nuclear activities

The holder of a licence for nuclear activities and other activities involving radiation has the primary responsibility for maintaining safety, ensuring the safe handling and disposal of spent fuel and radioactive waste, and the safe decommissioning and dismantling of facilities in which the activities will cease.

As illustrated in Figure A3, the utilities operating nuclear power reactors cooperate as regards implementation of the general obligations. The most important elements in this cooperation are:

- to establish and carry out a research and development (RD&D) programme for the safe handling and disposal of spent fuel and nuclear waste, see also sections A.8.2 and E.2.1.1; and
- to estimate costs for management and disposal of spent fuel and nuclear waste as a basis for payments to be made to the Swedish Nuclear Waste Fund, see also sections A.4 and E.2.1.4.

The utilities operating nuclear power reactors have joint ownership of the Swedish Nuclear Fuel and Waste Management Company, SKB, which fulfils the utilities' aforementioned shared obligations and assists them in executing their responsibilities.

SKB is tasked with the planning and construction of facilities required for the management of spent nuclear fuel and radioactive wastes, and the research and development work associated with these facilities. SKB also calculates the costs associated with the management of spent fuel and radioactive waste, as well as for future decommissioning of the nuclear power plants and SKB's own facilities.

Adequate financial resources for ensuring the fulfilment of these responsibilities and for maintaining qualified staff is provided through disbursements from the Nuclear Waste Fund and, in the case of operational radioactive waste, directly by the nuclear power plant utilities.

A.6.2.2 General obligations for licensees for non-nuclear activities

For non-nuclear activities, the Radiation Protection Act requires all parties that have produced radioactive waste to ensure the safe management and disposal of this waste, including securing of financial resources. This applies to all non-nuclear activities where radioactive material is used such as medicine, industry and research, see sections A.8.3.4, E.2.1.4, J and K.3.2.1.

A.6.3 RD&D programme for spent fuel and nuclear waste

The Act on Nuclear Activities requires the utilities that operate nuclear power reactors, in cooperation, to develop and implement the R&D programme (since 1992 denoted as the programme for Research, Development and Demonstration, the 'RD&D programme') needed for the safe management and disposal of spent nuclear fuel and nuclear waste, as well as safe decommissioning and dismantling of nuclear power plants.

Every three years, on the behalf of the operators, SKB submits a report on this programme to the regulatory authority for review. SSM invites a large number of interested parties to comment on the report. The report is

to include an overview of all measures that may be necessary and must specify the actions to be taken within a period of at least six years. Based on SSM's review recommendations, the Government approves or rejects the general direction of the continued programme. In connection with the decision, the Government may also issue conditions on the content of future research and development work.

An important goal of the programme was fulfilled when an application for a licence to construct a disposal facility for spent nuclear fuel was submitted to SSM and the Land and Environment Court on 16 March 2011.

The most recent RD&D programme was published by SKB and submitted to SSM in September 2019. Specific attention was paid to the more detailed planning for a future disposal facility for long-lived LILW waste (SFL), and on management on waste from decommissioning of nuclear facilities. From its review and evaluation, SSM concluded that the programme fulfils statutory requirements and that the programme demonstrates progress in developing and implementing necessary solutions for management of spent fuel and nuclear waste in a manner consistent with licence holders' obligations under the Act on Nuclear Activities. SSM also concluded that the RD&D Programme 2019 complied with the conditions imposed by the Swedish Government in the decision on the RD&D Programme 2016, as regards transparency of the programme, competence development in the perspective 50-100 years, plans for disposal of long-lived LILW and the safe management and transport of decommissioning waste.

The overall system for managing spent fuel and nuclear waste including future plans for its implementation, as presented in SKB's RD&D Programme 2019, is described in section A.8 and schematically illustrated in figure A.2.

A.6.4 Financing arrangements

Since the beginning of the 1980s a system apply for financing costs for management and disposal of spent nuclear fuel and radioactive waste by requiring licensees to pay fees and provide financial guarantees. This arrangement implements the 'polluter pays' principle and also aims to minimise the risk for the state and future generations to bear these costs. The fees are deposited in a nuclear waste fund. The funded assets are managed by a Government authority, the Nuclear Waste Fund. The legislation on financing is presented in more detail in section E.2.1.4.

The licensees' cost estimates are reviewed by the National Debt Office. Based on the review and statement of the Debt Office, the Government decides on the fees and financial guarantees for the nuclear power plants for a period of three years. The financial guarantees constitute securities to cover fees that have not yet been paid and to cover costs in connection with unexpected events.

To date, the Nuclear Waste Fund has covered expenses for the central interim storage facility for spent nuclear fuel (Clab), for the transport system and for the research and development needed, including the siting and method development for a spent fuel disposal system. Future expenses include construction and operation of the encapsulation plant and repository for spent fuel, repositories for low and intermediate level waste, the decommissioning of nuclear power plants and continued research and development work.

Since 2011, the nuclear waste fees paid by the power plants have increased from an average of SEK 0.01 per kWh of produced nuclear electricity (approx. EUR 1.0 per MWh) to an average of SEK 0.05 (approx. EUR 5.0 per MWh) for the period 2018–2020. The increase is due to higher cost estimates as well as enhanced assessments of future electricity production and real price drivers for the nuclear waste programme. Falling interest rates and the lowering of discount rate curves used in the calculations have also had a substantial effect. In addition, the reduced number of units in production, following the utilities' decision in 2015 to permanently shut down four reactors ahead of their estimated operating time, have resulted in higher fees for the remaining units at Oskarshamn and Ringhals and a greater variation in the size of fees between the power plant licensees. The revision of the Financing Act in 2017 has somewhat balanced the effect by enabling a broadening of the investment opportunities for the Nuclear Waste Fund and in basing the calculation of fees on 50 years of operation instead of the previous 40 years, for those nuclear power reactors in continued operation.

In October 2020, at the latest, the National Debt Office is to submit a new proposal for nuclear waste fees and financial guarantees to the Government for the period 2021–2023, based on its review of SKB's 2019 cost estimates.

For nuclear facilities other than power reactors, the Debt Office decides on, based on cost estimates, the three-year fees and financial guarantees. For the period 2017–2019, the licensees paid a total of SEK 50.9 million per year. In December 2019 the Debt Office decided on waste fees for the period 2020 through 2022, with a total SEK 219.5 million per year to be paid to the fund.

There is also a funding mechanism for legacy waste from historic nuclear activities. Until the end of 2017, a fee was levied on the nuclear power plant owners in order to cover expenses for liabilities originating from the establishment of a nuclear programme in Sweden. To date this funding has primarily contributed to the decommissioning of research reactors at Studsvik and the Ågesta reactor and the clean-up activities at the uranium mine in Ranstad (which was completed in 2019).

The licensees for nuclear power reactors are required to pay the additional fees necessary, in accordance with the provisions of the Financing Act, if the fund's assets are insufficient to cover the future liabilities.

There is also a state financing scheme administered by SSM for the recovery of orphan sources and clean-up of other non-nuclear legacy waste (see section J.1.2.2).

According to the Radiation Protection Act, all parties that have produced radioactive waste are required to ensure the safe management and disposal of the waste, including securing of financial resources. This applies to all non-nuclear activities where radioactive material is used such as medicine, industry and research. Institutional waste accepted by Cyclife Sweden AB is, as appropriate, disposed of in SFR or stored on site until SFL is in operation. In 1984, the Government agreed to a one-off compensation payment to the predecessor of Cyclife Sweden AB, Studsvik Energiteknik AB, to cover future costs for disposal in SFR of all radioactive waste originating from non-nuclear activities. Where radioactive waste is to be disposed of in SFL, the fee paid by the producer to Cyclife includes the cost for this disposal.

A.6.5 Environmental Objectives

In 1999, the Swedish Parliament laid down fifteen national environmental quality objectives, and in 2005, a sixteenth objective was adopted concerning biological diversity. Achieving these environmental quality objectives constitutes the basis for the Swedish national environmental policy and work. The environmental goals on a national level also incorporates the ecological dimension of the global sustainability goals in Agenda 2030.

The environmental objectives are of three different types; the Generational goal that defines the overall direction of environmental efforts, the 16 environmental quality objectives to facilitate these efforts and a number of milestone targets.

The Generational goal states that *"The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders."*

In practice, the generational goal means that the basic conditions for solving the environmental problems are to be achieved within one generation. This calls for an ambitious environmental policy – in Sweden, within the EU and in international contexts.

The 16 environmental quality objectives describe the quality of the environment that Sweden wishes to achieve. They should be followed up on a regular basis, with annual reports to the Government and an in-depth evaluation once every parliamentary term. A number of government agencies are engaged and the Swedish Environmental Protection Agency, working with all the agencies, prepares an overall report to the Government.

SSM is responsible for the quality objective A Safe Radiation Environment, which states that: *"Human health and biological diversity must be protected against the harmful effects of radiation."*

The environmental quality objective *A Safe Radiation Environment* aims to ensure that:

- human exposure to harmful radiation in occupational and other environments is limited as far as reasonably possible;
- discharges of radioactive substances into the environment are limited so as to protect human health and biodiversity;
- the annual incidence of skin cancer caused by ultraviolet radiation is lower than in the year 2000; and
- exposure to electromagnetic fields in occupational and other environments is so low that there is no negative impact on human health or on biodiversity.

The environmental quality objective *A Safe Radiation Environment* play an important role in the Swedish radioactive waste management system in targeting and evaluating non-nuclear radioactive waste. The national policy and the provisions for nuclear waste management are more comprehensively addressed in the nuclear legislation and the specific requirements on RD&D and cost estimates.

The latest in-depth evaluation of the environmental quality objectives was published in 2019, and the overall assessment is that the environmental quality objective *A Safe Radiation Environment* is close to being achieved.

A.6.6 Regulatory control and supervision

A.6.6.1 Licensing

All nuclear facilities require a licence under both the Act on Nuclear Activities and the Environmental Code. The Government grants the licence based on the recommendations and reviews of the competent authority.

A key element of the regulatory framework is the clearly defined stepwise licensing process, see sections E.2.3 and E.2.9.

A.6.6.2 Roles and responsibilities

The Swedish Radiation Safety Authority (SSM) is the competent authority that supervises licensees of nuclear activities in fulfilling their responsibilities for safe operation of facilities and transports as well as in planning for decommissioning and disposal. SSM has the adequate levels of authority, competence and financial and human resources to fulfil its assigned responsibilities, see sections E.3.

A.6.6.3 Independence of the regulatory authority

The regulatory body's independence is of fundamental importance in the Swedish constitution. As a central administrative authority, SSM receives its budget appropriations and instructions on its general direction of operations from the Swedish Government. SSM is at the same time independent in its decision making under Swedish legislation.

Although the independence of the regulator is stated in Swedish legislation, it is also a matter of public service tradition and values. A strong, independent and fully accountable national authority is also confident and trustworthy in upholding high safety standards. As an example, the integrity of SSM has become increasingly vital with the progression of the licensing review of SKB's application for a spent fuel repository. Strict internal rules apply to interaction with an applicant or licensee to ensure the regulator's independence in relation to the nuclear industry in all its supervisory activities, see sections E.3 and K.3.1.4.

A.6.6.4 Regulatory inspections

In accordance with its legal authorisation and its mandate defined by the Government, the regulatory authority conducts regular inspections and assessments of nuclear and other facilities whose work involves radiation in order to ascertain compliance with regulations and licence conditions, see section E.2.5 and E.3.2.6.

A.6.6.5 Documentation and reporting

Extensive reporting from licence holders is required. Annual reports are to be submitted to SSM on activities at the facility, including experience gained and conclusions drawn with regard to safety, and on the management of nuclear waste and high activity sealed sources (HASS). A deficiency detected during the construction or operation of a nuclear facility, and that can lead to deterioration in safety in addition to what is anticipated in the safety analysis report, must be reported to SSM without unnecessary delay, see section E.2.5.3.

The licensee of a nuclear facility must also report to SSM on the discharge of radioactive substances into air and water, shown as discharge of activity, and doses to individuals in a reference group. In addition, the results of environmental monitoring must be reported, see section E.2.5.3.

At least once every ten years, licensees are required to perform a periodic safety review (PSR), i.e. an integrated analysis and assessment of the safety of a facility, see sections E.3.2.6 and K.2.3.

A.6.6.6 Prohibition and enforcement

The Swedish authorities have extensive legal, regulatory and enforcement powers. As a supervisory authority, SSM may issue any injunctions or prohibitions and revoke activities if so required in the specific case to ensure compliance, see section E.2.4.

A.6.7 Provisions for public engagement and transparency

Building public confidence and acceptance in the system for managing spent nuclear fuel and radioactive waste strongly benefits from a national system based on consistent and long-term strategies and planning. See also sections A.8 and K.3.1.1.

The legal framework for licensing of nuclear activities contains provisions governing transparency, openness and public participation. According to the Environmental Code, a prospective licensee is required to submit a plan for the formal process of consultation with stakeholders in order to develop an Environmental Impact Assessment.

Through the mandatory review of RD&D programme reports, SSM supervises the development of management and disposal systems in the pre-licensing process. The review process includes opportunities for broad public participation in the development of the Swedish system for managing spent fuel and radioactive waste.

To enable active participation in formal consultations during the licensing process, host municipalities, regional authorities and certain environmental organisations receive financial support through the Nuclear Waste Fund. Preceding the Government's licensing decision for a nuclear facility, the host municipality has a right to veto and is expected to formally declare its support or rejection of the decision.

The implementing organisation for spent fuel disposal, SKB, has involved stakeholders in its siting and development of a repository. The regulator, SSM, has taken several measures to support the engagement of municipalities, NGOs, the public and other stakeholders in both the pre-licensing and the licensing review for a spent nuclear fuel repository. See also sections E.2.8, E.3.2.9, K.3.1.5 and K.5.

A.7 Swedish National Plan

Sweden have implemented the European Union's directive on the responsible and safe management of spent fuel and radioactive waste in its legislative framework (2011/70/Euratom). Under the Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452), SSM must ensure that there is a current national plan in place which corresponds to the content required under Article 12 of the directive.

The Swedish National Plan, notified to the European Commission in 2015 as the national programme, is an up-to-date plan that provides a comprehensive account of Swedish policies (fundamental principles), the legal, regulatory and organisational system (national framework), in addition to the strategies (national programme) governing the management of spent fuel and all radioactive waste in Sweden. See sections A.5 and A.6.

The plan accounts for the origin, management, treatment, transport, interim storage and final disposal of spent nuclear fuel and radioactive waste in Sweden. It gives an account of the quantities of spent nuclear fuel and radioactive waste produced, as well as estimates of future quantities.

The Swedish National Plan is based on three strategic planning components; the programme for research, development and demonstration (the RD&D Programme), the financing system and cost estimates (the Plan Cost Estimates) and the national System of Environmental Objectives including the goal for a *Safe Radiation Environment*. See sections A.6, E.2.1.4, and K.3.1.

A.8 Management of spent nuclear fuel and radioactive waste

A.8.1 Overview of waste streams and management solutions

The following section gives an overview of waste streams and management solutions as illustrated in Figure A2.

A.8.1.1 Management of spent nuclear fuel

The spent fuel, after cooling on the reactor site, is transported by ship to the central interim storage facility, Clab, located next to the Oskarshamn nuclear power plant. Current practices foresee interim storage of the spent fuel for a period of about 30 years before being disposed of in a deep geological disposal facility.

In addition to spent nuclear fuel from nuclear power reactors (including fuel from the Ågesta reactor), materials to be disposed of includes fuel residues from testing programmes at Studsvik, as well as MOX fuel (mixed oxide fuel). Approximately 20 tonnes of spent nuclear fuel from Ågesta and approximately two tonnes of spent nuclear fuel from Studsvik Nuclear AB's research activities are currently in interim storage in Clab. Clab is also used to store 23 tonnes of MOX fuel obtained from Germany in exchange for fuel that was sent to France (La Hague) for reprocessing at an early stage of the Swedish programme. A small amount of spent nuclear fuel from the first reactor at Oskarshamn was sent for reprocessing in Sellafield, England. No fuel or radioactive waste from that reprocessing will be returned to Sweden.

A.8.1.2 Management of long-lived low- and intermediate level waste

Long-lived waste from the NPPs consists of used core components, reactor pressure vessels from PWRs and control rods from boiling water reactors BWRs. The waste is currently stored at the nuclear power plants, Clab and the Studsvik site. The total quantity of long-lived low and intermediate level waste is estimated to about 16,000 m^3, about one third of which comes from the NPPs. The rest comes from facilities operated by Studsvik Nuclear AB, Cyclife Sweden AB and AB Svafo. SKB plans to dispose of the long-lived waste in a geological facility for long-lived low- and intermediate level waste, SFL.

A.8.1.3 Management of short-lived low- and intermediate level waste

Short-lived low- and intermediate level waste is disposed of in SFR, operated by SKB. According to current projections, about 180,000 m^3, including nine segmented reactor pressure vessels from BWRs will be disposed of in SFR. Most of the short-lived waste originates from the nuclear power plants. Other waste originates from Clab and from Cyclife AB, Studsvik Nuclear AB and AB Svafo.

A.8.1.4 Management of very low-level short-lived waste

Very low-level waste is disposed of in shallow land burials operated by the nuclear power plants. Under the current licences, a total of about 37,000 m^3 of short-lived very low-level waste operational waste may be disposed of in shallow land burials at the Forsmark, Oskarshamn and Ringhals nuclear power plants.

A.8.1.5 Transportation system

All transportation of spent nuclear fuel and radioactive waste from the four nuclear power plant sites to SKB's facilities is by sea, since all the nuclear facilities are situated on the coast (however radioactive waste from Forsmark NPP for disposal in SFR is transported a short distance on land). The transportation system, which has been in operation since 1982, consists of a purpose-built INF class 3 vessel, transport casks and containers, and terminal vehicles for loading and unloading. Figure A2 provides a schematic illustration of the management system for spent nuclear fuel and radioactive waste.

A.8.1.6 Planned facilities

Facilities that remain to be realised are an encapsulation plant for spent fuel, repositories for spent fuel and long-lived low and intermediate level waste, and an extension of SFR to accommodate decommissioning waste.

A.8.1.7 Research and demonstration facilities

SKB operates several research and demonstration facilities to assist them in the development of remaining facilities. These include the underground Äspö Hard Rock Laboratory for the investigation of engineered and geological repository barriers, the Canister Laboratory for the development of sealing technology for copper canisters, and the Multi-purpose Test Facilities for the testing of bentonite properties and development of methods for backfilling and plugging of repository tunnels. All facilities are situated in the Oskarshamn area.

A.8.1.8 Other important facilities in relation to management of nuclear and radioactive waste

Westinghouse fuel fabrication plant in Västerås

Westinghouse Electric Sweden AB operates a nuclear fuel fabrication plant in Västerås, approximately 100 km west of Stockholm. The plant has been manufacturing fuel since the mid-1960s. Its annual production is approximately 500 to 600 tonnes of UO_2 fuel for PWRs and BWRs, mainly for customers abroad.

The manufacturing process generates some slightly uranium-contaminated wastes in the form of CaF_2, metal, construction waste, electronics, combustible wastes, sludge, filters, protective clothing, etc. Westinghouse disposes of wastes with very low uranium content, typically CaF_2, metal and construction wastes at municipal landfills as permitted by the Swedish Radiation Safety Authority. Prior to disposal, however, most of the uranium in the waste is extracted through special recovery processes in the Västerås plant. In addition, a new facility for waste processing (pyrolysis) at Cyclife AB has been developed, and currently processes combustible waste from Westinghouse. A minor proportion of the remaining waste may be considered for disposal in a future disposal facility for long-lived waste.

Figure A4 Storage pool in Clab. The top edge of the spent fuel is eight metres below the water surface.

The European Spallation Source (ESS) accelerator
On 31 August 2015, European Spallation Source ESS AB changed its structure to form a European Research Infrastructure Consortium, 'European Spallation Source ERIC' (ESS). The founding members of ESS are 13 European countries currently involved in constructing and operating a new neutron source. This source is based on a large accelerator that bombards a heavy target material (tungsten) with protons. The neutron source makes it possible to study materials in their smallest components. According to the current plan, the ESS facility should be operational in 2025 and it is envisaged that the facility will be in operation for about 40 years.

The ESS facility is not a nuclear facility, but it will house considerable quantities of radioactive material. Significant volumes of radioactive waste will be generated at the facility. The highest level of radioactivity will be generated in the tungsten target, but also to a lesser extent elsewhere, such as activation of the soil filling material surrounding the accelerator. The Swedish Radiation Safety Authority and the Land and Environment Court are licensing the ESS facility. On 12 June 2014 the Land and Environment Court approved the first ESS application submitted in 2012. This approval was, however, conditional and ESS was not allowed to produce any radioactive waste or start the accelerator until the company had reported on further investigations concerning certain radiation protection issues and the management of radioactive waste. The results of the investigations, including a proposal for final licensing conditions, was reported to the court by 31 December 2017.

The Swedish Radiation Safety Authority decided on 17 July 2014 to grant ESS authorisation for the facility to be established at the site in Lund, and on 30 June 2017, to allow ESS to install equipment that can generate radiation. Further permission will be required from the Authority before this facility may be commissioned. The general licence that ESS has today allows the company to import, acquire, install and own technical devices and other components for generation of ionising radiation. The licence is linked to a number of special conditions for the ESS facility in areas such as physical protection, emergency preparedness work and management of radioactive waste.

For the moment there is an ongoing review of an ESS application for trial operation of the normal conducting linear accelerator part of the ESS facility.

One of several challenges faced by ESS in the continuing licensing process with the Authority is to clarify and verify that the waste management can be conducted in a way that is safe in terms of radiation safety and radiation protection, and that it can be performed in compliance with applicable regulatory requirements, see section K.3.2.1.

A.8.2 Spent nuclear fuel management

A.8.2.1 Existing spent nuclear fuel management practices and facilities

Management practices at the NPP sites
Spent nuclear fuel from the nuclear power reactors is temporarily stored on site in water-filled fuel pools for at least nine months before being transported to the central interim storage facility for spent nuclear fuel, Clab.

Fulfilment of the requirements of SSM's general regulations is accomplished and verified through regulatory review and inspection activities at the nuclear power plants, as reported under the Convention on Nuclear Safety.

The central interim storage facility for spent fuel, Clab
Spent nuclear fuel from all Swedish nuclear power reactors is stored in Clab, situated adjacent to the Oskarshamn nuclear power plant. The facility has been in operation since 1985. The facility has around 100 employees.

The facility consists of two parts: one building above ground for unloading spent fuel assemblies from transport casks, and one underground section for storage in water filled pools with a rock cover of about 25 to 30 metres. The spent fuel is stored for at least 30 years before being encapsulated and deposited in the repository.

Clab is licensed for storage of 8,000 tonnes of spent fuel and SKB has applied for increasing the storage capacity to 11,000 tonnes. One of the storage pools is shown in Figure A4. Principal data as well as information on inventories are contained in section D.1.2.2.

A.8.2.2 Planned spent nuclear fuel management practices and facilities

The KBS-3-concept
The concept for disposal of spent fuel, KBS-3, involves emplacement of fuel elements in copper canisters (corrosion resistance) with ductile iron inserts (mechanical strength), see Figure A5. The canisters will be embedded in bentonite clay (protection against corrosion and rock movements, preventing water penetration and leakage of radioactive substances) in individual vertical deposition holes at a depth of about 500 metres in the bedrock (maintains the technical barriers for a long time and isolates the spent fuel from human beings and the environment).

Licensing processes for an encapsulation plant and a spent fuel disposal facility
SKB's submitted parallel licence applications in March 2011, under the Act on Nuclear Activities and the Environmental Code, for an encapsulation plant in combination with the existing interim storage facility at Oskarshamn and a geological repository for spent fuel at Forsmark. The applications have been subject to a thorough regulatory review by SSM and examination by the Land and Environment Court. The review phase has been concluded and the applications are currently pending Government decision.

After an initial assessment of SKB's primary licensing documents, SSM reviewed the quality and completeness of the two separate applications for nuclear facilities, including supporting technical material and references that were submitted by SKB. Over a period of three years, SSM requested and obtained from SKB substantial supplementary information and clarification at various levels of detail relating to both facilities, on topics ranging from the scope of SKB's assessment of alternative methods and locations to detailed scientific and technical analyses relating to specific aspects of the disposal system design and its performance. This included a comprehensive revision of the preliminary safety analysis for the combined encapsulation plant and interim storage facility, submitted by SKB at the end of 2014. By the end of 2015, SSM had completed the major part of its technical review of SKB's rationale for method and siting as well as SKB's preliminary safety analyses for the two facilities. In June 2016, SSM submitted a statement to the Land and Environment Court based on its review and as part of the Court's consultation process.

The Land and Environment Court's role is, in the first instance, to prepare a recommendation to the Government relating to the permissibility of SKB's plans for final disposal in relation to general principles established in the Environmental Code. Following formal public notification of the licence applications in January 2016, the Court

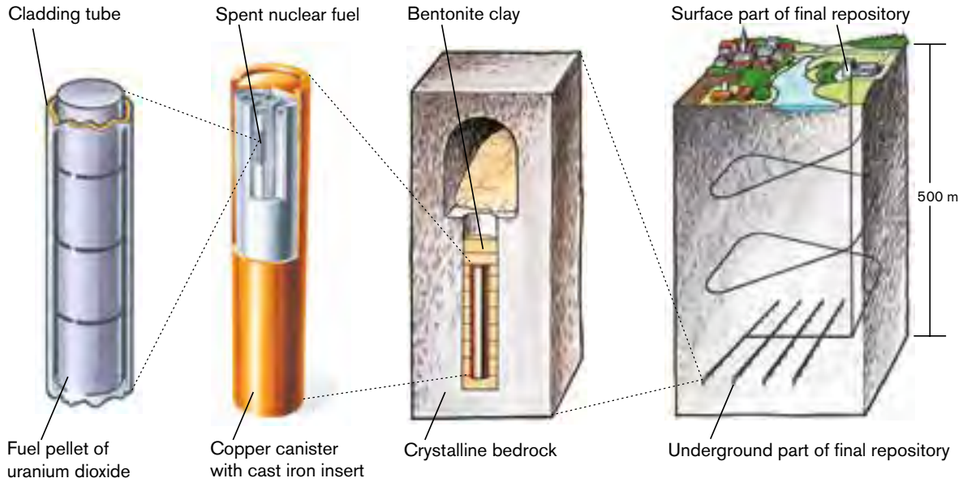


Figure A5 The KBS-3-method for disposal of spent nuclear fuel.

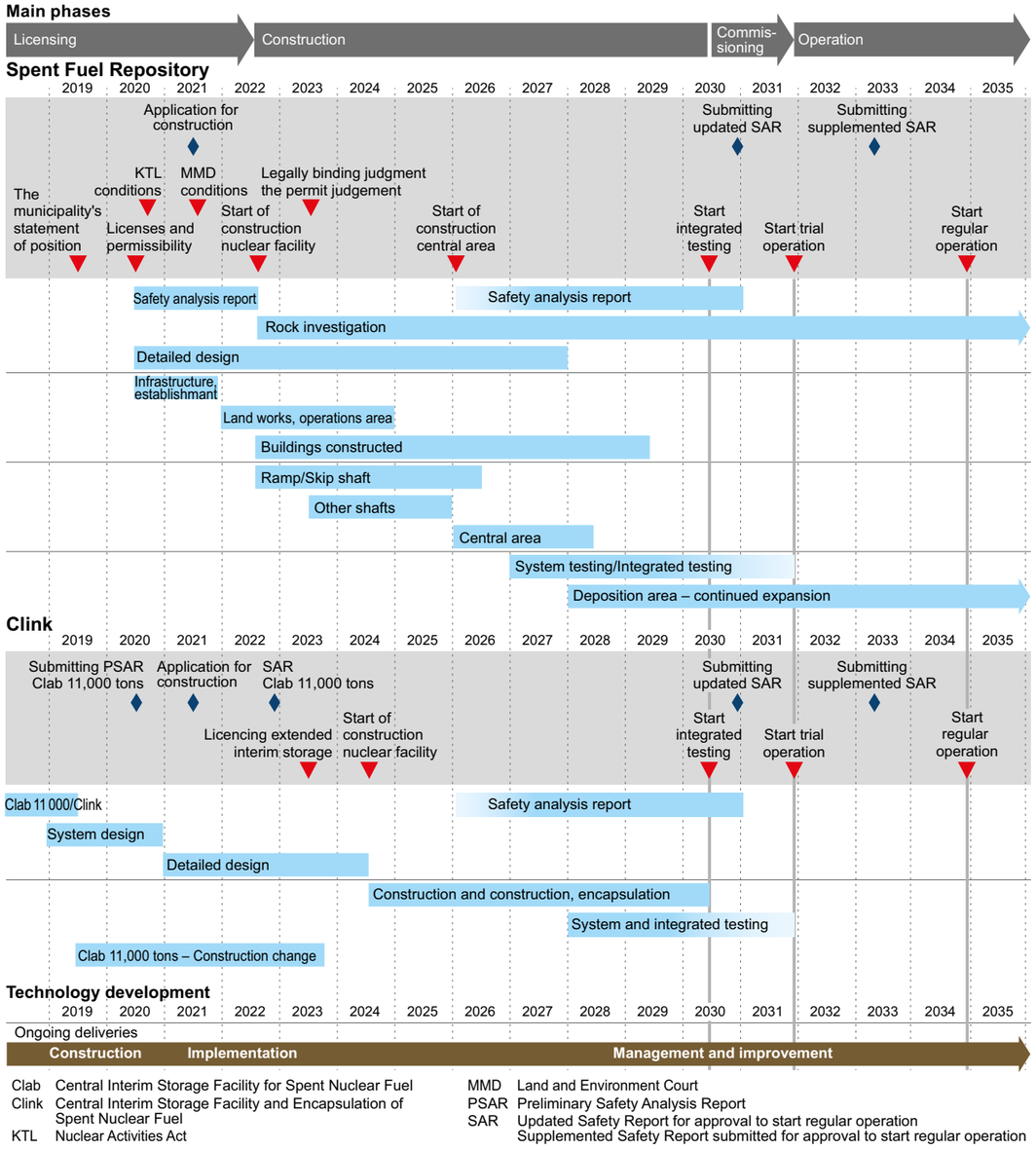


Figure A6 Estimated general timetable for establishment of the spent fuel repository and Clink based on the current status of the licensing process for KBS-3.

received statements from a range of referral bodies in Sweden and neighbouring countries. In September and October 2017, the Court conducted a five-week public court hearing on SKB's licence application under Sweden's environmental legislation. SSM participated in the Court's consultation process and gave independent testimony on matters relating to radiation safety during the public hearing. During the hearing, certain long-term safety issues were debated in detail, in particular the potential extent of degradation of copper canisters by various corrosion mechanisms in the repository post-closure environment.

The role of SSM has been to review SKB's licence applications for a Government decision under the Act on Nuclear Activities. This also included a formal national consultation process involving a wide range of referral bodies, including local, regional and national authorities, higher education institutions and environmental organisations. SSM's review and assessment of the licence applications has entailed judgment as to whether SKB has made a credible case for the feasibility of its plans for the facilities and whether, when taken forward to detailed design and industrial implementation, they can be expected to comply

Figure A7 The facilities at Studsvik.

with all relevant radiation safety requirements, including those applying to the repository safety case after closure.

In January 2018, both SSM and the Court submitted their final review statements to the Government. SSM recommended the approval of SKB's licence applications to possess, construct and operate an encapsulation plant and a final repository under the nuclear activities act. The Court on the other hand stated that SKB would need to present further documentation clarifying the long-term protective function of copper canisters, in order for the repository to be considered permissible in accordance with the provisions of the Environmental Code. In addition, the Court highlighted the need for legal clarification regarding responsibility for the repository after its final closure.

In April 2019, SKB submitted supplementary information requested by the Government, including results from further experimental and theoretical studies relating to potential corrosion mechanisms identified by the court. In a public consultation, stakeholders were given the possibility to state their opinions on the additional material. Some maintained their previously expressed view that more time is needed for additional research and development of the repository concept. SSM, after a thorough technical review of the new material, reiterated its earlier statement that SKB's preferred site is suitable, the disposal concept is feasible and the safety case fulfils strict regulatory requirements.

At the time of preparing this report, the licence applications remained with the Government for decision. See Figure A6 with SKB's tentative time schedule below.

A.8.3 Radioactive waste management

A.8.3.1 Existing radioactive waste management practices and facilities

Management practices at the nuclear power plant sites
Waste management at the NPP sites is fully integrated into the operations at each site. Fulfilment of the requirements of SSM's general regulations is accomplished and verified through regulatory review and inspection activities at the nuclear power plants, as reported under the Convention on Nuclear Safety. Most of the low and intermediate level radioactive wastes (LILW) are conditioned (solidified, compacted, etc.) at the point of origin, i.e. at the reactor sites. Some wastes are sent to Studsvik's waste treatment facilities for incineration or melting. More details are found in section D.1.4.1.

Management practices at the Studsvik site
Early nuclear research activities started in Stockholm in the 1950s and some nuclear laboratories were also established at the Studsvik site, located around 30 km from the town of Nyköping (see Figure A7). Basically all nuclear research activities were moved during the 1960s to Studsvik, where also research reactors were constructed and operated until 2005. As of today, three companies operate facilities at the site under a nuclear licence, i.e. Studsvik Nuclear AB (SNAB), Cyclife Sweden AB and AB Svafo.

Studsvik Nuclear AB (SNAB) provides services in fuel and materials technologies to the nuclear power industry. Facilities operated by SNAB include the hot cell laboratory (HCL), the active metal laboratory (AKL) and the storage facility (FA).

Cyclife Sweden AB, owned by French EDF, manages Studsvik's waste treatment facilities. These include the incineration facility (HA), the melting facility (SMA) and treatment facilities for radioactive non-nuclear waste (FR0-A and R0-A).

Svafo, which is owned by the companies operating nuclear power reactors, treats and stores radioactive legacy waste from former research and development operations conducted in Sweden. Svafo also manages liquid radioactive waste from other Studsvik facilities. Svafo is in addition responsible for decommissioning the R2/R2-0 research and materials testing reactor at Studsvik that was shut down in 2005, see Figure A8. Decommissioning of the reactor is ongoing and expected to be finished in 2020. Facilities operated by Svafo are the treatment facility for intermediate waste (HM) and the interim storage facility for low and intermediate level waste (AM).

The radioactive waste treatment and management facilities at the Studsvik site are described in more detail in section D.1.4.1.

Repository for radioactive operational waste, SFR
SFR is located approximately 140 kilometres north of Stockholm, close to the Forsmark nuclear power plant. The facility is situated in crystalline bedrock beneath the Baltic Sea, covered by about 60 metres of rock. It is designed for disposal of short-lived low and intermediate level radioactive waste from Swedish nuclear power plants and Clab, and for disposal of similar waste from other usage in industry, research and medicine.

SFR currently consists of four 160-metre-long waste vaults, plus a 70-metre-high cavern in which a concrete silo has been built. The facility was taken into operation in 1988. Its total capacity is 63,000 m^3 and about 40,000 m^3 had been used by the end of 2019. The silo is shown in Figure A9. Principal data as well as information on inventories are contained in section D.1.4.2.

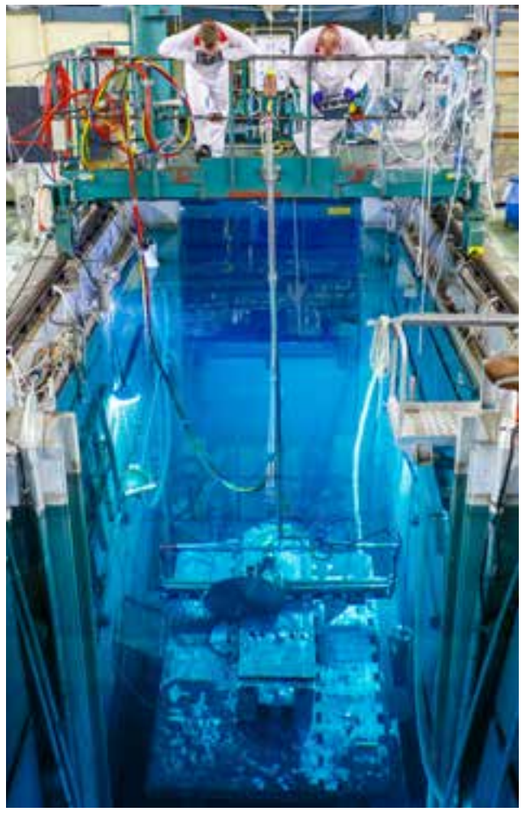


Figure A8 Decommissioning of the R2 research and materials testing reactor at Studsvik.

Figure A9 Photo from the top of the silo in SFR and an illustration of the design. Waste packages are placed in shafts in the silo.

Shallow land burials
The nuclear power plants at Ringhals, Forsmark and Oskarshamn, as well as the Studsvik site, have shallow land burials for solid short-lived low-level operational waste (<300 kBq/kg). Each burial is licensed for a total activity of between 100 and 1100 GBq (the highest level permitted under the legislation is 10 TBq, of which a maximum of 10 GBq may consist of alpha-active substances).

Clearance
Material may be cleared for unrestricted use or for disposal as conventional non-radioactive waste (see also sections E.2.9.4 and F.6).

A.8.3.2 Planned radioactive waste management practices and facilities

The low and intermediate level waste programme comprises three main activities: the extension of the SFR facility to receive decommissioning waste; development of a repository for long-lived low and intermediate level waste, SFL; and interim storage of long-lived waste. The general timetable is illustrated in Figure A10 and described below.

Extension of the SFR facility
In December 2014, SKB applied for permission to extend the final repository for short-lived low and intermediate level waste at Forsmark (SFR) so that it can also accommodate decommissioning waste (see Figure A11). Licence applications have been filed with regard to both the Environmental Code and the Act on Nuclear Activities. The two applications were reviewed in parallel by the Land and Environment Court and SSM, respectively. During the review, SSM issued a statement to the Court regarding its

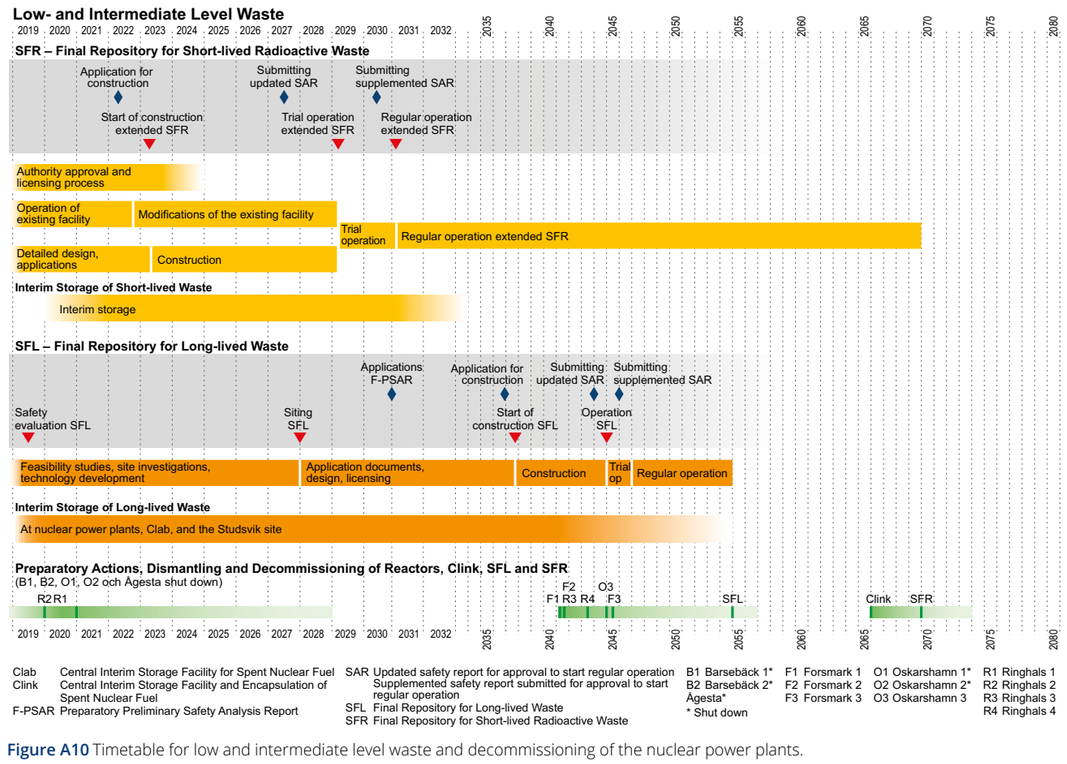


Figure A10 Timetable for low and intermediate level waste and decommissioning of the nuclear power plants.

view on the completeness of the application on matters relating to radiation safety and the permissibility of the planned extension.

The objective of SSM's review was to assess whether the proposed extension is sited, designed and can be expected to be operated and closed in such a way that nuclear safety, security, and radiation protection requirements, as well as the general 'rules of consideration' stipulated in the Environmental Code, are met. SSM undertook an initial review of the completeness of the application and issued a number of requests to SKB for clarification and supplementary information.

SSM participated in the Court's consultation process and gave independent testimony during the two-week public hearing that was held in September 2019. Shortly afterwards, in its final review statement to the Government in October, SSM recommended the approval of SKB's licence application for the proposed extension and continued operation of the SFR facility. One month later, the Land and Environment Court also recommended in its statement to Government that the extension be considered a permissible activity according to the Environmental Code.

At the time of preparing this report, the licence applications remained with the Government for decision. If the Government decides to approve the licence applications, however, the Municipality of Östhammar will first be requested to issue a statement regarding its right to veto the decision. A Government licence under the Act on Nuclear Activities is then followed by a stepwise process whereby SSM's approval of updated safety analysis reports, plans and other related documentation is required prior to authorisation for the construction, start of trial operations and start of routine operations (see also section E.2.9.1). Furthermore, SSM may stipulate additional licence conditions.

The Land and Environment Court will issue permits and licence conditions under the Environmental Code after a new hearing has been held.

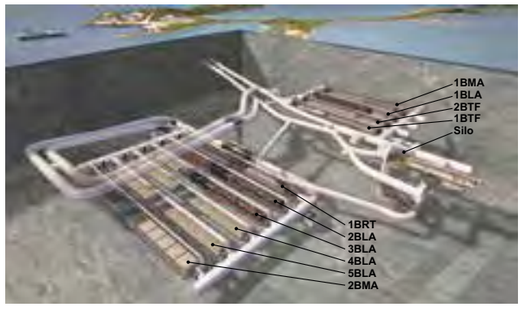
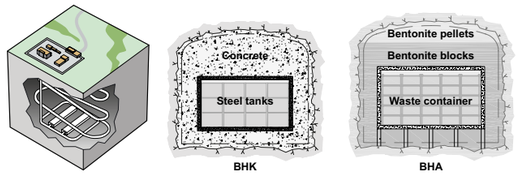


Figure A11 The existing facility in Forsmark for short-lived low and intermediate level operational radioactive waste, SFR (the silo and vaults in the upper right-hand part of the figure) and the planned extension (lower left). The extended SFR will consist of four additional waste vaults for low-level waste (2–5 BLA), one additional waste vault for intermediate level waste (2BMA) and one waste vault for segmented reactor pressure vessels (1BRT).

Repository for long-lived low and intermediate level waste (SFL)
According to the current plans, a licence application to build a repository for long-lived low and intermediate level waste, SFL, will be submitted in 2030 and operations are planned to commence in 2045. The origin of this waste is legacy waste (primarily research), industry, medical applications, used reactor core components, reactor pressure vessels from PWRs, and control rods from BWRs. The legacy waste is currently stored at Studsvik, core components and control rods are stored at the nuclear power plants and at Clab. The volume of SFL will be relatively small compared to SKB's other disposal facilities. The total volume is estimated to 16,000 m^3. According to the current concept, SFL is designed as a deep geological repository with two different sections (see Figure A12):

– one waste vault, designed with a concrete barrier, for metallic waste (core components and control rods) from the nuclear power plants;

– one waste vault, designed with a bentonite barrier, mainly for legacy waste.



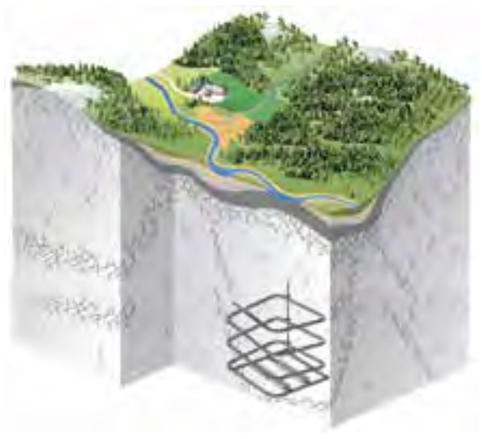


Figure A12 Illustration of the current concept for SFL as a geological repository with two different sections. Metallic waste from the nuclear power plants is placed in a waste vault (BHK) designed with a concrete barrier, and legacy waste is placed in a waste vault (BHA) designed with a bentonite barrier. An evaluation of the post-closure safety for this design was presented in 2019.

During the period 2015–2019, an evaluation of post-closure safety for the proposed repository concept has been carried out with the purpose to provide input to the subsequent, consecutive steps in the development of SFL. These consecutive steps include further development of the design of the engineered barriers, waste acceptance criteria and the site selection process for SFL. The evaluation was performed by analysing several cases that together indicate under what conditions the repository concept has the potential to fulfil regulatory requirements. Furthermore, the results have been used to identify areas for further RD&D, including safety analysis methodology and its implementation, efforts needed to address the full set of post-closure regulatory requirements, the siting process, assessment model development, and technical design improvements.

The stepwise siting process for SFL was initiated during the period. The first step constituted an account of background data and fundamental conditions and points of departure for the siting process for SFL and is described in SKB's RD&D Programme 2019. The results of the evaluation of post-closure safety for SFL, as well as experience of safety assessments previously conducted by SKB for repositories in crystalline bedrock, were taken into account. The plan for the consecutive steps, include an initial feasibility study phase, a site investigation phase and site selection.

Technological development of the repository concept for SFL will commence in the next few years and is planned to result in a choice of concepts for SFL by the mid-2020s.

Acceptance criteria for the long-lived low and intermediate level waste will be established in conjunction with the submission of the SAR for SFL. However, today there is a need to clarify the planning prerequisites for management of the waste arising during operation and decommissioning of the nuclear facilities. The recently completed safety evaluation for SFL provides some guidance for future requirements on the waste. In addition to requirements related to the post-closure safety of the repository, requirements related to the construction, transportation and handling during operation will serve as a basis to further define acceptance criteria for the waste. As the details of the repository design are progressively finalised, it will be possible to further define the set of requirements and eventually establish acceptance criteria. The nuclear power plants should not commence final conditioning of waste until a verified repository concept exists.

Interim storage of long-lived waste
SFL is planned to be commissioned around 2045. Since several reactors according to the current plan will be decommissioned before the repository is finished, capacity for interim storage of the long-lived waste from decommissioning is needed. The nuclear power plants will arrange for interim storage at their sites or elsewhere. One example is the establishment of an interim storage facility for long-live waste from segmentation of reactor internals that was established on the Barsebäck site in 2015. Another example is a planned new storage building in Studsvik for low- and intermediate level decommissioning waste from the research reactor R2, which will be established and taken into operation in 2021.

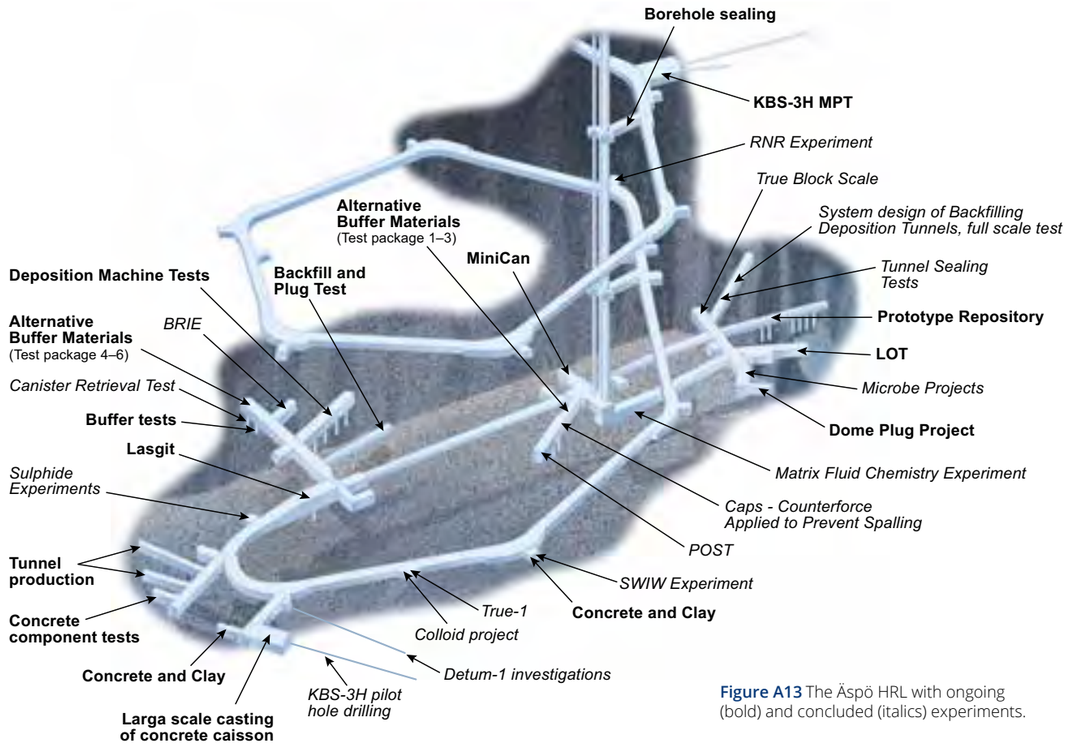


Figure A13 The Äspö HRL with ongoing (bold) and concluded (*italics*) experiments.

The transportation system will be supplemented with a new type of transport container for shipping long-lived waste placed in steel tanks. The transport container is called ATB 1T. It is, due to its activity content, designed in accordance with the IAEA requirements type B(U), and delivery of the first container is expected at the earliest in 2021.

A.8.4 Research and demonstration facilities

The Äspö Hard Rock Laboratory
The Äspö Hard Rock Laboratory (HRL) is situated on the island of Äspö, north of the Oskarshamn nuclear power plant. The main tunnel descends in two spiral turns to a depth of 460 metres. Various experiments are conducted in niches in the short tunnels that branch out from the main tunnel. An illustration of the HRL and concluded and ongoing (2019) experiments are shown in Figure A13.

The Äspö HRL is used to investigate the behaviour of the barriers in the repository for spent nuclear fuel (canister, buffer, backfill and rock). Also, research on LILW is performed here. Development and demonstration of equipment to be used in future facilities are also performed in the HRL.

The Canister Laboratory
The Canister Laboratory, situated in the harbour area at Oskarshamn, has been in operation since 1998. The laboratory is used for developing sealing technology for the copper canisters, including welding and non-destructive testing techniques for the canister components. Figure A14 illustrates equipment for friction stir welding of copper lids.

The Multi-purpose Test Facilities
The Multi-purpose Test Facilities were taken into operation in 2007. The facilities are situated adjacent to the Äspö HRL and supplements the experiments being conducted there, see Figure A15.

In the Multi-purpose Test Facilities, the properties of the bentonite are tested by (for example) simulating water conditions in a controlled manner. Here, SKB is also developing methods for backfilling of repository tunnels and construction of plugs to seal deposition tunnels.

A.9 Swedish participation in international activities to enhance safety and radiation protection

Sweden is a member of the IAEA and the OECD Nuclear Energy Agency (NEA), with permanent delegations to both organisations. Sweden has been a member state of the European Union (EU) since 1995.

Sweden is party to the relevant conventions applicable to a country with nuclear power plants in operation, encompassing nuclear safety, emergency preparedness and response, nuclear liability, spent nuclear fuel, radioactive waste and physical protection. Sweden has also formally committed to implement the Code of Conduct on the Safety and Security of Radioactive Sources and the Supplementary Guidance on the Import and Export of Radiation Sources.

A.9.1 The regulatory authority

The regulatory authority's missions and tasks are defined in the Ordinance (2008:452) with instructions for the Swedish Radiation Safety Authority (SSM), see section E.3. The Ordinance declares that SSM (among other tasks) shall carry out Swedish obligations in accordance with conventions, EU ordinances/directives and other binding agreements (e.g. to provide points of contact, reporting, and act as the national competent authority), undertake international cooperation work with national and multinational organisations, and monitor and contribute to the progress of international standards and recommendations.

In addition, SSM is involved in international development cooperation within the areas of reactor safety, radiation protection, nuclear waste safety and non-proliferation, see section A.9.2.

SSM's international liaison activities encompass about 150 international groups, the majority of which are related to nuclear safety and radiation protection issues. Such cooperation takes place within the frameworks of the IAEA, NEA and EU, in connection with international conventions ratified by Sweden, and through networks such as the Western European Nuclear Regulators' Association (WENRA), the European Nuclear Security Regulators' Association (ENSRA), the Heads of European Radiation Control Authorities (HERCA), and the International Nuclear Regulators' Association (INRA).

IAEA safety standards form the main basis of SSM's regulatory requirements and guides. SSM is represented in the IAEA safety standards committees (CSS, NUSSC, WASSC, RASSC, EPReSC and TRANSSC) and nuclear security guidance committee (NSGC).

As a member of the European Union, Sweden is obliged to comply with the directives and legal requirements emanating from the Euratom Treaty. SSM has a key role in the transposition of Euratom directives into Swedish legislation.

SSM is a member of ENSREG (European Nuclear Safety Regulators' Group), an independent, expert advisory group to the European Commission. It is composed of senior officials from national regulatory or nuclear safety authorities from all EU member states. SSM has been active in developing implementation and reporting guidelines for the directive on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste (2011/70/Euratom).

SSM has contributed significantly to WENRA's work on harmonising safety approaches between European member countries with regard to the development of common safety reference levels for decommissioning, storage of waste and spent fuel and geological disposal and waste processing.

SSM also contributes to the work performed within the Convention on Nuclear Safety (CNS) as well as the Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR) and the Helsinki Commission (HELCOM) conventions for reduction of releases of radioactive substances from nuclear facilities.

In addition to multilateral collaboration, SSM has bilateral agreements with twelve countries relating to liaison and exchange of information on agreed issues (e.g. nuclear safety, emergency preparedness, occupational exposure, environmental radiological protection, and radioactive waste management). These countries are Australia, Finland, France, Georgia, Germany, Japan, the Republic of Korea, Russia, Lithuania, Ukraine, the United Kingdom and the United States. Additionally, Sweden has special agreements concluded with the Nordic countries (Denmark, Finland, Iceland and Norway) regarding emergency preparedness and information exchange on the technical design of nuclear facilities. A bilateral protocol on liaison and information exchange regarding emergency preparedness has been signed with the Russian Federation. A Memorandum of Understanding on liaison and information exchange has also been signed between the Nordic regulatory bodies (the Norwegian Radiation and Nuclear Safety Authority, the Finnish Radiation and Nuclear Safety Authority and the Swedish Radiation Safety Authority) and the Ministry for Emergency Situations of the Republic of Belarus.

A multinational liaison group (DGRRF) has been established by the nuclear regulators of Sweden (SSM), Canada (CNSC), Finland (STUK), France (ASN), Switzerland (ENSI) and the United States (NRC) with the objective of sharing regulatory experiences in the licensing, siting, safety assessment and construction of deep geological repositories (DGRs) through annual workshops. The latest workshop, held in France in January 2020, was hosted by the French Nuclear Safety Authority (ASN).

SSM also participates in international research, primarily in the frameworks of the EU research programmes, but also as part of the IAEA and OECD/NEA.

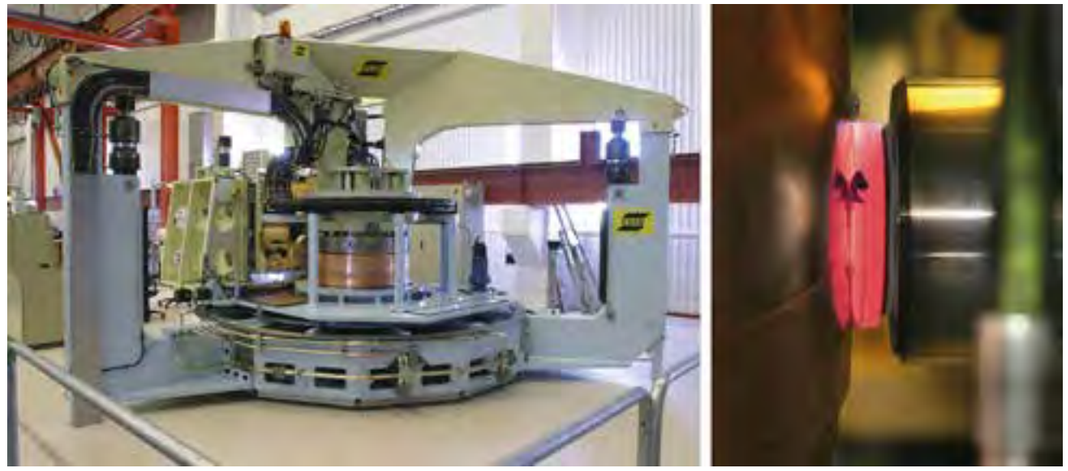


Figure A14 Friction stir welding of copper lids. The image to the left shows Canister Laboratory equipment for development, and the image to the right shows the rotating tool that is pressed into the joint between the parts that are to be combined.

Figure A15 The Multi-purpose Test Facilities at Äspö. The photo shows the testing of a self-positioning robot for backfilling a deposition tunnel with bentonite blocks.

SSM regularly provides experts to assist in international peer review missions, mainly in the framework of the IAEA's IRRS and ARTEMIS review services.

SSM's international involvement and work is continually reviewed with respect to available staff resources and as part of upholding competent regulatory supervision of licensees and activities in Sweden. In order to support priority decisions, a classification scheme and a policy for international work are part of SSM's integrated and process-based management system.

A.9.2 SSM's international support programmes

Since 1992, Swedish authorities have been engaged in providing assistance to states of Eastern and Central Europe in the areas of nuclear safety, nuclear security and radiation protection. Today, the aims of the bilateral assistance that is carried out by the Swedish Radiation Safety Authority, SSM are to:

- improve reactor safety and minimise the risk of a nuclear accident involving uncontrolled radioactive releases at the facilities in question;
- improve conditions so that radioactive waste, including spent nuclear fuel, shall be handled and stored in a manner that is acceptable from the point of view of safety and radiation protection, regarding personnel, the public and the environment;
- strengthen non-proliferation measures and institutions;
- improve national preparedness and awareness as far as concerns radiation protection of people and the environment;
- strengthen the legislation and regulatory framework related to the operation of nuclear facilities and handling of radioactive waste;
- contribute to the development and strengthening of the countries' authorities and organisations within national emergency preparedness systems and to establish cooperation in the event of an emergency situation in the Baltic region; and
- support regional cooperation in the areas of nuclear and radioactive waste safety among the GUAM countries (Georgia, Ukraine, Azerbaijan and Moldova).

Since 2018, SSM has also taken on a new role as implementing organisation for international support projects, funded by the European Commission and by the Swedish International Development Cooperation Agency, addressing challenges related to management of legacy radioactive waste and radioactive sources in Georgia and Moldova,. These projects aim at strengthening the national radioactive waste management system, development of siting and disposal programmes and supporting capacity building of national authorities, waste management organisations and other key national institutions.

Currently, Sweden's cooperation partners are Russia, Ukraine, Moldova, Georgia, and Belarus. As of 2020 there are also plans for establishing cooperation with Armenia.

A.9.3 Licence holders

A.9.3.1 General information

Utilities in Sweden have a tradition of being quite active in international cooperation to enhance nuclear safety by sharing experiences, contributing to work on international regulations and guidelines, and participating in safety assessments and peer reviews.

Swedish fuel cycle facility licence holders, such as Studsvik Nuclear AB, Cyclife Sweden AB and Westinghouse Electric Sweden AB, are global companies offering a wide range of advanced technical services to the international nuclear power industry in areas including waste treatment, consultancy services and fuel and materials products and technology. Also, representatives from e.g. SKB, AB Svafo and Barsebäck Kraft AB participate actively in international working groups whose focus is on waste management and decommissioning.

A.9.3.2 SKB

SKB gives international cooperation high priority and works together with corresponding waste management organisations in Canada, Finland, France, Germany, Japan, Spain, Switzerland, the United Kingdom and the United States of America.

The aim of SKB's international activities is to monitor research and development work conducted in other countries and to participate in international projects within the field of spent nuclear fuel and radioactive waste management but also to share knowledge and developed methods with others. The international work provides perspectives to the domestic programme and contributes to maintaining state-of-the-art competence in relevant scientific areas.

SKB participates actively in different IAEA, EU and OECD/NEA committees and working groups. SKB is involved also in a large number of research projects within these international organisations. SKB takes an active role within the executive group of the 'Implementing Geological Disposal of Radioactive Waste Technology Platform' (IGD-TP) in which twelve waste management organisations collaborate. The IGD-TP identifies and prioritises research and technological development initiatives that are necessary and time-critical for ensuring that the first geological repositories in Europe will be in operation by 2025. The IGD-TP has no financial resources at its disposal but has an indirect influence on how the EU's research funding is allocated within the area. This influence has become more direct since IGD-TP acts as one of the colleges in the joint programming of EURAD, the new initiative for radioactive waste research in EU. SKB is also directly engaged in the Bureau of the EURAD.

SKB's rationale for continuous participation in the platform is that it provides a shared arena for scientific cooperation and exchange throughout Europe.

SKB's collaboration with Posiva in Finland is the most extensive forum, comprising projects in the fields of repository and encapsulation technology. SKB has also extensive collaboration with the Nuclear Waste Management Organization, NWMO, in Canada comprising research projects related to rock mechanics and canister integrity.

An important example of SKB's international research cooperation is represented by the Äspö Hard Rock Laboratory, where organisations from Finland, the United Kingdom, Germany and Japan conduct joint studies. The research on bentonite conducted at Äspö also includes collaboration with Russian scientists.

SKB International, a wholly owned subsidiary of SKB, provides services related to the laboratory work as well as providing knowledge transfer and safety case services to organisations in China, Taiwan, Japan, Denmark and the Czech Republic.

A.9.4 International peer review missions

In 2016, a follow-up IRRS mission was performed in Sweden. Section K.1.6 gives an account of the completion of the actions arisen from that follow-up mission. With the 2012 full scope mission and the 2016 follow-up mission, Sweden completed the first round of international safety peer reviews. The Swedish Government has since officially requested the IAEA to carry out a new IRRS mission to Sweden in autumn 2022, followed by an ARTEMIS mission in spring 2023 on Sweden's waste management implementation (see section K.4).

Section B – Policies and Practices

B.1 Article 32.1: Reporting

1. In accordance with the provisions of Article 30, each Contracting Party shall submit a national report to each review meeting of Contracting Parties. This report shall address the measures taken to implement each of the obligations of the Convention. For each Contracting Party the report shall also address its:

(i) spent fuel management policy;
(ii) spent fuel management practices;
(iii) radioactive waste management policy;
(iv) radioactive waste management practices; and
(v) criteria used to define and categorise radioactive waste.

B.1.1 Spent fuel and radioactive waste management policy

Swedish policy for spent fuel and radioactive waste management is based on the legal requirements contained in the Act on Nuclear Activities, Radiation Protection Act and Environmental Code. The national policy is also in accordance with the European Union's Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent nuclear fuel and radioactive waste (the Euratom waste directive), which has been formally implemented in Swedish legislation since August 2013.

The most important legal principles that constitute the national policy can be summarised as follows:

1. The licence holder of a nuclear activity as well as the operatsor of activities involving ionising radiation are to safely manage and dispose of spent nuclear fuel and radioactive waste arising from their activities.
2. Funding liability
   - » The expenses for management of spent nuclear fuel and radioactive waste from nuclear activities shall be covered by revenues from the production of energy that has given rise to these expenses.
   - » The producer of radioactive waste outside of the nuclear fuel cycle shall provide financial security for the waste management costs and recovery measures that the activity can incur.
3. The state has ultimate responsibility for spent nuclear fuel and radioactive waste.
4. Each country is responsible for the spent nuclear fuel and radioactive waste generated in that country. Disposal of spent nuclear fuel and radioactive waste from a foreign country is not allowed in Sweden other than in exceptional cases. It is also prohibited to dispose of Swedish spent fuel or radioactive waste in another country, unless a number of conditions are fulfilled in line with the Euratom waste directive and international conventions.

Another basic presumption as regards spent fuel management is the principle of direct disposal, i.e. that reprocessing will not take place even though this is not prohibited by law. In practice, spent nuclear fuel is both considered and treated as waste, although it is not legally defined as waste according to the Act on Nuclear Activities until disposed of in a repository.

The national policy is further based on the principles in Article 4 of the European Union's radioactive waste and spent fuel management directive 2011/70/Euratom, which in addition to the above requires that:

- the generation of radioactive waste shall be kept to the minimum that is reasonably practicable;
- the interdependencies between all steps in spent fuel and radioactive waste generation and management shall be taken into account;
- spent fuel and radioactive waste shall be safely managed, including in the long term with passive safety features;

– implementation of measures shall follow a graded approach; and
– an evidence-based and documented decision-making process shall be applied with regard to all stages of the management of spent fuel and radioactive waste.

Other principles constituting national policy are also included in the legal and regulatory framework. The Radiation Protection Act is based on the International Radiation Protection Commission's (ICRP) principles on justification, optimisation and dose limitation. The objective of the Swedish Environmental Code is to promote sustainable development and ensure a healthy environment for current and future generations. The general 'rules of consideration' established in the Code identify important principles that are applicable even to nuclear activities and activities involving radiation, e.g. the knowledge principle, the precautionary principle and use of best available technology (BAT), the selection of the most suitable site and the remediation liability principle. These are further described in section E.2.1.

B.1.2 Spent fuel and radioactive waste management practices

B.1.2.1 Spent fuel and radioactive waste from nuclear activities

Under the Act on Nuclear Activities, a party that holds a licence to conduct nuclear activities in Sweden has an obligation to ensure that the nuclear material, spent nuclear fuel and nuclear waste generated by the operations are safely managed and disposed of. This obligation signifies an extensive commitment on the part of a licensee until a final disposal facility for this waste has ultimately been closed. The utilities operating nuclear power reactors are also subject to a specific obligation collaboratively to establish and carry out a research and development (RD&D) programme for the safe handling and disposal of spent fuel and nuclear waste. They are further obliged collaboratively to prepare cost estimates for management and disposal of spent fuel and nuclear waste as a basis for payments to be made to the Swedish Nuclear Waste Fund.

Very low level short-lived waste (VLLW-SL) is disposed of in shallow land burials that are licensed under the Act on Nuclear Activities or subject to clearance in accordance with the regulatory authority's requirements and decisions. Waste subject to clearance may be released for unrestricted use, disposed of in municipal landfills or incinerated using specific furnaces (only applicable to contaminated oil).

Short-lived low and intermediate level waste (LILW-SL) is treated and packaged according to a standardised system with predefined waste type descriptions (WTD) and disposed of in the repository for operational waste (SFR) in rock caverns in crystalline bedrock beneath the Baltic Sea, covered by about 60 metres of rock. The repository consists of five different caverns, including a 50 m deep silo. Wastes are directed to different parts of the repository depending on factors such as activity content and chemical characteristics.

Long-lived low and intermediate level waste (LILW-LL) will be disposed of in a deep geological repository situated in rock caverns in crystalline bedrock. Until this repository has been constructed, the long-lived waste is stored at the reactor sites, at the Studsvik site, or in storage pools in the interim storage facility for spent nuclear fuel (Clab).

Spent nuclear fuel is stored in fuel pools at the nuclear power plants for at least nine months before it is transported to the central interim storage facility for spent nuclear fuel (Clab). The safety and security measures taken at the NPPs do not differentiate between spent or partially spent fuel. According to the current plans, following a storage period in Clab of about 30–40 years, fuel elements will be encapsulated in copper canisters and transported to the spent nuclear fuel repository for disposal. The proposed disposal method is based on the conceptual design of a deep geological repository in hard rock, with a system of engineered barriers ensuring post-closure safety through containment over very long periods of time.

B.1.2.2 Radioactive waste from non-nuclear activities

The practices developed through the nuclear waste management programme also apply to radioactive waste from non-nuclear activities. Waste arising outside of the nuclear fuel cycle may therefore, when needed and if appropriate, be disposed of in disposal facilities for nuclear fuel cycle wastes.

B.1.3 Criteria for defining and categorising radioactive waste

B.1.3.1 Definitions

The definition of nuclear waste according to the Act on Nuclear Activities is:

– spent nuclear fuel that has been placed in a repository;
– radioactive material that has been generated in a nuclear facility and that has not been produced at or taken from the facility to be used for educational or research purposes or for medical, agricultural engineering or commercial purposes;
– material or any item that has belonged to a nuclear facility and become contaminated by radioactivity and which shall no longer be used in such facility, and
– radioactive parts of a nuclear facility that is being decommissioned.

The definition of radioactive waste according to the Radiation Protection Act is:

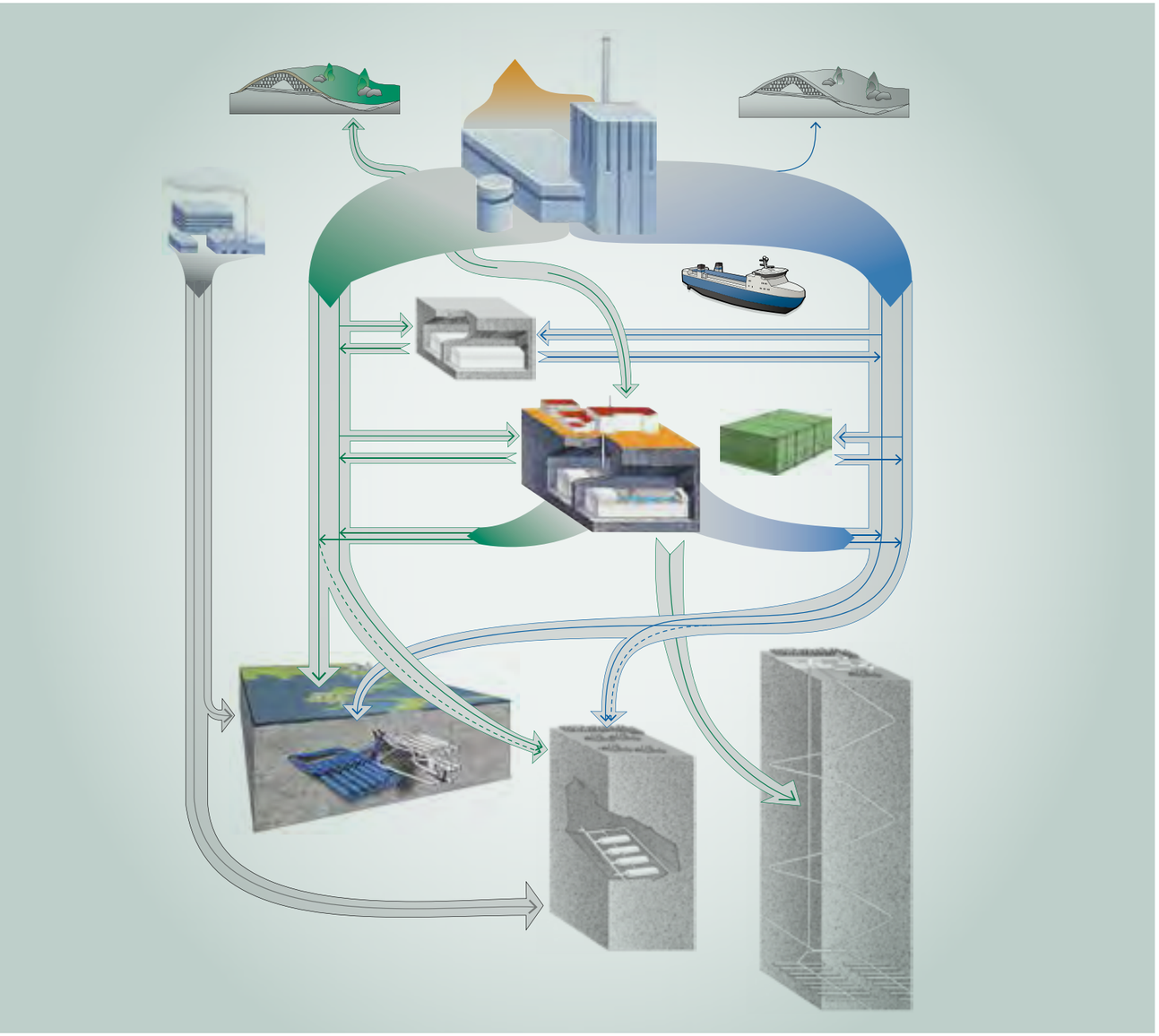
– any substance or object that the holder disposes of or intends or is obliged to dispose of.

Table B1 Waste classification scheme used by the Swedish nuclear industry.

	Cleared material	Very low level waste short-lived (VLLW-SL)	Low level waste short-lived (LLW-SL)	Intermediate level waste short-lived (ILW-SL)	Low and intermediate level long-lived waste (LILW-LL)	High level waste (HLW)
Definition	Material with so small amounts of radioactive nuclides that it has been released from regulatory control.	Contains small amounts of short-lived nuclides with a half-life less than 31 years; dose rate on waste package is less than 0.5 mSv/h. Long-lived nuclides with a half-life greater than 31 years can be present in restricted quantities.	Contains small amounts of short-lived nuclides with a half-life less than 31 years; dose rate on waste package (and unshielded waste) is less than 2 mSv/h. Long-lived nuclides with a half-life greater than 31 years can be present in restricted quantities.	Contains significant amounts of short-lived nuclides with a half-life less than 31 years; dose rate on waste package is less than 500 mSv/h. Long-lived nuclides with a half-life greater than 31 years can be present in restricted quantities.	Contains significant amounts of long-lived nuclides with a half-life greater than 31 years, exceeding the restricted quantities for short-lived waste.	(Nuclear fuel) Typical decay heat >2 kW/m^3 and contains significant amounts of long-lived nuclides with a half-life greater than 31 years, exceeding the restricted quantities for short-lived waste.
Specific considerations	–	–	–	Requires radiation shielding during transport.	Requires special containment during transport.	Requires cooling and radiation shielding during intermediate storage and transport.
Destination	No final repository needed.	Shallow land burial.	Final repository for short-lived radioactive waste (SFR).	Final repository for short-lived radioactive waste (SFR).	Final repository for long-lived radioactive waste (SFL).	Final repository for spent fuel.

B.1.3.2 Categorisation

There is no legally defined waste classification scheme in Sweden for nuclear or radioactive waste. There is, however, an established waste characterisation system that is used by the Swedish nuclear industry. The characterisation system is destination-driven and customised with regards to existing and planned repositories (end points) as shown in Table B1. Section F.3 describes the waste management process and application of waste acceptance criteria. See also section K.2.2.



Section C – Scope of Application

C.1 Article 3: Scope of application

- This Convention shall apply to the safety of spent fuel management when the spent fuel results from the operation of civilian nuclear reactors. Spent fuel held at reprocessing facilities as part of a reprocessing activity is not covered in the scope of this Convention unless the Contracting Party declares reprocessing to be part of spent fuel management.
- This Convention shall also apply to the safety of radioactive waste management when the radioactive waste results from civilian applications. However, this Convention shall not apply to waste that contains only naturally occurring radioactive materials and that does not originate from the nuclear fuel cycle, unless it constitutes a disused sealed source or it is declared as radioactive waste for the purposes of this Convention by the Contracting Party.
- This Convention shall not apply to the safety of management of spent fuel or radioactive waste within military or defence programmes, unless declared as spent fuel or radioactive waste for the purposes of this Convention by the Contracting Party. However, this Convention shall apply to the safety of management of spent fuel and radioactive waste from military or defence programmes if and when such materials are transferred permanently to and managed within exclusively civilian programmes.

C.1.1 Scope of application

Reprocessing of spent fuel is not included in the Swedish waste management programme and is therefore not subject to reporting under this Article.

Sweden does not declare waste containing only naturally occurring radioactive material and which does not originate from the nuclear fuel cycle as radioactive waste for the purpose of the Joint Convention pursuant to Article 3, paragraph 2, second sentence.

C.1.2 Conclusion

Sweden complies with the obligations under Article 3 regarding spent fuel that results from the operation of civilian nuclear reactors, radioactive waste that results from civilian applications, and spent fuel or radioactive waste within military or defence programmes.

Section D – Inventories and Lists

D.1 Article 32.2: Reporting

1. This report shall also include:

(i) a list of the spent fuel management facilities subject to this Convention, their location, main purpose and essential features;

(ii) an inventory of spent fuel that is subject to this Convention and that is being held in storage and of that which has been disposed of. This inventory shall contain a description of the material and, if available, give information on its mass and its total activity;

(iii) a list of the radioactive waste management facilities subject to this Convention, their location, main purpose and essential features;

(iv) an inventory of radioactive waste that is subject to this Convention that:

a. is being held in storage at radioactive waste management and nuclear fuel cycle facilities;

b. has been disposed of; or

c. has resulted from past practices.

This inventory shall contain a description of the material and other appropriate information available, such as volume or mass, activity and specific radionuclides;

(i) a list of nuclear facilities in the process of being decommissioned and the status of decommissioning activities at those facilities.

D.1.1 Management of spent nuclear fuel

Spent nuclear fuel from Swedish NPPs is temporarily stored in fuel pools before being transported to the central interim storage facility for spent nuclear fuel (Clab), where it will be stored for at least 30 years before being encapsulated and deposited in a disposal facility.

Most spent nuclear fuel in Sweden emanates from commercial nuclear power plants at the Forsmark, Oskarshamn and Ringhals sites, but also from the Barsebäck site, which was permanently shut down on 31 May 2005. Small amounts of spent nuclear fuel originate from the research reactor R2 at the Studsvik site. In addition, some spent nuclear fuel from the closed Ågesta reactor and from the decommissioned research reactor, R1, must be managed.

The spent fuel from the closed research reactor R2 at the Studsvik site has been exported to the United States according to contractual agreements.

About 3.3 kilograms of separated plutonium and approximately 9 kilograms of natural and depleted uranium, mainly from reprocessing of some spent fuel from the Ågesta reactor, was exported to US Department of Energy in 2012 within the framework of the Global Threat Reduction Initiative (GTRI). All remaining spent fuel from the operation of the Ågesta reactor is currently stored in Clab awaiting future disposal in Sweden.

The fuel rods used in the R1 research reactor consist of rods of metallic uranium enclosed in an aluminium alloy casing. These have been interim stored at the Studsvik site since the closure of the reactor. This type of metallic fuel is not suitable for the anticipated method for disposal of spent nuclear fuel. The intact part of the spent fuel was therefore separated from the corroded parts and in 2007 sent for reprocessing in the United Kingdom. The separated 1.2 kilograms of plutonium remain in storage in United Kingdom. The remaining waste from the reprocessing activities was sent back to Sweden in 2009.

Ownership of the separated plutonium was transferred to the UK Nuclear Decommissioning Authority (NDA) in 2014 together with the transfer of ownership of 834 kilograms of separated plutonium from reprocessing of spent fuel from OKG AB (see section A.8.1.1). The material, which is presently stored at the Sellafield site, is to be managed together with existing UK plutonium for future use in UK reactors in line with UK policies. The corroded parts of the R1 fuel are still being temporarily stored at the Studsvik site awaiting conditioning before

Table D1 Inventory of spent fuel in NPP pools.

Fuel pool at NPP	Pool capacity	Spent fuel stored as at 31 December 2019	
	No. of fuel assembly positions	No. of assemblies	Tonnes, uranium weight
Oskarshamn 1	969	0	0
Oskarshamn 2	1,052	0	0
Oskarshamn 3	1,040	263	46
Forsmark 1,2,3	3,577	1,010	167
Ringhals 1	1,426	166	29
Ringhals 2	432	230	106
Ringhals 3	381	148	69
Ringhals 4	364	149	69

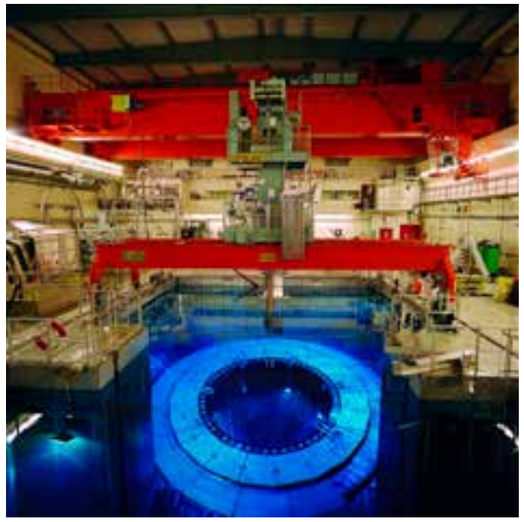


Figure D1 Reactor top and pools at one of the Swedish reactors.

being disposed of in the planned disposal facility for long-lived waste (SFL).

No spent nuclear fuel is currently being disposed of in Sweden.

D.1.2 Spent nuclear fuel facilities and inventories

D.1.2.1 Interim storage at the nuclear power plants

Each NPP unit has a fuel pool close to the reactor vessel in which spent fuel is stored temporarily for at least nine months before being transported to Clab, see Figure D1. The fuel pools constitute integrated parts of the reactor facilities and are for the purpose of the Joint Convention not considered as separate spent fuel management facilities. The quantities of spent fuel stored in pools at the nuclear power reactors as at 31 December 2019 are presented in Table D1. The pool capacity listed corresponds to the storage capacity for spent fuel. The pools also have space for the plundered reactor core, fresh fuel, scrap and boxes.

D.1.2.2 Clab, the central interim storage facility for spent nuclear fuel

Spent fuel assemblies are to be stored at the Clab facility for at least 30 years. The main reason is to allow the thermal output to decay by about 90 per cent before encapsulation and disposal take place. Other highly radioactive components, such as control rods from reactors, are also stored in Clab awaiting disposal. A schematic illustration of Clab is shown in Figure D2.

After being removed from the transport cask in an unloading pool, the spent fuel assemblies are transferred to storage canisters for subsequent transport and storage. A water-filled elevator cage takes the storage canister down to the storage section, where it is placed in a predetermined position in a storage pool. Thus, unloading and all subsequent handling of spent fuel assemblies are performed under water using hydraulic machines. The water, which circulates in a closed system, acts both as a coolant and as an effective radiation shield, and no additional radiation

Figure D2 The Clab facility.

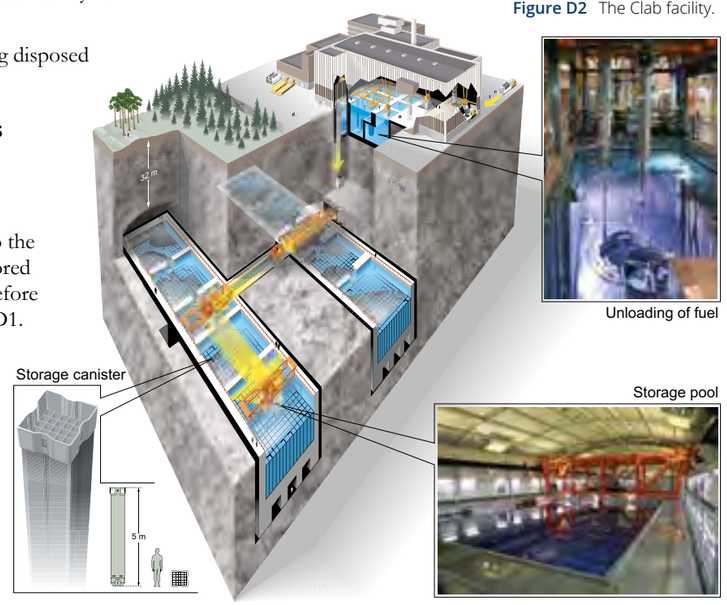


Table D2 Inventory of spent fuel stored in Clab as at 31 Dec. 2019.

Specification	Spent nuclear fuel stored as at 31 Dec. 2019	
	No. of assemblies	Tonnes
BWR fuel	30,451	5,127
PWR fuel	3,783	1,632
Fuel from Ågesta district heating nuclear power reactor	222	20.2
Fuel from Studsvik	26	3
German MOX fuel (exchanged for Swedish fuel reprocessed in France)	217	22.5
Total	**34,699**	**6,805**
Storage capacity		8,000

Table D3 Spent fuel from the research reactor R1 temporarily stored at Studsvik.

Spent nuclear fuel in storage as at 31 December 2019		
Origin	**No. of assemblies**	**Kg**
R1	1	40

protection equipment is needed. The water is circulated through filters to keep it clean before being returned to the pools. The heat is removed in heat exchangers and cooled by seawater in an intermediate cooling system. All safety systems have backups. Vital parts of the monitoring and control systems can be powered by a battery backup system. The storage pools are designed to withstand seismic loads as well as extreme temperature loads in the event the cooling systems should fail.

Approximately 100 people work at the facility; one-third of them with day-to-day operation, and others with radiation protection, chemical sampling, maintenance and repairs. The number of fuel assemblies of different types stored at the Clab facility and corresponding tonnages are listed in Table D2 above.

D.1.2.3 Spent nuclear fuel facilities and inventories at Studsvik

As described in section D.1.1, remaining waste from reprocessing of the intact parts and corroded parts of the R1 fuel is temporarily stored on site at Studsvik prior to transport to a disposal facility, see Table D3.

D.1.3 Management of radioactive waste

D.1.3.1 The Waste Management Process

SKB and the utilities operating nuclear power reactors established early on a systematic approach by means of a 'waste management process' for efficient management of nuclear waste from the reactors. There are two important basic elements in the waste management process; the Waste Acceptance Criteria (WAC), and the Waste Type Description (WTD) for different waste streams. WAC must be developed by the licensee for the specific disposal facility in question, based on an appropriate facility-specific safety case and associated safety assessments. WTD must be developed by the licensee of the activity or facility where the waste is generated, e.g. the licensee of a nuclear power reactor. The WTD should provide an account for all steps involved in the process from when the waste is generated up until the finally conditioned waste package is delivered to the disposal facility, and thus ensure conformity with the WAC in question. Among other things, the WTD need to consider the type of waste package to be used to ensure conformity with the handling equipment at the disposal facility. Another important consideration is the potential restrictions imposed by e.g. transport regulations and radiation protection. The waste management process is further described in section F.3.2.

D.1.3.2 Management of radioactive waste at the nuclear power plants

Waste management at the NPP sites is fully integrated into the operations at each site. Fulfilment of the requirements of the Swedish Radiation Safety Authority's general regulations is verified through regulatory review and inspection activities at the nuclear power plants, as reported under the Convention on Nuclear Safety.

Waste with very low activity (VLLW) is disposed of in shallow land burials on site, with the exception of Barsebäck, which disposes of VLLW in SFR.

Short-lived low and intermediate level waste (LILW) from the nuclear power plants consists of ion exchange resins from filters, metal scrap, pipes, valves, pumps, tools and protective clothing. The waste is classified and handled initially on site in preparation for disposal. The purpose of the waste handling at the power plants is to reduce its volume, solidify wet waste in concrete or bitumen, and suitably package the waste. The standardised types of packages used are shown in Figure D3.

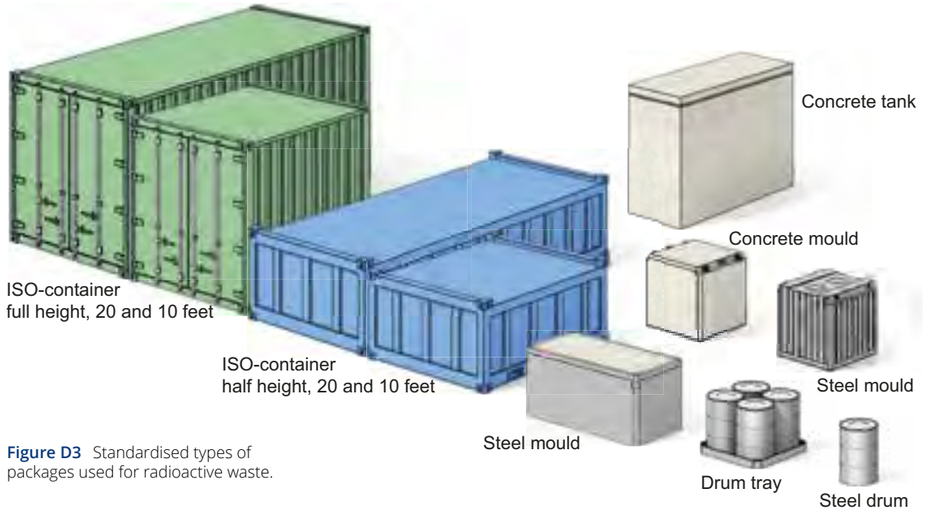


Figure D3 Standardised types of packages used for radioactive waste.

Waste is treated differently at the different nuclear power plants. Table D4 below illustrates the methods used and packages for operational waste produced at the nuclear power plants.

Waste packages are placed temporarily in storage on the site before being transported to SFR, the repository for operational waste. As waste packages from the NPP sites are transported to SFR on a regular basis, it is not relevant for the purpose of the Joint Convention to present a list of the inventories for the interim storage at the sites.

At the Oskarshamn site, the interim storage facility for low and intermediate level waste is located in a rock cavern. At the other nuclear power plants' sites, there are special buildings used for interim storage of conditioned operational waste on the respective site. Operation of storage buildings at the sites are fully integrated in the operation of the NPP. The safety procedures and safety documentation for those activities constitutes integrated parts of the safety procedures and safety documentation for the NPP. The safety documentation describes the facility and the waste handling activities, the content of radioactive substances, supervisory activities, as well as safety analyses. See section D.1.6 as regards interim storage of decommissioning waste.

D.1.4 Radioactive waste management facilities and inventories

D.1.4.1 Management of radioactive waste and inventories at Studsvik

Studsvik Nuclear AB (SNAB) materials research facilities

SNAB provides services in fuel and materials technologies to the nuclear power industry. Testing of materials and reactor fuel is performed in its own laboratories on site. The pools are presently used for temporary storage of spent fuel prior to examinations performed in HCL.

Hot cell laboratory, HCL

The Hot Cell Laboratory is primarily used to investigate irradiated nuclear fuel, although it is also used for studying other types of irradiated materials. In addition, the laboratory is used for conditioning, treatment and encapsulation of spent fuel fragments in packages suitable for interim storage in other facilities. The laboratory has seven cells with thick concrete walls, and lead windows to protect personnel from ionising radiation. All waste is removed from the laboratory after conditioning.

Table D4 Waste treatment methods at Swedish NPPs.
(Note: operational waste is no longer generated at the Barsebäck site following the closure of this plant.)

Type of waste	Ringhals	Barsebäck	Oskarshamn	Forsmark
Ion exchange resins	Solidified in concrete moulds and steel moulds	Solidified in concrete and packed in steel drums	Solidified in concrete and packed in concrete drums	Solidified in bitumen and packed in steel moulds
Trash and Metal scrap	Cast in concrete and packed in concrete moulds Packed in standard ISO containers	Packed in concrete moulds Packed in standard ISO containers Packed in steel tanks	Cast in concrete and packed in concrete moulds Packed in standard ISO containers Packed in steel tanks	Packed in steel moulds Packed in standard ISO containers Packed in steel tanks
Sludge	Solidified in concrete, packed in concrete moulds	N.A.	N.A.	N.A.

The active metal laboratory, AKL

The Active Metal Laboratory is primarily used to investigate irradiated metallic materials. The laboratory has several cells with lead walls to protect personnel from ionising radiation. All waste is removed from the laboratory after conditioning.

The storage facility, FA

This facility, which contains three water pools, was built in 1965 for interim storage of spent nuclear fuel from the Ågesta power reactor. As all fuel from Ågesta has since been transferred to Clab, the facility can be used for other purposes, such as storing spent fuel from other reactors and storing other radioactive materials or for temporary storage of spent fuel prior to examinations performed in HCL. Small quantities of spent nuclear fuel that have been examined at Studsvik are transported to Clab, the interim storage facility for spent nuclear fuel.

Cyclife AB's radioactive waste management facilities

Cyclife provides services by means of treatment of waste from national and international customers based on commercial contracts. A principal precondition for such contract agreements as regards international customers is that the radioactive material and radioactive waste is returned to the customer.

The incineration facility, HA

The facility is used for incineration or pyrolysis of low-level waste (LLW) from NPPs, fuel fabrication plants, hospitals, research institutions and facilities at Studsvik.

The work also comprises management, radiological measurement and final conditioning of the waste. Up until 2006 ash has been stabilised in concrete for disposal (or if the waste comes from overseas, returned to the country of origin for further management). However, as of 2016 SKB does not accept ash conditioned in concrete for disposal and work is ongoing to develop a new method for conditioning and packaging of ash. The current licence conditions allow for treatment of 600 tonnes of combustible waste annually.

The melting facility, SMA

The melting facility at Studsvik is used for volume reduction of contaminated metal, see Figure D4. After having carried out melting and radiological measurement, the material may be exempted from regulatory control or returned to the customer for further management. Most often the metal ingots can be free-released while slag and dust is returned to the customer. The current licence allows for treatment of 5,000 tonnes of metal annually.

Treatment facilities for radioactive non-nuclear waste, FR0-A and R0-A

Disused sealed sources and radioactive waste from medical use, research and industry are mainly managed in the two facilities FR0-A and R0-A. In R0-A, ionising smoke detectors are dismantled or sorted, whereas all other disused sealed sources and radioactive waste are treated in FR0-A. Depending on the activities, dose rate, material, etc., treatment comprises sorting, volume reduction, packing and conditioning. Some of the disused sealed

Figure D4 The melting facility (SMA) at Cyclife Sweden AB.

sources and radioactive waste may also be treated in the facilities HA, SMA or AB Svafo's facility HM (see below). Some radioactive sources are sent abroad for recycling.

AB Svafo radioactive waste management facilities
The following are the most important facilities operated by AB Svafo at the Studsvik site.

Treatment facility for intermediate waste, HM
This facility is used for the treatment of intermediate level solid and liquid waste from facilities at the Studsvik site. Treatment of solid waste comprises sorting, volume reduction (compaction), packing and conditioning by means of stabilisation using concrete. Treatment of liquid waste comprises evaporation and solidification by means of stabilisation using concrete.

Interim storage facility for low and intermediate level waste, AM
The AM facility was constructed in the 1980s for interim storage of conditioned waste from facilities at the Studsvik site. The storage facility is constructed in a cavern in bedrock with a rock cover of at least 20 metres. The rock mass is grouted with concrete, the walls are reinforced by means of rendering concrete, and special arrangements have been made to drain the rock. The storage facility is dimensioned to receive waste until around the year 2045. The storage area is divided into two parts: one part is used for waste requiring shielding, and the other is used for waste not requiring shielding. The shielded part of the AM storage facility has a capacity of about 4,000 m^3, corresponding to 1,632 moulds and 1,020 four-drum unit trays; the unshielded part has a capacity of about 1,120 m^3, corresponding to 660 moulds and 264 four-drum unit trays. A further 1,000 drums can be deposited in other parts of the storage facility. The waste is conditioned and packed in special containers before being positioned in the storage. The ventilation and drainage systems are monitored for any radioactive substances.

The following types of waste originating from facilities on the Studsvik site are currently being stored at AM (see also Table D5):

- operational waste from the R2 research reactor and testing performed in the reactor;
- irradiated and contaminated material from the production of isotopes;
- irradiated and contaminated material from the fuel testing laboratory; and
- start sources from an old research reactor and operational waste from the waste handling facilities.

In addition, the following externally-produced types of waste currently being stored at AM:

- residual products from incinerated waste from nuclear power plants, hospitals and industry;
- residual products from use of isotopes in industry and hospitals;
- decommissioning waste from old nuclear facilities; and
- waste from treatment of steam generators from Ringhals.

Table D5 Inventory of stored radioactive waste in AM as at 31 Dec. 2019.

Number of packages	Volume (m^3) incl. packaging	Activity (Bq)
3,565	2,750	8E15

Storage facilities for radioactive waste, AU and AUA
The AU facility is an interim storage facility for long-lived low level waste that has been conditioned. It is a simple unheated building made of concrete and steel. The AU storage facility contains drums with historical waste embedded in concrete. The waste was reconditioned in the 1990s. About 7,000 drums were previously stored in the facility. The waste will ultimately be disposed of in the planned disposal facility for long-lived waste.

The AUA facility is an interim storage under construction, expected to be in operation 2021. It will store decommissioning waste from Ågesta and the R2 research reactor.

Monitoring of facilities at the Studsvik site
Whenever there is a risk of airborne emissions, ventilation and/or exhaust systems are monitored for any radioactive substances. Likewise, to avoid contamination from waste water, drainage systems are monitored for any radioactive substances before the water is discharged.

D.1.4.2 Repository for short-lived low and intermediate level waste (SFR)

General information
The repository is situated beneath the Baltic Sea, covered by about 60 metres of rock. Two one-kilometre-long access tunnels lead from the harbour in Forsmark to the repository area. The facility currently consists of four 160-metre-long waste vaults; the rock vault for intermediate level waste (BMA), two rock vaults for concrete tanks (1BTF, 2BTF) and a rock vault for low level waste (BLA), plus a 70-metre-high cavern in which a concrete silo has been built. Wastes are directed to different parts of the repository depending on factors such as activity content and chemical characteristics.

The total capacity of SFR is approximately 63,000 m^3. By 31 December 2018, roughly 40,000 m^3 of waste had been disposed of. In the safety assessment for the facility, the total radioactivity of the waste in the filled repository is assumed to be 10^{16} Bq.

The repository is designed to isolate the waste from the biosphere in order to avoid harmful consequences for people and the environment both during operation and after closure. This is accomplished by emplacement in bedrock under the seabed and by the technical barriers surrounding the waste, see Figure A11.

The silo
The waste designated for SFR that has the highest radioactivity is intended for disposal in the silo. This waste comes from many different waste streams, but the most important one comprises ion exchange resins in a concrete or bitumen matrix from the nuclear power plants. Other waste, such as metal components of different origins, is also disposed of in the silo. The amount of organic material is kept to a minimum. The maximum surface dose rate permitted on a package is 500 mSv/h. All handling of waste packages is performed using remote control equipment. The dominant nuclides are Co-60, Cs-137 and Ni-63.

The silo consists of a cylindrical concrete construction with shafts of different sizes for waste packages. The concrete cylinder is approximately 50 m deep with a diameter of approximately 30 m. The largest shafts measure 2.5 m by 2.5 m. The waste packages are placed in the shafts, normally in layers of four moulds or 16 drums. The spaces between the waste packages are gradually backfilled with porous concrete. The walls of the silo are made of 0.8 m thick reinforced concrete. In between the walls and the surrounding rock, there is a bentonite backfill averaging 1.2 m thick. The 1 m thick concrete floor at the bottom of the silo is placed on a layer of 90/10 sand/bentonite mixture.

According to the present plans, a 1 m thick concrete lid will cover the top of the silo. After closure, the lid will be covered with a thin layer of sand, then a 1.5 m thick layer of sand/ bentonite mixture (90/10), and the remaining space will be filled with sand, gravel or sand stabilised with cement.

The rock vault for intermediate level waste (BMA)
The radioactivity in the waste that is disposed of in BMA is generally lower than in the waste contained in the silo. The waste in BMA comes from many different waste streams. The most important one is ion exchange resins from the nuclear power plants. Other waste, such as metal components of various origins as well as contaminated rubbish, is also disposed of in BMA.

The maximum surface dose rate permitted on packages is 100 mSv/h, and the radionuclide content is fairly low. BMA has been designed to accommodate approximately 6% of the total activity content in SFR. The dominant nuclides are Co-60, Cs-137 and Ni-63. The waste packages are of the same type as in the silo, i.e. moulds and drums.

The rock vault is approximately 160 m long, 19.5 m wide with a height of 16.5 m. Inside the cavern, a concrete construction has been constructed so that the vault is divided into 15 compartments. The moulds and drums are placed in the compartments using remote-controlled equipment.

The waste is stacked on top of the concrete floor in such a way that the concrete moulds act as support for prefabricated concrete slabs, put in position as soon as the compartments are filled. It is also possible to backfill the void between the waste packages in a compartment. Lastly, a layer of concrete will be cast on top of the lid. Between the concrete structure and the rock wall there is a 2 m wide space, which will be filled with sand before closure. The space above the concrete structure may be left unfilled, but it could also be backfilled. Plugs will be placed in the two entrances to the vault when the repository is closed.

The rock vaults for concrete tanks (BTF)
There are two rock vaults in SFR for concrete tanks: 1BTF and 2BTF. The waste in 1BTF mainly consists of drums containing ash and concrete tanks containing ion exchange resins and filter parts, whereas the waste in 2BTF consists of only the latter. Moreover, some large components of metal, e.g. steam separators and reactor vessel lids, may be disposed of in the caverns.

The maximum surface dose rate permitted on packages is 10 mSv/h. The radionuclide content is fairly low, and the dominant nuclides are Co-60 and Cs-137. The rock vaults are approximately 160 m long, 14.8 m wide with a height of 9.5 m. The concrete tanks, each 10 m^3 in volume, are stacked in two levels with four tanks in each row. A concrete radiation protection lid is placed on top of the stacks. The space between the different tanks is backfilled with concrete and the space between the tanks and the rock wall will be filled with, for example, sand stabilised with cement.

The rock vault for low level waste (BLA)
The waste disposed of in BLA, short-lived waste, is mainly low level scrap metal (iron/steel, aluminium), cellulose (e.g. wood, textile, paper), other organic materials, non-organic materials (e.g. plastics, cables) and other waste such as insulation (e.g. rock wool) packed in ISO-standard steel containers.

The maximum dose rate permitted on the surface of the waste packages is 2 mSv/h. The radionuclide levels are low, and the dominant nuclide is Co60. Some of the waste inside the containers is placed in steel drums and other types in bales.

The rock vault cavern is approximately 160 m long, 15 m wide with a height of 12.5 m. The design is very simple: it

Table D6 Inventories of radioactive waste dispwosed of in SFR as at 31 Dec. 2018.

Repository section	Volume (m^3)	Activity (Bq) per 31 Dec. 2018
Silo	7,644	6.74E14
BMA	9,777	2.53E14
1 BTF	2,513	2.16E12
2 BTF	7,680	9.65E12
BLA	12,300	6.64E11
SFR total	**39,914**	**9.39E14**

is basically only a concrete floor, on which the containers are placed. During the operational phase, a ceiling is suspended above the waste in order to minimise water dripping onto the waste. This suspended ceiling will be dismantled before the repository is closed.

The containers are stacked three high in rows of two. Most of the containers are half-height, allowing six to a pile. No backfilling is planned.

Inventory of nuclear waste disposed of in the SFR facility
The inventory of nuclear waste disposed of in the SFR facility is listed in Table D6 below. The nuclide-specific activity content can be seen in Figure D5.

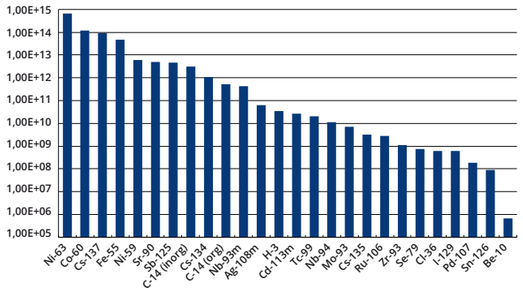


Figure D5 Radionuclide-specific activity content in SFR. The data reflects the situation as at 31 December 2018.

Figure D6 The shallow land burial at OKG.

D.1.4.3 Shallow land burials

The nuclear power plants at Ringhals, Forsmark and Oskarshamn as well as the Studsvik site have shallow land burials for very low-level waste. The total activity content is, according to the licence, limited to between 100 and 1100 GBq per burial.

In addition to the total activity content, waste acceptance criteria specify the nuclide-specific activity concentration and surface dose rate of the individual packages. The (remaining) activity concentration is specified for the future point in time when the shallow land burial is planned to be released from a radiation protection point of view, see Table D7.

The waste is disposed of at the three nuclear power plants as part of campaigns undertaken at three to five year intervals, with the burial facilities closed in between these periods. The waste consists of low-level scrap and residues from the operations of the NPPs. These include piping, tools, insulation material and protective clothing as well as rubbish such as plastics, paper and cables, etc. The dominant nuclides are generally Co-60, Cs-137 and Ni-63. The shallow land burial at Studsvik contains waste from decommissioning of various old nuclear installations plus operational waste from other Studsvik facilities.

The design and layout of the shallow land burials differ, but all facilities have a top sealing layer to reduce infiltration of water, see Figure D6. The design of the top sealing layer differs between the facilities: bentonite liners, plastic membranes and massive layers of glacial clay or mixes of bentonite and sand have been used, as well as mixed designs. The sealing layer of the facilities is covered with a drainage layer and, on top of that, a protective layer of e.g. soil, approximately 1 metre thick. At the newer installations at Ringhals and Oskarshamn, a geological barrier has been installed down-gradient of the burials. At the burials at Forsmark and Studsvik, a natural or semi-natural geological barrier reduces leakages to the environment. There are monitoring programmes in place for sampling leachate water, for example with respect to radionuclides. The licence period includes a 30-year surveillance period (50 years for OKG) after final closure.

Table D7 Inventories of waste disposed of in shallow land burials. The burial facilities at Studsvik (AB Svafo) are closed permanently.

Site	Licence conditions			Waste disposed of as at 31 Dec 2019		
	Licence period until	Volume (m3)	Max. activity / max. alpha activity (GBq)	Mass (tonnes)	Volume (m3)	Activity (GBq)
Forsmark	2070	17,000	200/0.2	4,395	6,572	23.7
Oskarshamn	2075	10,000	200/0.2	5,415	11,252	26.4
Ringhals	2060	10,000	1100/0.1	5,940	9,180	292
Studsvik (Svafo)	2040	1,540	100/0.1	781	900	140

D.1.5 Nuclear facilities under decommissioning

This section presents an update and overview of the current status for nuclear facilities permanently shut down or being decommissioned. Table D8 lists all nuclear facilities under decommissioning. More detailed information on regulation of decommissioning as well as decommissioning practices is presented in section F.6.

D.1.5.1 Barsebäck NPP

The twin BWR units Barsebäck 1 and 2 were shut down permanently in 1999 and 2005, respectively, as a result of political decisions. All spent nuclear fuel was removed by 2006, and reconditioning and removal of nuclear waste from the operational phase is ongoing. Preparations for and detailed planning of dismantling and demolition have intensified since 2016. Segmentation of the reactor pressure vessel internal components has been completed. A decommissioning licence according to the Environmental Code was obtained from the Land and Environment Court in 2019. The final dismantling and demolition work will start in 2020. Site release in accordance with regulatory requirements is planned for mid-2030s.

D.1.5.2 Oskarshamn NPP

In 2015 the owner decided to permanently shut down the two oldest BWR units 1 and 2 at the Oskarshamn NPP before 2017. Oskarshamn 1 was permanently shut down in June 2017. In practice, Oskarshamn 2 was never restarted following an extended period of shutdown. Dismantling of the internal reactor parts from Oskarshamn unit 1 and 2 are planned to be completed in 2020.

The necessary licences for decommissioning units 1 and 2 pursuant to the Environmental Code were obtained in 2019.

D.1.5.3 Ringhals NPP

In 2015, the owner decided to permanently shut down the two oldest reactors at the Ringhals NPP, unit 1 (BWR) and unit 2 (PWR). Unit 2 was permanently shut down in December 2019 and unit 1 is planned to shut down in December 2020. Dismantling of the internal reactor parts from both units 1 and 2 is planned to start 2022.

D.1.5.4 Ågesta PHWR

The Ågesta reactor was shut down in 1974. A licence according to the Environmental Code for dismantling and demolition of the reactor was obtained in 2019. Dismantling activities are planned to commence in 2020.

Table D8 Nuclear facilities under decommissioning.

Nuclear facility	Current projects	Start of project	Anticipated completion	Status	Details
Ranstad – uranium mining/milling	Decommissioning & clearance	2013	2019	Complete	Section A.4
Studsvik R2 facility, materials testing reactors	Dismantling & demolition	2015	2020	Ongoing	Section A.8.3.1, F.6
Barsebäck nuclear power plant – unit 1,2	Dismantling & demolition	2020	2027	Ongoing	Section A.4, F.6, K.3.1.6
Oskarshamn nuclear power plant – unit 1,2	Dismantling & demolition	2020	2027	Ongoing	Section A.4, F.4.2.1, F.6, K.3.1.6
Ågesta	Dismantling & demolition	2020	2022	Ongoing	Section A.4, F.6.2.2

D.1.5.5 Studsvik materials testing reactors

The final dismantling of Studsvik's R2 materials testing reactor, which began in 2015, is in its final stage. Applications for clearance of the remaining buildings and sub-surface structures are expected during 2020.

D.1.5.6 Installations in Ranstad

The uranium mining and milling facilities in Ranstad were constructed and operated in the 1960s. The decommissioning of the Ranstad uranium mining and milling facility is completed and the site has been released from any further regulatory control.

The general timetable for the nuclear power companies' and SKB's planned decommissioning of their facilities is presented in Figure D7. The current period is dominated by activities at the nuclear power reactors Barsebäck 1 and 2, Oskarshamn 1 and 2, Ringhals 1 and 2, and the Ågesta reactor.

D.1.6 Interim storage of decommissioning waste

The timing for final shutdown is an important planning premise for a decommissioning project, and for the overall system of radioactive waste management. Radioactive waste management requires, for example, that waste type descriptions be revised and approved for decommissioning waste, that handling and techniques for management of large components be developed, and that waste containers that are desirable from a decommissioning perspective be developed and licensed. Furthermore, pathways need to be available for radioactive material that will not be disposed of by SKB, such as a licence for shallow land burial of very low-level decommissioning waste at the nuclear power plants.

Waste from decommissioning of the first nuclear power reactors is being produced before the extended SFR repository will be available for the disposal of short-lived decommissioning wastes and before the construction of the SFL repository for long-lived decommissioning wastes. For this reason, the radioactive waste must be placed in interim storage prior to disposal. The load on the transportation system will increase when the extended SFR and SFL repositories are commissioned, and the interim stored wastes can be transferred for disposal.

As regards radioactive waste materials arising from the decommissioning of the Barsebäck reactors, this means planning for additional interim storage capacity for low-level waste on site in addition to the recently constructed interim storage facility for long-lived intermediate level waste. Waste produced during decommissioning of the reactors at Oskarshamn and Ringhals will need to be stored on site in existing facilities until these wastes can be transferred to the extended SFR or SFL repository. Radioactive wastes produced during decommissioning of the Ågesta reactor are planned to be transferred to the new storage building in Studsvik for storage pending disposal. Some of these licensees are also investigating the possibilities for shallow land burial on site for very low level decommissioning wastes.

When it comes to management of long-lived decommissioning wastes, approximately half of this waste is expected to arise before the planned commissioning of SFL. Since the waste cannot be finally conditioned before acceptance criteria for SFL are determined, which presupposes a defined site and concept, the long-lived waste needs to be placed in waste containers pending final conditioning. According to the current timetable, final conditioning can commence at the earliest in conjunction with SKB obtaining a licence to build SFL, which is planned for the late 2030s.

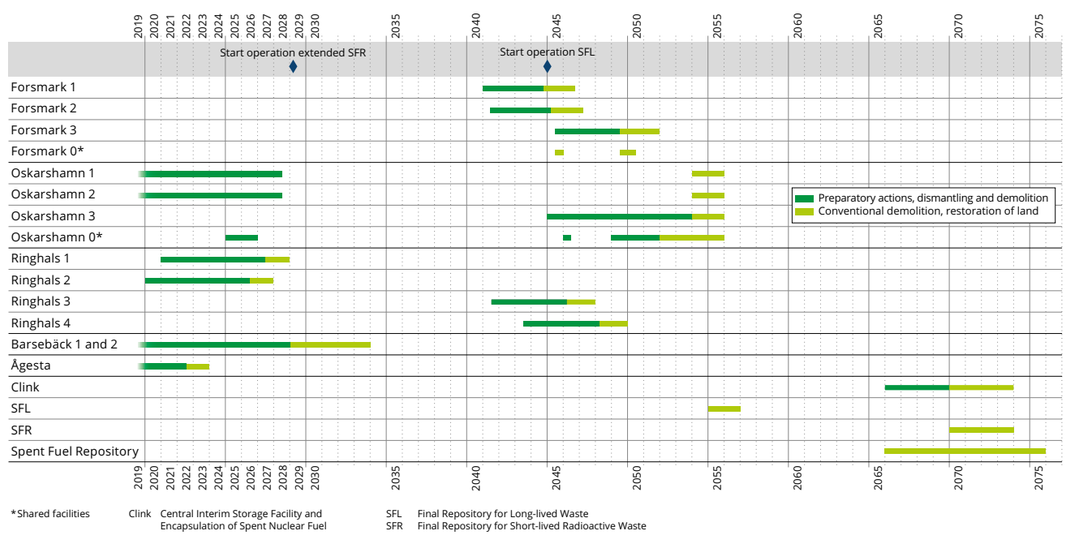


Figure D7 Schematic overview of the nuclear power companies' and SKB's timetables for decommissioning (F0 and O0 are shared facilities on the sites).

Section E – Legislative and regulatory system

E.1 Article 18: Implementing measures

Each Contracting Party shall take, within the framework of its national law, the legislative, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

The legislative, regulatory and other measures to fulfil the obligations of the Joint Convention are discussed in this report.

E.2 Article 19: Legislative and regulatory framework

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management.

2. This legislative and regulatory framework shall provide for:

(i) the establishment of applicable national safety requirements and regulations for radiation safety;

(ii) a system of licensing of spent fuel and radioactive waste management activities;

(iii) a system of prohibition of the operation of a spent fuel or radioactive waste management facility without a licence;

(iv) a system of appropriate institutional control, regulatory inspection and documentation and reporting;

(v) the enforcement of applicable regulations and of the terms of the licences;

(vi) a clear allocation of responsibilities of the bodies involved in the different steps of spent fuel and of radioactive waste management.

1. When considering whether to regulate radioactive materials as radioactive waste, Contracting Parties shall take due account of the objectives of this Convention.

This section is divided into five parts. The first part (section E 2.1) presents basic prerequisites for the legal and regulatory framework. The second part (section E 2.2) contains more detailed information about requested legal requirements for the licensing system, prohibition, institutional control, regulatory inspection, documentation and reporting, enforcement of regulations and terms of a licence, and a description of the allocation of responsibilities of the bodies involved. The third part (section E 2.3) describes the regulatory framework, which refers to the various authorities' regulations. The fourth part (section E 2.4) reports on regulatory review activities. The fifth part (section E 2.5) describes the relevant regulatory bodies relating to different aspects of spent fuel and radioactive waste management.

E.2.1 National legislative framework

The framework of Sweden's legislation in the fields of waste management, nuclear safety and radiation protection is mainly regulated in the following four Acts with associated Ordinances:

- Act (1984:3) on Nuclear Activities and Ordinance (1984:14) on Nuclear Activities;
- Radiation Protection Act (2018:396) and Radiation Protection Ordinance (2018:506);
- Environmental Code;
- Act (2006:647) on Financing of Management of Residual Products from Nuclear Activities;

The main features of these enactments are reported below, as well as some additional relevant acts to be applied.

As also reported below, the Swedish Radiation Safety Authority (SSM) has a mandate to issue regulations concerning radiation safety under the Act on Nuclear Activities and the Radiation Protection Act on the basis of Government Ordinances.

E.2.1.1 The Act and Ordinance on Nuclear Activities

The Act on Nuclear Activities is the basic law regulating nuclear safety (as well as nuclear security, physical protection,

information security and non-proliferation, but outside of the scope addressed in this convention). It contains basic provisions concerning safety in connection with nuclear activities, and applies to management of nuclear material and nuclear waste as well as to the operation of nuclear power plants.

The Act does not contain provisions concerning radiation protection. This area is regulated in a separate act, the Radiation Protection Act, see section E.2.1.2. As far as nuclear activities are concerned, the Radiation Protection Act and Act on Nuclear Activities should be applied in parallel and in close association with each other.

The Ordinance on Nuclear Activities contains detailed provisions regulating areas such as definitions, applications for licences, reviews, evaluations, inspections and certain exemptions from the application of the Act on Nuclear Activities. The Ordinance also mandates SSM to decide on exceptions in individual cases if there are special circumstances and if the purpose of the law is not violated.

The Ordinance also specifies that SSM is authorised to issue permits for e.g. shallow land burials for very-low level wastes and other facilities managing low levels of radioactive waste. SSM is also authorised to issue permits for transports of nuclear materials and nuclear waste.

Furthermore the Authority is authorised to impose licence conditions and to issue general regulations concerning measures to maintain the safety of nuclear activities.

Safety Requirements
Nuclear activities shall be conducted so as to meet safety requirements and fulfil the obligations pursuant to Sweden's agreements for the purpose of preventing the proliferation of nuclear weapons and unauthorised dealing with nuclear material and spent nuclear fuel.

A nuclear installation must be designed, located, constructed, commissioned, operated and decommissioned to avoid radiological emergencies and, if a radiological emergency still occurs, so that the consequences of the emergency can be managed.

Safety in nuclear activities shall be maintained by taking all the measures required to prevent errors in equipment, or its defective function, to prevent incorrect handling or any other circumstances that could result in a radiological accident, and to prevent unlawful dealings with nuclear material or nuclear waste. The Government or the authority appointed by the Government may issue more detailed provisions concerning these areas. As mentioned above, SSM has the mandate to impose detailed regulations.

At least once every ten years, a new integrated analysis and assessment of the safety of a nuclear facility shall be performed by the licence holder (periodic safety review). The analyses and assessments, as well as the measures proposed on the basis of these, must be documented and submitted to the regulatory authority for review.

Definitions
The handling or transport of nuclear waste or other dealings with this waste are defined as a nuclear activity.

General obligations of licensees and licence conditions
The licence holder for a nuclear activity shall be responsible for ensuring that all the measures necessary are taken for:

- maintaining safety, with reference to the nature of the activities and the conditions under which they are conducted;
- ensuring the safe handling and disposal of nuclear waste arising from the activity or nuclear material arising therein that is not reused; and
- the safe decommissioning and dismantling of plants in which the nuclear activity no longer will be conducted.

In addition to the three bullet points above, the Act on Nuclear Activities also requires the application of the general 'rules of consideration' contained in the Environmental Code, see section E.2.1.3.

The holder of a licence for a nuclear activity must ensure that all the necessary measures are taken for maintaining safety. These general requirements are supplemented by more detailed regulations issued by SSM (see below) and, if needed, licence conditions that the Authority may issue in individual cases. The licensing conditions are imposed when a licence is issued. Licensing conditions can also be imposed during the period of validity of a licence.

Disposal of nuclear waste – Safe management and RD&D programme
The holder of a licence for nuclear activities is responsible for the management and disposal of the waste produced and for decommissioning. The holder of a licence for the operation of a nuclear power reactor shall – in liaison with the other holders of a licence for the operation of nuclear power reactors – establish and carry out an RD&D programme for the safe handling and disposal of spent fuel and nuclear waste. Every third year, a report describing the programme shall be submitted to SSM for review. An important step in the review process is that the programme is sent to a large number of stakeholders for consultation and comment, such as other government organisations, municipalities, environmental organisations, research institutions and universities.

Following the review, SSM sends a review statement regarding the RD&D programme to the Government. The Government determines whether or not the programme can be approved. In connection with this decision, the Government may issue conditions concerning the content of the nuclear power operators' (through SKB) future research and development work.

E.2.1.2 The Radiation Protection Act and Ordinance

Requirements for radiation protection are set out in the Radiation Protection Act and in the Radiation Protection Ordinance. Precautionary measures listed in the Act apply not only to activities that require permits or notification but also to activities that does not require neither of this.

The purpose of the legislation is to protect human health and the environment against the harmful effects of radiation.

Persons engaged in activities involving radiation are obliged to take the requisite precautionary measures.

The persons conducting activities are also responsible for proper handling and disposal of the radioactive waste produced in or brought to the activity, which includes covering the costs associated with both the handling and disposal of the waste.

The Radiation Protection Ordinance contains detailed provisions on e.g. dose limits, licence and notification, documentation of sources, reporting on orphan sources and supervision.

The Ordinance stipulates that the regulatory authority assigned by the Government may issue regulations regarding further provisions concerning general obligations, radioactive waste and prohibitions against activities with certain materials, etc. The Ordinance also stipulates that certain provisions in the Act do not apply to very low-level radioactive materials and technical equipment emitting only low-level radiation (exemption). The regulatory authority may also issue regulations concerning the release of very low-level radioactive material.

Radiation Protection Requirements
Definitions
The Act applies to all activities involving radiation. These are defined to include all activities involving radioactive substances and technical devices capable of generating radiation.

Consequently, the Act applies to radiation from nuclear activities and to harmful radiation, ionising as well as non-ionising, from any other source (medical, industrial, research, consumer products and NORM). As far as nuclear installations, such as management and disposal facilities for spent fuel and radioactive waste, the Radiation Protection Act and the Act on Nuclear Activities are applied in close association with each other.

The Government or the mandated authority may, to the extent it does not conflict with the purpose of the Act, prescribe exemptions in full or in part from the application of the Act. An exemption may also be combined with special conditions. Furthermore, specific conditions may be stipulated on radioactive substances or technical devices capable of generating radiation which are not otherwise covered by the Act.

Basic requirements for radiation protection
The Radiation Protection Act is based on the International Commission on Radiological Protection (ICRP's) internationally recognised principles. These principles are:

Justification: No activity is to be introduced until it has been shown to provide greater advantages than disadvantages to society. The basic principle of justification with regard to management of nuclear and non-nuclear radioactive waste cannot be questioned at this stage. The waste has been generated as a result of previous decisions.

Optimisation: All radiation doses to individuals, the number of exposed individuals, as well as the probability of receiving doses must be kept as low as reasonably achievable, while taking into account economic and societal factors. This is often called the 'ALARA principle' (As Low As Reasonably Achievable).

Dose limitation: Individual exposure to radiation (dose) must not exceed the established limits for the particular circumstances. The dose limit or dose constraint can be viewed as a limit for optimisation; thus, individual doses must not exceed the established limits, even if the collective dose would be reduced as a result.

The Government or the authority assigned by the Government may also issue further regulations as required for protection against, or control of, radiation as specified in the Act.

General obligations of licensees and licence conditions
In addition to the above mentioned principles the basic requirements as listed below apply for any person who conducts activities involving radiation:

- measures to limit the production of radioactive waste;
- measures to limit discharge of radioactive substances and exposure of the environment to ionising radiation.

Furthermore; any person who conducts activities involving ionising radiation shall, to the extent necessary from the radiation protection point of view and with regard to the nature and conditions of the activity:

- control and maintain the radiation protection in the places where radiation may occur;
- maintain technical devices and measuring or radiation protection equipment used in the activity;
- take any other measures and precautions necessary to prevent or counteract damage to human health or the environment;
- ensure that everyone who works in the activity and may be exposed to ionising radiation has the knowledge and competence needed for the radiation protection to function satisfactorily.

Anyone who conducts activities shall also comply with the requirement that sufficient financial, administrative and personnel resources are available to meet the obligations arising from the Act, regulations issued under the provisions of the Act and decisions issued in accordance with the Act.

The provision implies that all the necessary measures should be taken to improve radiation protection; it is thus

insufficient to solely comply with the regulations or conditions issued by the responsible authority.

The Government or the authority assigned by the Government may also issue any further regulations required for protection against, or control of, radiation in the respects specified in the Act.

When a licence is, or has been, issued under the provisions of the Radiation Protection Act, the responsible authority may impose the conditions needed for radiological protection. Such radiation protection conditions can also be imposed on activities licensed within the legal framework of the Act on Nuclear Activities.

Disposal of radioactive waste – Safe management
Anyone who conducts activities involving radiation is required to treat and, as necessary, dispose of the radioactive waste which may arise in or otherwise brought to the activity.

Anyone who conducts or has conducted activities using a technical device that can emit radiation shall, to the extent stipulated by the Government or the authority appointed by the Government, ensure that the device is destroyed when it is no longer being used in the activity.

E.2.1.3 The Environmental Code

The objective of the Swedish Environmental Code is to promote sustainable development and thereby ensure a healthy environment for current and future generations. The Code includes general provisions on environmental protection. The Code is applicable to nuclear activities and activities involving radiation and must be applied in parallel with the Act on Nuclear Activities and Radiation Protection Act. A number of ordinances supplement the Code. These are laid down by the Swedish Government.

Requirements for Protective Measures, etc.

Definitions
In the Code, environmentally hazardous activities are defined as:

- the discharge of wastewater, solid matter or gas from land, buildings or structures onto land or into bodies of water or groundwater;
- any use of land, buildings or structures that entails a risk detrimental to human health or the environment due to discharges or emissions other than those referred to above, or to pollution of land, air, bodies of water or groundwater; or
- any use of land, buildings or structures that may be detrimental to the surroundings due to noise, vibration, light, ionising or non-ionising radiation or similar impact.

General rules of consideration
The general rules of consideration define several important principles that must be complied with by the implementer, e.g.:

- The knowledge principle means that the implementer must possess the knowledge that is necessary regarding the nature and scope of the activity to protect human health and the environment against damage or detriment.
- The precautionary and BAT principles mean that the implementer shall put into practice protective measures, comply with restrictions, and take any other precautions that are necessary in order to prevent, hinder or combat damage or detriment to human health or the environment as a result of the activity. For the same reason, the best available technology shall be used in connection with occupational activities.
- The most suitable site principle means that as regards activities for which land or water areas are used, a suitable site shall be selected while taking into account the goals of the Environmental Code. Sites for activities must always be chosen in such a way as to make it possible to achieve their purpose with a minimum of damage or detriment to human health and the environment.
- The after-treatment liability principle means that everyone who has pursued an activity that causes damage or is detrimental to the environment shall be responsible for restoring it to the extent deemed reasonable. An individual who is liable for after-treatment shall carry out or pay for any after-treatment measures necessary. The general rules of consideration function as a preventive tool based on the polluter-pays principle.

The requirements of the first three bullet points above apply to the extent that it cannot be considered onerous to comply with them. In making this assessment, particular consideration should be given to the benefits of protection measures and other precautions as compared to the cost of such measures (by means of cost-benefit analysis).

E.2.1.4 Legislation on financing

Nuclear power plants
The purpose of the financing arrangements, established in 1981, is to secure financing for the nuclear licensees' future costs for the management and disposal of spent nuclear fuel and nuclear waste. The objective is to minimise the risk of the state and future generations being forced to bear costs considered to be the liability of the licensees. The licensees pay a fee to the Nuclear Waste Fund. If there is insufficient money in the Fund to pay for the costs, the licensees will nevertheless still be liable.

SKB coordinates the nuclear power utilities' cost estimates and submits these to the National Debt Office every three years. The Debt Office reviews the cost estimates and calculates the nuclear waste fees and financial guarantees individually for each utility. The fees are calculated on the assumption that each reactor will generate electricity for 50 years, though always with a minimum remaining operating time of six years. Based on the Debt Office's proposal, the Government decides on the nuclear waste fees and financial guarantees for a period of three years. The nuclear waste funds' assets are managed by a Government authority, the Nuclear Waste Fund.

The power plant utilities must also provide financial guarantees as securities to cover fees that have not yet been paid (the credit risk amount), and to cover costs in connection with unexpected events (the risk margin).

To date, the Nuclear Waste Fund has covered SKB's expenses for the central interim storage facility for spent nuclear fuel (Clab), for the transport system and for the research and development needed, including for the siting and method development for a spent fuel repository system. Future expenses should cover the encapsulation plant and repository for spent fuel, repositories for low and intermediate level waste, the decommissioning of nuclear power plants and the continued research and development work.

Other nuclear facilities
Nuclear licensees other than power reactor operators must also pay fees to the Nuclear Waste Fund. This in practice applies to certain nuclear fuel cycle, research and waste management facilities. The build-up of adequate financial resources is based on the facilities expected remaining period of operation. The licensees must also provide a financial guarantee to cover fees that have not yet been paid (the credit risk amount). The National Debt Office decides on the nuclear waste fees and financial guarantees for a period of three years.

Legacy waste
There is also a funding mechanism for legacy waste from historic nuclear activities. Until the end of 2017, a fee was levied on the nuclear power plant licensees under the provisions of the so-called 'Studsvik Act', in order to cover expenses for liabilities originating from the establishment of a nuclear programme in Sweden. This special funding primarily contributes to the decommissioning of old installations.

The licensees for nuclear power reactors are required to pay the additional fees necessary, in accordance with the provisions of the Financing Act, if the fund's assets are insufficient to cover the future liabilities. There is also a state financing scheme administered by SSM for the clean-up of orphan sources and other non-nuclear legacy waste. See section J.1.2.2.

Non-nuclear waste
A licence under the Radiation Protection Act, may for its validity be made dependent on that the licence holder intending to conduct the activity provides financial security for the waste management costs and recovery measures that the activity can incur. The financial security can be set gradually according to a plan that at all times meets the current need for financial security. If it can be assumed that financial security is no longer sufficient, the licensing authority may decide on additional collateral. This applies to all non-nuclear activities in which radioactive materials are used: in medicine, industry, agriculture, research and education.

The state, municipalities, county councils and municipal associations need not to provide any financial collateral.

E.2.1.5 Other relevant Acts

The Act on the Control of Dual-use Items and Technical Assistance
Export of nuclear material and equipment is governed by the Act on the Control of Dual-use Items and Technical Assistance, as well as by Council Regulation (EC) No 428/2009 of 5 May 2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items. See also information under Article 27, section I.1.1.

The Civil Protection Act
The Civil Protection Act contains provisions on how community rescue services are to be organised and operated. According to the Act, the County Administrative Board is responsible for rescue operations in cases where the public needs protection from a radioactive release from a nuclear installation and in cases where such release seems imminent. The Act also stipulates that a rescue commander with a specified competence and having extensive authority is to be engaged for all rescue operations. In addition, the Act requires the owner of hazardous installations to take the measures necessary to minimise any harm to the public or environment if an accident were to occur in the installation.

The Civil Protection Ordinance contains general provisions concerning emergency planning. The County Administrative Board is obliged to draw up a radiological emergency response plan. The Swedish Civil Contingencies Agency (MSB) is responsible at national level for coordination and supervision of the preparedness for rescue services response to a radioactive release.

SSM decides on necessary measures for nuclear installations.

The Occupational Safety and Health Act
The Occupational Safety and Health Act contains requirements for the work environment and provisions regarding protection from accidents caused by technical equipment, dangerous materials or other work conditions. The Act also contains detailed provisions concerning responsibility and authority with respect to occupational safety issues.

The Transport of Dangerous Goods Act
The Transport of Dangerous Goods Act and Transport of Dangerous Goods Ordinance contain provisions for the purpose of preventing, hindering and limiting damage caused by transports of dangerous goods.

E.2.2 National regulatory framework

With reference to its legal mandate, SSM, in its Regulatory Code (SSMFS), issues legally binding safety and radiation protection regulations for nuclear activities and other activities involving radiation.

In addition, SSM may issue general advice on interpretation of the safety regulations. The general advice is not legally binding per se. Measures should be taken according to the general advice or, alternatively, methods justified to be equivalent from the point of view of safety should be implemented.

In connection with a major review and update of SSM's entire Regulatory Code, SSMFS, a model was introduced with guidance to the regulatory requirements. The guidance explains the purpose, background, application, considerations and references of each of the provisions.

SSM's regulations also implement binding EU legislation and international obligations. As part of preparing SSM's regulations, consideration is given to IAEA safety standards, international recommendations, industrial standards and norms, and the rulemaking of other Swedish authorities. SSM's regulations are issued in accordance with an established management procedure that stipulates technical and legal reviews of draft versions. Under governmental rules, a review is performed of the final draft by authorities, licensees, various stakeholders and industrial and environmental organisations.

Section L.1 contains a brief summary of the most relevant regulations relating to the safety of spent fuel and radioactive waste management.

E.2.3 Licensing

E.2.3.1 The Act on Nuclelar Activities

In principle, all activities involving nuclear material or nuclear waste constitute a nuclear activity for which a licence under the Act on Nuclear Activities is required. However, nuclear waste and nuclear material with a very low level of radiation can be released from regulatory control.

The Government is the licensing authority for nuclear facilities. SSM reviews the licence application and prepares a statement with recommendation for the Government's decision. After a Government licence decision, SSM authorises the continued construction, operation and closure of the facility in a step-wise manner and may stipulate conditions under the Act under each phase. For certain smaller facilities and activities, SSM has the mandate to issue a licence.

E.2.3.2 The Radiation Protection Act

For activities outside the nuclear fuel cycle all handling of radioactive substances requires a licence under the Radiation Protection Act and for which SSM issue licences. In the case of export of radioactive substances, a licence may instead be required under the Act (2000:1064) on the Control of Dual-use Items and Technical Assistance.

A separate licence according to the Radiation Protection Act is not required for activities licensed according to the Act on Nuclear Activities.

E.2.3.3 The Environmental Code

According to the provisions of Environmental Code, a licence is required for environmentally hazardous activities, which include facilities for the treatment, storage or disposal of spent fuel, nuclear waste or radioactive waste. A licence is also needed for the decommissioning of nuclear reactors.

For certain activities, including any facility requiring a Government licence under the Act on Nuclear Activities, the Land and Environment Court examines the application and submits comments to the Government as a basis for the Government's decision regarding the permissibility of the proposed activity. After the Government's decision, the case is handed over to the Land and Environment Court to determine provisions concerning environmental supervision, inspections and checks, the safety and technical design of the activity, and conditions that are necessary to prevent or limit any harmful or other detrimental impact.

E.2.3.4 Environmental impact assessments

General

The Act on Nuclear Activities, Radiation Protection Act and Environmental Code, require submission of an Environmental Impact Assessment (EIA) as a basis for the licensing.

An EIA is required for e.g. nuclear activities, such as waste management activities and facilities and decommissioning of reactors.

In other cases, with activities involving radiation, the Government or an authority appointed by the Government may, in licensing cases, prescribe that the applicant prepare an EIA before permission is given.

Legislation regarding EIA is in accordance with Council Directive 85/337/EEC of 27 June 1985, amended by Council Directive 97/11/EC of 3 March 1997 and by Directive 2003/35/EC of 26 May 2003, on the assessment of the effects of certain public and private projects on the environment. An EIA is to be submitted together with an application for a permit for environmentally hazardous activities.

The purpose of an EIA is to identify, describe and assess environmental impacts when planning and deciding plans and programmes (strategic environmental assessments) and activities and actions (specific environmental assessments). Environmental impact means direct or indirect effects that are positive or negative, that are temporary or permanent, that are cumulative or non-cumulative and that occur in the short, medium or long term. Below are examples of some basic components that should be included in an EIA:

- possible alternative designs and the reasons for the chosen design with regard to environmental effects;
- possible alternative locations and the reasons for the choice of site, taking into account differences in the environmental effects between the chosen site and the alternatives;
- information on existing environmental conditions before the start of activity and how those conditions are expected to develop if the activity is not started or taken;
- information on the measures envisaged to prevent, hinder, counteract or mitigate the adverse environmental effects, and
- a statement of the consultations that have taken place and what has emerged in the consultations.

The information to be included in the environmental impact assessment must have the extent and degree of detail that is reasonable in the light of current knowledge and assessment methods and is needed to make an overall assessment of the significant environmental impacts that the activity may be expected to cause.

The EIA-process

The following steps apply in the process of preparing an EIA.

Scoping – public consultation

In an initial scoping step the developer shall, before the work on the actual environmental impact assessment starts, conduct consultations on the location, scope and design of the activity and its environmental effects, and on the content and form of the environmental impact statement.

Prior to the scoping consultation, consultation documents must be prepared and submitted to the parties concerned, which are the County Administrative Board, the supervisory authority and the individuals who may be assumed to be particularly affected by the activity, as well as with the other state authorities, the municipalities, the general public and NGOs who may be assumed to be affected by the activity.

Consultation with other countries

In case of activities assumed to have a significant environmental impact in another country or if a country that may be considerably affected by the activity so requests, the Swedish Environmental Protection Agency shall inform the other country and give a reasonable time to comment on whether it wishes to participate in the environmental assessment. These provisions incorporate the requirements contained in the Aarhus Convention and the Espoo Convention.

Assessment of EIA in the licensing process

When the developer has submitted the application and the environmental impact assessment to the authority, the authority shall assess whether the impact assessment, to the extent and degree of detail that is reasonable in the light of current knowledge and assessment methods and is needed, enables an overall assessment of the significant environmental impacts that the activity may be expected to cause. After this, the EIA shall be announced and made available to the public for comments during at least 30 days.

In a decision of its own or in connection with the final review of the application, the licensing authority shall decide whether the environmental impact assessment meets the requirements. The authority shall also complete the environmental assessment by identifying, describing and making a final and comprehensive assessment of the environmental impact, taking into account the content of the environmental impact assessment and what emerged during the review process of the case.

When the application with an EIA has been approved, the licensing authority shall announce this as soon as possible. The announcement shall describe how the public can access the content of the decision.

E.2.4 Prohibition, revocation and sanction

It is prohibited to carry out nuclear activities or activities involving radiation without a permit or licence. Any person who deliberately, or through negligence, operates an activity without the necessary permission shall be fined or sentenced to not more than two years imprisonment. The same penalty (for unauthorised environmental activity) applies under the Environmental Code.

The licensing authority may revoke a licence to conduct nuclear activities under the Act on Nuclear Activities if:

- conditions have not been complied with in some essential respect;
- the licensee has not fulfilled its obligations concerning research and development work on waste management and decommissioning, and there are very specific reasons from the point of view of safety to revoke the licence; or
- there are any other very specific reasons for revocation from the point of view of safety.

This means that revocation of a licence may be decided in cases of severe misconduct by the operator or otherwise for exceptional safety reasons. If the licence to operate a nuclear power plant is revoked, the licence holder nevertheless remains responsible for waste management and decommissioning.

Under the Radiation Protection Act the licensing authority may decide to fully or partially revoke a licence if the licensee in any material respect does not comply with regulations or conditions imposed pursuant to the Act, if there are particular reasons from a radiation protection point of view or if the licensee requests it. Furthermore, the Government, or the authority appointed by the Government, may issue additional regulations on prohibitions and other precautions to protect human health against the risk of damage from ionising radiation.

Under the Environmental Code, a supervisory authority may in individual cases impose the injunctions or prohibitions that are required on an operator for compliance with the obligations of the Code.

The Act on Nuclear Activities also contains provisions on sanctions. Anyone who conducts nuclear activities without a licence, or disregards conditions or regulations, will be sentenced to pay a fine or imprisoned for a maximum of two years. If the crime is intentional and aggravated, the individual shall be sentenced to imprisonment for a minimum of six months and a maximum of four years. Liability shall not be adjudged if responsibility for the offence may be assigned under the Penal Code or the Act on Penalties for Smuggling (2000:1225), or if the offence is trivial.

Under the Radiation Protection Act fines or imprisonment can be sentenced for violations of the law. Anyone who intentionally or through gross negligence violates the law can be sentenced to a fine or imprisonment for a maximum of two years. Anyone who intentionally or negligently violates certain provisions of the law can be

sentenced to a fine or imprisonment for a maximum of six months. Liability under the Act is not adjudged if responsibility for the offence may be assigned under the Penal Code or the Act on Penalties for Smuggling. Nor is liability adjudged in the instance of a minor offence deemed to be a trivial case.

Under the Environmental Code, the supervisory authority may issue any injunctions and prohibitions that are necessary in individual cases to ensure compliance with the requirements of the Code and provisions, judgements and other decisions issued in pursuance thereof.

Regulations on civil liability for radiological damage are contained in the Atomic Liability Act. The Act is largely based on the contents of the Paris Convention on Nuclear Third Party Liability from 1960 and the Brussels Supplementary Convention from 1963, to which Sweden has acceded.

E.2.5 Institutional control, regulatory inspection, documentation and reporting

E.2.5.1 Institutional control

According to regulations or licence conditions on radiation protection, the licence holder must conduct environmental monitoring. All discharges from facilities for storage or disposal of radioactive waste must be monitored by a nuclide specific measuring programme. The dose to any individual in the critical group is not allowed to exceed 0.1 mSv/y.

The general obligations contained in the regulations SSMFS 2008:1 and several other regulations are applicable also to decommissioning and dismantling activities, for example regarding provisions with respect to the monitoring of discharges and unplanned and uncontrolled releases. SSM, has also issued additional licence conditions for the decommissioning of reactors which complement the provisions in the regulations, concerning for example measurement programmes for the clearance of materials and for site release.

The legal framework for the design of a geological disposal facility contain requirements on passive post-closure safety solutions, meaning there should be no need for additional safety measures or environmental monitoring after closure. Following the closure of a disposal facility and the termination of licensee responsibilities, the institutional control will be overtaken by the state, including for example maintaining records, safeguards or land use restrictions. The Swedish parliament adopted amendments to the Act on Nuclear Activities and the Environmental Code in June 2020 to further formalise the state's ultimate responsibility for a closed geological repository, in accordance with Sweden's international commitments (see section E.2.7).

SSM has also issued conditions regarding institutional control of existing shallow land burials, stipulating that institutional control shall continue until the radioactivity no longer is a 'significant' hazard to public health and the environment. The municipalities' detailed development plans are also of importance by providing conditions concerning the use of the land.

The Swedish Environmental Protection Agency manages a national funding programme on remediation of contaminated land from past practices. Potentially contaminated areas are identified, investigated and classified. No area has yet been identified for remediation in respect of radioactive substances only. However, identification of potentially contaminated areas is an ongoing process.

E.2.5.2 Regulatory inspections

Nuclear activities and activities involving radiation are subject to extensive inspections under various laws. For radiation protection, nuclear safety and security, SSM is responsible for supervision of compliance with the Act on Nuclear Activities and Radiation Protection Act, the Environmental Code as well as with conditions or regulations imposed under the Acts.

As far as concerns other environmental aspects covered by the Code, the County Administrative Board performs supervision.

According to the Ordinance to the Environmental Code, SSM is also to provide regulatory guidance regarding supervision of pollution damage and other environmental damage caused by radioactive substances.

The implementer must on request submit to the Authority the information and documentation required for its supervision. The Authority is also to be given access to the installation or site where the activities are conducted for investigations and sampling to the extent required for supervision. The police authority shall provide assistance if needed for the supervision. See section E.3.2.6 for a more detailed description of SSM's supervisory processes and methods.

E.2.5.3 Documentation and reporting

Reporting requirements on licensees

The Act on Nuclear Activities, the Radiation Protection Act and the Environmental Code contains a number of different documentation and reporting requirements.

The Nuclear Activities Act and the Radiation Protection Act focus on issues related to safety and radiation protection. The Environmental Code requires operators to annually submit a general environmental report. The environmental report shall describe the measures taken to comply with the conditions in the licence and the results of the measures.

SSM's regulatory code requires a number of detailed documentation and reporting. Below are some examples of interest in the context of Joint Convention:

- Licensees for nuclear reactors shall report annually to SSM what measures have been taken or planned to be taken to limit emissions of radioactive substances.
- Results from environmental monitoring shall be reported to SSM in accordance with a defined program
- Events leading to increased emissions of radioactive substances from nuclear facilities should be reported to SSM as soon as possible, presenting the measures taken to limit the emissions.
- Annual reporting to SSM on the management of nuclear waste:
  - » the quantities of nuclear waste occurring on the site or that have in any other way been transferred to this site;
  - » nuclear waste that has been transferred to disposal or which has been transported from the facility for processing or storage at another facility, or which has been subjected to clearance;
  - » nuclear waste at the site at year-end, indicating the nuclide and the locations where nuclear waste is stored; and
  - » operating experience from waste management, and monitoring of waste management plans.
- Annual reporting to SSM on radioactive waste with information on:
  - » amount of waste with its various properties;
  - » content of radioactive substances in the waste;
  - » who is responsible for the disposal of the waste; and
  - » planned final goal of the waste with a schedule and reference to the waste plan.
- A waste plan on the radioactive waste shall describe how and when the waste should be disposed of. The plan shall be based on an evaluation of different ways of handling the waste and kept up to date.
- Before a plant is constructed, a decommissioning plan must be drawn up for the future decommissioning of the facility. Not later than one year after the final closure of the plant, the decommissioning plan shall be renewed and reported to SSM. The plan shall include extensive details about the:
  - » documentation on the plant;
  - » planning conditions; and
  - » decommissioning operations
- Annual information to SSM from all licensees of high activity sources (HASS) regarding the following:
  - » when a new source has been acquired;
  - » if the conditions specified in a record sheet have changed;
  - » when the holder has transferred the source to a new holder or to a recognised installation, supplemented with information about the recipient of the source; and
  - » when the practice has ceased and no sources are held.
- The licence holders for nuclear activities shall:
  - » Annually report to SSM on the measures that have been taken or are planned to be taken in order to limit the discharge of radioactive substances, with a view to reaching defined goals. If the reference values are exceeded, the measures planned with a view to reaching the reference values shall be reported.
  - » Semi-annually report to SSM on the discharge of radioactive substances into air and water, shown as discharge of activity, and doses to individuals in a reference group.
  - » Semi-annually report to SSM on the results of environmental monitoring.
- At least once every ten years, licensees are required to perform a periodic safety review (PSR), i.e. an integrated analysis and assessment of the safety of a facility. The PSR should cover both nuclear safety and radiation protection with the purpose of clarifying how requirements stated in relevant legislation as well as issued in the form of regulations and conditions are met, and are expected to be met, over the following ten-year period. SSM conducts a comprehensive review and assessment of the submitted review and its references, and determines whether the necessary conditions exist to operate the facility in a safe manner until the next review; this outcome is documented in a review report. In the case of nuclear power reactors, the report is submitted to the Government.

Reporting requirements on the Regulatory body (SSM)

Reporting requirements also apply to SSM in accordance with the appropriation directions, Government decisions and acts and ordinances. In this context, the following reports may be mentioned:

- Annual Activity Report and Financial Statement, with a summary of results, effects and costs of the regulatory activities, in accordance with general regulations issued by the Government and Swedish National Audit Office for such annual reports issued by all government authorities. In its annual report, SSM gives an overview of the Authority's supervisory activities and the status of radiation safety in society.
- Every three years, the regulatory authority is required to submit to the Government a review report on the nuclear industry's research, development and demonstration programme for disposal of spent fuel and nuclear waste, and the dismantling and decommissioning of nuclear installations (i.e. SKB's RD&D programme). In addition to the findings, conclusions and recommendations as to the purposefulness and quality of the programme, the review report also proposes conditions for the future conduct of the SKB RD&D programme that the Government may wish to prescribe under the Act on Nuclear Activities.
- The regulatory authority assigned by the Government shall on an annual basis report to the Government on the licences granted concerning the export, import or transit of nuclear waste and the construction, possession or operation of shallow landfill sites.
- The regulatory authority also issues reports to a number of organisations, such as the European Commission, UNSCEAR, OECD, the IAEA, etc. on a regular basis,

in compliance with international conventions. Most of this reporting is within the area of environmental radiation protection, but some parts also relate to occupational radiation protection.

In addition to the abovementioned reports, the regulatory authority issues periodic reports in order to inform the public of major activities. The regulatory authority also issues reports related to its regulatory research programme and regulatory reviews. All reports published by the regulatory authority are readily available to the media and general public.

Reporting requirements on the National Debt Office
Every three years, the regulatory authority appointed by the Government (the National Debt Office) is required to submit a proposal for the nuclear waste fees to be paid by the licensees of nuclear power reactors in order to cover the costs for disposal of spent fuel and nuclear waste and the dismantling and decommissioning of nuclear installations. The regulatory authority also includes a review report on the cost estimates provided by the licensees.

E.2.6 Enforcement of regulations and terms of licences

The authorities have extensive legal, regulatory and enforcement powers. As described in section E.2.4 concerning prohibition, a licence may be revoked for activities that do not fulfil the obligations set out in the legislation. If there is an ongoing licensed activity that does not comply with regulations or terms of the licence, the supervisory authorities may issue any injunctions and prohibitions required in the specific case to ensure compliance. Injunctions or prohibitions under the Acts may carry contingent fines.

If a person fails to carry out a measure incumbent upon him or her under the Acts or Ordinances, or regulations or conditions issued pursuant to the Acts, or under the supervisory authority's injunction, the authority may arrange for the measure to be taken at his or her expense.

E.2.7 Allocation of responsibilities

The Swedish legal framework allocates a clear division of responsibilities between the bodies involved. As already mentioned, the producer of spent fuel and radioactive waste has the responsibility of safely handling and disposing of the waste produced. All the necessary measures and precautions should be taken by the waste producer. The authorities independently supervise, regulate and review existing or planned activities involving spent fuel and radioactive waste.

The ultimate responsibility for ensuring the safety of spent fuel and radioactive waste rests with the State. This has previously been considered to be 'a matter of course' and not been explicitly expressed in the legislation. However, as stated in section A.4, this will be formalised in an amendment to the Act on Nuclear Activities that will enter into force 1 November 2020.

E.2.8 Information and transparency provisions at existing nuclear facilities

It is considered crucial to give the general public insight into and information on nuclear activities. In municipalities where major nuclear facilities are located (power reactors, research reactors and facilities for manufacturing, handling, storage or disposal of nuclear material or nuclear waste), it is particularly important to provide the residents with correct and reliable information. For this purpose, 'local safety boards' have been established in the municipalities hosting nuclear power plants.

The licence holder of a major nuclear power plant is required to give the local safety board insight into the safety and radiation protection work at such plant. The licence holder must, at the request of the board, provide the board with information on the facts available and not only give the board opportunities to study relevant documents, but also access to plants and sites.

The function of these boards is to obtain insight into safety and radiation protection matters and to inform the public about these areas. Consequently, it is important to point out that the board does not have the powers to impose requirements on nuclear power plants, or to prescribe safety-enhancing or other measures for these plants. These functions rest exclusively with the regulatory authorities.

For a more comprehensive description of measures for openness and transparency, see sections A.6.7, E.3.2.9, G.3.1.2, K.3.1.5 and K5.

E.2.9 Licensing – implementation in practice of legal and regulatory framework

The following text describes the licensing system for the treatment and disposal of spent fuel, radioactive waste, very low-level radioactive waste, and non-nuclear radioactive waste. The system of release is also mentioned in this context.

E.2.9.1 Facilities for the management and disposal of spent fuel and radioactive waste

General about the Licensing Process
The Environmental Code and Act on Nuclear Activities govern the licensing of facilities for handling and disposal of spent fuel and radioactive waste from the nuclear fuel cycle. In addition, the Radiation Protection Act applies to establishing radiation protection conditions for the activity. These acts have different purposes and involve several authorities (see Figure E1).

During the licensing process, an important instrument is the Environmental Impact Assessment (EIA). Early consultation with the individuals likely to be affected, as well as with the government agencies, affected municipalities and organisations, is emphasised in Swedish EIA legislation. The consultations must relate to the location, scope, design and environmental impact of the activity and to the content and structure of the EIA.

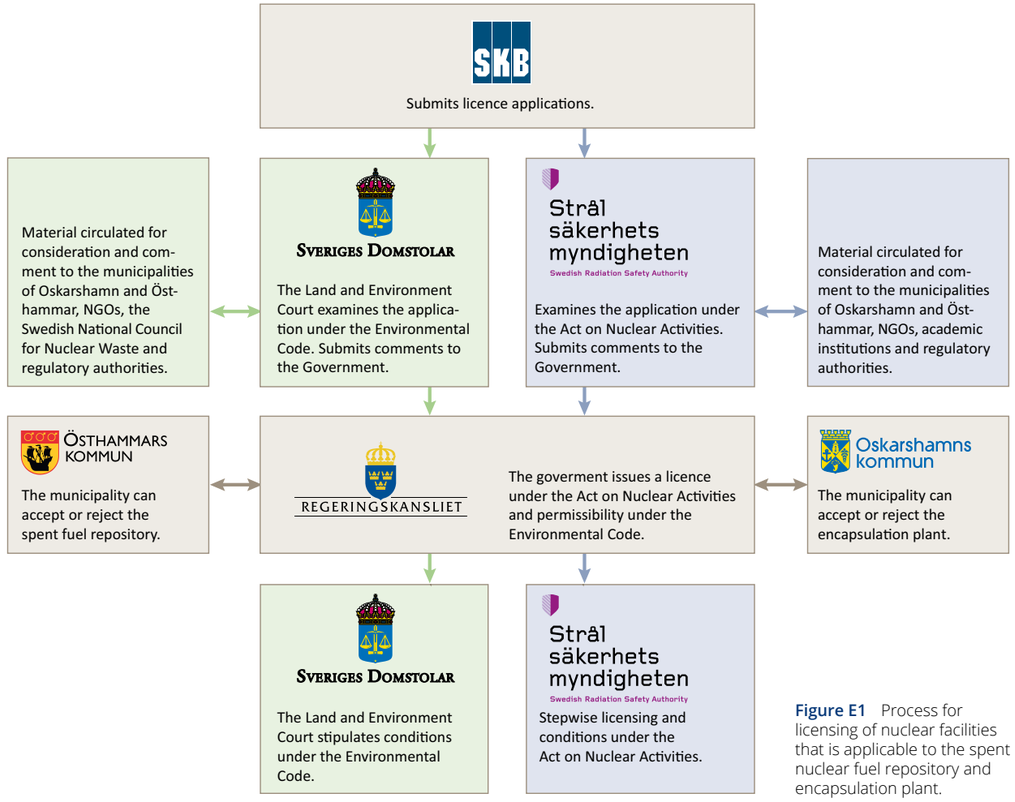


Figure E1 Process for licensing of nuclear facilities that is applicable to the spent nuclear fuel repository and encapsulation plant.

If an activity or measure is likely to have a significant environmental impact in another country, the Swedish Environmental Protection Agency must inform the responsible authority in that country about the planned activity or measure, and give the country concerned and the citizens affected the opportunity to take part in a consultation procedure concerning the application and the EIA.

Permissibility according to the Environmental Code
According to the Environmental Code, the Government is to consider the permissibility of certain activities such as interim storage or the disposal of spent fuel or radioactive waste. An environmental impact statement must be submitted for the permissibility assessment. The Land and Environment Court reviews an application from the point of view of permissibility, which is thereafter forwarded to the Government for final consideration.

Municipal right of veto
According to the Environmental Code, the Government may only decide on the permissibility provided that the municipal council concerned agrees that the activities may be located in the municipality (municipal right of veto). However, without prejudice to the municipal approval, the Government may permit an activity that involves interim storage or disposal of spent fuel or waste if the activity is of utmost importance with regard to national interests. This shall nevertheless not apply in cases where another site is considered to be more appropriate for the activity, or if an appropriate site has been designated for the activity in another municipality that is likely to approve the activity.

Approval according to the Act on Nuclear Activities and Environmental Code
If the Government grants permissibility in accordance with the provisions of the Environmental Code, licensing approval needs to be issued for the nuclear activity under the Act on Nuclear Activities and for the environmentally hazardous activity under the Environmental Code. The Government (or the authority appointed by the Government) grants a licence under the Act on Nuclear Activities, based on review by the regulatory authority assigned by the Government. A licence under the Radiation Protection Act is not required for activities covered by the Act on Nuclear Activities.

Following a Government permissibility decision, the Land and Environment Court grants a licence and issues conditions regarding environmentally hazardous activities under the Environmental Code. SSM may issue licence conditions under the Act on Nuclear Activities and Radiation Protection Act as part of a stepwise authorisation process following a Government licensing decision (see below).

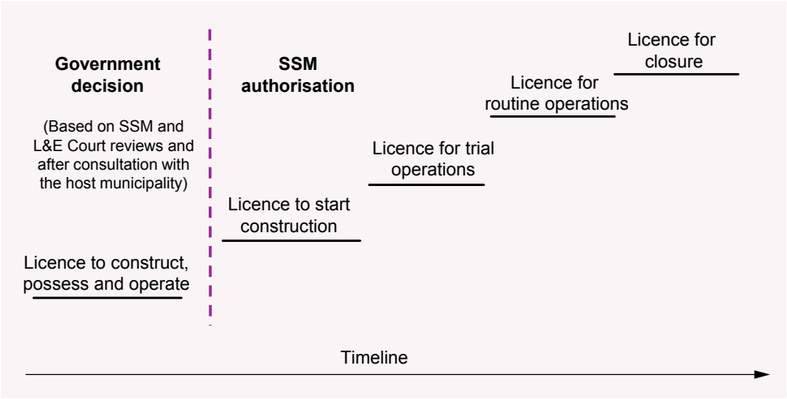


Figure E2 The stepwise process of regulatory authorisation and supervision following a Swedish Government decision on licensing of a nuclear facility.

It may be noted that the review of an application under the Environmental Code takes place in open court hearings at the Land and Environment Court. At that hearing, all interested parties may attend, pose questions and make comments. The applicant must verbally describe all relevant aspects of its case. Prior to the court hearings, SSM submits a statement on whether the application meets the requirements of the Environmental Code. This statement is mainly based on SSM's parallel review of the licence application in accordance with the Act on Nuclear Activities. SSM is expected to participate in the hearings as the competent authority concerning nuclear safety and radiation protection issues.

Continued Stepwise Process of Regulatory Authorisation
Following Government approval, the regulatory authority (SSM) authorises the start of construction, the start of trial operations, the start of routine operations, and the decommissioning of the facility (see Figure E2). A Government decision is again needed for delicensing and the exemption from responsibilities. The authority reviews the application to ensure that all obligations and licensing conditions have been fulfilled.

Safety Analysis Report
The safety analysis report (SAR) is central in the review process and must be kept up to date throughout all the steps. The SAR should provide an overall view of how the safety of the facility is arranged in order to protect human health and the environment against nuclear accidents. The report is to reflect the facility as it is built, analysed and verified, as well as show how the requirements for its design, function, organisation and activities are met.

In addition, and as appropriate, SSM examines the organisational, human and administrative capacity to carry out work to the extent and quality required as well as preliminary plans for decommissioning of the facility.

E.2.9.2 Shallow land burials
Shallow burial is used in Sweden for very low-level radioactive waste from nuclear activities. Like other nuclear installations, shallow land burials are licensed under both the Act on Nuclear Activities and the Environmental Code. In the Ordinance on Nuclear Activities, SSM is given the mandate to licence nuclear installations such as shallow land burials up to a specified inventory limit of 10 TBq, of which a maximum of 10 GBq may consist of alpha active substances. Furthermore, shallow land burial is defined as an environmentally hazardous activity and must be approved under the Environmental Code by the Land and Environment Court. No approval by the Government is needed before the Land and Environment Court can issue a licence, including licence conditions, under the Environmental Code.

Similar to other repositories for nuclear waste, applications are to be filed in accordance with the Act on Nuclear Activities and the Environmental Code, to SSM and the Court respectively. An important instrument during the licensing process is the Environmental Impact Assessment (EIA), which is required as a part of both licence applications. The applicant should involve the individuals, government agencies, municipalities and organisations concerned in a consultation procedure. The consultations must relate to the scope, design and environmental impact, and to the content and structure of the EIA.

Licensing conditions can be issued under the Act on Nuclear Activities, Radiation Protection Act and Environmental Code. This means that SSM and the Land and Environment Court can issue the conditions necessary from specific aspects concerning nuclear safety, radiation protection and environmental protection, respectively. Conditions may be issued in connection with licensing or during the period of validity of the licences.

E.2.9.3 Radioactive waste from medical use, research and industry
Handling and disposal of radioactive waste from medical use, research and industry require a licence under the Radiation Protection Act and Environmental Code.

E.2.9.4 Clearance
Clearance of nuclear materials or nuclear waste must be in accordance with the provisions of the Act on Nuclear Activities as well as with the Radiation Protection Act, and approved by the regulatory authority. Material may be cleared for unrestricted use, or for disposal as conventional non-radioactive waste. A licence under the Environmental Code, as is applicable to non-radioactive waste, may be needed if material that has been 'cleared' is to be disposed of as non-radioactive waste.

E.2.9.5 Decommissioning
According to the Act on Nuclear Activities, no specific licence is required for decommissioning of nuclear facilities. However, according to the Environmental Code, a licence is needed for decommissioning and dismantling of nuclear power reactors. In addition to the specific requirements (see also section E.2.1.3), the applicant is also required to demonstrate compliance with a number of principles, e.g. the knowledge principle, the precautionary and BAT principles, and the after-treatment liability principle. (F.6.1)

E.2.10 Conclusion
Sweden complies with the obligations of Article 19.

E.3 Article 20: Regulatory body

> **1.** Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 19, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.
>
> **2.** Each Contracting Party, in accordance with its legislative and regulatory framework, shall take the appropriate steps to ensure the effective independence of the regulatory functions from other functions where organisations are involved in both spent fuel or radioactive waste management and in their regulation.

E.3.1 How Sweden is governed
The Swedish Constitution is the legal basis for Sweden's parliamentary form of government and the political principles by which the state is governed. It defines and delimits the tasks of Government, establishes the basic rights and freedoms of the people of Sweden and prescribes the procedures for elections to the Riksdag (Swedish parliament).

The Government governs Sweden by executing decisions taken by the Riksdag and initiating new laws and legislative amendments. The Government is accountable to the Riksdag and must have its support to be able to implement its policies.

The Government is led by the Prime Minister, who is supported by a number of ministers, each with their own area of responsibility. Each ministry is responsible for a number of government authorities, tasked with applying the laws and carrying out the activities decided on by the Riksdag and the Government. Government decisions are taken collectively in Cabinet, which means that all ministers must be in agreement. The ministers' performance of their official duties and the handling of government business is scrutinised by the Riksdag Committee on the Constitution (KU).

The Government issues instructions and yearly appropriation directions for the government authorities. These set out the tasks and objectives of the authorities' activities and the funding available to them. The Government thereby has quite substantial scope for directing the activities of government authorities, but it has no powers to interfere with how an authority applies the law or decides in a specific case.

The Government is responsible for recruiting and appointing the heads of government authorities. A Director General is normally appointed for a period of six years.

Government authorities have to submit annual reports and financial statements to the Government, which summarise major results, effects, revenues and costs of its activities. The Swedish National Audit Office, under the auspices of the Riksdag, scrutinises the government authorities and enterprises to ensure their compliance with directives, rules and regulations.

The level of requirements imposed on Swedish authorities for openness and provision of information services to the public, politicians and media is very high. The principle of public access to official documents has been enshrined in one of the fundamental laws, the Freedom of the Press Act. No one needs to justify a request to view a public document or to reveal their identity in order to gain access to a particular document. The principle of public access also means that officials and others working in central government, municipalities and county councils have constitutional freedom of communication to the media. The principle of public access entitles the general public to access official documents, unless a decision has been made to classify them as confidential under the Public Access to Information and Secrecy Act (2009:400).

In sections E.3.2.2, E.3.2.9 and E.3.2.10, the issues of independence of the regulatory function and transparency in regulatory activities and communication with the public are further elaborated.

E.3.2 The Swedish Radiation Safety Authority (SSM)
The Swedish Radiation Safety Authority (SSM) is a central administrative authority under the auspices of the Ministry of the Environment.

The term "radiation safety" in Sweden encompasses the areas of:

- radiation protection;
- nuclear safety;
- nuclear security and non-proliferation; and
- information security.

In its function as the central regulatory body in radiation safety, SSM has different roles and responsibilities. SSM is

mandated to supervise, authorise, issue regulations and guides, coordinate nuclear and radiological emergencies, and to provide expertise and services with regard to all activities that apply to radiation in society.

In this respect, SSM is the authorised regulatory body for the management of spent fuel and radioactive waste in accordance with the provisions of the Act on Nuclear Activities, the Radiation Protection Act and the Environmental Code.

E.3.2.1 Missions and tasks

The Governments' directives on missions and tasks for SSM are specified in the Ordinance (2008:452) with Instructions for the Swedish Radiation Safety Authority. Provisions on funding, reporting and specific assignments are found in the Governments' annual appropriation directions for SSM.

The missions and tasks can broadly be distributed into either a national or an international context, as briefly described below.

National responsibilities
SSM shall work proactively to maintain a high level of radiation safety in society, and through its activities strive to:

- prevent radiological accidents and ensure radiation safe operations and radiation safe waste management at nuclear facilities;
- minimise risks and optimise the effects of radiation in medical applications;
- minimise radiation risks in the use of products and services, or which arise as a by-product in the use of products and services;
- minimise the risks of exposure to naturally occurring radiation; and
- contribute to an enhanced level of radiation safety internationally.

Further according to the instruction, SSM shall:

- ensure that regulations and work routines are cost effective and straightforward for citizens and enterprises to apply and/or understand;
- provide the information and analyses within its area of responsibility that the Swedish National Debt Office needs to be able to carry out its tasks under the Financing Act (see section E.1.2.4);
- take the initiative for research, education and studies, and conduct external analysis and development activities in order to contribute to national competence for needs today and for the future;
- be in charge of the Swedish metrology institute for ionising radiation;
- operate a national dose register and, as appropriate, issue national individual dose passports;
- contribute to national competence development within the Authority's fields of activities; and
- provide data for radiation protection assessments and maintain the competence to predict and manage evolving issues.

International cooperation
SSM's missions and tasks with regard to international cooperation include to:

- carry out Swedish obligations in accordance with conventions, EU ordinances/directives and other binding agreements (e.g. point of contact, report drafting and being the national competent authority);
- supervise that nuclear material and equipment are used as declared and in compliance with international commitments;
- carry out international cooperation work with national and multinational organisations;
- monitor and contribute to the progress of international standards and recommendations;
- coordinate the activities needed to prevent, identify and detect nuclear or radiological events, also to organise and lead the national organisation for expert advice to authorities involved in or leading rescue operations.

Appropriation direction for 2020
In its appropriation directions for the fiscal year 2020, SSM was assigned to report to the Government on how the authority has worked to contribute to the development of national competence for today's and future needs within the authority's areas of activity. SSM shall also present an overall status report of the national competence within the Authority's areas of activity in relation to the needs. Another reporting requirement concerns how the Authority has developed its work to integrate Agenda 2030 into the national context within its area of operation to help achieve the global goals for sustainable development.

E.3.2.2 Effective independence

The de jure and de facto independence from political pressure and promotional interests is well provided for in Sweden. The regulatory body in radiation safety, the Swedish Radiation Safety Authority (SSM), reports to the Ministry of the Environment. Energy policy is managed within the Ministry of Infrastructure. The Ministry of Finance represents the Government's ownership in Vattenfall AB (one of the major owners of several nuclear power reactors in Sweden). All Government matters are decided on collectively by the Prime minister and his/her ministers, in Cabinet.

SSM performs its regulatory work autonomously and independently. The Government has no powers to intervene in a government authority's decision making in applying the law or discharging its authority in individual cases. All Swedish authorities are directed by the Government by Ordinances and annual budget appropriations, with decisions on funding, tasks and the general orientation of operations. Government authorities report on its activities and decisions to the relevant ministry, but a minister has no power to intervene in an authority's day-to-day operations, as 'ministerial rule' is prohibited. By this means the regulatory authority's effective independence in its decision making is ensured.

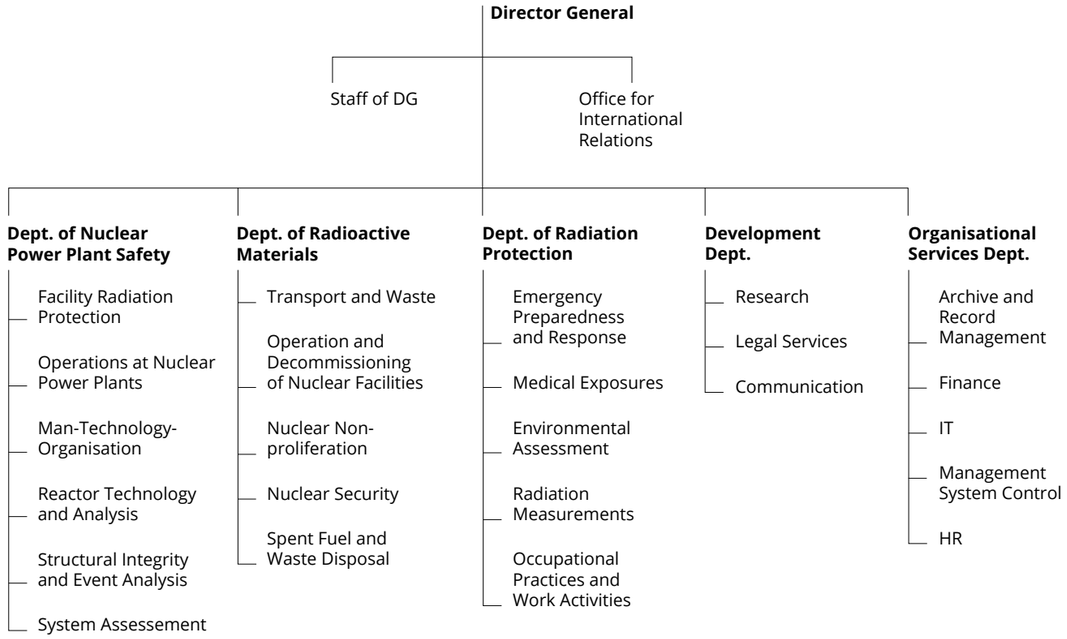


Figure E3 The present organisation of SSM (1 April 2020).

E.3.2.3 SSM's organisational structure

As reflected in SSM's organisational structure, shown in Figure E3, the Department of Radioactive Materials is the responsible department for all regulatory issues concerning spent fuel and radioactive waste management, as well as the supervision and authorisation of fuel cycle facilities and decommissioning of nuclear facilities. The department also has an overall responsibility for transports, nuclear security and nuclear non-proliferation issues.

The Department of Nuclear Power Plant Safety focuses on the supervision of nuclear safety and radiation protection on the part of nuclear power reactors in operation.

The Department of Radiation Protection coordinates national nuclear and radiological emergency preparedness activities and maintains a function on duty around the clock for response to incidents and other urgent matters, as well as the emergency organisation when mobilised.

The department also regulates the use of radiation sources in industrial and medical applications, performs laboratory measurements and calibrations, and is responsible for non-ionising radiation issues and environmental monitoring.

International development partnership activities are managed by the Office for International Relations.

All regulatory work is coordinated between the departments with respect to providing the right skills and resources to assigned activities, based on shared priorities and goals.

The Director General is exclusively responsible for the Authority's activities and reports directly to the Government. The Authority is supported by an advisory council consisting of a maximum of ten members appointed by the Government, usually members of parliament, high-level agency officials or representatives of interest groups. The council has no decision-making powers. The function is to advise the Director General and ensure public transparency (insight) in relation to the Authority's activities.

SSM's advisory committee on the safe management of spent fuel and radioactive waste is chaired by the head of the Department of Radioactive Materials. Its members are appointed by the Director General and represent other national or international authorities and independent institutions with relevant competence. The committee supports SSM regarding waste management practices and regulations and provides advice prior to key decision-making points and pronouncements.

SSM also has permanent advisory committees on reactor safety and research and development, as well as in other fields such as UV, EM fields and the use of ionising radiation in oncology.

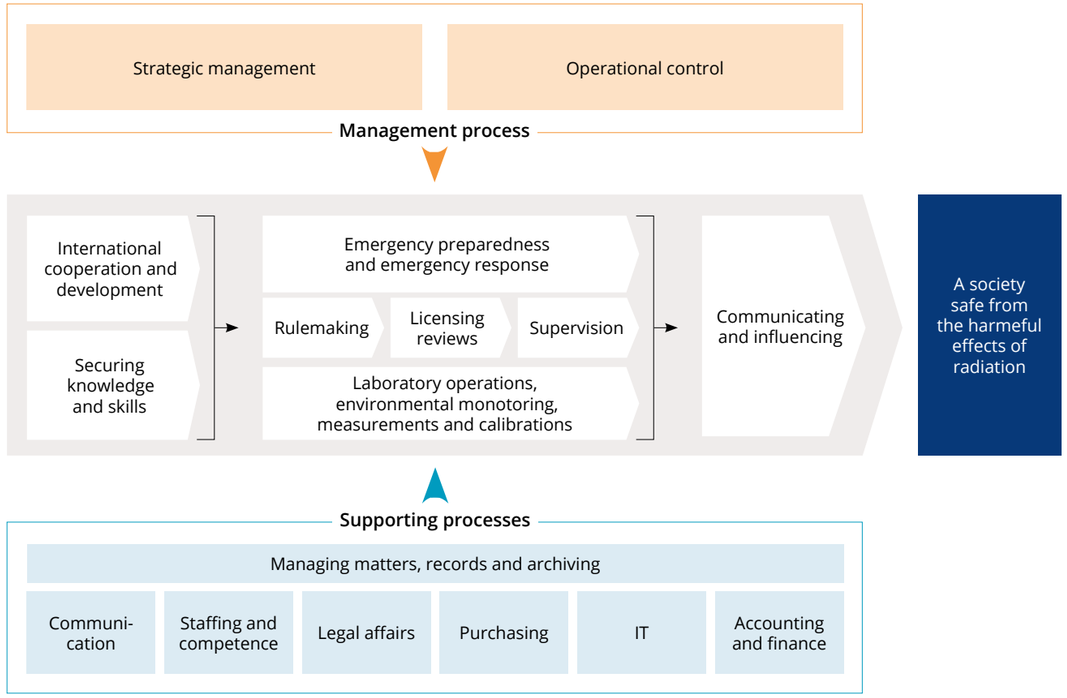


Figure E4 SSM's management system process scheme.

E.3.2.4 Leadership for safety

The Swedish Radiation Safety Authority (SSM) has, on the highest management level, established and integrated fundamental values in the form of a vision, goals and strategies for safety as well as key organisational values, as a basis for a strong safety culture and commitment to safety within its whole organisation.

Vision

– A society safe from the harmful effects of radiation.

Mission statement

– SSM works proactively and preventively to protect people and the environment from harmful effects of radiation, now and in the future.

– SSM has a systematic and structured approach to continual improvements to our processes in order to develop our operations, render them more efficient and achieve our objectives (see management system below).

Key values

– *Credibility,* i.e. decisions based on facts and science.

– *Integrity*, i.e. accountable and independent, no undue influence.

– *Openness*, i.e. transparent, actively informative, provisions for public insight.

E.3.2.5 Integrated management system

SSM has an integrated and process-based management system which is certified in the areas of environment, quality management and occupational health and safety in accordance with SS-EN ISO 14001:2015, SS-EN ISO 9001:2015 and SS-ISO 45001:2018. The current certificates are valid until December 2021. The National Metrology Laboratory is supervised regularly by SWEDAC, the Swedish Board for Accreditation and Conformity Assessment, in accordance with the standard SS-EN ISO 17025:2018. The management system encompasses all of SSM's operations. The system is supplemented by a section devoted to information security, which follows SS-ISO/IEC 27001:2017 although the management system is not certified in that area. Internal and external audits are performed yearly, which are one of the bases for continuous improvements to the system.

An interactive process tool is available through SSM's intranet. The comprehensive process map highlights the sequence of all key processes, and has been updated since 1 January 2019 to enable an active ownership of all processes. Process information and associated guidance materials are readily accessible within the interactive process tool. The processes and a robust document management system support the users in the daily work. Figure E4 illustrates SSM's present comprehensive process map.

Internal and external audits

SSM ensures that annual internal and external audits of the Authority's activities are carried out. The SSM management system accounts for internal and external requirements; the latter including ISO standards, statutes and legal provisions.

The objective of internal audits is to check compliance with external and internal requirements, to investigate how the 'shared values' are integrated in the day-to-day work, and to check whether the management system is effective and fit for purpose. SSM's internal auditors are appointed by the Director General. Audit teams are formed based on experience, competence and audit objectives.

External audits are carried out every year. Audits on the annual report, finances and effectiveness are conducted by the Swedish National Audit Office. The requirements of ISO 9001, ISO 14001, ISO 45001 and other relevant requirements are audited by contracted external auditors accredited by the government authority SWEDAC. From the last external audit of SSM, conducted in September 2019, three deviations were identified and some proposals were made for improvement of the management system. The deviations and proposals are addressed within the management system.

SSM places an increasing focus on development of processes and approaches. The fundamental driving force is to raise the level of quality of our work and consequently achieve continually improving results. Other rationales are rendering our operations more efficient and improving the work environment for employees.

The work is comprehensive and the objective is to further elaborate the processes including policies, procedures and routines in order to achieve clarity and give the support that is needed for all employees.

E.3.2.6 Supervisory processes and methods

Regulatory supervision including inspection, review and safety assessments are carried out by SSM as authorised by the Ordinance on Nuclear Activities and the Radiation Protection Ordinance.

The documented findings from the supervisory activities provide a basis for SSM's annual integrated radiation safety evaluation for each authorised facility or activity.

Supervisory practices

SSM has continued to develop its supervisory processes and methods, which are also part of SSM's overall management system. Since 2015, internal projects have been carried out with the aim of improving and simplifying and thereby increase the quality and efficiency of SSM's supervision.

The supervisory process is divided into the following seven sub-processes in SSM's management system:

– Compliance inspections

– Surveillance inspections

– Reviews

– Managing events

– Managing reports

– Integrated safety assessments

– Periodic safety review, PSR

These processes are used in the supervisory programme as described below.

Supervisory programme

Over the past three years, SSM's supervisory programme has been fundamentally revised to provide better overview, assure complete alignment with regulations, and introduce a higher degree of risk-information in the frequency and scope of supervision.

The new supervisory programme was tested in 2017, and formally introduced within the reactor safety department in 2018. The programme was expanded and introduced also for non-reactor nuclear facilities in 2019, with due regard to a risk-informed graded approach. The programme entails considerable changes and improvements to the planning, implementation, and follow-up of supervisory activities. The supervisory programme is structured with two basic parts, baseline supervision and demand-based supervision (see Figure E5).

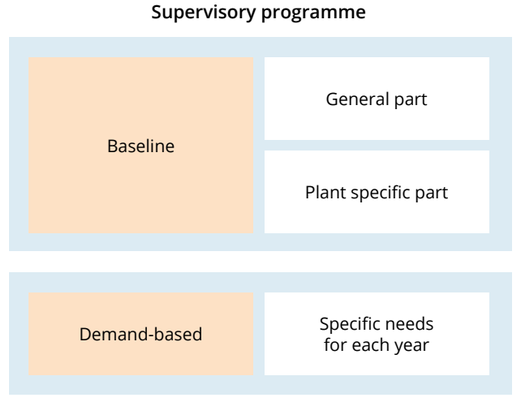


Figure E5 Supervisory programme structure.

Baseline supervision

The requirements building up the baseline supervision plan are divided into six fundamental aspects (see Figure E6):

– Management and control

– Safety analysis

– Design

– Plant status

– Operation

– Environmental impact

The baseline supervision plan covers a period of 10 years and describes the basic supervision groups that are carried out each year for nuclear facilities in operation. By the term supervisory groups is meant the delimitation of a supervisory area, e.g. maintenance, which includes a number of

requirements. Over the 10-year period, the baseline supervision programme covers every requirement in the regulations at least once.

The supervision groups are carried out every three, five or seven years, with due regard to a risk-informed graded approach. There are a total of 36 supervision groups, including, e.g.:

- Safety analysis
- Operations
- Management system
- Safety review
- Experience feedback
- Security
- ALARA programme

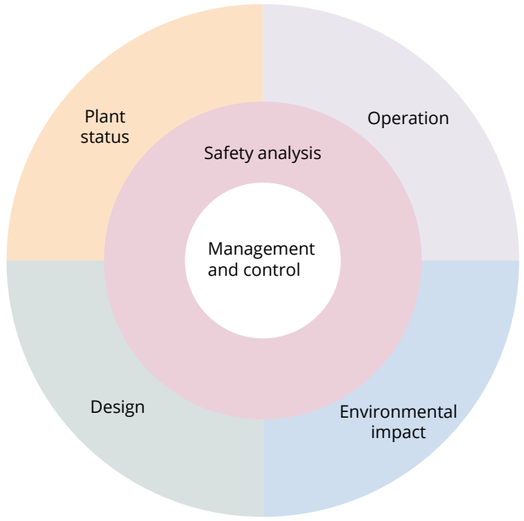


Figure E6 Fundamental aspects of baseline supervision.

Demand-based supervision – Identification of supervision needs
As an important complement to the baseline supervision, the demand-based supervision is defined for each facility on a yearly basis. It can therefore differ from year to year, depending on:

- Results from integrated safety assessments
- Results from inspections carried out or events that have occurred
- Identified areas where supervision is deemed necessary from, e.g., events or concerns
- Major ongoing changes, technical or organisational
- Other identified needs

Inspections
Compliance inspections are carried out by teams composed of the site inspector(s) and one or more experts on the subject matter of the inspection. An exit meeting is held where preliminary results are communicated to the licensee. The inspection report documents the purpose and objectives of the inspection, observations, compliance and deviations from requirements, an assessment of the significance of any deviations, and a proposal on any further regulatory actions.

In addition to compliance inspections, SSM carries out surveillance inspections to gather general information on safety issues and overall activities at the facility. For non-reactor nuclear facilities, these surveillance inspections are carried out on an ad-hoc-need basis including an annual meeting with the management of the facility. Some surveillance inspections take place in connection with events, to follow up organisational change, and relating to other current issues, such as findings from earlier inspections. In many cases, these inspections focus on non-technical issues, such as safety management and safety culture.

Preparation and documentation of surveillance inspections are simplified in comparison with compliance inspections, but the results are systematically documented and reported at SSM management meetings. Each surveillance inspection typically takes 1–2 days on site for 1–2 inspectors. Often, a specialist on the subject matter for the visit accompanies the inspector.

If necessary, SSM also undertakes a process known as 'special supervision'. Its use is decided by the Director General and is applied when the Authority is dissatisfied with the safety performance of a licensee. For other safety reasons, e.g. during test operations after a large plant modification, intensified supervision may be applied, meaning that more inspections are done and particular progress reporting is required.

Under SSM regulations, inspection of the licensee programmes, activities and results of surveillance, and in-service inspection of mechanical components, are performed by an accredited control body ('third-party control'). If the requirements are fulfilled, a compliance certificate is issued by the control organisation.

Periodic Safety Reviews
Requirements for Periodic Safety Reviews (PSR) to be carried out for nuclear power reactors at least every 10 years were introduced in the early 1980s. The requirements, developed to meet corresponding guidance in the IAEA Safety Standards, were extended in 2010 to cover also non-reactor nuclear facilities.

The requirements prescribe that the PSR should be carried out in a systematic way. The purpose of the PSR is for the licence holder to re-assess, verify and continuously improve the safety of its nuclear installations. In addition, the PSR addresses any issues that might compromise the safety of facility for the remaining planned operating period, and planned measures to counteract any such issues. Licensees are required to make all reasonably practicable improvements in line with a risk-informed graded approach. SSM reviews the licensee's PSR regarding confidence in the level of nuclear safety and radiation protection, and the licence holder's ability to maintain and increase it in the future. SSM's review is partly based on benchmarking against regulatory supervisory activities, while including an assessment of the licensee's ability to operate the facility safely until the next PSR.

SSM's integrated safety assessments
SSM's integrated safety assessments comprise radiation safety assessments of each major facility under SSM's supervision every two to three years, depending on the character of the facility at hand, in line with a risk-informed graded approach. Based on all compliance inspections, surveillance inspections, reviews, authority decisions and other relevant information, evaluations and a general appraisal are made of the nuclear safety, radiation protection, security and non-proliferation control status of the facility in relation to relevant requirements. The basic material should also cover earlier information and conclusions in order to identify trends that could otherwise be difficult to detect in a short-term perspective. The reports are presented at top-level management meetings with the licensees.

An aspect of importance when drafting the report is the traceability from the basis of data, via the analysis, to the final conclusions and the assessment. It should be clearly described how SSM evaluated the relevant issues, and the report should be comprehensible to interested parties lacking expert knowledge in the assessed areas. In order to perform the integrated safety assessments more effectively and to improve the quality of the assessment, SSM register all identified deficiencies and issues from performed supervisory activities in a designated database.

Table E1 SSM's competence supply model.

Measures	Aims	Examples of Methods
Attract	To attract staff with the right education, experience and competence	Elaborated guidelines on how to systematically attract staff Internal programmes for competent staff – A general introductory programme for new staff – Development programme for staff working with supervision
Recruit	To recruit the right person with the right competence	Documented recruitment procedure – Recruitment procedure based on the operational need for the right competence at the right time and place
Develop	To develop the right competence for each task	Competent leadership – Basic education and training of managers – Evaluation of each manager's leadership
Keep	To keep right competencies	Competence transfer concept – Structured competence transfer aiming to, when staff retire, preserve competence that only one or a few staff members have
Terminate	To terminate the employment in a structured manner	Exit interview – For staff whose employment is terminated, a final discussion is conducted for receiving feedback

E.3.2.7 Human resources

General Information
In 2019, 307 employees were employed at SSM; 168 men and 139 women. Their average age was 49. The same year 63 new employees were recruited. The staff turnover rate, including retirements, was 13 per cent, which is an increase from earlier years.

Compared with many other Swedish authorities, the staff of SSM have a relatively high level of educational background. This is a result of the many specialist areas covered by the Authority.

In an international comparison, the number of regulatory staff in Sweden is relatively small for the size of the nuclear programme. Many staff members are typically involved in several tasks, such as inspections, regulatory reviews and approval processes, revision of regulations, managing research contracts and participation in public information activities.

SSM applies a competence supply model (see Table E1). The objective of the model is to provide an overview of the methods and other measures that SSM uses in order to acquire and maintain the competence needed by the Authority.

Actions to attract and keep competence
SSM has continued to work on developing the Authority's brand in order to attract and keep employees. Shorter videos have been produced that highlight the professional profile of some employees, ads have been designed with new images from the authority's brand. SSM has also participated in student fairs with the aim of promoting the Authority as an attractive employer.

Employees on average undergo six days of training per year. In 2019, a compulsory full-day education in administrative law, state values and what it means to be a civil servant was arranged for all employees at SSM.

The purpose of the education was to strengthen the culture that should characterise a government agency, SSM's governance values and culture and convey that a good management culture is about the behaviours and attitudes that should characterise all government employees. This is in turn the basis for an efficient, legal and functioning authority.

Section K.1.4 describes how SSM works with challenges in securing national competences in the short and long term.

Management programme
SSM has developed a management supply programme with the aim of providing the Authority with new managers. Following nomination, interviews and testing, 10 employees have been selected to undergo a managerial and leadership training in 2020. With this program, SSM creates an attractive career path that contributes to providing competent managers in the long-term.

The programme will run throughout the year. It will include training in managerial skills and leadership as well as communication. SSM provides every participant with an experienced manager from SSM which acts as a mentor during the year.

Competent supervision
A continuous professionals training programme named Competent Supervision, is compulsory for all employees involved in SSM's regulatory supervision activities. The objective is for all inspectors to have the same basic skills for performing consistent supervisory work in accordance with SSM's internal processes and procedures, regardless of the facilities or activities that are the focus of one's supervision.

E.3.2.8 Financial resources

The regulatory activities of SSM are largely financed through yearly state budget appropriations. However, specific supervisory activities regarding spent fuel and nuclear waste disposal as well as nuclear decommissioning are reimbursed from the Nuclear Waste Fund, as decided by the Government.

The costs of the regulatory activities and related research financed through budget appropriations are largely recovered from the licensees in the form of fees recovered to the state budget. The amounts of the fees are proposed annually by SSM but decided by the Government. The budgets for 2017, 2018 and 2019, including the funding of the separately-financed international cooperation and development work, are shown in Table E2.

In addition, fees for reviewing certain applications or licensing work are paid directly to the Authority. The financial resources of the regulatory body have increased in real terms as compared to what was reported in the sixth Swedish national report. The 2019 budget for SSM has been increased further and totals approximately 532 million SEK.

Regulatory research and assistance by external experts
According to the Ordinance with Instructions for the Swedish Radiation Safety Authority, the main purposes of SSM's research are to:

- maintain and develop competence of importance for radiation protection and nuclear safety work, and
- ensure that SSM has the knowledge and tools needed to carry out effective regulatory review and supervisory activities.

SSM supports basic and applied research, including development of models, software and experimental studies. SSM has a total yearly research budget of approximately 70 million SEK (7 million euros). In addition, research relating to nuclear waste management (mainly spent fuel disposal) is financed through the Nuclear Waste Fund, in the order of 10 million SEK per year.

SSM provides funding for a number of research projects and positions at Swedish universities in order to develop and sustain national competence and teaching capacity. Key areas include reactor physics, severe accidents and non-proliferation. Research is also funded through open calls in the areas of radiation protection, waste management and Man-Technology-Organisation (MTO).

Regulatory Research in the Area of Waste Management
The former regulatory authorities, SKI and SSI, decided already in the late 1980s to develop a high level of in-house competence in geological disposal and post-closure safety assessments. This was in order to prepare for the regulatory review of SKB's anticipated licence application for a spent nuclear fuel repository. Subsequently, the authorities developed an extensive research programme covering different technical aspects of spent fuel disposal and safety assessment methodology. Sweden has no government-appointed TSO (Technical Support Organisation), instead the Swedish regulators have developed a network of national and international experts by involving universities, institutes and consulting firms, both nationally and internationally, in their research programme. In the 1990s, SKI also carried out two comprehensive safety assessment projects of the KBS-3 disposal method for spent nuclear fuel (Project-90 and SKI SITE-94). In parallel with these research activities, SKI and SSI initiated a number of international research initiatives in the areas of hydrogeology (e.g. Intracoin and Hydrocoin), model validation (e.g. Intraval), radionuclide transport, rock mechanics modelling (e.g. Decovalex), biosphere modelling (e.g. BIOMOVS) and protection of the environment (the European Commission FASSET and Erica projects).

In addition to the more technical research programme, Swedish regulators in the past also carried out a research programme on stakeholder dialogue together with environmental organisations, other non-governmental organisations and the municipalities involved in SKB's programme for siting of a spent nuclear fuel repository (e.g. the RISCOM I and the European Commission Riscom II projects). These projects have contributed to developing methods and fora for stakeholder dialogue and a better understanding of the roles and needs of different groups of actors.

In the years up until 2010, SSM's budget for research funding in the area of nuclear waste management varied between 1.5 and 2 million euros per year. However, during SSM's assessment of SKB's licence applications for a spent fuel repository (2011–2018) and for an extension of the repository for short-lived radioactive waste, SFR (2014–2019), there has been a shift in funding from research over to external review support. During the assessment period the main focus of the research has been on processes linked to SKB's suggested barrier system for the geological repository for spent nuclear fuel and on biosphere issues connected to dose estimation. About three times more funding, a total of 3.5 million euros, has been used for external review support than for research between 2011 and 2019. Since 2018, SSM has again increased its budget for external research in spent fuel disposal to around 1 million euros per year, in order to build competence and continuity in knowledge in preparation for the future regulatory review of SKB's updated safety analysis reports in the authorisation steps for construction and operation of a spent fuel repository that would follow a government licensing decision.

E.3.2.9 Transparency in regulatory activities

According to the Ordinance with Instructions for the Swedish Radiation Safety Authority shall by means of communication and transparency contribute towards public insight into all operations encompassed by the Authority's mandate. The aim of this work shall for example be to provide advice and information about radiation, its properties and areas of application, and about radiation protection.

SSM publishes all its significant decisions on its website. Through an e-register on the website, the general public can view the documents sent from the Authority or submitted to it. The Constitution gives everyone the right to access the documents held by the Authority. This does not apply to documents subject to confidentiality due to e.g. security aspects or other specified reasons. The Authority provides documents not subject to confidentiality upon request from the general public and journalists (see also sections K.3.1.5 and K.5).

Before issuing regulations, the financial and administrative implications for the companies concerned must be examined. An important aim of this analysis is that the requirements in the regulations must be justified, and not unnecessarily increase costs or the administrative burden for the operators. For this reason, SSM always communicates drafts through a referral process to obtain opinions on these and other aspects of the proposed regulations.

As part of the preparation of an Environmental Impact Assessment (EIA), an applicant must, before the application documents are submitted, consult with the County Administrative Board, relevant authorities, the potential host municipality, other stakeholders, the public (includes NGOs). The purpose of this consultation is to provide information about the planned activities and to obtain comments and suggestions on issues that need to be addressed in the EIA. If the planned activity is large and complex, a number of consultation meetings with different stakeholders may be required. SSM also participates in consultation meetings primarily intended for the municipality and other stakeholders concerned. The Authority can thus explain its role in the assessment process and the legal requirements underlying the review of the application.

An application submitted to the Authority is sent on referral to a large number of stakeholders, e.g. other authorities, the municipality concerned, County Administrative Boards, universities and NGOs. The application will also be published on the Authority's website and is open for anyone to submit comments on. In the event the

Table E2 Budget of SSM in million SEK (1 SEK is about 0.1 euro).

Budget item	2017	2018	2019	Source of funding
Nuclear safety, emergency preparedness and radiation protection (including administration)	308.5	317	321	Mainly fees
Supervision of nuclear facilities (proportion of above)	145	163	166	Fees
Licensing of new nuclear facilities, including new nuclear reactors	10	15	15	Fees
Scientific research and development work	76	76	76	Mainly fees
Final disposal of radioactive waste, including licensing, financial control and decommissioning	63	60	60	Nuclear Waste Fund
Historical wastes, etc.	8	3	3	Tax revenues
Crisis management	5.5	26	26	Tax revenues
International cooperation and development	39.5	31.5	31.5	Tax revenues
Total (million SEK)	**510.5**	**528.5**	**532.5**	

planned nuclear activity is large and complex, an international peer review of the application documents will be arranged.

According to the Environmental Code, the municipality concerned generally has the right to veto siting of facilities for final disposal of spent nuclear fuel and nuclear waste. A municipality may also arrange for an advisory referendum before it takes a final decision on whether to approve the project or exercise its right of veto.

E.3.2.10 SSM's communication policy

According to the Government ordinance with instructions, SSM shall, through information and transparency, contribute to providing the public with insight into all activities covered by its mandates. SSM's communication policy specifies the responsibility of employees and managers for internal and external communication. The policy also emphasises the Authority's key values of credibility, integrity and openness while defining its implementation.

Credibility

- SSM's messages are based on the laws and regulations governing its operations.
- SSM clearly conveys that its recommendations and decisions are based on objectivity and facts.

Integrity

- SSM communicates based on its mission: achieving a radiation-safe society. The Authority does not allow itself to be influenced by other interests.
- SSM clearly distinguishes between its own mission and actions, and those of others.

Openness

- SSM communicates proactively and in an understandable and accessible way regarding its activities and the issues it addresses.
- SSM is open even with respect to issues that might have a negative impact on the Authority.
- SSM is attentive to the needs of its stakeholders, and seek new ways of communicating with them.

SSM's communication policy states that all employees are responsible for communicating in accordance with the Authority's mission and fundamental values. It also states that all employees have the right to anonymously inform the media about our operations, according to the principle of public access and officials' freedom of communication.

SSM's communication policy is accompanied by an overall communication strategy, listing different key target groups. The strategy sets out how SSM's vision and governance goals can be achieved from:

- strategies for guidance of communication work, and
- criteria for navigating selection of communication activities.

The strategy has both an internal and an external perspective and applies to all employees.

Other strategy documents include a media strategy and an Internet strategy. The crisis communication strategy was formed through the experience gained during the accident at the Fukushima Daiichi NPP.

E.3.3 Other relevant authorities

The following subsections describe additional Swedish government authorities with regulatory functions that are the most relevant to this Convention, as listed below.

- Swedish National Debt Office
- The Swedish Civil Contingencies Agency
- The Swedish Environmental Protection Agency
- The Swedish Work Environment Authority
- The Swedish National Council for Nuclear Waste
- County Administrative Boards
- The Nuclear Waste Fund

E.3.3.1 Swedish National Debt Office

The Swedish National Debt Office is the central government financial manager. The Debt Office tasks include providing banking services for the central government, managing central government debt, providing state guarantees and loans and to manage government support for banks.

Since 2018, the Swedish National Debt Office is also tasked with securing the financing of nuclear waste management. The Debt Office review cost estimates submitted by licensees in accordance with the provisions of the Act and Ordinance on Financing of Management of Residual Products from Nuclear Activities (see section E.2.1.4)

For each of the licensees, the Debt Office must prepare a proposal for the nuclear waste fee which, based on an assessment, the nuclear licensee should pay over the subsequent three calendar years.

E.3.3.2 The Swedish Civil Contingencies Agency

The task of the Swedish Civil Contingencies Agency (MSB) is to enhance and support societal capacities for the preparedness for and prevention of emergencies and crises. MSB coordinates emergency preparedness funding, offsite emergency planning and oversees the planning of regional County Administrative Boards. MSB also evaluates onsite and offsite emergency exercises and initiates educational efforts.

E.3.3.3 The Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency monitors conditions in the environment and progress in environmental policy. The Agency has the task of coordinating, monitoring and evaluating efforts involving many agencies to ensure compliance with the Swedish Environmental Code and to meet national environmental objectives.

E.3.3.4 The Swedish Work Environment Authority

The Swedish Work Environment Authority's overall objective is to reduce risks of poor health and accidents in occupational environments and to improve workplaces from a holistic perspective, i.e. from the points of view of physical, psychological and organisational aspects. The Authority is tasked with (for example) ensuring compliance with occupational health and safety legislation.

E.3.3.5 The Swedish National Council for Nuclear Waste

The Swedish National Council for Nuclear Waste is an independent body under the Ministry of Environment. The Council's mandate is to study issues relating to nuclear waste and decommissioning of nuclear facilities, and to advise the Government and certain authorities on these issues. Council activities are financed through the Nuclear Waste Fund, as approved by the Government. The members of the Council are experts within different areas relating to the disposal of radioactive waste, not only in technology and science, but also in areas such as ethics and social sciences.

According to the Government instructions from 1 March 2018, the Council shall:

- Assess the research and development programme of the Swedish Nuclear Fuel and Waste Management Company (SKB), licence applications and reports of relevance to the disposal of nuclear waste.
- At the latest nine months after SKB has reported on its RD&D programme, present an independent assessment of the research and development activities and other measures presented in the RD&D programme. The Council shall also monitor the activities carried out in the area of decommissioning and dismantling of nuclear facilities.
- Investigate and highlight issues regarding the management and final storage of spent nuclear fuel and nuclear waste, as well as on the decommissioning and dismantlement of nuclear facilities. The Council shall advise the Government on these issues. Important target groups in addition to the Government are the authorities concerned, the nuclear power industry, municipalities, interested organisations and politicians and the media.
- During February, every two years from 2018, report on the previous years' work and their independent assessment of the current situation in the nuclear waste area.
- Monitor the development of other countries' disposal programmes for spent nuclear fuel and radioactive nuclear waste. The Council should also monitor and, when necessary, participate in the work of international organisations as regards disposal of radioactive nuclear waste and spent nuclear fuel.

E.3.3.6 County Administrative Boards

The County Administrative Boards exercise supervision under the Civil Protection Act (2003:778) and Ordinance (2003:789) and are responsible for planning and implementing rescue operations in cases where the public needs protection from a radioactive release from a nuclear installation, or in cases where such release seems imminent.

E.3.3.7 The Nuclear Waste Fund

The Nuclear Waste Fund is a government authority whose mission is to receive and manage the fees paid by nuclear power companies and licensees of other nuclear facilities in Sweden. The Nuclear Waste Fund makes payments in accordance with Swedish National Debt Office's decisions.

The authority has no staff of its own. It is governed by a board of directors representing public service as well as the power plant owners. The board is responsible for maintaining an investment strategy that ensures a good return and satisfactory liquidity. Fund assets must be deposited in an interest bearing account at the National Debt Office, or invested in treasury bills issued by the state or in covered bonds. The administration of the Nuclear Waste Fund is managed by the Legal, Financial and Administrative Services Agency.

E.3.4 Conclusion

Sweden complies with the obligations of Article 20.

Section F – Other General Safety Provisions

F.1 Article 21: Responsibility of the licence holder

1. Each Contracting Party shall ensure that prime responsibility for the safety of spent fuel or radioactive waste management rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

2. If there is no such licence holder or other responsible party, the responsibility rests with the Contracting Party that has jurisdiction over the spent fuel or over the radioactive waste.

F.1.1 Regulatory requirements

F.1.1.1 The prime responsibility

The licence holder has prime responsibility for the safety of spent fuel and radioactive waste management. A thorough presentation of the overall legal requirements imposed on a licensee under the Nuclear Activities Act, the Radiation Protection Act and the Environmental Code follows from section E.

Additional requirements at a more detailed level are set out in, inter alia the Swedish Radiation Safety Authority's (SSM) Regulations on Safety in Nuclear Facilities (SSMFS 2008:1) containing a number of functional requirements for safety management, design and construction, safety analysis and review, operations, nuclear materials/waste management and documentation/archiving. In addition, it is clearly pointed out in these regulations that safety shall be monitored and followed up by the licensee on a routine basis, and deviations identified and corrected so that safety is maintained and further developed according to valid objectives and strategies.

The continuous preventive safety work required includes reassessments, analysis of events in one's own and other facilities, and analysis of relevant new safety standards, practices and research results. Any reasonable measure useful for safety shall be taken as a result of this proactive and continuous safety work and be documented in a safety programme that is to be updated annually.

The basic safety documentation (Safety Analysis Report, SAR, including Operational Limits and Conditions, plans for emergency response and physical protection) must be formally approved by SSM. Plant and organisational modifications and changes in the safety documentation are to be notified and SSM can, if needed, impose additional conditions and requirements. All other issues are dealt with as part of licensee self-assessments. SSM examines how this responsibility is managed.

The basic radiation protection principles (justification, optimisation and dose limitation) mentioned in section E.2.1.2 as well as the use of the best available technique (BAT) apply to waste handling and disposal. These requirements are contained in for example SSM's Regulations Concerning the Protection of Human Health and the Environment in Connection with the Final Management of Spent Nuclear Fuel and Nuclear Waste (SSMFS 2008:37) and, regarding discharges, in Regulations on Protection of Human Health and the Environment in connection with Discharges of Radioactive Substances from certain Nuclear Facilities (SSMFS 2008:23).

SSM shall ensure that regulations and procedures used are cost effective and useful for individuals as well as companies. They must be written and designed so that the regulatory body does not take over the prime responsibility for safety and radiation protection.

The supervision that SSM carries out shall ensure that licensees fulfil the responsibility that lies with them according to the provisions of laws, ordinances and regulations, and that they operate the activity in a safe way and while maintaining radiation protection.

F.1.1.2 The ultimate responsibility

The State has an overall responsibility for activities regulated by the Act on Nuclear Activities. The ultimate responsibility for a closed geological repository rests with the State (see section A.4 and E.2.7).

F.2 Article 22: Human and financial resources

Each Contracting Party shall take the appropriate steps to ensure that:

(i) qualified staff are available as needed for safety related activities during the operating lifetime of a spent fuel and a radioactive waste management facility;

(ii) adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning;

(iii) financial provision is made which will enable the appropriate institutional controls and monitoring arrangements to be continued for the period deemed necessary following the closure of a disposal facility.

F.2.1 Regulatory requirements

F.2.1.1 Qualified staff during the operating lifetime

A detailed presentation of the overall legal requirements imposed on a licensee under the Nuclear Activities Act, the Radiation Protection Act and the Environmental Code follows from section E.

Basic provisions concerning the organisation and financial, administrative and human resources for the nuclear activity are contained in the Act on Nuclear Activities.

These basic provisions are expressed in further detail in regulations (SSMFS 2008:1 and SSMFS 2018:1). According to requirements in these regulation the activity must be conducted with an organisation that has sufficient financial and human resources designed to maintain safety. As a part of the management system, it must be ensured that those who work in the activity have the skills and aptitude needed for tasks that are important for radiation safety. The skills needed and the skills that are available must be systematically identified and documented. If it is necessary to achieve and maintain the needed skills, training should be conducted or other measures taken.

The regulations require that contractors and other hired personnel, have the competence and suitability otherwise needed for the tasks that are of importance for safety in the nuclear activity, and are to ensure that this is documented. The regulations also require an appropriate and justified balance between the use of in-house personnel and contractors for safety related tasks. The regulations require procurement of products and services of importance for safety in the nuclear activity to be governed by the management system, and that the management system should clearly specify how contractors and suppliers of services and equipment for the nuclear activity are assessed and how these assessments are kept up to date.

The regulations also contain provisions stipulating that the staff must be fit for their duties. This implies the stipulation of medical requirements for fitness to work, drug testing, etc.

F.2.1.2 Adequate financial resources to support safety during operation and decommissioning

The general obligations in the Act on Nuclear Activities stipulate that in order to obtain a licence, financial resources must be committed in order to manage the general obligations, including safety obligations. Each prospective licensee must be assessed in this respect during the licensing procedure.

As regards nuclear power reactors and nuclear fuel cycle facilities, funding of decommissioning is provided by means of investments in government-controlled funds. Licensees of nuclear facilities must pay a fee to the Nuclear Waste Fund in accordance with the Act on Financing of Management of Residual Products from Nuclear Activities, as described in section E.2.1.4. This is to ensure financing of decommissioning work and safe handling and disposal of spent fuel and nuclear waste, including the research needed for these activities.

F.2.1.3 Provisions for institutional control and monitoring after closure

As described in section E.2.1, the holder of a licence for nuclear activities are responsible for ensuring that all measures are taken that are needed for the safe handling and disposal of spent fuel and nuclear waste resulting from the activity. The legal framework does not require institutional control and monitoring after closure. This is because regulatory requirements on a disposal facility for spent fuel or nuclear waste mean that the facility is to be designed such that no institutional control or monitoring is required. It ensures that a licensee may be exempted from its responsibilities when decommissioning and dismantling have taken place and all spent fuel and nuclear waste have been disposed of in a sealed and closed disposal facility.

The State has an overall responsibility for activities regulated in the Act on Nuclear Activities. It follows that the State assumes responsibility for the arrangements and costs of any institutional control or monitoring conducted once a licensee has been exempted from its responsibilities (see sections A.4 and E.2.7).

F.2.2 Measures taken by the licence holders

F.2.2.1 Qualified staff during the operating lifetime

SKB has in its management system implemented a process for systematically developing the organisation and ensuring qualified staff and competence. The process is based on a systematic approach for complying with internal and external requirements to ensure that adequate competence is available for maintaining high safety and achieving the goal of the activities in the short and long term. This process also clarifies roles and responsibilities within the process.

In conjunction with the annual planning of activities, a competence and staffing analysis is carried out. The competence analysis shows the competence needed in a position or role in order to perform required tasks in accordance with the needs of the activities. Roles of specific strategic importance or of importance for radiation safety are identified. The analysis is made on both individual and group level and with a timeframe of four to five years. Strategic competence analyses with a timeframe of about ten years are conducted regularly but with slightly longer intervals than the annual planning of activities. The purpose of the strategic analyses for the planned construction of new nuclear facilities is to identify staffing needs (competence and number of personnel) and how competence is to be secured during the different construction phases.

The analyses show the competence needed to execute the activities and the need for competence development either by further training of existing personnel or by new recruitment. Training programmes are established for individuals and groups when necessary to complement the general introductory training for all new employees.

SKB has a competence management system in which competence assurance (documentation of competence and any gaps between requirements and assessed level) is performed for own personnel and consultants.

The competence of personnel is developed for example through rotation programmes where employees are given an opportunity to work within different areas and in different roles. SKB also has a competence transfer programme to prepare for generation changes and to reduce the vulnerability to loss of competence.

Regarding competence management in the very long term, i.e. a 50–100 year perspective, there are two important prerequisites that must be considered:

- SKB's activities are long-term and are planned to continue for about another 70 years, i.e. up until around 2090.
- SKB is a dominant actor in Sweden when it comes to the management of radioactive waste, but tasks of substantial extent will also be carried out by the owner companies, suppliers and regulatory authorities.

The first point is an advantage as competence development and competence management can be planned in the long term.

SKB has developed strategic competence management plans and analysed the risks and problems that may arise when it comes to competence management in the long term. SKB considers potential problems to be manageable.

F.2.2.2 Adequate financial resources to support safety during operation and decommissioning

Business planning is performed on a yearly basis according to SKB's management system. SKB's board of directors, who also decide on the strategic plan for the subsequent year and ultimately the yearly budget, initiate the planning. The plan, together with the RD&D Programme (section A.6.3), cost calculations and plans for projects and investments, are the basis for issuing instructions to the organisation. Based on a payment plan, SKB then requests funds from the Nuclear Waste Fund (sections A.8.3 and E.2.1.4) and directly from SKB's owners depending on the type of costs.

F.2.2.3 Provisions for institutional control and monitoring after closure

Post-closure institutional control and monitoring is not required by the legal framework (see section F.2.3.3 below).

F.2.3 Regulatory control

F.2.3.1 Qualified staff during operation

Compliance with the requirements for competence assurance has been inspected by SSM since SKB took over the operation of Clab and SFR. The regulatory authority concluded at the time that the required systematic approaches are in place to ensure long term staffing and competence of operations staff.

During 2013 and 2014, SSM initiated a more systematic inspection programme directed at SKB's nuclear facilities, i.e. Clab and SFR. The outcome indicated that there was room for improvement in several areas. SSM therefore issued injunctions requiring SKB to more clearly define matters such as: the distribution of responsibilities, safety management routines, control of requirements, management of deviations, and methods for continuous improvements in general. SSM thereafter closely monitored SKB's activities to improve the situation by means of in total three surveillance inspections in addition to review of reporting on progress from SKB. SSM concluded in the end of 2018 that the situation had improved such that the requirements imposed by the injunctions were fulfilled and that SKB conducts improvement work in a systematic and satisfactory manner. SSM concluded that regulatory control thereafter should be carried out as part of the baseline supervision plan for SKBs facilities.

F.2.3.2 Adequate financial resources to support safety during operation and decommissioning

SSM reviews the adequacy of financial resources to support safety during operation and during decommissioning as an integral part of the yearly inspection programme. In addition, the National Debt Office reviews the adequacy of resources directed to SKB through payments from the Nuclear Waste Fund, and decides on the reimbursements made from the Fund.

F.2.3.3 Provisions for institutional control and monitoring after closure

The legal framework for the design of a geological disposal facility contain requirements on passive post-closure safety solutions, meaning there should be no need for additional safety measures or environmental monitoring after closure. Following the closure of a disposal facility and the termination of licensee responsibilities, the institutional control will be overtaken by the state, including for example maintaining records, safeguards or land use restrictions (see sections A.4 and E.2.7).

F.2.4 Conclusion

Sweden complies with the obligations of Article 22.

F.3 Article 23: Quality assurance

Each Contracting Party shall take the necessary steps to ensure that appropriate quality assurance programmes concerning the safety of spent fuel and radioactive waste management are established and implemented.

F.3.1 Regulatory requirements

In June 2018, new general requirements were implemented in the form of regulation SSMFS 2018:1. Among many areas, this regulation covers quality assurance, thus replacing similar requirements that were contained in SSMFS 2008:1. What differ the new general requirements from earlier requirements in this area is a more detailed regulatory framework, including additional requirements and clearer guidelines that are provided. SSMFS 2018:1 requires nuclear activities with regard to related design, construction, operation and decommissioning to be managed, controlled, assessed and developed by means of a management system so designed that requirements for safety will be met. The management system, including the necessary routines and procedures, must be kept up to date and be documented. This view on the integration of quality and safety with other business concerns into a total integrated management system is in line with the IAEA Safety Requirements on Leadership and Management for Safety, GSR Part 2.

The management system should cover all nuclear activities at the facility. It is furthermore required by SSMFS 2018:1 to have the application of the management system, and its efficiency and effectiveness, audited systematically and periodically by a function having an independent position in relation to the activities being audited. An established audit programme must be in place at the facility.

Furthermore, it should be made clear by the management system how contractors and vendors are to be audited, and how to keep the results of these audits up to date. The internal audit function should have a sufficiently strong and independent position in the organisation and should report to the highest management of the facility. The audits should have continuity and auditors should have good knowledge about activities being audited. Audit intervals should take into account the auditing activity itself and the management function of the facility should also be periodically audited.

The legal conditions for supervision of suppliers have been changed through changes made in the Act on Nuclear Activities. This gives the regulatory body the possibility to monitor how the safety requirements are followed concerning activities conducted by suppliers or their subsuppliers and contractors or their subcontractors or other parties delivering services to the licensed organisation.

F.3.2 Measures taken by the licence holders

F.3.2.1 Quality programmes and management systems

Licensees in Sweden, generating or managing spent fuel and radioactive waste, have had their own management systems since the 1970s. The trend has been to move from quality programmes to management systems, which include quality assurance of various critical processes.

The management systems are to varying degree process oriented but important common elements are graded approach, safety classification, and validation and verification. The purpose is to create a management system where design, construction, operation and decommissioning is managed, controlled, assessed and developed, so that requirements for safety are met. The overarching goal is to create a management system that supports leadership and management for safety.

The management system contains processes for managing requirements. These processes ensure that external requirements such as laws, regulatory requirements and permits, as well as internal requirements are transformed into working methods within the different processes, and accounted for in the design of facilities.

The management system has a strong link to the safety analysis report (SAR), which normally is considered a part of the management system.

Typically, the management systems are described in a series of documents structured in a hierarchical pyramid. The number of levels in the hierarchical structure is established by each licensee. The highest level typically contains a comprehensive description of the organisation with responsibilities for functions and processes, division of responsibilities and management principles together with policies and directives to all departments and staff units. The next level contains commitments defined by the managers responsible on how to work with the tasks delegated from the highest level. This includes process descriptions, objectives and instructions for the different areas of responsibility. The lower levels contain instructions for specific activities and tasks, technical documentation, job descriptions etc.

The management system is available to everyone within the organisation as well as contractors, consultants and regulatory authorities. Information and training in the management system is given in proportion to needs.

A common approach at all licensees is: *"If we follow the management system, we comply with requirements"*.

F.3.2.2 SKB's management system

In the past three years SKB has transformed its management system to a process based management system. To support this transformation SKB has reinforced the Requirements Management Process, and restructured the Management Review Process. The purpose is to ensure that all requirements are met, that the processes are safe and efficient, and that the management system supports the line management to implement policies and to fulfil the organisation's goals and objectives.

A central part has been to define and implement 'Line management with process support'. Each process has an owner from SKB's executive management team, and is supported by a processes team for the continuous process development. To support the new structure and visualisation of the management system, a model has been development in the form of a 'House', where all parts of the management system can be reached on the intranet (Figure F1).

Figure F1 SKB's 'House', the entrance to the management system.

The 'House' consists of the following parts:

- 'Overarching' contains the Management system manuals, e.g. Roles & Responsibilities, and the Policies, as well as the Business plan, Programmes for improvement, and Scorecard/Dashboard
- 'Organisation' contains Organisation charts, and descriptions of all organisational units and their tasks and duties.
- 'Processes' contains descriptions of all processes and process instructions.
- 'Facilities' contains specific information for each facility, for example Operations and maintenance instructions, Safety analysis reports (SAR) and all technical documentation of the facilities.
- 'Projects' contains descriptions and documentation of ongoing Programmes and Projects.

It is essential to evaluate performance, and therefore SKB has several ways of assessing compliance with requirements and the management system, and for learning and experience feedback:

- A Safety Management Process that monitors safety, e.g. the operations management and decision making related to, for example, events and modifications of facilities or organisation. This process is supported by a Safety Review Process.
- A process for defining 'Programmes for improvement', e.g. developing an internal audit programme that is graded in frequency and depth, depending on risk and impact on safety. The audit programme addresses both daily operations and projects for modifications of existing facilities or development of new facilities.
- A process for Internal Audits to review compliance with the management system and to identify for areas for improvements. The internal audit function itself is normally audited by a team where the team leader is from another licensee (or from the corporate level), to ensure independence. The result from the internal audits is reported to SKB's Managing Director and managers accountable for observed deviations.
- A Purchasing Process, which includes evaluation of suppliers, using a graded approach that might include supplier audits. The processes secure that all purchases of goods and services which might affect, directly or indirectly, safety, the environment or personnel, will be audited. Supplier audits are performed in a similar way by other licensees, to facilitate sharing of experiences from audits and to optimise learning.

F.3.2.3 The Waste Management Process is owned by SKB

To fulfil the obligations in the licences to operate the nuclear facilities SKB has defined a Waste Management Process as one of the main processes in its management system, see Figure F2. To make it work it is essential that all other licensees (waste producers) whose radioactive wastes SKB receive and eventually dispose of align their waste management activities with this process. The process is supported by another process for defining Waste Acceptance Criteria (WAC). It is essential to secure that all handovers of waste in the overall waste management process are in compliance with the relevant WAC. It is also essential to keep records of all waste, since there is a long time perspective (decades) from where the process starts to where it ends.

The Waste Management Process, which is owned and controlled by SKB, ensures that the process from an overall perspective is understood and agreed by all waste producers. In order to increase the understanding of process, WAC and other SKB controlled and shared central documents SKB has set up joint committees with all major waste producers, primarily the nuclear power plants. In addition to the central documents, each waste producer does a breakdown of the Waste Management Process into underlying instructions, which are part of the individual producer's management system.

The central SKB-controlled and shared documents in the Waste Management Process are:

- A Waste Handbook, that describes the Waste Management Process. In the handbook it is stated for example which information SKB needs in the specifications from the waste producers and what information the waste type descriptions must contain.
- Waste Acceptance Criteria (WAC). This document is owned by SKB and stipulates the WAC applicable to SKB's repositories. All waste producers using SKB's repositories are obliged to follow these WAC.

In addition, SKB controls the Waste Type Descriptions (WTD) which is set up with every waste producer individually. This is a safety report for each waste type from each waste producer. The document covers all steps in the waste

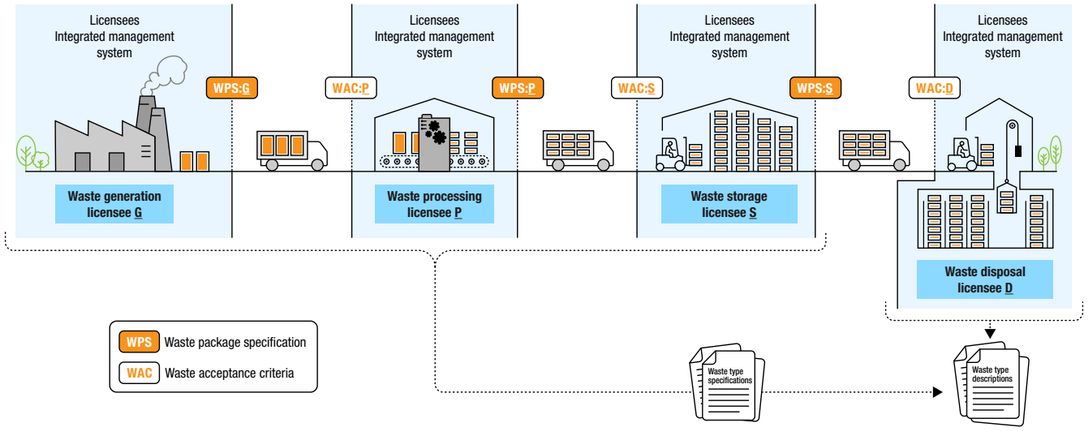


Figure F2 Description in principle of how the Waste Management Process works, but not the exact description in the main process in SKB's management system.

management process (waste production, conditioning, storage, transportation, reception and operational safety in the repository and post-closure safety) and present verification of WAC. SKB produces this document using a specification from the waste producer (covering the first steps; waste production, storage and transportation) as a reference.

The Waste Management Process is regularly evaluated by SKB together with the interested parties, including the waste producers, to ensure that safety is not compromised. In addition, SKB regularly audits the handling of radioactive waste at the nuclear power plants and other waste producers to ensure compliance with the waste management process. These audits are defined as 'process function audits' that complement the waste producers' internal audits.

F.3.3 Regulatory control

As per the new supervisory programme, SSM conducts baseline inspections in all areas. The MTO section has recently conducted baseline inspections of the licensees' management systems, organisations, and organisational change management. The purpose of the baseline inspections regarding the management system is to monitor the current status and progress of the licensees' principles for, and their systematic work on, their respective systems. This is to ensure that their management systems direct, control, evaluate and develop the organisation's activities. Another purpose is also to determine whether the management system is suitable, up-to-date, accessible and effective enough.

As far as concerns the baseline inspections in relation to an organisation, the purpose is to determine the current status of the licensees' organisations and their systematic work on ensuring that they have an organisation with an appropriate design for maintaining nuclear and radiation safety now and in the long term, as well as to judge the suitability of the organisation. The inspections also include looking into licensee management of organisational changes.

Furthermore, SSM conducts continuous supervision of the internal audit process. The results of internal audits are covered in most inspections and reviews of specifically defined technical areas, and sometimes the subject of inspections focusing specifically on audit programmes.

F.3.3.1 SKB's management system

During 2013 and 2014, SSM intensified inspection activities by means of a more systematic inspection programme directed at SKB's nuclear facilities, i.e. Clab and SFR. The outcome indicated that there was room for improvement in several areas. SSM therefore issued injunctions requiring SKB to more clearly define matters such as: the distribution of responsibilities, safety management routines, control of requirements, management of deviations, and methods for continuous improvements in general. SSM thereafter closely monitored SKB's activities to improve the situation by means of in total three surveillance inspections in addition to review of reporting on progress from SKB. SSM concluded in the end of 2018 that the situation had improved such that the requirements imposed by the injunctions were fulfilled and that SKB conducts improvement work in a systematic and satisfactory manner. SSM concluded that regulatory control thereafter should be carried out as part of the baseline supervision plan for SKBs facilities.

F.3.3.2 The 'Waste management process'

Regulatory review of the 'waste management process' is central in SSM's regulatory activities. In addition to baseline inspections of waste management activities, SSM reviews the waste acceptance criteria (WAC) documents developed by SKB as well as the waste type description (WTD) documents developed by the nuclear waste producers.

F.3.4 Conclusion

Sweden complies with the obligations of Article 23.

F.4 Article 24: Operational radiation protection

1. Each Contracting Party shall take the appropriate steps to ensure that during the operating lifetime of a spent fuel or radioactive waste management facility:

(i) the radiation exposure of the workers and the public caused by the facility shall be kept as low as reasonably achievable, economic and social factors being taken into account;

(ii) no individual shall be exposed, in normal situations, to radiation doses which exceed national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection; and

(iii) measures are taken to prevent unplanned and uncontrolled releases of radioactive materials into the environment.

2. Each Contracting Party shall take appropriate steps to ensure that discharges shall be limited:

(i) to keep exposure to radiation as low as reasonably achievable, economic and social factors being taken into account; and

(ii) so that no individual shall be exposed, in normal situations, to radiation doses which exceed national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection.

3. Each Contracting Party shall take appropriate steps to ensure that during the operating lifetime of a regulated nuclear facility, in the event that an unplanned or uncontrolled release of radioactive materials into the environment occurs, appropriate corrective measures are implemented to control the release and mitigate its effects.

F.4.1 Regulatory requirements

In order to regulate and create a basis for effective supervision of radiation protection at nuclear facilities, including those for management of spent nuclear fuel and radioactive waste, basic radiation protection requirements are laid down in the radiation protection act and in regulations issued by SSM.

On the 1 of June 2018, a new Radiation Protection Act (2018:396) and a corresponding Radiation Protection Ordinance (2018:506) entered into force. On the same day a package of eleven SSM-regulations also came into force, which together with the new Act and Ordinance transposed the Council Directive 2013/59/EURATOM. Among these, SSMFS 2018:1, *The Swedish Radiation Safety Authority's regulations on basic requirements for licensed activities with ionising radiation*, has a particular over-arching role in laying down the fundamental requirements in the area of nuclear safety and radiation protection and defining basic concepts to be applied. This includes, inter alia, evaluation of work conditions and events, a management system, required competence, protection and categorisation of workers and work places, proof on fitness for duty, protection of the public and the environment, etc. Further requirements are then to be found in more detailed regulations under this 'umbrella'.

Some additional SSM regulations, specifically referring to radiation protection and safety at nuclear facilities, are yet to be issued. In the meantime, necessary amendments have been made to the earlier, existing regulations.

F.4.1.1 Regulatory requirements for occupational radiation protection

Swedish occupational radiation protection requirements follow the requirements of Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. The principal provisions as regards occupational radiation protection in nuclear facilities are stipulated in the Radiation Protection Act (2018:396) and in SSM's regulations SSMFS 2018:1, 2008:24 and SSMFS 2008:26; see also section L.1.

General requirements

Anyone who conducts an activity involving ionising radiation shall ensure that a) it is justified, i.e. the benefits to society or individuals outweigh the radiation harm; b) the radiation protection is optimised and that c) exposure of workers and the public is kept below the applicable dose limits. Consequently, the licensee must have the necessary staff (knowledge, abilities and skills), economic resources and a management system and an effective organisation in order to take on these responsibilities and to ensure proper radiation protection.

Optimisation

Anyone who conducts a practice using or resulting in ionising radiation shall ensure that the radiation protection is optimised and that dose limits are not exceeded. In this context, dose constraints should be used as prescribed and appropriate. The licensee must ensure that goals are set, optimisation is performed and that the needed resources are made available in order to perform the actions and work towards the established goals.

Dose limits for workers

The limit for any worker in terms of effective dose is 20 mSv in a calendar year. The corresponding limits for the lens of the eye, skin and extremities are, in terms of equivalent dose, 20 mSv and 500 mSv, respectively. Lower limits, including age limits, apply for students and apprentices. Specific regulations also apply for pregnant and breast feeding workers.

Data on intakes and individual radiation doses are kept in a national dose register. Dose records are retained until an individual reaches the age of 75, and for a minimum of 30 years after their work involving ionising radiation has ceased.

The average individual dose (for those who incur a radiation dose above or equal to 0.1 mSv during at least one month of the year) at Swedish nuclear power plants is approximately 1 mSv. Since 2016, no more than five persons have received radiation doses above 10 mSv during a single year and no-one has received an annual effective radiation dose above 20 mSv since 2009 (see also Article 15 Radiation Protection in Sweden's eighth national report under the Convention on Nuclear Safety, Ministry Publication Series, Ds 2019.16).

Medical examinations
Each year, all workers must arrange to obtain a new doctor's certificate as proof of their being fit for service. A full medical examination must be performed the first time a certificate is issued.

When renewed the physician, in consultation with the employee, taking into account the employee's health condition and the risks of exposure to ionising radiation, should assess if the future service assessments need to be made at shorter intervals than a year, whether future service assessments should be based on medical examinations or health declarations, and the scope of the medical controls.

Supervised and controlled areas
Workplace zoning and a division into supervised and controlled areas are regulatory requirements. Areas must be marked and information provided about dose rates, sources, contamination levels, entrance restrictions, etc. There must be documented routines for the work with ionising radiation.

If in an area there is a risk of spreading radioactive substances (contamination) to other premises, or the annual effective dose might exceed 6 mSv, the workplace must be classified as a controlled area. Access is then more restricted, protective clothing and personal protection equipment might be mandatory, specific information/education is required and a personal dosimeter is to be issued and worn. Within a controlled area, if the risk of receiving an annual effective dose of more than 50 mSv is non-negligible, then the premises must be explicitly marked and admittance particularly restricted.

Information and education
All workers, both permanent staff and contractors, must be informed about radiation risks, alarms, internal procedures, and receive proper education and training prior to working within a controlled area. The training shall be adjusted to the scope and type of work to be performed and to the existing radiological working environment. It should be repeated at least every third year. In addition, more specific training is often required and the scope and focus must then be adapted to the nature and environment of the work to be performed.

Site-specific instructions, radiation protection expertise
The licence holder shall establish site-specific instructions for radiation protection and appoint a radiation protection manager. SSM approves the radiation protection managers, their capacity to act as a controller of the licensee's implementation of the radiation protection legislation and to promote radiation protection work. A separate radiation protection expert function, approved by SSM, should also be available for the licensee to provide expertise as necessary.

Instruments and equipment
All instruments used for radiation protection and control of radiation doses shall be calibrated, with metrological traceability, and before use undergo regular functional checks. There must be documented routines for use, maintenance and functional control.

Policy in the event of fuel failures
At a nuclear power plant, it is mandatory to have a documented policy and strategy for avoiding fuel failures as well as managing occurring failures. The aim is to avoid unnecessary radiological impact to workers and the public and minimise the production of wastes with long-lived radionuclides.

Reporting
Annual reports are required describing the radiation protection work, the progress and evaluation of optimisation work, and experiences from outages. In the case of an accident or events that led or could have led to the spread of contamination or high doses, rapid communication to the regulatory body is required. Various other reports are also required. The radiation protection expert oversees timely and accurate reporting.

F.4.1.2 Regulatory requirements for environmental radiation protection

The principal provisions as regards environmental radiation protection for nuclear facilities under normal operation are stipulated in the Radiation Protection Act (2018:396), the Swedish Radiation Safety Authority's regulation (SSMFS 2018:1) on basic requirements for licensed activities with ionising radiation, and the Swedish Radiation Safety Authority's regulations (SSMFS 2008:23, amended in 2018) concerning the protection of human health and the environment from discharges of radioactive substances from certain nuclear facilities. Below is a description of key provisions.

Public dose limits, dose constraints and critical group
The effective dose limit for members of the public is 1 mSv per year. A dose constraint for discharges of radioactive substances to water and air (authorised releases) is set at 0.1 mSv per year and site, including all nuclear facilities located at that site. The dose constraint is subject to comparison with the calculated dose to the most exposed individual (similar to critical group). The dose models used are approved by SSM.

The dose constraint is compared with the sum of a) the effective dose from annual external exposure, and b) the committed effective dose resulting from a yearly discharge. A 50-year integration period is used for the committed effective dose. If the calculated sum dose exceeds 0.01 mSv per year, realistic calculations of the individual radiation doses, using measured dispersion data, food habits, etc., shall be performed.

Discharges, optimisation and best available technology
According to the Radiation Protection Act, measures should be taken to reduce discharges of radioactive substances as far as possible and reasonable taking into account existing technical knowledge and economical and social factors. For nuclear power plants, such measures should be reported to SSM each year. These measures are then evaluated against specific reference and target values suggested by the licence holder and approved by SSM.

The reference and target values can be set for specific radionuclides or for groups of radionuclides and are established in Becquerel (Bq). The dose constraints of 0.1 mSv per year for discharges are used in the planning and the work with limiting releases and restricting radiation dose to the critical group.

The dose to the public is calculated taking all relevant exposure pathways into account. The dose constraint is a tool for optimisation and the doses are supposed to be kept and optimised well below the dose constraint during normal operation.

Release monitoring
Releases of radioactive substances shall be monitored. All non-monitored releases must be investigated and an upper boundary shall be set for possible undetectable leakage to air and water from each facility.

Releases via the main stacks of nuclear power reactors are to be controlled by means of continuous nuclide-specific measurements of volatile radioactive substances such as noble gases, continuous collection of samples of iodine and particle bound radioactive substances, as well as measurements of carbon-14 and tritium.

Discharges of radionuclides to water shall be controlled through measurements of representative samples from each release pathway. The analyses shall cover nuclide specific measurements of gamma- and alpha-emitting radioactive substances as well as, where relevant, strontium-90 and tritium.

Controls and testing
The function and efficiency of measurement equipment and release limiting systems shall be checked periodically and whenever there are any indications of malfunctions.

Environmental monitoring
Environmental monitoring in the areas surrounding nuclear facilities is performed in accordance with programmes determined by SSM. These programmes specify type and sampling frequency, sample treatment, radionuclides to consider, reporting, etc. The licensees carry out the environmental monitoring themselves or by hired performers. Samples are analysed by laboratories that have adequate quality assurance systems. To verify compliance, SSM performs inspections and takes random subsamples for control measurements (bilateral inter-comparisons) at SSM or at other independent laboratories, and regularly arranges proficiency tests for the laboratories used by the nuclear facilities.

Reporting
Releases of radioactive substances to air and water as well as results from environmental monitoring must be reported twice a year to SSM. Furthermore, the licensees report annually to SSM on adopted or planned measures to limit radioactive releases with the aim of achieving their specified target values. If established reference values are exceeded, actions to meet the reference values shall be reported. Events that lead to an increase in releases of radioactive substances from a nuclear facility shall as soon as possible be reported to SSM together with a description of the actions taken to reduce the releases.

F.4.1.3 Protection of the environment

Protection of the environment is included in international recommendations and the Swedish legal framework.

The International Basic Safety Standards, GSR Part 3 are *"designed to identify the protection of the environment as an issue necessitating assessment, while allowing for flexibility in incorporating into decision making processes the results of environmental assessments that are commensurate with the radiation risks"* (paragraph 1.35).

Furthermore, in the EU BSS it is stated: *"While the state of the environment can impact long-term human health, this calls for a policy protecting the environment against the harmful effects of ionising radiation. For the purpose of long-term human health protection, environmental criteria based on internationally recognised scientific data (such as published by EC, ICRP, United Nations Scientific Committee on the Effects of Atomic Radiation, International Atomic Energy Agency (IAEA)) should be taken into account"* (no. 27 of the perambulatory clauses).

The Swedish Radiation Protection Act (2018:396) states that *"The aim of this Act is to protect people and the environment against harmful effects of radiation"*. Requirements in Swedish legislation regarding protection of the environment are found in SSMFS 2008:37, the Swedish Radiation Safety Authority's Regulations Concerning the Protection of Human Health and the Environment in Connection with the Final Management of Spent Nuclear Fuel and Nuclear Waste. These regulations specify 'protection of the environment' as protection of biodiversity and the sustainable use of biological resources, and require an assessment to be performed describing effects from a radiation protection view in habitats and ecosystems, and thereby demonstrating that the environment is protected.

The Swedish Radiation Safety Authority's regulation (SSMFS 2018:1) states that *"The consequences of an activity from a radiation protection point of view for the public and the environment must be assessed and documented based on the activities nature and extent"*.

Assessments of the protection of the environment were performed in connection with the planned Swedish spent nuclear fuel repository and for the European Spallation Source. Requirements for such assessments are also included in the licence conditions for decommissioning of the nuclear power plants entering this phase and in the licence for the pilot operation of the European Spallation Source. A similar requirement will also be included in the up-coming regulations for the operation of nuclear power reactors and for the operation of other nuclear facilities.

F.4.2 Radiation impact of spent nuclear fuel or radioactive waste management facilities

F.4.2.1 Occupational radiation doses

In general, individual and collective doses from managing radioactive waste at nuclear power plants are low when compared to the control, maintenance and service work connected with the operation. Nevertheless, work activities are planned, in compliance with the requirements, to

Table F1 Radiation dose data for staff at Clab during the period 2012–2018.

Year	No. of exposed staff members	Collective dose (mmanSv)	Maximum effective dose (mSv)	Average effective dose (mSv)
2012	35	24.2	3.1	0.7
2013	34	19.9	2.0	0.6
2014	34	22.7	2.8	0.7
2015	45	23.1	2.7	0.5
2016	54	32.6	3.0	0.6
2017	54	28.1	3.3	0.5
2018	36	23.8	3.3	0.7

ensure that the radiation protection is optimised. The annual collective effective dose for staff working with radioactive waste at the nuclear power plants is, per site, in the order of tens of milli-mansievert (mmanSv). This section presents examples of radiation doses received at other facilities, including spent fuel and radioactive waste management facilities.

Clab

At the central interim storage facility for spent nuclear fuel (Clab), radiation doses are incurred during normal operation, including receiving, unloading and cleaning of transport containers. In addition, maintenance and service of Clab's internal lifting and handling equipment as well as the upkeep of the water purification system also result in radiation doses. The collective effective dose has varied in the range of 15–35 mmanSv in recent years depending on the activities performed. Radiation dose data for the operation of Clab during the period 2012–2018 are shown in Table F1.

SFR

Open radiation sources are only in exceptional cases managed at SFR, the Swedish disposal facility for low and intermediate level waste. The wastes received are conditioned in standard waste packages fulfilling waste acceptance criteria (WACs). Thus, radiation doses should originate from external radiation only. Contamination of transport casks and waste packages has never occurred to the extent that any airborne radioactivity, excluding naturally occurring radon and radon daughters, has been measured or reported. Since the start of operation of SFR, the total radiation dose (collective effective dose) has varied between 0.0 and 6.0 mmanSv. This is lower than the 25 mmanSv per year that the repository was designed for.

The Studsvik site

Nuclear activities at the Studsvik site are undertaken by three licensees, Studsvik Nuclear AB, AB Svafo and Cyclife Sweden AB. The majority of these activities are related to decommissioning and waste management, but some development work and research is also carried out, especially regarding nuclear fuel and materials relevant for the nuclear sector. The two research reactors, R2 and R2-0, were permanently closed in 2005. In 2010, the licences were transferred to AB SVAFO. Decommissioning is ongoing and is expected to be completed at the end of 2020 after which conventional dismantling will start. The incurred collective and individual radiation doses have been low, at most a few tens of mmanSv per year and the highest individual doses below a few mSv.

The annual collective effective dose for the activities at the whole Studsvik site varied between 0.15 and 0.23 manSv during the period 2016-2019. The average yearly individual effective dose varied from 0.7 to 1.4 mSv per year, while the highest annual individual effective doses ranged from 7.8 to 12.4 mSv during this period. The large variation in incurred radiation doses reflects the varying types of work and activities carried out at the site. It must be underlined that a fair fraction of the collective dose is not directly connected to waste management activities, but rather to materials testing, fuel research and hot-cell activities. The same is generally true for the highest individual doses.

Westinghouse fuel fabrication plant

For staff working with waste management at the fuel fabrication plant Westinghouse Electric Sweden (WSE) AB, annual individual effective doses are reported to be of the order of a few mSv. To put this into perspective, in 2018 (2017) the average effective dose due to external and internal exposure (committed effective dose) for all staff at WSE was 1.7 (1.4) mSv, respectively and the highest individual radiation doses were 10.8 (8.7) mSv.

The collective dose for WSE varied between 0.3_0.4 manSv during 2013–2018, mostly in the lower half of the interval. It should be noted that about 60–65% of the dose is due to internal exposure. The measurements of radiation doses improved from 2013 when OSL-dosimeters were employed which better measure the high-energy beta contribution than earlier TLDs.

Ågesta

From the closed and partially dismantled Ågesta reactor (PHWR), small amounts of tritium are released through drainage of the rock chamber where the shutdown reactor is situated. The corresponding radiation doses to the public have been negligible.

On July 15, 2019, Vattenfall AB was granted permission by the Land and Environment Court to dismantle the Ågesta reactor. The plan is to start the dismantling work during 2020. SSM decided in 2018 on new licence conditions for the dismantling work. The estimated collective dose for this activity is below 100 mmanSv.

F.4.2.2 Radiation doses from releases of radioactive substances

Figure F3 displays the estimated effective dose to the representative person ('critical group') from the releases of radioactive substances from operating power plant sites for the years 2009 to 2018. The resulting estimated effective doses are less than 1% of the stipulated dose constraint of 100 microsievert (μSv) at all sites. The operation of PWRs at Ringhals, due to carbon-14, results in slightly higher releases from this site.

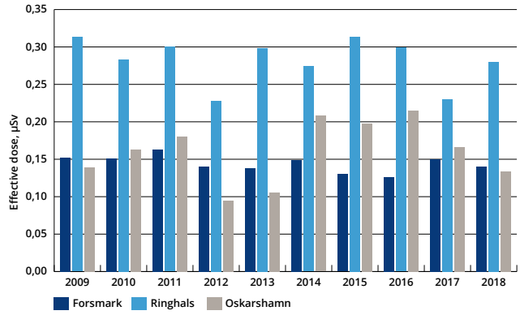


Figure F3 Estimated effective dose (μSv) to the representative person in the critical group from releases of radioactive substances from sites with operating NPPs.

The releases of radioactive substances from the Barsebäck NPP (no operating reactors) and the facilities at Studsvik and Ranstad are shown in Figure F4 below. Extraction of uranium from waste at Ranstad Mineral stopped in 2009 and decommissioning activities subsequently started. The estimated doses due to releases from Clab, SFR and Ågesta are not shown as they would not be discernible on the figure.

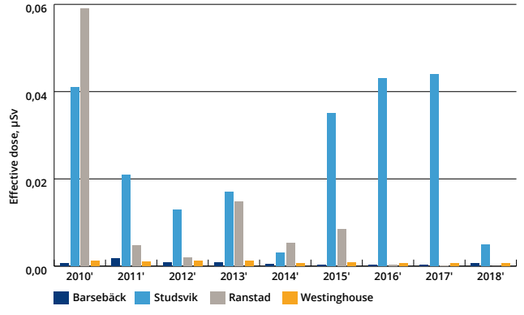


Figure F4 Effective dose (μSv) to the representative person in the critical group. Releases from Barsebäck NPP, Studsvik site, Ranstad site and Westinghouse fuel fabrication plant.

F.4.3 Regulatory control

See sections E.3.2.6 and E.2.5.2 about SSM's control and inspection work.

F.4.4 Conclusion

Sweden complies with the obligations of Article 24.

F.5 Article 25: Emergency preparedness

1. Each Contracting Party shall ensure that before and during operation of a spent fuel or radioactive waste management facility there are appropriate on-site and, if necessary, off-site emergency plans. Such emergency plans should be tested at an appropriate frequency.

2. Each Contracting Party shall take the appropriate steps for the preparation and testing of emergency plans for its territory insofar as it is likely to be affected in the event of a radiological emergency at a spent fuel or radioactive waste management facility in the vicinity of its territory.

F.5.1 Regulatory requirements

The emergency plans for the three operating NPPs and the industry facilities at Studsvik Nuclear AB, AB Svafo and Cyclife Sweden AB include the installations for spent fuel and radioactive waste management at these facilities. SKB has an emergency plan for the Clab interim storage facility for spent nuclear fuel. There is no formal requirement for an emergency plan at SFR; however, a crisis management and rescue organisation is nevertheless in place. SSM's revised regulations for emergency preparedness and response impose new requirements that, eventually, will lead to a new investigation of SFR and possible revisions of the formal requirements for an emergency plan. Westinghouse Electric Sweden AB (WSE) operates the fuel fabrication facility in Västerås. This facility also has an emergency plan as per SSM's regulations.

Requirements for on-site emergency activities and plans for the nuclear facilities are included in several legally binding documents:

- Act on Nuclear Activities (1984:3);
- Civil Protection Act (2003:778) regarding protection against accidents with serious potential consequences for human health and the environment;
- Civil Protection Ordinance (2003:789) regarding protection against accidents with serious potential consequences for human health and the environment;
- SSM's regulations (SSMFS 2008:1) concerning safety in nuclear facilities;
- SSM's regulations (SSMFS 2014:2) concerning emergency preparedness at nuclear facilities; and
- SSM's regulations (SSMFS 2018:1) concerning basic regulatory requirements for all licensed activities involving ionising radiation.

The overarching objective of the Civil Protection Act (2003:778) is civil protection for the entire country – with consideration given to local conditions – for life, health, property and the environment against all types of incidents, accidents, emergencies, crises and disasters. The Act requires preventive measures and emergency preparedness to be arranged by the owner or operator of a facility conducting dangerous activities. The Act also defines the responsibilities for the individual, the municipalities and the state in cases of serious accidents, including radiological accidents. The Act contains provisions on how

municipal fire brigades shall be organised and operated and stipulates that a rescue commander with a specified competence, with far reaching authority, is to be engaged for all rescue operations. According to the Act, the County Administrative Board is responsible for rescue operations in cases where the public needs protection from a radioactive release from a nuclear installation or in cases where such release seems imminent.

The Civil Protection Ordinance (2003:779) contains general provisions concerning emergency planning and is more specific about reporting obligations, information to the public, and the responsibility of the County Administrative Boards for planning and implementing public protective measures, content of the off-site emergency plan, competence requirements for rescue managers and emergency planning zones around major nuclear facilities. The County Administrative Board is obliged to draw up a radiological emergency response plan. At a national level, MSB is responsible for the coordination and supervision of preparedness work for the rescue services' response to radioactive releases. SSM decides on necessary measures for emergency planning at the nuclear installations and supervises the nuclear installations regarding these plans.

The Act on Nuclear Activities contains general provisions on emergency response in the event of accidents at a nuclear facility. The Act requires the licensee to have an organisation with sufficient financial, administrative and human resources to carry out protective measures in connection with an accident at the facility.

SSM's regulations SSMFS 2008:1 require the licensee in the event of an emergency to take prompt action in order to:

- Classify the event according to the alarm criteria;
- alert the facility's emergency preparedness organisation;
- assess the risk and size of possible releases and time related aspects;
- return the facility to a safe and stable state; and
- inform the responsible authorities.

The actions must be documented in an emergency preparedness plan that is subject to safety review by the licensee and must be approved by SSM. The plan shall be kept up to date and validated through regular exercises. SSM is to be notified of changes to the plan. The licensee is required to assign the staff and provide the suitable facilities, technical systems, tools and protective equipment needed to perform the emergency preparedness tasks. The emergency planning should include all design basis accidents, as well as beyond design basis events including severe events, and combinations of events such as fire or sabotage in connection with a radiological accident.

SSM's former regulations concerning on site emergency preparedness (SSMFS 2008:15) have been replaced by new regulations. The new regulations concerning on site emergency preparedness (SSMFS 2014:2) were issued in 2014 and entered into force on 1 January 2015. Like the previous enactment, SSMFS 2014:2 uses the concept of emergency preparedness categories (1, 2, 3 and 4) based on the IAEA's emergency preparedness categories, which introduces, the application of a graded approach depending on the radiological hazard at the nuclear facility.

SSM's regulations SSMFS 2014:2 concerning emergency planning and preparedness have a radiation protection perspective, including requirements for the following:

- Emergency planning including alarm criteria and alarming;
- logistics centre;
- emergency rooms, premises, facilities and assembly places;
- training and exercises;
- iodine prophylaxis;
- personal protective equipment;
- evacuation plan;
- contacts with SSM;
- radiation monitoring;
- emergency ventilation;
- collection of meteorological data; and
- communication equipment.

Depending on the radiological hazard potential at the facility, the requirements differ regarding logistics centre, radiation monitoring, emergency ventilation and collection of meteorological data.

SSM's regulations SSMFS 2018:1 includes regulations on basic regulatory requirements for all licensed activities involving ionising radiation. The regulations also transpose provisions of Council Directive 2013/59/Euratom, which have not been included in the new Radiation Protection Act. The regulation SSMFS 2018:1 came into force on 1 June 2018. SSMFS 2018:1 impose extensive requirements relating to human factors on the following:

- Safety monitoring and follow-ups;
- the operating organisation and its design;
- management system, including safety culture;
- safety objectives and strategies;
- responsibilities and levels of authority;
- competence assurance, fitness for duty;
- occupational environment;
- planning of nuclear activities;
- design adapted to human capabilities and limitations;
- operational experience feedback; and
- event investigation.

F.5.2 National structure

Appointed central or regional authorities (i.e. county authorities) are responsible for managing nearly all accidents and emergency situations involving nuclear technology with potential off site consequences. However, if a national emergency with the potential of affecting many citizens, with, linked, major negative cross sectoral or

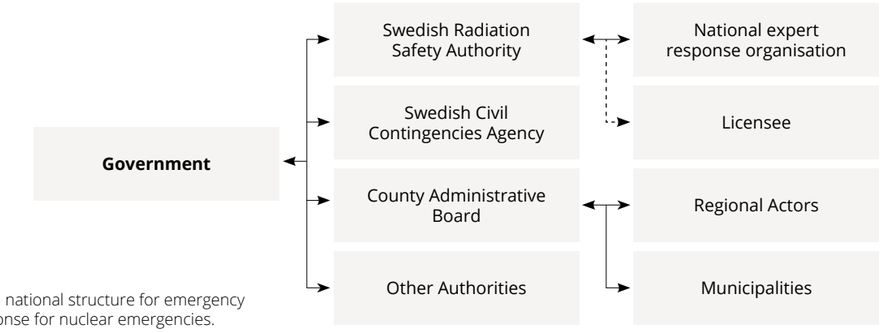


Figure F5 The Swedish national structure for emergency preparedness and response for nuclear emergencies.

cross regional economic, environmental or other detrimental societal effects should occur, this will require decisions and actions by the Government. Sweden's structure for emergency preparedness and response for nuclear emergencies is shown in Figure F5.

The County Administrative Board in each affected region is responsible for planning and leading the regional emergency preparedness work. The board decides on measures to be taken to protect the public, issues warnings, provides information to the public, and is responsible for decontamination following radioactive fallout and releases. The responsibility for directing rescue services also rests with the County Administrative Board in each affected county unless the Government decides otherwise.

A national contingency plan for dealing with a nuclear accident has been in place since 2015. This national plan describes basic preconditions such as the relevant legislation and the authorities involved in the management of an incident and the responsibilities of these authorities. The plan also describes national coordination and liaison work of relevant authorities. The document outlines the resources available at national level and how they are requested and coordinated. International assistance is also described in the plan. In addition to this contingency plan, there is a national action plan for improvements to emergency preparedness work.

The Government is responsible for emergency management at a national level. The Government's mandate is primarily strategic national issues. Responsibility for management and coordination of operational work rests with the relevant authorities. The Government has the overall responsibility to ensure that an effective crisis management system is in place and that the crisis communication is credible. The Government is also responsible for certain contacts with international organisations. The Government Offices assist the Government in the crisis management work.

A senior official for crisis management has a post at the Ministry of Justice. During emergencies, the senior official has the task of ensuring that the crisis management work begins promptly, this official is also responsible for the coordination and assistance of crisis management work at the Government Offices. The senior official is assisted by the Secretariat for Crisis Management. The Secretariat monitors threat and risk developments around the clock, both domestically and internationally, and is the central focal point in the Government Offices. The Government's strategic direction for the Government Offices is prepared by a group for strategic coordination that consists of the state secretaries of all the ministries involved in the management of a serious incident. This strategic coordination group is convened by the Ministry of Justice's state secretary or by an appointed state secretary.

MSB has the responsibility in preparedness work to support coordination of preparedness measures taken by local, regional and national authorities. MSB also provides communication networks for competent authorities during extraordinary events. It has the overall responsibility for the Swedish national digital communication system ('Rakel') that is used by national emergency services and others in the fields of civil protection, public safety and security, emergency medical services and healthcare during emergency situations. MSB also assists the Swedish Government Offices by providing documentation and information in the event of emergencies, providing methods for crisis communication, and coordinating official information to the public.

SSM has the responsibility of coordinating necessary emergency preparedness and response measures for preventing, identifying and detecting nuclear and radiological events that can damage human health or the environment. In the event of an emergency involving nuclear technology in Sweden, or outside Sweden with consequences for Sweden, SSM is the appointed National Competent Authority and is responsible for:

- Providing advice and recommendations concerning protective measures in the area of radiation protection;
- radiation measurements;
- maintaining and leading a national organisation for measurement and expert support; and
- providing advice and recommendations to the authorities assigned to deal with the impact of the event.

SSM is also responsible for keeping the Government informed about the situation, expected developments,

available resources and measures taken as well as planned, and, following a request by the Crisis Management Coordination Secretariat at the Prime Minister's Office, or by MSB, to provide the information needed in order to give an overview of the situation.

A number of authorities, organisations and laboratories will work together, or operate as supporting functions to the national organisations mentioned above, in the event of a nuclear or radiological emergency. Participating authorities that have liaison roles for crisis management include, for example, the Swedish Food Agency (SFA), which is responsible for taking decisions on action levels for the content of radioactivity in foodstuff, and the Swedish Board of Agriculture (SJV), which is responsible for taking decisions on action levels regarding agricultural practices and products. Other authorities that have responsibilities during crises and that liaise with SSM, or receive advice and recommendations from SSM, include the County Administrative Board, MSB, the Swedish Board of Health and Welfare, the Swedish Customs, the Swedish Meteorological and Hydrological Institute (SMHI), the Swedish National Police Board, the Swedish Coast Guard and the local rescue leader, police officers and medical personnel.

SMHI assists SSM by providing weather forecasts, weather data and some dispersion calculations in the event of a radiological or nuclear emergency.

In an international context, and in regards to the Community arrangement on early exchange of information, it is SSM's responsibility as both an EU and IAEA designated Competent Authority, to promptly inform the European Commission, neighbouring countries that might be affected and the IAEA in accordance with the IAEA's Conventions on assistance and early warning and the European Commission's Convention on early warning. Furthermore, SSM is also responsible for continuously providing information on the measures that Sweden intends to take due to an emergency situation.

In the event of an emergency at a Swedish NPP, the licensee is responsible for immediately contacting the national alarm centre (SOS Alarm AB), which will in its turn alert the authorities and organisations responsible for emergency management, see Figure F6. In the event of an emergency at a nuclear facility categorised in emergency preparedness category 2, the alarm chain is similar in terms of the role of SOS Alarm AB.

In the event of a radiological or nuclear emergency abroad (including a possible request for assistance), the alert will go to SMHI, which is the national warning point. Upon an alert, SMHI will, through SOS Alarm AB, contact the officer on duty at SSM. The officer on duty at SSM will then contact the Government ministry offices and central and regional authorities with roles and responsibilities in the acute phase of a nuclear accident or incident.

F.5.3 National monitoring

The national expert response organisation comprises government authorities, organisations and laboratories that have expertise in radiological assessment and radiation monitoring. This organisation, coordinated by SSM, has as its main purpose to perform radiation measurements. Figure F7 lists the contracted authorities, organisations and laboratories that have capabilities encompassing laboratory analysis and field monitoring, mobile and airborne monitoring, weather forecasting and plume dispersion prognoses. In addition to the tasks belonging to the national expert response organisation, individuals engaged in this response organisation may also have a role in providing expert advice during the response.

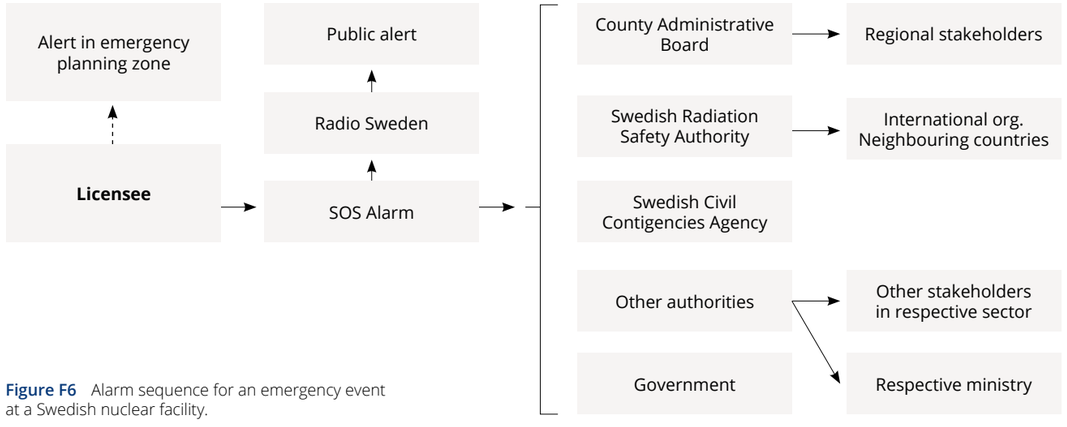


Figure F6 Alarm sequence for an emergency event at a Swedish nuclear facility.

Expert Response Organisation

- Swedish Defence Research Agency, FOI (Umeå)
- Geological Survey of Sweden, SGU (Uppsala)
- Cyclife Sweden AB (Nyköping)
- Linköping University (Linköping)
- Göteborg University (Göteborg)
- Lund University (Malmö region)
- Swedish Meteorological and Hydrological Institute, SMHI (Norrköping)
- SSM (Stockholm region)

Figure F7 Sweden's national expert response organisation for nuclear and radiological emergencies.

Sweden has a gamma monitoring network that presently has 28 permanent stations spread throughout the country. The stations are designed to provide warnings and rapid information about radiation levels. Each gamma station continually records the dose rate and can be monitored online. If the dose rate exceeds a predefined alarm level, notifications are automatically transmitted to SSM's radiation monitoring data management system where, depending on the alarm, further actions will be taken by the officer on duty at SSM. The alarm level is set to detect deviations from prevailing conditions. In addition to the national gamma monitoring network, new stations were installed around the NPPs in Sweden in 2019. The new monitoring stations provides information on the dose rate at 90 locations around the NPPs. While the national gamma monitoring network is primarily used as an early information system, the new stations provide fast, reliable and automatic information on dose rates to be used in decision making on early public protective actions in the case of an accident at a Swedish NPP. Figure F8 shows monitoring stations set up around the Forsmark NPP.

Sweden also has six permanent air sampling stations operated by the Swedish Defence Research Agency (FOI) and a Comprehensive Nuclear-Test-Ban Treaty (CTBT) station located in Stockholm. These stations continuously sample air in order to collect any airborne radioactive material. Air filters are regularly collected and transported to a laboratory for measurement and evaluation. The detection system is sufficiently sensitive to measure activity levels in the order of tens of microbecquerel per cubic metre [$\mu Bq/m^3$] and is also used for environmental monitoring.

As the County Administrative Boards are responsible for implementing public protective actions during and after a nuclear emergency, the boards' emergency response planning also encompasses radiation monitoring. Monitoring of dose rates and collection of air samples for the purpose of public protective actions are performed by local rescue services from municipalities within each county at predefined locations or routes. During a nuclear emergency, the relevant County Administrative Board coordinates response and monitoring activities with the national expert response organisation and government authorities.

F.5.4 Medical emergency preparedness

The county council is responsible for medical disaster preparedness. Injured persons are treated at the site of the emergency, in hospitals or at medical health centres.

At major national hospitals, mainly university hospitals in Sweden, more advanced treatment and care can be arranged. Cooperation and sharing of resources also take place between European hospitals in the event of major accidents. The Nuclear Medical Expert Group (RNMEG) is part of the operative emergency resources available to the National Board of Health and Welfare (NBHW) in connection with radiological incidents. They assist the

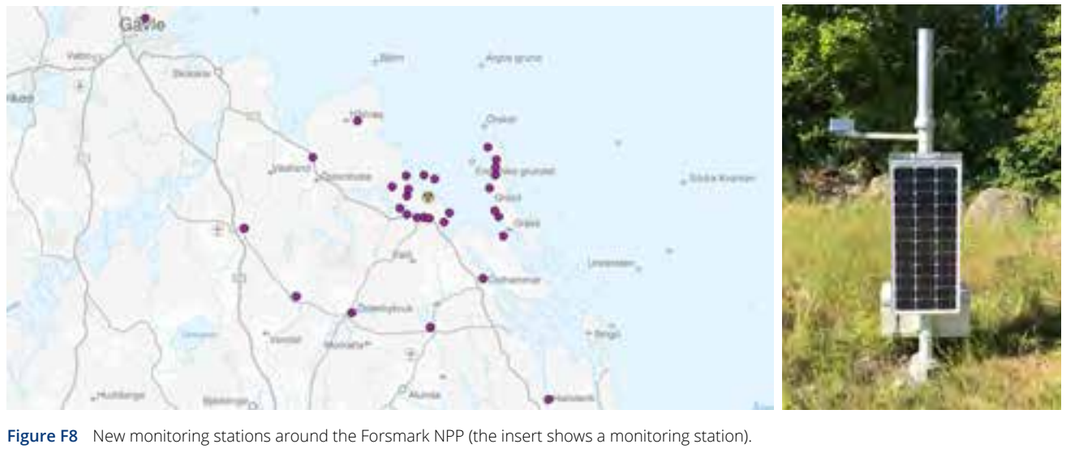


Figure F8 New monitoring stations around the Forsmark NPP (the insert shows a monitoring station).

NBHW, and through the NBHW also other authorities, with specific medical advice regarding, for example, acute and late radiation injuries, and treatment thereof. Practitioners from the medical fields of haematology, oncology, radiology, and disaster medicine are represented in RNMEG.

F.5.5 Exercises

A number of emergency preparedness exercises of various scopes are conducted every year in Sweden. These vary in complexity from simple tests of alarm systems to full-scale national exercises. Periodical testing of the alerting systems between the power plants and authorities is performed each year.

Every other year, a large exercise is carried out at one of the three nuclear power sites for the purpose of checking the planning and capability of the on and off site organisations. The full-scale exercises are designed to enable evaluation of command at the regional level, national interagency liaison and public communication. The full-scale exercises are often also used for testing of international communications.

The respective County Administrative Board where the plant is located has the responsibility for planning these exercises, often with the assistance of MSB, which is also in charge of evaluations and follow-up analyses. SSM participates in planning and evaluation. Usually, 15 to 30 organisations participate in these exercises, including the regulatory bodies and the Government.

In 2019 the County Administrative Board of Uppsala arranged the *Sea Eagle* exercise. It was the largest nuclear exercise ever organised in Sweden. The exercise comprised of four different parts:

1. An alarm exercise to test the alarm chain.
2. A main nuclear exercise that lasted for 36 hours. This part of the exercise tested the national, regional and local abilities to act and coordinate rescue services during disrupted conditions (known as a 'grey zone' scenario),
3. A radiation monitoring exercise, including two days of radiation monitoring in the field including international assistance.
4. A table top exercise where the long term effects of the accident were discussed.

In addition, a number of more limited on site functional exercises are conducted at all the Swedish NPPs every year. Specific plans exist for these exercises. Exercised functions include accident management, communication within the emergency preparedness organisation, environmental monitoring and sampling, assessment of core damage and source terms and assessment of total environmental consequences of a scenario. The rescue forces are exercised regularly, as well as first aid and emergency maintenance. SSM frequently participates in such exercises both as an observer and in its supervisory role, or for the purpose of exercising the authority's own emergency staff.

Sweden has a long tradition of participating in international emergency preparedness exercises. This allows for testing of aspects related to bilateral and international agreements on early notification and information exchange. Sweden regularly participates in the IAEA Convention Exercises (ConvEx), the OECD/NEA International Nuclear Emergency Exercises (INEX), and yearly ECURIE exercises.

F.5.6 Measures taken to inform neighbouring states

Sweden has ratified the International Convention on Early Notification and the Convention on Assistance in the Case of a Nuclear Accident. An official national point of contact has been established that is available around the clock. Sweden has registered field and laboratory resources with the international assistance programme, Response and Assistance Network (RANET), managed by the IAEA under the Convention on Assistance in the Case of a Nuclear Accident, and participates actively in developing the RANET system.

Sweden has bilateral agreements with Denmark, Norway, Finland, Germany, Ukraine and the Russian Federation regarding early notification and exchange of information in the event of an incident or accident at an NPP in Sweden or abroad. An agreement at regulatory body level has also been signed with Lithuania. Sweden uses the ECURIE information system for information exchange within the European Union and the Unified System for Information Exchange in Incidents and Emergencies (USIE) system for notification and information exchange between the IAEA member states.

In addition, the five Nordic countries of Denmark, Finland, Iceland, Norway and Sweden have compiled a Nordic manual (NORMAN) for cooperation between their respective regulators in response to and preparedness for nuclear and radiological emergencies and incidents. The manual describes practical arrangements regarding communication and information exchange to fulfil the stated obligations in bilateral agreements between the Nordic countries. These arrangements also apply to a response to events or threats of malicious use of radioactive material and threats or malevolent acts concerning nuclear facilities. Other aspects include small scale events, such as the spreading of rumours and minor incidents, having consequences limited to public concern and interest by the media, or a need for exchange of technical information between nuclear and radiation safety regulatory bodies. The arrangements defined in the document include all phases of events, including intermediate and recovery phases.

NORMAN also takes into consideration the current international development concerning response to and preparedness for nuclear and radiological incidents and emergencies, as well as other key international aspects. Communication exercises are performed five times per year, in compliance with NORMAN. These exercises include procedures for alerts and communication by means of video conference systems.

F.5.7 Nuclear accidents abroad

As demonstrated by the effects on Sweden due to the 1986 Chernobyl accident, Sweden can be affected by radiological consequences as a result of a nuclear accident abroad. Although the foreseeable consequences are such that the use of iodine tablets, sheltering, evacuation or relocation of people due to fallout is unlikely, the impact can be substantial on agriculture, animal breeding, forestry, hunting, recreation and private household activities (fishing, mushroom picking, game hunting, vegetable gardening, etcetera).

SSM and other authorities distribute information in case of a transnational emergency. County Administrative Boards that are affected still have the responsibility to provide information and take any protective action needed in their respective regions. During the Fukushima Daiichi accident, which had no direct impact on Sweden, SSM and other central authorities, such as NBHW and MSB, were responsible for communicating the consequences of the event. SSM's emergency response organisation was activated and worked around the clock for three weeks analysing and evaluating the situation in order to give advice to the Swedish embassy and Swedish citizens in Japan. The nuclear accident at the Fukushima Daiichi NPP underlined the importance of international cooperation concerning information exchange. SSM's role as an advisory authority is maintained in the event of a nuclear accident abroad.

F.5.8 New developments in emergency preparedness

A system for electronic transmission of plant process parameters from the Swedish NPPs in operation is now in place at SSM's emergency centre. Together with the parameter transmission, an online visualisation tool has been developed in close cooperation with the Swedish NPPs, where a graphical interface of the reactor and key safety systems are shown. There are about 20 graphical views per unit and identical views are shown at the NPPs and SSMs emergency centre in order to facilitate communication and minimise misunderstandings. Work is ongoing on how to best implement and utilise the information provided during a crisis. SSM's staff needs to be educated, trained and exercised on how to manage the system and therefore exercise scenarios of events have been provided by Ringhals AB and OKG AB. With regard to Forsmark AB, scenarios are under development. The expectation is that this work will be completed in 2020. Furthermore, the information flow from the NPPs to SSM have to be modified in order to optimise the interaction.

Models for the Bayesian belief network based (BBN) software tool for fast source term predictions (RASTEP) has been developed for all Swedish reactor units that will be in operation after 2020. The implementation of RASTEP in the crisis organisation is an ongoing activity, it includes the use of RASTEP in relation to deterministic approaches, available and prioritised information, and interpretation of results.

MSB has developed recommendations for shared grounds for collaboration and management, which will contribute to an improved capability to cope with emergency situations in Sweden. The aim is to provide guidance to authorities on joint methods and processes for enabling shared direction and coordination. The recommendations developed by MSB have resulted in a review of SSM's emergency response organisation to enable SSM to efficiently provide advice and recommendations to other authorities.

On 22 October 2015, the Government of Sweden commissioned SSM, in consultation with MSB, relevant County Administrative Boards and other involved authorities and stakeholders, to perform a review of emergency planning zones and emergency planning distances applying to activities involving ionising radiation. On 1 November 2017, SSM published its report on new emergency planning zones and distances for nuclear power plants and other nuclear facilities in Sweden. In order to implement new zones for the nuclear power plants, amendments to the Civil Protection Ordinance have been prepared by MSB. The amendments entered into force 1 July 2020 and will be implemented on 1 July 2022 at latest.

With regard to fuel cycle and waste management facilities, SSM in its report identified that the Västerås fuel fabrication plant could retain its present emergency planning zone, though with small adjustments, and that the emergency planning zones and emergency planning distances applying to the facilities at the Studsvik site near Nyköping could be discontinued. These changes have been implemented following decisions made by SSM and the regional County Administrative Boards. With regard to the Clab facility, situated close to the Oskarshamn NPP, an extended planning distance of two kilometers is being prepared but pending the Government's decision on the NPP's emergency zones.

A national strategy for radiation measurements in the event of a nuclear or radiological accident is being developed by SSM, MSB and the County Administrative Boards. The project focuses primarily on a possible accident at a Swedish NPP. After this, the project will broaden its scope to cover other nuclear and radiological emergencies.

SSM has developed a new Radiation Geographical Information System (RadGIS) software for reporting, storing, extracting and visualising radiation monitoring data and environmental samples collected during an emergency. The new software, RadGIS 2, replaces RadGIS 1, which was developed in the 1990s. RadGIS 2 was launched on 15 April 2019 and is used by all Swedish organisations that perform radiation monitoring and sampling during a nuclear emergency.

Drawing upon the Nordic Flag Book, SSM is in the process of developing national guidelines on protective actions during a nuclear or radiological emergency at facilities and activities belonging to emergency preparedness category 4. In this process, SSM collaborates with other authorities involved in emergency preparedness and response. The guidelines will supplement the review of Swedish emergency planning zones and distances (SSM Report 2017:27) which took into consideration facilities

belonging to emergency preparedness categories 1, 2 and 3. The guidelines will use the concepts of reference levels, dose criteria and operational intervention levels in an emergency exposure situation, in line with recommendations contained in ICRP 103 and IAEA GSR Part 7. An official draft has been sent out for comments and the guidelines are expected to be finalised during 2020.

FOI, MSB, SFA, SJV and SSM collaborate closely within the national expert council on remediation (NESA). The purpose of NESA is to collect and share information on different aspects of remediation among the participating organisations, other central authorities and the County Administrative Boards. The work of the council includes revision of national guidelines on remediation and food production in the event of fallout of radioactive substances in Sweden.

In addition, a new radiation monitoring system for fallout mapping in Sweden is currently undergoing development. The system will be based on mobile gamma spectrometry and be used for detailed mapping of dose rates around Swedish NPPs in the case of a nuclear accident. The plan is to have the new system up and running by the end of 2020. It will replace the current system, which involves measurement of dose rates using handheld instruments in discrete positions.

Regarding implementation of Council Directive 2013/59/Euratom, the analysis for identification of necessary amendments to the Swedish regulatory framework has led to several changes relating to emergency preparedness and response in the Swedish radiation protection legislation. Hence, the following developments are also of relevance with regard to the obligations of Article 25:

- A new Radiation Protection Act (2018:396) which entered into force on 1 June 2018. It is applicable to workers and the public during an emergency.
- A new Radiation Protection Ordinance (2018:506) which entered into force on 1 June 2018. It sets reference levels to be applied in the case of a radiological emergency and includes requirements for optimisation.
- Updated regulations, SSMFS 2014:2 (revised through SSMFS 2018:26), concerning on site emergency preparedness and response, entered into force on 1 June 2018. The regulation contains new requirements for logistics centres and provisions concerning the ability to receive aid and support from external organisations. Also, some concepts have been renamed.
- The structure of the regulation has been changed. Some requirements that were previously found in SSMFS 2014:2 (on site emergency preparedness and response) are now instead found in SSMFS 2018:1 (basic regulatory requirements for all licensed activities involving ionising radiation).
- New monitoring stations have been installed around the NPPs in Sweden. The new stations will provide information on dose rates at 90 locations around the NPPs. The last stations went online at the end of 2018 and are currently undergoing an evaluation process.
- Two ordinances, 2015:1052 and 2015:1053, entered into force on 1 April 2016. These ordinances replace the former Emergency Preparedness and Heightened Alert Ordinance (2006:942) that is now split into two parts without any major revisions of the content having being made.

F.5.9 Regulatory control

Over the past few years, regulatory control of on-site emergency preparedness and response has focused on implementation of the new requirements regarding logistics centres introduced in the regulations SSMFS 2014:2. During 2018 and 2019, surveillance inspections were carried out at all the nuclear facilities in emergency preparedness category 1, to ensure that the facilities had established logistics centres as required (the requirements concerning logistics centres entered into force on 1 July 2018) (see Table F2).

In addition to this, a couple of inspections of facilities in emergency preparedness categories 2 and 3 have been carried out, as well as observations of a couple of exercises at facilities in emergency preparedness category 1.

Regulatory control has shown that on site emergency preparedness at the Swedish nuclear facilities has been strengthened in recent years and that the main elements of SSMFS 2014:2 have been effectively implemented.

F.5.10 Conclusion

Sweden complies with the obligations of Article 25.

Table F2 Swedish nuclear facilities by emergency preparedness category.

Facility	Emergency preparedness category
Forsmarks Kraftgrupp AB (NPP)	1
OKG AB (NPP)	1
Ringhals AB (NPP)	1
SKB Clab (central interim storage facility for spent fuel)	2
Westinghouse Electric Sweden AB (fuel fabrication facility)	2
Studsvik Nuclear AB (facilities for fuel and materials testing)	3
Cyclife Sweden AB (facilities for waste treatment)	3
AB Svafo (waste management and storage)	3
Barsebäck Kraft AB (permanently shut down NPP)	3

F.6 Article 26: Decommissioning

Each Contracting Party shall take the appropriate steps to ensure the safety of decommissioning of a nuclear facility. Such steps shall ensure that:

(i) qualified staff and adequate financial resources are available;

(ii) the provisions of Article 24 with respect to operational radiation protection, discharges and unplanned and uncontrolled releases are applied;

(iii) the provisions of Article 25 with respect to emergency preparedness are applied; and

(iv) records of information important to decommissioning are kept.

F.6.1 Regulatory requirements

According to the Act on Nuclear Activities, a licence holder for a nuclear activity is responsible for ensuring that all measures are taken in order to ensure safe decommissioning of facilities in which the operation has been discontinued until such date that all operations at the facilities have ceased and all radioactive waste has been disposed of. It follows that a licence holder is not exempted from responsibilities under the Act until decommissioning has been completed and all radioactive waste has been disposed of in a final repository that has been closed.

According to the Radiation Protection Act a licence holder for a nuclear activity must take all the measures necessary for radiation protection of people and the environment. Furthermore, when a nuclear facility is to be decommissioned the licence holder must take all the measures necessary for clearing remaining buildings and the site as soon as reasonably possible.

According to the Act on Nuclear Activities, no specific licence is required for decommissioning of nuclear facilities. However, according to the Environmental Code, a licence is needed for decommissioning and dismantling of nuclear power reactors. In addition to the specific requirements (see also section E.2.1.3), the applicant is also required to demonstrate compliance with a number of principles, e.g. the knowledge principle, the precautionary and BAT principles, and the after-treatment liability principle.

The general regulations SSMFS 2008:1 define 'decommissioning' as measures adopted by licensees after the final shutdown of a facility in order to dismantle and demolish the facility in a safe manner, as well as to reduce the amount of radioisotopes from the nuclear activities in the remaining buildings and the site to such levels so that they can be cleared. The general regulations SSMFS 2018:1, and in particular SSMFS 2008:1, set out a number of general requirements relating to decommissioning. These include requirements relating to documentation of the facility, prerequisites for planning, and the decommissioning activity itself.

During 2016, a dialogue was initiated with licensees of soon to be dismantled nuclear reactors about allowed preparatory activities and requirements on the safety report and supporting documents for dismantling and demolition. First in 2017, and subsequently updated in 2018, SSM issued additional licence conditions for decommissioning of Units 1 and 2 of the Barsebäck, Oskarshamn and Ringhals nuclear power plants as well as the Ågesta reactor. These licence conditions complement the provisions of SSMFS 2018:1 and especially of SSMFS 2008:1, concerning:

- allowed preparatory activities before dismantling and demolition is authorised;
- the content of the following safety documentation:
  - » safety report for dismantling and demolition,
  - » operational limits and conditions for the facility,
  - » waste management documentation,
  - » final decommissioning plan,
  - » decommissioning strategy for the entire site, and
  - » work package notifications and reports.

Additionally, the licence conditions specify requirements for discharges and environmental monitoring as the regulation SSMFS 2008:23 is not applicable during dismantling and demolition of a nuclear power reactor.

These additional licence conditions facilitated the licensee's efficient preparation of the safety report and supporting documents for dismantling and demolition.

SSM's authorisation is based on the reviews and approvals of the safety documentation and the environmental monitoring programme for dismantling and demolition. The safety documentation consists of the safety report, the operational limits and conditions, the waste management documentation, and supporting documents such as the final decommissioning plan and the decommissioning strategy. If deemed necessary, the safety documentation and environmental monitoring programme have to be revised and approved by SSM during the execution of decommissioning.

Before dismantling and demolition activities are allowed to commence, the licensee is required to notify SSM of the work package. These notifications complement and concretise the previously approved safety documentation. After the completion of the work package the licensee has to prepare and submit a work package report to SSM. This report contains, amongst other things, information on the amount, content and treatment of the radioactive waste produced.

Moreover, a final decommissioning report on the actual execution of the decommissioning work is required to be compiled and submitted to SSM after the dismantling and demolition work is completed. This report must include descriptions of the experience gained and the final state of the facility. The final decommissioning report should also include a description of the management of all the wastes arising from dismantling and demolition, including conventional wastes.

The regulations contained in SSMFS 2008:38 require archiving of documentation at nuclear facilities. The licence holder must archive safety documentation and documentation related to radiation protection aspects of a practice. If the practice ceases, the archives are to be transferred to the National Archives of Sweden or Regional Archives.

Detailed requirements on keeping registers for radioactive waste at nuclear facilities are stipulated by SSMFS 2008:1. The register must for instance contain information on the waste's origin, its amount and radionuclide-specific content.

During the current period, SSM has developed its rules for clearance of materials and release of sites and issued the regulations SSMFS 2018:3 concerning exemptions from the Radiation Protection Act and the clearance of materials, building structures, and sites. The regulations replace the former regulations SSMFS 2011:2.

The main criteria for clearance of potentially contaminated waste, materials, and buildings are:

- Removal of contamination as far as reasonably achievable
- Dose criterion in the order of 10 μSv per year to any member of the public.
- The main criteria for site release are:
- Removal of contamination as far as reasonably achievable
- Dose criterion 100 μSv per year to any member of the public
- In the case of release for restricted use: Reliable restrictions must be in place such that the effective dose to any member of the public would not exceed 1 mSv per year if the restrictions should fail.

The clearance of building structures and areas in accordance with a control programme has to be approved by SSM.

Clearance of waste, materials or buildings is only applicable on potentially contaminated objects, i.e. not on objects that are judged to be free from contamination or activation from the licensed activity. In some cases, this is checked by taking samples or making in-situ measurements. It is then praxis to require that the detection limits for these measurements should be less than in the order of 10 % of the clearance levels.

SSM's regulations concerning safety in nuclear facilities (SSMFS 2008:1) were primarily developed for nuclear reactors in power operation. With few exceptions, there is currently no mechanism in the Swedish regulatory framework for automatic lifting of requirements that were applicable during power operation, even in cases where all the nuclear fuel has been removed. Instead, the licensees have to apply for exemptions on a case by case basis. In order to facilitate this process, SSM published a guideline in 2015 containing an assessment of requirements that remain applicable following the removal of nuclear fuel.

The remaining general obligations contained in the regulations SSMFS 2018:1, SSMFS 2008:1, and several other regulations are applicable to decommissioning and dismantling activities regarding:

- availability of qualified staff and financial resources (as accounted for in section F.2);
- application of provisions with respect to operational radiation protection, discharges and unplanned and uncontrolled releases (as accounted for in section F.4); and
- application of provisions with respect to emergency preparedness (as accounted for in section F.5).

F.6.2 Measures taken by the licence holders

Licence holders are responsible for decommissioning of their nuclear facilities. Decommissioning of the plants is described in plans that are maintained throughout the facilities' operation. The degree of detail depends on the amount of available information. These decommissioning plans also form the basis of decisions on financing for decommissioning activities, see sections A.4, E.2.1.4 and F.2.2.2.

Management of decommissioning waste is coordinated through SKB. Future transport and disposal of decommissioning waste are also tasks of SKB.

F.6.2.1 Nuclear power plants

Twelve commercial reactors were commissioned at the Ringhals, Forsmark, Oskarshamn and Barsebäck sites in southern Sweden between 1972 and 1985, see Figure A1. As a result of political decisions, the twin BWR units Barsebäck 1 and 2 were shut down permanently in 1999 and 2005, respectively. In 2015, the operators decided on an additional phase-out of the four oldest reactors at Oskarshamn (BWR units 1 and 2) and Ringhals (BWR unit 1 and PWR unit 2) by 2020. The decisions were based on the overall business and energy market situation with falling electricity prices.

Oskarshamn 1 was permanently shut down in June 2017. Oskarshamn 2 has not been in operation since a substantial modernisation programme was begun in 2013, and has been permanently shut down since December 2016. The operator, OKG, applied for a licence to decommission the reactors pursuant to the Environmental Code. The Land and Environment Court authorised OKG in 2017 to proceed with its post-shutdown planning activities and authorised SSM to issue additional requirements as necessary. The licences for decommissioning unit 1 and 2 were obtained in 2019.

As regards the reactors at Ringhals, unit 2 was permanently shut down in December 2019 and unit 1 is planned to shut down in December 2020. Work is ongoing to assess the prerequisites for decommissioning and to evaluate how the specific decommissioning steps should best be resolved.

As far as the remaining six operating reactors are concerned, the planned operating time is currently 60 years. This applies to the reactors Forsmark 1, Forsmark 2 and Forsmark 3, Oskarshamn 3 as well as Ringhals 3 and Ringhals 4, all of which were commissioned between 1980 and 1985.

At Barsebäck 1 and 2, all spent nuclear fuel was removed by 2006. Reconditioning and removal of nuclear waste from the operational phase are ongoing. Preparations for and detailed planning of dismantling and demolition have intensified since 2016. Segmentation of the reactor pressure vessel internal components has been completed. Following completion of the segmentation activities, the next stage of dismantling is planned to commence in 2020. The licence from the Land and Environment Court for the dismantling and demolition, including on-site interim storage of waste, was obtained in 2019. Site release in accordance with regulatory requirements is planned for mid-2030s.

SKB has been contracted by the nuclear power companies to participate in planning and execution of the future decommissioning. SKB's participation mainly involves compilation of the development needs identified by the licensees, coordination of general methods and procedures for transport and disposal of radioactive waste, and compilation of the decommissioning-related costs reported by the licensees. The nuclear power companies have jointly agreed on the tasks SKB coordinates in connection with waste management, for example development of industry guidelines for clearance and industry guidelines for reporting of decommissioning plans. In the future, each nuclear power company will be responsible for the future decommissioning nuclear waste inventory, while SKB will be responsible for compiling the inventory and imposing requirements for the waste (waste acceptance criteria) so that it can be transported and disposed of in the appropriate repository.

Plant-specific and scenario-specific decommissioning studies have been performed for all the Swedish nuclear power plants in order to estimate waste quantities, timetables and costs. The studies serve as a basis for determining capacities in SKB's planned waste management system and fees to be allocated to the Nuclear Waste Fund.

SKB and the nuclear power companies participate in various national and international fora and collaborations regarding decommissioning that may be of value for activities in Sweden.

The challenges posed by the accelerated timetable for the decommissioning of four reactors at Ringhals and Oskarshamn, as well as the start of segmentation and interim storage of reactor pressure vessel internal components at the Barsebäck nuclear power plant, have led to an increased focus on decommissioning planning by the licence holders and SKB. As a consequence of the dismantling and demolition of Barsebäck 1, Barsebäck 2, Oskarshamn 1, Oskarshamn 2, Ringhals 1 and Ringhals 2 commencing before the extended SFR is ready to receive decommissioning waste, the licensees need to provide interim storage of this waste at their sites or externally.

The decisions to permanently shut down four reactor units have made the competence and staffing plans even more important. Activities regarding competence planning have therefore been intensified and the plans are now more detailed. The goal is to secure competencies during the entire decommissioning process and to support a good transition process when the sites are progressing from having several reactors in operation to only having one or two at each site. The need for special training in relation to decommissioning activities will influence training activities in the future.

F.6.2.2 Ågesta PHWR

The pressurised heavy water reactor in Ågesta was permanently shut down in 1974. Two steam generators were dismantled and waste treated at Studsvik in the early 1990s as part of an NEA research project. A licence for continued care and maintenance until 2020 was issued under the Environmental Code by the local Land and Environment Court in November 2008.

In 2019, the licensee obtained a new licence under the Environmental Code for the dismantling and demolition of the reactor. Also, SSM approved the safety documentation and the environmental monitoring programme for dismantling and demolition. Dismantling and demolition activities are planned to commence in 2020.

During the current period, a radiological characterisation was performed and a 3D model has been made of selected parts of the facility. Certain for the dismantling and demolition necessary systems have been upgraded or will be upgraded in the near future, e.g. the electrical power supply and the lifting and ventilation systems.

Since the Ågesta reactor is an older facility that has been shut down for decades, a number of measures have been taken to update the documentation. These include collecting all the relevant documentation and digitalising selected parts of this in order to provide a good basis for defining the extent and limitations of the decommissioning project.

The different waste streams that will be generated in conjunction with dismantling and demolition of the Ågesta reactor have been identified. For each waste stream, different steps are being evaluated up to clearance or final disposal through one of the available deposition alternatives.

F.6.2.3 Old research and other facilities at Studsvik

Studsvik materials testing reactors

The two materials testing reactors at Studsvik (one tank type and one mobile pool type) were permanently shut down in 2005. A number of preparatory activities have been performed, e.g. decontamination of two test loops in 2008, before dismantling of the reactors commenced in 2015.

By the end of 2019, most of the building structures have been emptied, i.e. the reactors and their auxiliary systems, as well as the reactor pools have been dismantled. The building structures are currently being prepared for clearance for demolition. Structures more than one meter below the ground surface will be left in place after

clearance. Applications for clearance of the buildings and sub-surface structures are expected during 2020. Only the laboratory wing of the facility will be kept by the licensee to be used for other purposes, such as management of nuclear waste.

Other installations
There are a number of other old facilities at the Studsvik site that are to be decommissioned in the future. Preliminary decommissioning plans for these facilities have been prepared by the licence holders and submitted to SSM for evaluation, in accordance with requirements contained in the general regulations.

F.6.2.4 Studsvik Nuclear and Cyclife facilities at Studsvik
Studsvik Nuclear and Cyclife are licensees of a number of nuclear facilities at Studsvik. Preliminary decommissioning plans for these nuclear facilities have been prepared and submitted to SSM in accordance with requirements in the general regulations.

F.6.2.5 Installations in Ranstad
The uranium mining and milling facilities in Ranstad were constructed and operated in the 1960s. In total, about 200 tonnes of uranium were produced. The uranium open-cast mine and mill tailings deposits were restored and covered in the 1990s. Until 2009, part of the facility was used for extraction of uranium from waste originating from nuclear fuel fabrication.

All dismantling, demolishing and restoration activities have been completed during the current period. In 2019, SSM approved the clearance of the site which has been released from regulatory control.

Only the mill tailings deposits will remain under institutional control. The remaining duties for the licensee consist of the preparation of the final decommissioning report and compilation of an archive.

F.6.2.6 SKB facilities
In preparation for its application under the Act on Nuclear Activities for the extension of SFR, which was submitted in 2014, SKB developed a new decommissioning plan for the facility. Decommissioning of SFR will begin when operation ceases. Decommissioning is completed when the above-ground facility has been released from regulatory control and there are no radiological reasons to prevent the establishment of another industrial activity on the site. Current plans call for 60 years of operation for the nuclear power plants and a few more years for Clink. Decommissioning of SFR could thereby start in the early 2070s.

SKB has conducted a decommissioning study of the combined Clab and encapsulation facility (Clink), based on the current planning while also focusing on waste volumes, the content of radionuclides and costs. A preliminary decommissioning plan for Clab was updated and submitted to SSM in 2017.

A preliminary decommissioning plan has been prepared for the spent nuclear fuel repository. It was included in the application under the Act on Nuclear Activities for disposal of spent fuel and under the Environmental Code for the KBS-3-system. An update of the decommissioning plan was made in 2017 in order to harmonise with current regulations and to follow the industrywide structure for a decommissioning plan.

No decommissioning plan has yet been prepared for SFL, since the design of the facility is only in the conceptual stage. Decommissioning will start in conjunction with repository closure, which is expected to take place in the mid-2050s.

F.6.2.7 Westinghouse fuel fabrication plant
A preliminary decommissioning plan for the Westinghouse fuel fabrication plant has been prepared and submitted to SSM in accordance with requirements in the general regulations.

F.6.3 Regulatory control
See sections E.3.2.6, E.2.5.2 and F.3.3 for details on SSM's system of controls and inspections.

In addition to issuing additional licence conditions for decommissioning, see section F.6.1, SSM analysed its personnel resources needed for authorising dismantling and demolition activities and their regulatory control. During the current period, new staff was recruited and trained in advance of the gradually increasing workload.

SSM also adapted its approach to reviewing safety reports to better address the issues which are specific to dismantling and demolition. Thereby, SSM could within 18 months thoroughly review and approve the safety reports and supporting documents for dismantling and demolition of Units 1 and 2 of the Barsebäck and Oskarshamn nuclear power plants and the Ågesta reactor.

During the current period, SSM gained additional experience from applying the general regulatory requirements to a number of dismantling projects, e.g. the two materials testing reactors at Studsvik (section F 6.2.3) and the segmentation of reactor internals from Units 1 and 2 of the Barsebäck nuclear power plant and Unit 2 of the Oskarshamn nuclear power plant. The existing general regulations have proven to be sufficiently well suited for the purposes of nuclear safety and radiation protection for these projects. SSM is confident that the existing general regulations are also well suited for the planned large scale decommissioning projects during the next period.

During the decommissioning period of a nuclear reactor, SSM's regulatory control is twofold: first, based on a systematic basic inspection programme for nuclear facilities; and second, linked to work packages. Typically, all dismantling and demolition measures are bundled into 8–12 work packages per reactor. An example of a typical work package is the segmentation of the reactor pressure vessel. As a matter of course, SSM also conducts on-site inspections in order to supplement the review process encompassing the work packages. Follow-up inspections are conducted during implementation of the work package. Following completion of a work package, a final report has to be submitted to SSM for review.

SSM is currently performing regulatory control of ongoing dismantling measures at Units 1 and 2 of the Barsebäck and Oskarshamn nuclear power plant and the Ågesta reactor. During the coming period, SSM's regulatory control at Units 1 and 2 of the Ringhals nuclear power plant will focus on preparatory activities and the authorisation of dismantling and demolition.

SSM is currently also reviewing and inspecting procedures for clearance of materials from the dismantling of Units 1 and 2 of the Barsebäck nuclear power plant, Units 1 and 2 of the Oskarshamn nuclear power plant and of the Ågesta reactor.

During the current period, SSM's regulatory control of decommissioning was not only restricted to the classical tools of reviews and inspections. SSM decided to take a more proactive stance and arranged, for instance, twice a year workshops on the various technical and regulatory issues of decommissioning. Regularly, some 80–100 participants from the industry join these workshops. The mix of lectures given by nationally and internationally recognised experts and group discussions supported the building-up of knowledge and networks necessary for the safe and efficient conduction of the large-scale decommissioning programme in Sweden.

F.6.4 Conclusion
Sweden complies with the obligations of Article 26.

Section G – Safety of Spent Fuel Management

The articles of the Joint Convention that specifically relate to the safety of spent fuel management (Articles 4 to 10 are covered in this section) have many similarities to the articles that specifically address the safety of radioactive waste management (Articles 11 to 17, covered in section H). To avoid unnecessary duplication, reporting on the matters (primarily regulatory requirements) that are common to both section G and section H is presented in full in section G only. Where appropriate, references to these accounts are made from the corresponding parts of section H. Where the Convention's requirements differ between the safety of spent fuel management and the safety of radioactive waste management, this is stated in the respective section. All aspects of the safe management of spent nuclear fuel, including development of a geological disposal facility, are covered by this section, whereas the relevant aspects of the programme for other radioactive waste repositories are described in section H.

G.1 Article 4: General safety requirements

Each Contracting Party shall take the appropriate steps to ensure that at all stages of spent fuel management, individuals, society and the environment are adequately protected against radiological hazards. In so doing, each Contracting Party shall take the appropriate steps to:

(i) ensure that criticality and removal of residual heat generated during spent fuel management are adequately addressed;

(ii) ensure that the generation of radioactive waste associated with spent fuel management is kept to the minimum practicable, consistent with the type of fuel cycle policy adopted;

(iii) take into account interdependencies among the different steps in spent fuel management;

(iv) take into account interdependencies among the different steps in spent fuel management;

(v) provide for effective protection of individuals, society and the environment, by applying at the national level suitable protective methods as approved by the regulatory body, in the framework of its national legislation which has due regard to internationally endorsed criteria and standards;

(vi) take into account the biological, chemical and other hazards that may be associated with spent fuel management;

(vii) strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation;

(viii) aim to avoid imposing undue burdens on future generations.

G.1.1 Regulatory requirements

G.1.1.1 The general obligations of licence holders

Licence holders of nuclear power plants are expressly responsible for the safe management and ultimate disposal of the spent nuclear fuel and radioactive waste that they generate. As accounted for in section E.2.1.1, the Act on Nuclear Activities requires that the holder of a licence for the operation of a nuclear power reactor shall – in liaison with the other holders of a licence for the operation of nuclear power reactors – establish and carry out an RD&D programme for the safe handling and final disposal of spent fuel and nuclear waste associated with their activities. Every third year, the programme must be submitted to the Government, or to an authority assigned by the Government (i.e. the Swedish Radiation Safety Authority, SSM), for evaluation.

The legal obligations on licence holders of nuclear power plants do not formally extend to requiring them to provide facilities for disposal of wastes from nuclear facilities other than commercial nuclear power reactors, or radioactive waste originating from non-nuclear activities. However, the scale of operations relating to disposal of licence holders' nuclear wastes is such that other wastes, including wastes

from historic nuclear activities and radioactive wastes of institutional origin (collected and treated by Cyclife Sweden AB) can be accommodated in the licence holders' repository facilities. Costs for management and disposal of wastes from non-nuclear activities are covered by fees paid by the producers to Cyclife Sweden AB (section E.2.1.4).

G.1.1.2 Basic provisions and licence obligations

Basic safety obligations on licence holders for nuclear facilities are stipulated in the Act on Nuclear Activities. The requirements are further clarified in the basic regulatory requirements for radiation safety in association with licensed activities (SSMFS 2018:1) as well as in general regulations on safety in nuclear facilities (SSMFS 2008:1). In these regulations it is stated that, in order to ensure adequate protection at all stages of spent fuel management and radioactive waste management, the licensee shall:

- undertake all licensed activities, including the management of spent fuel, in such a way that the quantity of waste that is generated as well as its content is restricted as far as is reasonably practicable;
- ensure that a documented plan is drawn up and maintained for all radioactive wastes arising from or supplied to the licensed activity, based on an evaluation of alternative management options;
- undertake, document and maintain a safety analysis showing how facilities and management systems for spent fuel and radioactive waste management, alongside other relevant aspects of facility safety, ensure compliance with regulatory requirements regarding design, function, organisation and operation;
- establish documented guidelines for how safety shall be maintained at the facility as well as ensure that the personnel performing duties important for safety are well acquainted with the guidelines;
- ensure that the activities carried out at the facility are controlled and developed with the support of a quality system which covers those activities of importance for safety;
- ensure that decisions on safety-related issues are preceded by adequate investigation and consultation so that the issues are comprehensively examined;
- ensure that adequate personnel are available with the necessary competence and suitability in all respects with regard to those tasks that are of importance for safety, as well as ensure that this is documented;
- ensure that responsibilities and authority are defined and documented with respect to personnel carrying out work that is important for safety;
- ensure that the personnel are provided with the necessary conditions to work in a safe manner;
- ensure that experience from the facility's own activities and from similar activities elsewhere is continuously utilised and communicated to the personnel concerned; and
- ensure that safety, through these and other measures, is maintained and continuously developed.

In the Radiation Protection Act (2018:396) it is stipulated that radioactive waste shall be handled and disposed of in a manner that is satisfactory from a radiation protection point of view.

General requirements on the design and assessment of post-closure safety for disposal facilities are established in two separate regulations. These include specific regulations on the protection of human health and the environment in connection with the final management, including disposal, of spent nuclear fuel and nuclear waste, with a focus on application of radiation protection principles for the long term (SSMFS 2008:37). There are also regulatory requirements concerning principles for assuring and assessing post-closure safety of a disposal facility (SSMFS 2008:21).

G.1.1.3 Criticality and removal of residual heat

The general safety regulations (SSMFS 2008:1) state that radiological accidents are to be prevented by the design, construction, operation, monitoring and maintenance of a facility. Requirements relating to the prevention of unintended criticality are addressed in provisions for defence in depth, while heat generation and removal of residual heat must be considered when establishing the operating limits and conditions of any nuclear facility, including storage facilities, both for normal operation and design-basis events. Provision shall be made in design of storage arrangements for reserve capacity to enable relocation of material. Passive safety functions shall be used as far as is reasonably practicable in the design of systems for storage of spent fuel.

G.1.1.4 Interdependencies among the different steps in spent fuel management

The fact that licence holders are responsible for the handling and disposal of the spent nuclear fuel that they generate provides an incentive to consider all steps from generation to disposal. Detailed requirements are stipulated in SSM's general regulations on safety in nuclear facilities (SSMFS 2008:1) and with regard to the control of nuclear material (SSMFS 2008:3):

- Measures for the safe on-site handling and storage of spent fuel shall be analysed and verified, and included in the safety report of the facility. The safety report shall also include measures that need to be taken on-site to prepare for the safe subsequent transport, storage or disposal of spent fuel. (SSMFS 2008:1)
- An inventory of all spent fuel on-site must be kept updated at all times. (SSMFS 2008:3)
- Plans shall be drawn up providing a general description of management, including final disposal, of spent nuclear fuel likely to be generated while operating the facility (SSMFS 2018:1). The plans shall be reported to the authorities for approval before commissioning of nuclear reactor facilities and incorporated in the safety report (SSMFS 2008:1).
- Where deviations in the type, quantity or condition of spent nuclear fuel occur relative to the plans as stipulated above, necessary measures for management of the non-conforming material shall be explained and documented in a separate plan. This plan shall be independently reviewed for safety implications and reported to the authorities before the measures are implemented (SSMFS 2008:1).
- Acceptance criteria shall be derived stating the properties of the spent nuclear fuel that can be received for storage, final disposal or any other treatment. Acceptance criteria shall, so far as is reasonably practicable, be formulated while taking into account safety and radiation protection throughout all stages of spent fuel management and shall be included in corresponding safety analyses. Procedures must be in place for the verification of material against acceptance criteria on receipt by facilities further along the management chain, as well as for the management of material that does not meet the acceptance criteria, e.g. by returning it to the consignor or by taking measures to rectify identified deviations (SSMFS 2008:1).

G.1.1.5 Protection of individuals, society and the environment

General safety provisions relating to radiation protection are described in section F.4.1. Radiation protection of the public and the environment in connection with operational spent fuel management is addressed in general regulations relating to the safety of nuclear facilities (SSMFS 2008:1). As noted above (section G.1.1.2), safety and radiological protection objectives for disposal facilities, with a focus on post-closure protection of individuals, society and the environment, are established in separate regulations (SSMFS 2008:37, SSMFS 2008:21); see also section L.1. Fundamental principles and requirements for radiological protection in relation to spent fuel management and disposal can be summarised as follows:

- Human health and the environment shall be protected from the detrimental effects of ionising radiation during all stages of the final management of spent nuclear fuel or nuclear waste, as well as in the future, in accordance with internationally endorsed criteria and standards.
- A disposal facility for spent nuclear fuel and/or nuclear waste shall be designed so that the annual risk of harmful effects after closure does not exceed 10^{-6} for a representative individual in the group exposed to the greatest risk.
- Disposal of spent nuclear fuel and nuclear waste shall be implemented so that biodiversity and the sustainable use of biological resources are protected.

G.1.1.6 Account of biological, chemical and other hazards

Biological, chemical and other hazards associated with an activity are addressed from a regulatory perspective in the licensing process under the Environmental Code (sections E.2.3 and E.2.9). During operation the operator is required to continuously take protection measures and precautions to prevent or hinder their activities from causing detriment to human health or the environment from chemical, biological and other hazards, as well as from a radiological point of view. Any such risks that might be associated with the activity in question should be analysed and reported in the corresponding Environmental Impact Assessment (EIA). The EIA should also include a description of the measures, through design and management actions, that are envisaged to prevent, reduce or remedy adverse effects associated with these hazards (section E.2.3.4). Specific licence conditions relating to mitigating measures taken by the operator are typically established at the time of licensing.

Supervision of activities that deal with chemical and biological hazards is primarily exercised by County Administrative Boards.

G.1.1.7 Striving to avoid impacts and undue burdens on future generation

As described in section B.1.1, the overall system for management of spent fuel and radioactive waste is governed by fundamental principles adopted by the Swedish Parliament. The first governing principle is that financial costs for the treatment and disposal of spent fuel and radioactive waste from nuclear activities shall be covered by fees that licensees are required to pay. The second principle is that the licensees are to safely dispose of spent nuclear fuel and radioactive waste from nuclear activities. Although the state formally has the ultimate responsibility for spent nuclear fuel and radioactive waste from nuclear activities, these principles imply that a burden on future generations should be avoided, especially with regard to the fundamental aspects of safety and financial costs. The principles also imply that action should be taken without undue delay, i.e. the generation that has benefited from the nuclear power generation should also deal with the management and disposal of the spent nuclear fuel and radioactive waste.

SSM's regulations on discharges of radioactive substances (SSMFS 2008:23) require that human health and the environment shall be protected from harmful effects of ionising radiation during the operation of a nuclear facility as well as in the future. Furthermore, the regulations SSMFS 2008:37 specifically require that human health and the environment shall be protected from detrimental effects of ionising radiation during all stages of the final management of spent nuclear fuel or nuclear waste, including after closure of a disposal facility.

G.1.2 Measures taken by the licence holders

G.1.2.1 The general obligations of licence holders

RD&D programme 2019

The nuclear industry, through its co-owned company, SKB, has since the mid-1970s performed research on the long-term management of spent fuel and final disposal of radioactive waste. The formal requirement for an RD&D programme to be submitted for regulatory evaluation was established in 1984 when the Act on Nuclear Activities was promulgated. Since 1986, SKB has produced twelve RD&D programmes, with a central focus on development of the KBS-3 system as the industry's preferred alternative for the disposal of spent fuel. The current status of SKB's licence applications in relation to establishing KBS-3 is outlined in sections A.9.4, A.10.2 and K.1.1.

In September 2019, SKB submitted the most recent RD&D programme to the regulator, SSM, for review and a public consultation, in preparation for the Government's decision concerning the licence holders' fulfilment of their legal obligations. In their RD&D Programme 2019, SKB presents its plans for research, development and demonstration during the period 2020–2025 (SKB Report TR-19-24, December 2019, can be downloaded from www.skb.se).

The programme consists of three parts:

Part I SKB's activities and plan of action

Part II Waste and final disposal

Part III Decommissioning of nuclear facilities

The plan of action developed by SKB on behalf of its owners gives the rationale for the research, development and demonstration need in order to construct and commission new facilities for spent nuclear fuel and waste management. As regards the KBS-3 system for final management of spent nuclear fuel, what remains is the construction and commissioning of a new facility for encapsulation of spent nuclear fuel adjacent to the Clab interim storage facility, the spent fuel repository, and the development and manufacture of transport casks for canisters of spent nuclear fuel. While SKB's licence applications remain under consideration by the Government, the company is preparing the next applications, including a preliminary safety analysis report, which will need to be submitted to SSM for approval to start construction. SKB is also preparing the necessary documentation regarding changes to Clab that will be necessary to make use of the increase in licensed storage capacity that has been applied for.

Even when SKB has reached the maturity in research and development required to obtain licences under the Nuclear Activities Act, further research and technology development is needed to support construction and commissioning of the facilities. Identified areas of research relating to the final repository for spent fuel are focused on providing knowledge to enable a more realistic assessment of post-closure safety that can be used as a basis for optimisation of repository component design and layout. Among other things, this includes further work on process understanding regarding the characterisation and behaviour of spent fuel, processes affecting canister corrosion mechanisms and slow resaturation of the bentonite buffer.

Technology development is focused on completing the detailed design of both the encapsulation plant and spent fuel repository. Prior to the construction of the encapsulation plant, technology and methods for the industrial production of canisters must be developed and described. The necessary technical systems must be specified, including methods for nuclear fuel measurement, the drying of fuel assemblies as well as the remote welding and inspection of canisters during encapsulation. For the repository, technology development includes the definition of investigation methods to verify the site descriptive model for the Forsmark site, further development of technical systems for deposition, backfilling and sealing of deposition tunnels, as well as methods for construction of repository accesses and excavation of deposition tunnels and deposition holes. Technology development also takes place in the field of nuclear safeguards in liaison with IAEA, Euratom and SSM.

G.1.2.2 Basic provisions and licence obligations

Specific measures taken by the licensees regarding general safety requirements are discussed in sections G.3.2 (facility siting), G.4.2 (facility design and construction), G.5.2 (assessment of facility safety) and G.6.2 (facility operation). General measures that have been taken by licence holders with respect to the continued safe management of spent fuel include the following.

Spent fuel storage at reactor sites

All spent nuclear fuel was removed from the Barsebäck units 1 and 2 and transferred to the Clab central storage facility by 2006. Facilities for spent fuel storage have also been emptied at Oskarshamn units 1 and 2, which have been permanently shut down since June 2017 and December 2016 respectively. Defueling of units 1 and 2 at Ringhals is currently estimated to take 18 months and 26 months respectively, taking into account cooling requirements and the capacity for fuel transport to Clab.

The process of handling damaged fuel with failed cladding during the emptying nuclear power plants is the subject of special consideration. Two separate methods have been developed, both of which entail the use of water-tight special containers with the dimensions of PWR and BWR fuel. The intention is that these containers will then be encapsulated and disposed of in the same way as standard fuel elements. In the method used in the storage pools of the nuclear power plants, developed by Westinghouse and known as Quiver, the content of the container is dried after the cladding has first been punctured to ensure complete drying. An alternative method has been developed for damaged fuel that has been sent for analysis and/or treatment to Studsvik. Here the damaged fuel rods are segmented in hot cells before drying and transfer to special cases and finally into transport boxes that have the same dimensions of PWR or BWR fuel elements.

Central storage facility for spent nuclear fuel (Clab)

SKB is the licensee for Clab, the central interim storage facility for spent nuclear fuel located at the OKG site. From the start of operation in 1985 until 2006, the operations were contracted to OKG. In January 2007, SKB took over Clab's operations in order to manage the facility as part of SKB's own organisation.

The storage capacity at Clab is limited in two main respects: the permissible quantity of spent nuclear fuel in the facility, and the number of physical storage positions in the pools. According to forecasts from the nuclear power plants, the quantity of spent nuclear fuel in Clab will reach the current authorised limit of 8,000 tonnes at the end of 2023. As noted in sections A.9.4 and K.2.4, SKB has therefore, as part of its application for construction and operation of the combined encapsulation plant and interim storage facility, Clink, also applied for increasing the interim storage capacity to 11,000 tonnes. After a Government decision, SKB must submit a preliminary safety analysis report, describing the changes to be implemented, to SSM for approval. The upgrading of the facility and submission of the corresponding safety analysis are planned to take place at the latest in 2023.

The total cooling requirement for storage of 11,000 tonnes of fuel amounts to 12 MW. An upgrade of the existing cooling capacity in Clab has been implemented and the safety analysis report for the facility is being updated with respect to this. Other measures to free more storage space for fuel will be required beyond the year 2028. SKB has therefore initiated a project to segment the control rods from BWR reactors that currently occupy significant volumes space in Clab's storage pools. After segmentation, the control rods can be packed more tightly in new storage canisters and returned to the storage pools. It is estimated that the work will take approximately five years to complete. By this measure, the storage capacity is expected to be sufficient until around 2034.

If significant further delays arise in the programme for commissioning of the encapsulation plant and/or repository for spent fuel, it is conceivable that the unloading of Clab's storage pools could be delayed beyond 2034. SKB contingency plans in such an event include the possibility of transferring fuel that is currently still stored in normal storage canisters to compact storage canisters. This would enable continued operation of the facility, within the 11,000 tonnes limit, until around 2040. In addition, there is the potential for the core components and control rods in store at Clab to be unloaded and transferred to another site for storage, based on approved methods used for other activated metal components from nuclear power plants. Should even this measure prove to be insufficient to accommodate programme delays, SKB will consider both wet and dry interim storage options for further extending capacity.

Existing documentation shows that there is a small number of fuel assemblies with leaking fuel rods at Clab. A detailed plan for handling these fuels will be established as part of current RD&D programme, taking account of experience from the emptying the nuclear power plants of damaged fuel. In addition, the long-term inspection programme for fuels in interim storage has revealed weaknesses in the construction for certain fuel types that could potentially cause problems when handling the fuel. This information is being taken into account in the design development for the encapsulation facility.

As noted in Sweden's sixth report under the Joint Convention, all areas of improvement identified in the post-Fukushima stress test analysis of Clab have now been addressed by SKB. It has been shown that the facility can withstand an earthquake with a return frequency of 10^{-5}/year with a safety factor of 2. The updated SAR shows that boiling of the pool water after loss of electric power supply or other extreme disturbances of the cooling system will not occur within a period of 30 days.

Transportation of spent fuel

The annual transport volume is currently on average 90 casks with spent nuclear fuel between the nuclear power plants and Clab. A contract was signed in October 2013 with Holtec International Power Division, Inc. for the design, licensing and manufacture of five new spent fuel transport casks with auxiliary equipment. The NRC's approval of the new cask HI-STAR 80 was obtained at the end of September 2018 and the US Department of Transport has issued a licence. An application for validation of the licence was submitted to SSM at the end of 2018. Manufacturing has been initiated at the delivery of the first new fuel transport cask is planned for the spring of 2021.

New bottom shock absorbers for existing fuel transport casks (Type TN17/2) have been delivered. The cask supplier has updated the safety analysis report and applied for a new certificate from the French regulatory body, ASN. SKB plans to apply for Swedish validation of the certificate in the spring of 2020.

At present m/s Sigrid makes about 20 trips per year, which means that there is an overcapacity in the transportation system. After 2030, however, the need for transportation of spent nuclear fuel and radioactive waste is expected to double when several of SKB's new facilities have been commissioned. This includes, in particular, the additional transport of encapsulated nuclear fuel from the Clink facility to the spent fuel repository. Work is being carried out by SKB to ensure that assumptions regarding transport needs, including logistics associated with servicing and transhipments between sea and land, are verified and, where necessary, revised.

Biological, chemical and other hazards associated with spent fuel management

This topic was addressed as part of SKB's RD&D programme as well as during the national consultations carried out under the Environmental Code regarding SKB's plans for disposal of spent nuclear fuel. Non-radiological environmental risks arising during construction and operation of the planned facilities (encapsulation facility and geological repository) were assessed (SKB Report 2009, P-09-78, can be downloaded at www.skb.se) and the outcomes presented by SKB in the EIA submitted to the Land and Environment Court as part of the licence application for the disposal of spent nuclear fuel. A post-closure chemotoxic assessment for the disposal of spent nuclear fuel was also performed by SKB (SKB Report 2010, P-10-13, can be downloaded at www.skb.se).

G.1.3 Regulatory control

G.1.3.1 The general obligations of licence holders

Evaluation of the RD&D programme

In September 2019, SKB submitted the nuclear reactor licensees' twelfth programme for research, development and demonstration, RD&D Programme 2019, to SSM for review and broad consultation with national stakeholders. In March 2020, SSM submitted the results of its evaluation

and a statement to the Government with a recommendation to approve SKB's RD&D programme.

As was previously the case in 2017, and in the light of the ongoing scrutiny by Government of SKB's licence applications for an encapsulation plant and a spent fuel disposal facility (see section A.8.2.2 and K.1.1), the regulatory evaluation of the programme was constrained so as not to forestall an eventual licensing decision. However, the overall conclusion as regards spent fuel management was that the programme demonstrates progress in work to develop and implement necessary solutions in a manner consistent with licence holders' obligations under the Act on Nuclear Activities. Research and development activities were judged to take sufficiently broad perspective regarding the safe management of spent fuel. This includes work focused on understanding of spent fuel properties and behaviour, including criticality safety and radionuclide solubility. In addition, SKB's research and development activity relating to the disposal canister was considered to provide appropriate contributions to knowledge development relating to canister degradation, as well as an acceptable basis for future industrial implementation in design, manufacture, inspection, and testing.

G.1.3.2 Basic provisions and licence obligations

Inspections and surveillance

As noted elsewhere in this report, SSM undertakes compliance and surveillance inspections relating to the safe management of spent fuel in accordance with its legal authorisation and the mandate defined by the Government.

The results of inspections and surveillance are fed back to nuclear facility licensees on an ongoing basis, summarised annually in meetings at senior management level, and compiled routinely in reports that provide an integrated evaluation of radiation protection and safety. These reports are produced annually for nuclear power plants and every three years for SKB. In the latest integrated evaluation for SKB, published in June 2018, SSM assessed radiation safety associated with the Clab interim storage facility to be acceptable. Previously identified deficiencies in maintenance and inspection with regard to plant ageing, as well as the use of systematic methods for safety analysis were deemed to have been addressed in an appropriate manner. Moreover, SSM in July 2018 closed out the enforcement notice from three years previously relating to required overall improvements in SKB's organisation, management and control for safety.

Furthermore, an overall evaluation of a licensee's capacity to continue conducting its activities is made at least every ten years through periodic safety review. SSM completed in 2019 its scrutiny of SKB's latest periodic safety review of its activities. In its summary, SSM concluded that the company has the necessary prerequisites to continue operation of the Clab interim storage facility in accordance with requirements on nuclear safety and radiation protection. Identified weaknesses were associated primarily with how issues were reported and addressed in the documentation of the periodic safety review itself, rather than deficiencies in regulatory compliance.

G.1.4 Conclusion

Sweden complies with the obligations of Article 4.

G.2 Article 5: Existing facilities

> Each Contracting Party shall take the appropriate steps to review the safety of any spent fuel management facility existing at the time the Convention enters into force for that Contracting Party and to ensure that, if necessary, all reasonably practicable improvements are made to upgrade the safety of such a facility.

G.2.1 Review of existing facilities for spent fuel management

By the time the Joint Convention entered into force with regard to Sweden, the situation was satisfactory as regards safety of spent fuel management facilities. The elements of the Joint Convention have long been implemented in the form of requirements imposed by the Swedish legal and regulatory framework, as well as being implemented in management of spent fuel. Dedicated inspection and review activities carried out in the early 2000s confirmed that licensees' activities were in conformance with the legal and regulatory requirements. This conclusion has been reaffirmed during subsequent inspection and review activities.

G.2.2 Conclusion

Sweden complies with the obligations of Article 5.

G.3 Article 6: Siting of proposed facilities

> **1.** Each Contracting Party shall take the appropriate steps to ensure that procedures are established and implemented for a proposed spent fuel management facility:
>
> **(i)** to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime;
>
> **(ii)** to evaluate the likely safety impact of such a facility on individuals, society and the environment;
>
> **(iii)** to make information on the safety of such a facility available to members of the public;
>
> **(iv)** to consult Contracting Parties in the vicinity of such a facility, insofar as they are likely to be affected by that facility, and provide them, upon their request, with general data relating to the facility to enable them to evaluate the likely safety impact of the facility upon their territory.
>
> **2.** In so doing, each Contracting Party shall take the appropriate steps to ensure that such facilities shall not have unacceptable effects on other Contracting Parties by being sited in accordance with the general safety requirements of Article 4.

G.3.1 Regulatory requirements

G.3.1.1 Assessment of safety and environmental impact

Under the Environmental Code and the Act on Nuclear Activities, a licence is required in order to construct, possess and operate any nuclear facility (the licensing procedure is described in sections E.2.3 and E.2.9). An application must demonstrate that the requirements are fulfilled in accordance with these items of legislation as well as those of the Radiation Protection Act. It must also be made clear that the more detailed requirements established in SSM's regulations can be met. In relation to safety issues regarding the siting of proposed facilities for management of spent fuel, key regulations in this context are:

- Regulations concerning safety in nuclear facilities (SSMFS 2008:1)
- Regulations concerning safety in connection with the disposal of nuclear materials and nuclear waste (SSMFS 2008:21)
- Regulations concerning the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste (SSMFS 2008:37)

Key elements of the parallel licence applications are the Environmental Impact Assessment (EIA) and preliminary safety report.

The Environmental Code requires as part of the general 'rules of consideration' that site selection is undertaken in such a way as to make it possible for the objectives of the activity or development to be achieved with a minimum of damage and detriment to human health and the environment. The Environmental Code also specifies procedures for carrying out the EIA, as well as its content. The EIA must contain the following elements:

- a description of the planned activity or course of action with details of its location, design and scope;
- a description of the measures that are planned with a view to avoiding, mitigating or remedying adverse effects;
- the information needed to establish and assess the main impacts on human health, the environment and management of land, water and other resources that the planned activity or course of action is likely to have;
- a description of possible alternative sites and alternative designs, together with a statement of the reasons why a specific alternative was chosen, as well as a description of the consequences if the activity or measure is not implemented; and
- a non-technical summary of the information.

Requirements regarding the content of the preliminary safety report, submitted in support of a licence application under the Act on Nuclear Activities, are stated in the regulations concerning safety in nuclear facilities, and include (for example):

- A description of how the site and its surroundings can affect the safety of the facility during its operational lifetime.
- A description of the design basis, including the requirements that have determined the design and construction of the facility. Descriptions of facilities for the final management of spent fuel or nuclear waste shall contain requirements that are determined by how safety is to be achieved in the corresponding disposal facility after closure.
- A description of measures taken to ensure adequate protection of workers, the public and the environment from the harmful effects of radiation, as required by the Radiation Protection Act and regulations promulgated under that Act.

It is further explained in regulations relating to development of geological disposal facilities (SSMFS 2008:37) that site selection should be seen as contributing to identification and implementation of the best available technique for the repository system as a whole.

G.3.1.2 Public information and involvement

The legal framework for licensing of nuclear activities stipulates provisions on transparency, openness and public participation. There are several procedures that serve the purpose of involving the public as part of siting of new spent nuclear fuel management and nuclear waste facilities. As mentioned above, an EIA must be performed for any new nuclear facility. Swedish legislation emphasises the role of the public and other stakeholders in establishing the scope of the EIA. The programme for developing an EIA must for instance contain a plan for the formal process of consultation with stakeholders. In particular, the developer must initiate early consultations with those parties that might be affected by a new facility.

Parties that must be consulted include:

- municipalities that may host the facility,
- regulatory authorities, in the case of facilities for spent fuel and nuclear waste management these are primarily SSM and County Administrative Boards,
- national environmental organisations,
- local interest groups, and
- affected individuals, e.g. land owners or those living close to a proposed site.

County Administrative Boards have an important function besides participating in the consultations. They are required to assist the developer in identifying stakeholders and to facilitate consultations and the exchange of information.

In addition to requirements on the applicant for public consultation in the development of an EIA, the regulatory authority (SSM) invites a broad range of interested parties to provide comments in association with its evaluation every three years of the nuclear power plant licence holders' joint RD&D programme (see section G.1.1). In summary, interested parties are provided with information regarding, among other things, the programme for development of new facilities, as well as a possibility to influence the pre-licensing process through comment and opinion.

According to the Act (2006:647) and Ordinance (2008:715) on Financing of Management of Residual Products from

Nuclear Activities, the municipalities that might host a spent nuclear fuel or nuclear waste management facility, including a disposal facility, are to be reimbursed for information activities aimed at their residents. Since the mid-1990s, municipalities have been reimbursed for their information activities associated with SKB's siting process in connection with geological disposal of spent fuel. The municipalities of Östhammar and Oskarshamn continue to receive reimbursement as the prospective host communities for the disposal facility and encapsulation plant, respectively. In 2004 the Parliament approved a new regulation in the Financing Act, which made it possible for certain non-profit, non-governmental organisations as well to apply for financing for participation in the public consultation activities relating to SKB's licence applications. These organisations were entitled to financial support from the Nuclear Waste Fund at the discretion of SSM until 12 months after the EIA had been formally announced by the Land and Environment Court (for further details. As of January 2017, following the expiry of this period, the Government has made it possible for non-governmental organisations meeting the same criteria as before to instead apply for continued financial reimbursement as part of the state budget appropriation, first via the Swedish Environmental Protection Agency and subsequently via SSM.

Prior to the Government's final decision in relation to licensing the development of an encapsulation plant and a spent nuclear fuel repository, the host municipality concerned has a right to veto and is expected formally to declare its support or rejection of the decision. In practice, the formal consultations, financial support to host municipalities and certain environmental organisations, and the municipal right to veto have to date been very beneficial to the overall quality of engagement and to wider public acceptance of the licensing process for a spent fuel repository. Guided by recommendations from regulators and Government in their reviews of the reactor licensees' RD&D programme, SKB's strategy of involving local communities on a voluntary basis in the siting process for a spent fuel repository has been another important factor.

The Swedish approach to building trust in the high-level waste management system together with the integrity of the regulator was credited as a good practice in the 2012 IAEA IRRS review.

G.3.1.3 Consulting contracting parties

Sweden (as well as the EU, Canada and USA) has ratified the Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention). The purpose of the convention is to seek cooperation to prevent transboundary environmental effects and to impose the requirement for informing neighbouring countries and the general public about planned activities that might cause environmental effects. The provisions of the Convention are mainly implemented in the Swedish Environmental Code by means of the requirements imposed for consultation relating to the production of Environmental Impact Assessments (EIA). The Environmental Code specifies that if another country may be affected, the responsible authority as designated by the Government shall inform the competent authority in that country about the planned activity. The country concerned and the citizens who may be affected should be given the opportunity to take part in the consultation procedure. The Government has designated the Swedish Environmental Protection Agency to be responsible for this task.

As part of this procedure, and in accordance with Article 5 of the Espoo Convention, Sweden invited all countries around the Baltic Sea for a joint consultation meeting in March 2016 regarding SKB's KBS-3 licence application under the Environmental Code. The parties had previously been provided with information, compiled by SKB, and were given the opportunity to submit comments relating to the assessment of the environmental impacts of the project, covering both the planned encapsulation plant and geological disposal facility. A record of the process, including statements from neighbouring countries and SKB's response to issues raised, was submitted to the Land and Environment Court as part of the scrutiny of the licence application under the Environmental Code.

As an EU Member State, Sweden is also required to apply Article 37 of the Euratom Treaty. This Article obliges each Member State to provide the Commission with general data relating to any plan for the disposal or discharge of radioactive waste in whatever form to enable a determination on whether the implementation of such a plan is liable to result in the radioactive contamination of the water, soil or airspace of another Member State. Information regarding the planned encapsulation plant and repository for spent nuclear fuel, currently the subject of the Government's licensing review process (see section A.8.2.2 and K.1.1), will be submitted at the appropriate time to the Commission in accordance with Article 37.

G.3.2 Measures taken by the licence holders

All planned major facilities for spent fuel and radioactive waste management, including repositories, will be sited, constructed and operated by SKB. The supporting RD&D programme is also run by SKB. The following activities have recently been carried out or are in progress:

- The RD&D programme has been reported on every third year since 1986. The most recent RD&D report was submitted in September 2019.
- Consultations and an EIA for the planned encapsulation facility and repository for spent nuclear fuel began formally in 2002, but in practice started as part of SKB's siting programme in the mid-1990s. The consultations were concluded in May 2010.
- Consultations and an EIA for the planned extension of the final repository for short-lived radioactive waste, SFR, began in 2010 and a licence application was submitted to SSM in December 2014.

A summary of the siting process and related consultations in respect of the planned repository for spent nuclear fuel was provided in Sweden's fifth national report published in 2014.

G.3.3 Regulatory control

SSM and its predecessors (the Swedish Nuclear Power Inspectorate, SKI, and the Swedish Radiation Protection Authority, SSI) reviewed and analysed SKB's siting programme for a deep geological disposal facility for spent fuel over a period of more than three decades prior to the submission of the licence applications. The main instruments for regulatory control of SKB's siting programme have been:

- review of SKB's recurrent programme for research, development and demonstration (RD&D programmes),
- consultation meetings with SKB on their detailed site investigations at two candidate sites,
- participation in EIA consultation meetings led by SKB in accordance with the requirements in the Environmental Code, and
- independent review and analyses of SKB's site investigation data and site descriptive models.

Based on the outcome of review activities related to the RD&D programme, the Government concluded in a decision in 2001 that SKB could start detailed investigations at the candidate sites using the KBS-3 method as a planning premise for the site investigation. The Government noted that this did not remove the need for formal justification of method selection at the time of repository licensing.

The Government also concluded that SKB should conduct consultation meetings with SKI and SSI during the full duration of the site investigation programme. Both authorities contributed to these consultation meetings, which were held between 2001 and 2010, by asking questions and providing comments related to SKB's site investigation methods as well as their interpretation of site-specific information. A series of reports (available at www.ssm.se) is publicly available covering all external regulatory reviews and analyses of SKB's site investigation programme.

As part of its scrutiny of the licence application, SSM formally reviewed SKB's selection of Forsmark as the site for the proposed repository for spent nuclear fuel. SSM's conclusion was that, of the locations considered within the framework of the voluntary engagement process, Forsmark is the most suitable site from the perspective of radiation safety (SSM Report 2018:04, available at www.ssm.se). According to the Authority's assessment, none of the alternative locations considered during the site selection process demonstrated properties that, taken together, were more advantageous from the perspective of preventing, limiting and delaying releases from the engineered and geological barriers. The factors judged to weigh most heavily in favour of Forsmark in relation to the other locations are its relatively homogeneous rock mass with few water-bearing fractures at repository depth.

Moreover, SSM assessed that SKB's preferred location for the encapsulation plant adjacent to the central interim storage facility, Clab, is one that, from the perspectives of nuclear safety, radiation protection and safety, best meets the siting requirements of the Environmental Code. It is nevertheless recognised that constructing the encapsulation plant adjacent to Clab entails certain risks that SKB will need to take measures to minimise. The Land and Environment Court, in its statement to Government on the conclusions of its scrutiny of SKB's licence application under the Environmental Code, did not question SKB's arguments for siting either the encapsulation plant or the spent fuel repository.

Both SSM and the Land and Environment Court concluded that the consultation process undertaken by SKB in development of the EIA was acceptable. SSM found that consultation on matters relating to radiation safety was timely, that it involved the correct parties and that it considered the issues that should be addressed.

G.3.4 Conclusion

Sweden complies with the obligations of Article 6.

G.4 Article 7: Design and construction of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the design and construction of a spent fuel management facility provide for suitable measures to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases;

(ii) at the design stage, conceptual plans and, as necessary, technical provisions for the decommissioning of a spent fuel management facility are taken into account;

(iii) the technologies incorporated in the design and construction of a spent fuel management facility are supported by experience, testing or analysis.

G.4.1 Regulatory requirements

Regulatory requirements in Sweden for limiting the possible radiological impact on individuals, society and the environment, including impacts from discharges or uncontrolled releases, are founded upon the basic provisions contained in the Act on Nuclear Activities, Radiation Protection Act and Environmental Code.

G.4.1.1 Suitable measures to limit radiological impact

According to SSM's basic regulatory requirements for radiation safety in association with licensed activities involving ionising radiation (SSMFS 2018:1), there must be defence in depth, adapted to nature of the activity and involving the application of several consecutive technical, organisational and administrative measures, to counter the occurrence and limit the development of events and conditions that are of significance to the radiation safety. Such measures should also be designed to maintain the effectiveness of the barriers placed between a radiation source and workers, the general public and environment. All facilities, premises and locations where licensed activities are carried out must be designed so that radiological exposure of the

workforce to ionising radiation, as well as the dispersal of radioactive material, can be limited and measured. Moreover, their design must be such that release of radioactive material to the environment can be limited and monitored as far as is reasonably practicable and so that exposure of the public to ionising radiation is avoided. Results from monitoring of releases to air and water must be documented and reported.

SSM's general regulations concerning safety in nuclear facilities (SSMFS 2008:1) provide more detailed requirements that apply to the construction, operation and decommissioning of all types of nuclear installations, including facilities for the treatment, storage and disposal of spent fuel and radioactive waste. A basic requirement is that radiological accidents shall be prevented through a basic facility-specific design that incorporates multiple barriers as well as a facility-specific defence in depth system. The defence in depth shall be achieved by ensuring that:

- the design, construction, operation, monitoring and maintenance of a facility is such that abnormal events, incidents and accidents are prevented;
- multiple devices and measures exist to protect the integrity of the barriers and, if the integrity should be breached, to mitigate the ensuing consequences; and
- any release of radioactive substances, which still may occur as a result of extreme events, incidents and accidents, is prevented or, if this is not possible, controlled and mitigated through devices and prepared measures.

Further requirements on design and construction for limiting radiological impact are defined in specific regulations regarding safety and radiological protection objectives for the final disposal of nuclear material and nuclear waste (SSMFS 2008:21, SSMFS 2008:37). Safety after the final closure of a repository shall be maintained through a system of passive barriers, each of which should work, in one or more ways, to contain, prevent or delay the dispersal of radioactive material, either directly or indirectly through protecting other barriers in the disposal system. The barrier system should be durable against the conditions, events and processes that may affect the function of individual barriers and should be designed and implemented with regard to Best Available Technique (BAT). The objective is to ensure that all reasonable measures to assure the protective capability of a disposal facility are considered in all stages of its development, operation and final closure.

G.4.1.2 Conceptual plans and provisions for decommissioning

The Act on Nuclear Activities establishes that the holder of a licence for nuclear activities is responsible for the safe decommissioning of their facilities.

The Act on Nuclear Activities also states that licence holders of nuclear power plants shall ensure that comprehensive research and development activities are conducted in order to fulfil the requirements concerning decommissioning and waste management. Moreover, all licensees for nuclear activities are responsible for financing the measures needed in order to manage and dispose of nuclear waste and spent nuclear fuel, as well as to decommission and dismantle their facilities.

Regulations concerning safety in nuclear installations (SSMFS 2008:1) contain requirements regarding decommissioning plans for nuclear facilities, stating that safe decommissioning must be taken into account when designing a facility, and that conceptual plans for decommissioning shall be made available prior to construction and kept under review thereafter (see also section L.1).

G.4.1.3 Technology supported by experience

The general regulations concerning safety in nuclear installations (SSMFS 2008:1) specify requirements regarding design and construction. A facility must be designed so as to:

- be able to withstand component and system failures;
- have reliability and operational stability;
- be able to withstand events or conditions that can affect the installation's barriers or safety functions; and
- enable maintenance, inspection and testing of those systems, components and equipment that are relevant to safety.

Design principles and design solutions must be tested under conditions representative of those that may occur during the intended use of a facility. If this is not practicable, they must be tested or assessed in a manner that demonstrates that they have the durability, reliability and operational stability required for them to fulfil their function and importance to the safety of the facility. Consideration must also be given to the capability of operational personnel to monitor and manage the facility under normal operational conditions, as well as during abnormal events, incidents and accidents that may occur.

With regard to the design and construction of a repository, it is clear that the scope for testing and learning from experience is limited, especially in relation to the timescales for safety performance after final closure. This places particular emphasis on the evidence base for demonstrating, as noted above, good understanding of the conditions, events and processes that may affect the function of individual barriers in the disposal system, and that all reasonable measures to assure its protective capability have been considered.

G.4.2 Measures taken by the licence holders

G.4.2.1 Suitable measures to limit radiological impact

The safety philosophy applied in the design of all Swedish nuclear facilities is based on the principles of defence in depth and of using multiple barriers to prevent the unplanned release of radioactive material to the environment. Facilities are designed to ensure that releases of radioactive material in normal operation are limited as far as is reasonably practicable.

This safety philosophy underpins the design and planned construction of the encapsulation facility and final repository for spent fuel according to the KBS-3 system, currently the subject of the Government's licensing review process.

G.4.2.2 Conceptual plans and provisions for decommissioning

Implications of reactor decommissioning for intermediate storage of spent fuel

Removal of reactor internals and defueling comprise the first stage when decommissioning nuclear power plants, ultimately involving the transport of all remaining spent fuels from temporary storage at the reactor site to the central interim storage facility, Clab, which is operated by SKB. Dismantling and demolition of fuel storage pools on the reactor sites are planned to be undertaken as part of the overall programme of work defined by the power plant licensee.

Emptying of the final cores is also dependent on the capacity of Clab to receive the spent fuel. The closure of several nuclear power plants in the period 2016–2021 means an increased demand to receive spent fuel at Clab to accommodate the complete unloading of the reactors in a timely manner. This, in turn, requires careful planning of deliveries of spent fuel to ensure that reception at the interim storage facility can progress without significant delay in defueling, and hence other aspects of decommissioning, at the nuclear power plants. In the meantime, uprating of the cooling capacity for the storage pools at Clab has been achieved through the installation of a new residual heat removal system, which is a prerequisite for the facility to be able to accommodate an increased inventory of spent fuel over the current 8,000 tonnes licensed capacity.

According to current forecasts, this capacity will be reached by the end of 2023, i.e. close to the point in time when transferring the final cores from Ringhals units 1 and 2. SKB has applied (see section G.1.2) to increase the maximum inventory in Clab to 11,000 tonnes, and is preparing documentation regarding detailed changes to the facility and its operation.

In the 2040s, when it is planned that the most modern reactors will be decommissioned, Clab is not assumed to constitute a limitation. This is because fuel will start to be encapsulated and transported to the spent fuel repository and thereby free up space in pools at the interim storage facility.

Decommissioning of Clink

The decommissioning plan for the combined interim storage and spent fuel encapsulation facility (Clink) was updated by SKB in 2013 in conjunction with compiling supplementary documentation for the licence application for Clink. Clink will be decommissioned when all spent nuclear fuel has been encapsulated and disposed of in the spent fuel repository. The timetable depends on when the last nuclear power reactor is permanently shut down. According to current planning, decommissioning of Clink could commence in around 2070 and be concluded within five to seven years. During work on preparing the decommissioning plan for Clink, no reason has emerged why the decommissioning should be more complicated than for the other nuclear facilities, whose decommissioning is closer in time.

Decommissioning of the spent fuel repository

A preliminary decommissioning plan was prepared for the spent fuel repository and is included in the licence applications under the Act on Nuclear Activities for final disposal of spent nuclear fuel and under the Environmental Code for the KBS-3 system. An update of the plan was made in 2017 in order to harmonise with current regulations and to follow the industry-wide structure for a decommissioning plan. Decommissioning begins after operation is concluded, i.e. when all spent nuclear fuel has been disposed of and the deposition tunnels have been backfilled and sealed. Decommissioning entails closure of the remaining parts of the underground openings and demolition of the surface facilities. No contamination is expected to be present in the facility at the time of closure, for which reason demolition is carried out in the same way as for a conventional facility.

G.4.2.3 Technology supported by experience

General information

The principle of proven technology is broadly accepted and implemented in the design and construction procedures for nuclear facilities in Sweden. As is evident from the licence applications submitted for Clink and the spent fuel repository (see sections A.10.2 and K.1.1), a reference design has been adopted for the repository barriers for long-term safety that fulfils the design premises for the KBS-3 system. At the same time, a feasible approach to production and a quality control programme has been presented.

The licence applications for Clink and the spent fuel repository were developed against the background of SKB's research, development and demonstration programme, including experience from a number of preliminary safety analyses, starting with the KBS-3 report in 1983 (the first complete safety analysis of the KBS-3 method), followed by SKB-91 (focusing on the technical barriers), SR-97 (focusing on the geological barrier), and lastly SR-Can in 2006 (a 'dress rehearsal' for the development of the SR-Site safety analysis that supported SKB's licence application). These iterative safety analyses have had multiple roles including guiding the technical development of the disposal method and site selection, identifying areas requiring further research, and determining whether a repository for radioactive waste complies with the regulatory requirements for long-term safety. This stepwise process, including reviews by the authorities, international experts as well as interested stakeholders of both the safety analyses and SKB's RD&D reports, has proven to be an effective way of raising the level of knowledge regarding management and disposal of spent nuclear fuel. It has also provided feedback to SKB's technological development and design work.

The Canister Laboratory, Äspö Hard Rock Laboratory and Multi-purpose Test Facilities have all been used for several years in developing technologies for encapsulation and disposal of spent fuel. In addition, certain tests have been conducted and will continue to be undertaken in the future in collaboration with Posiva, SKB's sister organisation in Finland. There are also underground laboratories and laboratories for metallurgical research available in Europe and other parts of the world. In addition, there are industrial facilities in many countries with access to the knowledge and resources needed to carry out development work for SKB.

The experience gained from experiments and tests in these laboratories will continue to be used to move forward detailed design and construction work of the encapsulation plant and repository for spent nuclear fuel. Ongoing technological development is being pursued in order to proceed from the basis of schematic solutions to solutions tailored to an industrialised process involving stipulated requirements for quality, cost and time. A large proportion of the remaining development work consists of building up a production system with effective quality control.

Design premises
The design premises comprise requirements which the KBS-3 facilities with their barriers must satisfy in order to ensure safety both during operation and after closure. The design premises specify e.g. what mechanical loads the barriers must be able to withstand, limitations concerning the composition and properties of the barrier materials, acceptable deviations in the dimensions of the barriers, and acceptance criteria for the various under-ground openings.

An initial set of design premises and other requirements is specified in the applications for construction of the spent fuel repository and the encapsulation facility. However, it is not possible to specify all detailed design premises for a given product or process from the outset. Requirements, technological development and safety assessment must instead be defined as the work proceeds. A revision of the design premises that were presented in the licence applications has been carried out together with Posiva (Posiva SKB report 01). These revisions are being used as input for the preliminary safety analysis report (PSAR) (see section G.5.1) that is being developed by SKB.

The basic principles for evaluating design premises pertaining to several barriers in the spent fuel repository are:

- The design premises shall altogether lead to compliance with requirements related to the safety of the entire spent fuel repository.
- The design premises shall be feasible and verifiable for all the barriers concerned.
- Design premises that entail simple, robust and effective solutions are preferred.

These principles are used to establish requirements for fuel, canister, buffer, backfill, closure and underground openings in relation to each other. The revised design premises serve as a basis for the preliminary safety analysis reports which SKB compiles prior to the start of construction of the spent fuel repository and Clink's encapsulation plant. The design premises will be formally presented to SSM when the PSAR is submitted.

Further revision of the design premises will be performed in response to the conditions issued during the licensing process and in conjunction with updating of the safety analysis reports. More detailed specification or re-appraisal of the relative importance of requirements between different systems may also need to be done during detailed design or prior to implementation.

Quality control and inspection
'Quality control and inspection' refers to the measures that need to be taken to provide assurance that the requirements imposed on the facilities during operation and after closure of the spent fuel repository are satisfied. The goal is that the results obtained should conform to acceptable values for properties that contribute to safety and radiation protection.

Planned production methods as well as plans for quality control and inspections in the production of the barriers for long-term safety have been described in general terms in the production line reports that support SKB's licence applications. As development of production and testing methods progresses towards full-scale industrialisation, the work on quality control and inspection will also progress. Systems for quality control and inspections will be established and implemented to quality assure the production of the barriers.

A number of important activities in this process are to:

- establish principles for safety and quality classification;
- establish what aspects are to be quality controlled and quality inspected, points in time when quality control and inspections are to be performed, and by whom in terms of first, second and third parties;
- establish and qualify processes, methods, equipment and personnel for manufacturing and installation, testing and inspection;
- establish the procedures that are to be applied in production to ensure that the KBS-3 repository satisfies quality requirements.

Plans
In the short term, the goal of technological development is to ensure that the technology needed for starting construction of the spent fuel repository and encapsulation plant is available. In the case of the spent fuel repository, this mainly refers to investigation methods and technology for construction of the repository accesses. Such material is also needed to describe how matters relating to nuclear safety will be addressed prior to the start of trial operation, i.e. during construction of accesses, the central area and the first deposition area. This document is called 'Suus' (Swedish acronym for 'safety during construction of the final repository') and is being prepared by SKB prior to the start of construction. Technological development is also needed for the various systems that must be in place in the repository area, descriptions of which support the PSAR that will be presented by SKB in support of its application for approval to the start construction.

After submission of the PSAR, there are several other milestones during the design and construction of the planned facilities where key input is needed from technological development. This includes:

- When starting the detailed design of the encapsulation plant, the component technical systems must have essentially passed the detailed design phase. When starting the detailed design of the canister manufacturing facility, the technology and methods for production of canisters must be fully developed and work on an industrial scale.
- Prior to the start of construction of the encapsulation plant and canister manufacturing facility, the systems that have undergone detailed design shall have been procured and plans for qualification shall have been established and incorporated into the plans for construction.
- Before detailed design of the spent fuel repository's accesses can start, the observational method for underground construction must be implemented and a detailed characterisation programme for ramp and shafts must be available.
- Below the level of the top seal on the spent fuel repository, the design premises stipulate requirements for the permeability of the installations intended to seal the repository at depth. This in turn imposes other requirements for rock works below the level of the top seal. It must then be verified that excavation methods, inspection programmes and methods for rock support and grouting satisfy these requirements.
- Detailed design of the production of buffer and backfill shall be completed as a basis for detailed design of the production building at the repository site.
- Installation methods and methods for testing and inspection of buffer and backfill must have been designed in detail and verified prior to detailed design of the deposition area.

Technical systems that are needed in the combined storage facility and encapsulation plant, Clink, must have been purchased, fabricated, installed, tested and qualified prior to commissioning tests of the KBS-3 system. Furthermore, before commissioning tests can be conducted, methods and sub-processes for excavation of deposition tunnels and deposition holes in the repository must have been devised and qualified. The deposition system must also be put into non-active operation before commissioning tests can be undertaken, which means that technical systems for handling and transport of canisters, buffer and backfill must have been fabricated, installed and tested. The systems will undergo integration tests to ensure that equipment and technical systems are fully compatible as intended before conducting the commissioning tests.

Qualification of processes with associated equipment, personnel and suppliers must have been completed and documented. A comprehensive system for quality control and inspection of canister manufacturing, production of buffer and backfill components, handling and installation of canister, buffer and backfill, and the process of underground construction must also be implemented.

Before a licence can be obtained for trial operation of Clink and the spent fuel repository, a renewed safety analysis report (SAR), reflecting the facilities as they have been constructed, must be submitted. Before an operating licence can be obtained, a supplemented SAR must be prepared and submitted to SSM (see section G.5.1). Results and experience from commissioning tests and trial operation in each facility must be presented in this updated SAR. This means that the production reports relating to technology deployment will be updated using results and experience from full-scale tests, qualification work and commissioning tests.

G.4.3 Regulatory control
SSM and its predecessors (the Swedish Nuclear Power Inspectorate, SKI, and the Swedish Radiation Protection Authority, SSI) have over the past three decades reviewed SKB's development of the KBS-3 disposal method for spent nuclear fuel. The main instruments for regulatory control of SKB's design development work have been:

- regulatory review of the recurrent research, development and demonstration programmes (RD&D programmes),
- technical reviews, with support from international peer reviews, of SKB's preliminary safety assessments presented during the development of the KBS-3 method, and
- consultation meetings between SKB and SSM (and its predecessors) concerning site investigations and the content of SKB's safety reporting.

The authorities devoted considerable review resources over the pre-licensing period to evaluate a range of scientific and technical issues relating to the engineered and natural barriers, including the evolution and long-term behaviour of copper canisters and the bentonite buffer, as well as the effects of construction activities on the bedrock. Attention was also given to the suitability of safety assessment methods used to underpin SKB's design development. Based on these reviews, the authorities were able regularly to provide feedback to SKB on the technical basis for its development of a repository system for spent nuclear fuel.

As part of the review of the RD&D programmes, the authorities have also provided review comments and requested clarifications related to SKB's gradual evolution and refinement of barrier design as well as reference methods for rock excavation, construction and manufacturing activities. No definitive judgments regarding the acceptability of design options and manufacturing processes were made during these pre-licensing reviews since the responsibility for development of the disposal method rests entirely with the implementer.

A key requirement imposed on the implementer, as stated in the Act on Nuclear Activities, is that the RD&D programmes should be sufficiently broad in scope. This requirement is to a certain extent reflected in the regulatory requirement, noted above, that the barrier system for a repository should be designed and implemented giving wide consideration to reasonable measures to assure the protective capability of the facility. Against this background, SSM and its predecessors have over the years, including in the review of SKB's licence applications, requested additional reporting regarding alternative methods and disposal concepts, e.g. disposal of spent nuclear fuel in very deep boreholes, as a basis for comparison with the KBS-3 method.

When performing the licensing review, SSM gave detailed consideration to SKB's rationale for the choice of the KBS-3 method for final management of spent nuclear fuel. The Authority's conclusion was that SKB has adequately complied with the requirement on demonstrating use of Best Available Technique, both in relation to the choice of technical solutions for each individual barrier and to the barriers' collective function in achieving a radiologically safe repository to protect people and the environment against harmful effects from releases of radioactive materials after closure (SSM Report 2018:04, available at www.ssm.se). SSM recognised that extensive research and development, testing and analysis have been conducted with respect to the KBS-3 method, as well as to increase understanding of the properties, events and processes of importance for assessing the repository's protective capability.

As regards the planned encapsulation facility to be operated in conjunction with Clab, SSM deemed in its licensing review that SKB's design has the potential to meet requirements for limits, optimisation and Best Available Technique, for example through multiple systems and measures for treatment at source and limiting discharges of radioactive materials to air and water. The Authority considered that the facility is designed to be equipped with redundant systems to protect the integrity of barriers and prevent releases in the event of faults and failures.

The Land and Environment Court, in its statement to Government on the conclusions of scrutiny of SKB's licence application under the Environmental Code, did not call into question SKB's overall arguments for choice of method but, unlike SSM, considered that SKB would need to present further documentation clarifying the long-term protective function of the copper canisters, in order for the repository to be considered permissible in accordance with the provisions of environmental legislation. SKB, at the Government's request, submitted the results from additional theoretical and experimental studies in April 2019.

G.4.4 Conclusion

Sweden complies with the obligations of Article 7.

G.5 Article 8: Assessment of safety of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

(i) before construction of a spent fuel management facility, a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out;

(ii) before the operation of a spent fuel management facility, updated and detailed versions of the safety assessment and of the environmental assessment shall be prepared when deemed necessary to complement the assessments referred to in paragraph (i).

G.5.1 Regulatory requirements

G.5.1.1 Assessment of safety

Requirements for safety assessment, safety review and reporting are specified in SSM's regulations concerning safety in nuclear facilities (SSMFS 2008:1). These apply to the operation of all types of nuclear installations, including facilities for treatment, storage and disposal of spent fuel and radioactive waste. The basic provisions regarding safety assessment and review can be summarised in the following paragraphs.

Safety analysis

Analyses of conditions of importance for the safety of a facility shall be carried out before a facility is constructed and taken into operation. The analysis shall subsequently be kept up-to-date. The safety analyses shall be based on a systematic inventory of such events, event sequences and conditions that could lead to a radiological accident.

Safety report

A preliminary safety report (PSAR) shall be prepared before a facility is allowed to be constructed in order to show how relevant safety requirements are met. The safety report (SAR) shall be updated to reflect the plant as it has been constructed, analysed and verified before trial operation of the facility is allowed to start. The SAR and associated documentation of operating limits and conditions must subsequently be supplemented on the basis of experience from a programme of commissioning tests before the facility is allowed to be taken into routine operation. At each of the above steps, the safety report shall be evaluated and approved by SSM.

The safety report must subsequently be kept up to date. For example, plant modifications are to be assessed against conditions described in the SAR. Plans for substantial changes must be reflected in a new PSAR, which must be approved by SSM before being used as the basis for trial operation of the modified facility. New safety standards and practices, which have been assessed by the licensee and found applicable, shall be documented and inserted into the SAR as soon as corresponding modifications or other plant measures have been performed.

The content of the safety report is specified in the regulations SSMFS 2008:1. Not only the safety systems, but all plant structures, systems and components of importance for the defence in depth are to be described in the SAR.

Safety review

A safety review shall confirm that all applicable safety-related aspects of a specific issue have been taken into account and that appropriate regulatory requirements with respect to the safety in design, function, organisation and activities of a facility are met. The review must be carried out systematically and be documented. A safety review is to be performed first within those parts of the organisation responsible for the specific issues under consideration ('primary review'). A second safety review shall then be performed by an internal safety review function established for this purpose, which has an independent position relative to those parts of the organisation responsible for design and operation.

Safety programme

After it has been taken into operation, the safety of a facility shall be continuously analysed and assessed in a systematic manner. Any need for improvement regarding safety measures, engineering or organisational issues that arises as a result of such analyses and assessments shall be documented in a safety programme. The safety programme must be updated on an annual basis.

Periodic safety review of facilities

At least once every ten years, licensees are required to perform a periodic safety review (PSR), i.e. an integrated analysis and assessment of the safety of a facility, see sections E.2.5.3, E.3.2.6 and K.2.3).

Modifications

A safety review shall be performed for engineering or organisational modifications to a facility that can affect the conditions specified in the safety report, and essential modifications to the report made accordingly. Before such modifications may be included in the report, SSM shall be notified. SSM has the power to determine that additional or other requirements or conditions shall apply with respect to the modifications.

Post closure safety

Additional requirements concerning the long-term radiation protection and nuclear safety of a disposal facility are stipulated in the regulations concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21), as well as in the regulations and general advice on the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste (SSMFS 2008:37).

The regulations SSMFS 2008:21 contain requirements for the design of the repository, barrier functions and safety reporting. The safety assessment for a disposal facility shall address all features, events and processes that might lead to the dispersion of radioactive substances after closure. Such safety assessments are required as a basis for applications for construction, operation and closure of the disposal facility. The safety assessment must cover the length of time for which barrier functions are required, though at least ten thousand years.

The regulations SSMFS 2008:37 comprise basic requirements for protection of human health (expressed as a risk target), general environmental protection goals, and the application of optimisation and Best Available Technique (BAT). The corresponding guidance advises on reporting for different time periods after closure, selection of scenarios, calculation of risk, dealing with uncertainty, and risk dilution.

G.5.1.2 Environmental assessment

According to the requirements of the Act on Nuclear Activities, an environmental impact assessment (EIA) shall be prepared for a licence application under the Act. These are the same requirements as stated in the Environmental Code.

The Environmental Code also contains detailed requirements stating what an EIA should contain and how it should be prepared.

The purpose of an EIA is to establish and describe the direct and indirect impacts of a planned activity or measure as listed below. An environmental impact statement must contain the following information:

- a description of the planned activity or course of action with details of its location, design and scope;
- a description of the measures that are planned with a view to avoiding, mitigating or remedying adverse effects, for example action to prevent the activity or measure leading to an infringement of an environmental quality standard;
- the information needed to establish and assess the main impacts on human health, the environment and management of land, water and other resources that the planned activity or course of action is likely to have;
- a description of possible alternative sites and alternative designs, together with a statement of the reasons why a specific alternative was chosen, as well as a description of the consequences if the activity or measure is not implemented; and
- a non-technical summary of the information.

G.5.2 Measures taken by the licence holders

G.5.2.1 Safety assessments

Background

Some key aspects of the assessment work undertaken by SKB, including the role of external peer reviews, were described in Sweden's fifth national report, published in 2014. SKB is currently developing the basis for assessment so that the PSAR for the spent fuel repository and Clink can be submitted to SSM in support of an application to commence construction, provided that relevant licences for development of the facilities are granted by the Government. SKB also plans to prepare and submit to SSM a PSAR for the existing Clab facility in support of measures to increase Clab's interim storage capacity.

Interim storage facility, Clab
Based on the initial review of the licence application for an encapsulation plant for spent fuel to be co-located with Clab, SSM identified areas of improvement relevant for the safety analysis report of Clab. SSM subsequently (2013) issued an improvement notice to SKB to update the safety analysis report in areas relating to safety requirements, safety analysis and safety classification. SKB has since modernised the safety analysis report for Clab in several steps between 2016 and 2020.

Among other things, the safety analysis has most recently been supplemented with a probabilistic safety assessment, including a human reliability analysis of all safety-related manual actions. The basic safety concept of Clab relies on passive and inherent safety with extensive grace periods before any action is needed to avoid adverse conditions. The human reliability analysis strengthens the safety case for relying on manual actions to achieve a safe state in case of incidents or accidents in the facility. The safety demonstration has also been extended to include a more comprehensive risk assessment of beyond design basis accidents. The analysis, based on IAEA and WENRA guides for design extension conditions, is considered by SKB to demonstrate that there are sufficient margins in the design of the facility such that sequences leading to significant fuel degradation are practically eliminated.

Combined spent fuel storage and encapsulation facility, Clink
SKB's updated (January 2015) safety analysis for the combined encapsulation plant and storage facility, Clink, was undertaken in response to SSM's request for an improved system description and correspondingly updated preliminary safety analysis report (F-PSAR). The scope was also expanded to account for the safety implications of increasing the interim storage capacity in the storage pools of Clab from 8,000 to 11,000 tonnes of spent fuel. Updating of supporting materials to the licence application under the Act on Nuclear Activities also led to supplements made to the EIA submitted in support of the licence application under the Environmental Code.

The F-PSAR describes how nuclear radiation safety in Clink will be maintained. The design of the facility and description of how the requirements are met will gradually be clarified and specified in detail as technological development progresses and viewpoints are received from SSM during the licensing process.

SKB also provided an account of its assessment of the consequences of planned and potential discharges associated with operation of the Clink facility as part of the consultation procedure undertaken by the Swedish Environmental Protection Agency in accordance with Article 5 of the Espoo Convention.

Repository for spent nuclear fuel
More in-depth assessments and analyses of some aspects of the safety assessment SR-Site, based on SKB's reference design for disposal according to the KBS-3 method at Forsmark, were reported to SSM between 2013 and 2015 in response to requests for supplementary information during the regulatory review of the licence application under the Act on Nuclear Activities.

Furthermore, as noted elsewhere, SKB in April 2019 submitted as part of the licensing process, and at the Government's request, the results from additional theoretical and experimental studies relating to potential copper corrosion mechanisms, together with an updated analysis of their implications for radiation safety (SKB Report 2010, TR-19-15, can be downloaded at www.skb.se). This was partly in response to the Land and Environment Court's conclusion that further documentation was required in order to clarify the long-term protective function of the copper canisters in the KBS-3 disposal concept, if the repository were to be considered permissible in accordance with the provisions of environmental legislation. From SKB's perspective, however, the work was already planned as part of the updated supporting material for the PSAR to be submitted to SSM as part of an application to commence construction of the repository, once a licence had been granted. The central conclusions of SKB's safety analysis, that a KBS-3 repository capable of fulfilling long-term requirements for radiation protection and safety can be built and safely operated at the Forsmark site, remain unaltered.

G.5.3 Regulatory control

G.5.3.1 Clab
SSM has assessed the updated 'modern standards' Safety Analysis Report for Clab, submitted by SKB in several stages in response to the Authority's 2013 improvement notice. In September 2017, SSM concluded that SKB had responded to an acceptable extent to the main parts of the improvement notice. The following stage in SKB's updating of the SAR included an expanded probabilistic safety analysis. This was reviewed by SSM in 2018, concluding that the analysis was of generally high quality, but that work remained (albeit with limited relevance to overall safety) to address certain shortcomings – identified in SKB's own internal safety review – regarding the consistent management of uncertainties and analysis of specific initiating events. In its review of the next stage in updating the SAR, SSM assessed that SKB had demonstrated capacity to safely accommodate at Clab the elevated residual heat removal requirements associated with acceptance of the final cores from Oskarshamn units 1 and 2 as well as Ringhals units 1 and 2 over a relatively short period, following their early shutdown.

SSM is currently (at the time of preparing Sweden's seventh national report) undertaking a review of final main update of the SAR. In addition to providing a full comprehensive update of the safety analysis report for the facility, to underpin future operations, it is understood that this SAR will form the basis for a forthcoming application in support of necessary changes to the facility should the Government grant a licence for increased storage capacity at Clab.

G.5.3.2 SKB's licence applications
Some key aspects of the regulatory review activities undertaken by SSM, including an account of the parallel procedures for licensing under the Swedish Environmental Code and the Act on Nuclear Activities, were described in Sweden's fifth national report published in 2014. This description was supplemented in Sweden's sixth national report (2017) by a summary of the key findings from SSM's review of SKB's licence applications for the combined spent fuel storage and encapsulation facility and the planned repository for spent fuel.

Having submitted a comprehensive statement on the results of its scrutiny of SKB's licence applications to Government in January 2018, SSM plays no further direct part in the decision over licensing for these facilities under the Act on Nuclear Activities. Likewise, the Land and Environment Court, after submitting its findings to Government, also in January 2018, plays no further part unless and until a determination has been made on the permissibility of SKB's plans in accordance with the requirements of the Environmental Code. SSM has, however, responded to Government requests for further commentary and clarification in relation to criticisms raised by some stakeholders, and has taken part as a consultee in offering comments on SKB's supplementary analysis of potential corrosion mechanisms. After a thorough technical review of the additional material that had been submitted by SKB, SSM in September 2019 concluded that it reinforced the Authority's previous conclusions that SKB's preferred site is suitable, the disposal concept is feasible, and the safety analysis provides confidence that the disposal system fulfils strict regulatory requirements for safety and radiological protection, before and after final closure.

SSM is now making preparations to review the documentation, including PSAR, which SKB needs to submit in support of an application to begin construction of both the encapsulation plant and repository for spent nuclear fuel, if and when a licence is granted by Government.

G.5.4 Conclusion
Sweden complies with the obligations of Article 8.

G.6 Article 9: Operation of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the licence to operate a spent fuel management facility is based upon appropriate assessments as specified in Article 8 and is conditional on the completion of a commissioning programme demonstrating that the facility, as constructed, is consistent with design and safety requirements;

(ii) operational limits and conditions derived from tests, operational experience and the assessments, as specified in Article 8, are defined and revised as necessary;

(iii) operation, maintenance, monitoring, inspection and testing of a spent fuel management facility are conducted in accordance with established procedures;

(iv) engineering and technical support in all safety-related fields are available throughout the operating lifetime of a spent fuel management facility;

(v) incidents significant to safety are reported in a timely manner by the holder of the licence to the regulatory body;

(vi) programmes to collect and analyse relevant operating experience are established and that the results are acted upon, where appropriate;

(vii) decommissioning plans for a spent fuel management facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body.

G.6.1 Regulatory requirements
SSM's general regulations concerning safety in nuclear installations (SSMFS 2008:1) contain legally binding requirements relevant to all obligations under Articles 9 and 16. These requirements are summarised below.

G.6.1.1 Licence for facility operation
A comprehensive preliminary safety report shall be prepared by the licensee and assessed by SSM prior to starting construction of a nuclear facility (see section G.5.1.1). Following construction, the safety report (SAR) shall be updated to reflect the facility as constructed, analysed and verified through inspection and non-active tests before commissioning and trial operation is permitted. The SAR must subsequently be supplemented as necessary on the basis of experience from a programme of commissioning tests before the facility is permitted to be taken into routine operation. At each of the above steps, the safety report shall be evaluated and approved by SSM.

The safety report must subsequently be held up to date and revised as necessary to reflect modifications or changes to safety standards and practices.

G.6.1.2 Operational limits and conditions (OLCs)
Documented and up-to-date Operational Limits and Conditions (OLCs) are required for all facilities, containing necessary information as further specified in an appendix to the regulations. Preliminary OLCs must be defined by the licensee and approved by SSM prior to commissioning and trial operation of the facility. They must subsequently

be updated, alongside the safety report, to reflect experience from commissioning tests, as well as any subsequent operational experience and assessments.

The OLCs must, together with the operating procedures, ensure that the conditions postulated in the safety report are maintained during the operation of the facility. The OLCs must be subjected to a two-fold safety review by the licensee (see section G.5.1.1) and submitted to the regulatory authority for approval. The licensee must notify the regulatory authority about any proposed changes to OLCs after they also have been subjected to a two-fold safety review.

G.6.1.3 Programmes for collecting and analysing operating experience

Suitable, verified and documented procedures are required for all operational states, including accidents. The procedures for operability verification and procedures used in operational states other than normal operation shall be subjected to a two-fold safety review by the licensee. Procedures for maintenance that are important for safety are also covered by this requirement. Maintenance programmes are to be documented. Inspection and testing of mechanical components must be carried out according to qualified methods and verified procedures.

G.6.1.4 Engineering and technical support

The licensee shall ensure that appropriate personnel are available with the competence and suitability necessary to undertake those tasks that are important for safety, and also ensure that these qualifications are documented. A long-term staffing plan is required. Use of contractors as opposed to own personnel should be carefully considered in relation to developing and sustaining adequate in-house professional skills. The necessary competence should always be available in-house for procuring contractors and for managing and evaluating the results of contractors' work that is of importance for safety.

G.6.1.5 Reporting of incidents in a timely manner

The general regulations concerning safety in nuclear installations (SSMFS 2008:1) contain a specific chapter about reporting requirements and an separate appendix specifying these requirements for various types of events. Briefly, these can be summarised as:

- Reporting without delay: emergency alarm events and events and conditions in category 1 (see below)
- Reporting within 16 hours: INES events of Level 2 or higher
- Reporting within 7 days: a comprehensive investigation report about alarm events or events and conditions in category 1
- Reporting within 30 days: a comprehensive investigation report of events and conditions in category 2

In addition, there are requirements for daily reporting of the operational state and the occurrence of any abnormal events or disturbances, as well as requirements for a comprehensive annual report summarising all experience that is important for the safety of the plant. The regulations specify the content of the different reports, with further general guidance on the fulfilment of reporting requirements, including implementation of a graded approach, being provided in support of the regulations. One of the fundamental regulatory requirements concerns the actions to be taken by the licensee in the event of deficiencies in barriers or in the defence in depth system. These actions include first assessment, adjustment of the operational state, implementation of necessary measures, performance of safety reviews, and reporting to SSM.

In a further appendix to the regulations, events and conditions related to deficiencies in barriers and defence in depth are identified that require different responses depending on the category of events that they belong to. Three categories of incident are defined:

- Category 1: Observed severe deficiency in one or more barriers or in the defence in depth system, or an otherwise well-founded suspicion that safety is severely threatened. (In such cases, the facility must be brought to a safe state without delay.)
- Category 2: Observed deficiency in a barrier or in the defence in depth system, considered less severe than that referred to in category 1, or an otherwise well-founded suspicion that safety is threatened. (In such cases, the facility is allowed to continue operation during the period of time when corrective action is being taken and under certain limitations and controls.)
- Category 3: Temporary deficiency in the defence in depth system, arising when an event or condition is corrected that, in the absence of such measures, could lead to a more severe condition, and which is documented in the facility's operational limits and conditions.

In all three cases, corrective measures must be subjected to a two-fold internal safety review by the licensee. The results of these reviews shall be submitted to SSM. As regards category 3 incidents, there is no requirement to submit a specific report to SSM. Rather, it is sufficient to provide a compilation of these events in the annual report.

G.6.1.6 Programmes for collecting and analysing operating experience

The licensee shall ensure that experience from its own facilities and from similar activities in other relevant facilities is continuously analysed, used and communicated to the personnel concerned. Furthermore, all events and conditions that are detected and which are important for safety must be investigated in a systematic manner in order to determine sequences and causes, as well as to establish any actions required in order to restore safety margins and prevent recurrence. The results of such investigations are to be disseminated within the organisation as well as being submitted to SSM, and shall contribute to the continuous improvement of safety at the facility. Furthermore, according to SSM's regulations on the disposal of nuclear material and nuclear waste (SSMFS 2008:21), it is the responsibility of the licensee, for as long as a disposal facility is in operation, to keep itself and SSM continuously informed of conditions that can be of importance to the assessment of disposal facility safety, including implications for post-closure radiological safety.

G.6.1.7 Decommissioning plans

Decommissioning plans for a radioactive waste management facility other than a disposal facility are prepared and updated as necessary using information obtained during the operating lifetime of that facility. These plans are reviewed by the regulatory body.

Regulations set out a number of specific requirements relating to decommissioning, including:

- A preliminary plan for the future decommissioning of the facility, to be compiled before construction of such facility;
- Safety and radiation protection at the time of decommissioning shall be taken into account during the construction of a facility and before changes are made to an existing facility;
- The preliminary plan shall be supplemented and kept up to date for the duration of the facility's operation and shall be reported to SSM every ten years;
- During the operation of a facility, observations and events that have significance for planning and execution of decommissioning shall be documented on an ongoing basis;
- When a decision has been made on final shutdown of a facility within a certain period of time, an integrated analysis and assessment of how safety is to be maintained during the time remaining until the facility's closure shall be conducted without delay. An analysis and assessment must also be performed of organisational changes during the closure period and personnel requirements during decommissioning. The analyses, assessments and measures emanating from these must be documented and reported to SSM.

See also section F.6.1.

G.6.2 Measures taken by the licence holders

G.6.2.1 Licence for facility operation

SKB anticipates that authorisation to start operations of its planned facilities for the final management of spent fuel (the combined encapsulation plant and spent fuel storage facility, Clink, as well as the spent fuel repository), will follow the procedures specified in SSM's regulations. A full commissioning programme will be developed during the course of facility construction, and will be submitted to SSM for approval alongside the safety report for the completed facilities, taking into account results from inspection and non-active tests.

G.6.2.2 Operational limits and conditions (OLCs)

The operational limits and conditions for nuclear facilities are described in the OLC, a document which is considered to be one of the cornerstones of governing and regulating the operation of nuclear activities in Sweden. Each OLC is facility-specific and subject to approval by SSM as part of the licensing conditions. In the case of spent fuel management, this concerns arrangements for the handling of spent fuel at nuclear power plants as well as the Clab interim storage facility.

The original OLC for each facility is derived from the safety analyses in the SAR, in which the behaviour of the facility is described. Corrections and updates take place when new and better knowledge is available, either from research, tests or operational experience. Suggestions for changes in OLC are reviewed carefully from the point of view of safety at different levels in the operating organisation, and are ultimately approved by the regulatory body before being included in the document.

The fact that the OLC is reviewed and revised regularly has contributed to making it a living document. It is also part of the quality and management system and used frequently by the operations staff in particular. An essential part of the OLC is a general clause stating *"...should any uncertainty arise concerning the interpretation of the text, the general purpose of the OLC shall provide guidance. This means that the facility, in all indefinite situations, shall be maintained in, or brought to, a safe state."* Another component of the OLC is the descriptive background to the document. The account of the background is an important means of preserving the knowledge and experience of those who participated in the original production of the OLC, and communicating this information to new staff. Modified and maintained equipment must pass an operability test to verify that the equipment fulfils specified operational requirements before being accepted for use in continuous operation.

G.6.2.3 Established procedures

All activities that directly affect the operation of the facility are governed by procedures of different kinds covering normal operation, emergency operation and functional testing. Maintenance activities undertaken under a maintenance programme approved by the licence holder are also to a great extent accomplished according to procedures. These are, however, not always as detailed as the operating procedures, in which activities are described in step-by-step sequences. Signing off the completion of steps carried out under the procedures is mandatory in most cases in order to confirm the completion and facilitate verification.

The development of procedures follows specified directives, which include reviewing the documents, normally by more than one person other than the author before being approved by the operations manager or someone else at the corresponding level of authority. The same applies to revision procedures. Revision procedures are to be carried out continuously in particular maintenance procedures when new experience is obtained. Emergency procedures have been developed in order to deal with anticipated operational occurrences and design basis accidents/disturbances.

G.6.2.4 Engineering and technical support

The principles for staffing are reported in section F.2.1.1. Competencies that might not be completely available within the licensee's own organisation at all plants include,

for example, expertise and human resources for materials and chemical assessments, radiation shielding and environmental consequence calculations, expertise and resources for software for safety applications, and also process control and measurement techniques. IT functions in particular are normally outsourced, though are still available onsite. The intention is always to possess purchasing competence within the operating organisation, as well as have capability to evaluate the results of analyses and calculations, etc. that are performed by consultants.

G.6.2.5 Reporting of incidents in a timely manner

There are two main types of licensee event reports (LER). The more severe one, called ab abnormal event, requires the facility to inform SSM within one hour. A final report must be submitted within ten days from the time of the event, and the analysis of the event and appropriate measures to prevent recurrence are subject to approval by SSM. Only a very limited number of events of this category have occurred at Swedish nuclear facilities over the years; none have occurred at the waste management and spent fuel facilities. These events would typically also be of such a level of severity so as to warrant reporting in accordance with the International Nuclear Event Scale (INES).

The other type of LER, called 'RO' (Reportable Occurrence), is used for less severe events. This type of event is mentioned in the weekly report, which is sent to the regulatory authorities and followed up by a final report within 30 days. The reports are reviewed at different levels of the operating organisation and approved by the operations or production manager before submission.

The front of the standardised report form describes the event and related circumstances in general: identification number, title, reference to the OLC, date of discovery and length of time until corrective actions were completed, conditions at the time of occurrence, system consequences, a contact person at the plant and activities affected by the event. The reverse side of the document gives an account of the event, using the following headings:

- event sequence and operational impact,
- safety significance,
- direct and root causes,
- planned/decided measures, and
- lessons learned from the event.

If the description of the event is extensive, additional pages may be attached to the form. Reports are also required in accordance with the OLC when the permitted levels of activity release from the facility are exceeded, or in the event of unusually high radiation exposure to individuals. These types of non-routine reporting are primarily directed towards SSM.

G.6.2.6 Programmes for collecting and analysing operating experience

The objective of the analysis and feedback programme concerning operating experience is to learn from one's own and others' experience and thus prevent reoccurrence of events, particularly events that might affect the safety of the facility. The operating experience feedback process consists of a wide variety of activities within the plant organisation as well as externally.

G.6.2.7 Decommissioning plans

Before a facility may be constructed, a decommissioning plan is to be drawn up for the future decommissioning of the facility (see also section G.4.2.2). The degree of detail in the plan increases as the time for decommissioning approaches. The plan must be supplemented and kept up to date for as long as the facility is in operation, and is presented to SSM together with the periodic safety reviews.

Among other things, the decommissioning plan contains a facility description, a plan for the decommissioning activities, and plans for management and disposal of radioactive waste. Before a dismantling operation may commence, the decommissioning plan must be supplemented and presented to SSM. The safety analysis report for the facility must be supplemented and revised in accordance with the post-operational activities planned at the facility. The revised safety analysis report is reviewed and approved by SSM.

G.6.3 Regulatory control

G.6.3.1 Operational limits and conditions

SSM routinely reviews applications from licensees for changes to the OLCs at licensed facilities, as well as for temporary exemptions from the authorised OLCs. Based on the application and supporting information provided by the licensees, together with associated safety analyses, assessments are made regarding how the proposed changes or exemptions contribute to the risk profile of the facility.

The most significant modification to OLCs for spent fuel management facilities assessed by SSM in the period covered by the present report relates to SKB's proposed change to the cooling capacity at Clab from 8.5 MW to a nominal 10.8 MW (see also section G.5.3.1). This was notified, together with a supporting safety analysis for Clab with its newly upgraded cooling system, in September 2018. SSM concluded that SKB had demonstrated compliance with regulatory requirements regarding the extended heat removal requirements.

G.6.3.2 Procedures

Operational and maintenance procedures are normally not reviewed by SSM. Only in connection with event investigations would SSM request that a procedure be submitted for review.

One specific area of interest continues to be the inspection and maintenance programme in relation to storage ponds at the Clab storage facility. SSM has required SKB to develop and implement a control programme to ensure that possible structural changes are detected and evaluated in time. Surveillance of SKB's programme for rock and concrete inspections at Clab is undertaken on an annual basis.

G.6.3.3 Incident reporting

Licensee event reports are reviewed upon arrival at SSM by the site inspector in charge, who then asks the facility for clarification if necessary. As a matter of routine, all LERs are screened once a week by a permanent group of inspectors and specialists in order to assess the event, the analysis and the measures taken by the licensees. If there are any regulatory concerns, the issue is brought up at a management meeting and a decision made about any further measures to be taken by SSM.

G.6.3.4 Experience feedback analysis

Regulatory control in this area is achieved through the procedures described in section E.2.5.2. For example, SSM carries out regular planned surveillance of SKB's routine operations and incident follow-up at the Clab interim storage facility. This enables SSM to follow how the operations team works to transform experiences and lessons into preventative actions and to be proactive in working with safety. The experience feedback programme is also followed up by SSM in connection with specific event investigations and other inspections and reviews.

G.6.4 Conclusion

Sweden complies with the obligations of Article 9.

G.7 Article 10: Disposal of spent fuel

If, pursuant to its own legislative and regulatory framework, a Contracting Party has designated spent fuel for disposal, the disposal of such spent fuel shall be in accordance with the obligations of Chapter 3 relating to the disposal of radioactive waste

G.7.1 Regulatory requirements

According to the Act on Nuclear Activities, the following definitions apply:

- spent nuclear fuel which has not been disposed of in a disposal facility is defined as nuclear material; and
- spent nuclear fuel which has been disposed of in a disposal facility is defined as nuclear waste.

Reprocessing is not part of the back end of the nuclear fuel cycle in Sweden, (see section C), and the policy and practices for management of spent nuclear fuel are direct disposal, following interim storage for a period of some 30–40 years (see section B).

It is also clearly stated in the general obligations in the Act on Nuclear Activities (Section 10) that the holder of a licence for nuclear activities is responsible for ensuring that all measures are taken that are needed for:

- maintaining safety, with reference to the nature of the activities and the manner in which they are conducted, and
- ensuring the safe handling and final disposal of nuclear waste arising from the activities, or nuclear material arising therein that is not reused.

G.7.2 Measures taken by the licence holders

The practical implication is that spent fuel from Swedish nuclear power plants is de facto treated as high level radioactive waste.

G.7.3 Conclusion

Sweden complies with the obligations of Article 10.

Section H – Safety of Radioactive Waste Management

The articles of the Joint Convention that specifically relate to the safety of radioactive waste management (Articles 11 to 17, covered in this section) have many similarities to the articles that specifically address the safety of spent fuel management (Articles 4 to 10, covered in section G). To avoid unnecessary duplication, reporting on those matters (primarily regulatory requirements) that are common to both section G and section H is presented in full in section G only. Where appropriate, references to these accounts are made from the corresponding parts of section H. Where the Convention's requirements differ between the safety of spent fuel management and safety of radioactive waste management, this is stated in the respective section. The programme for radioactive waste repositories is described in this section, whereas the issues relevant to the development of a geological disposal facility for spent nuclear fuel are described in section G.

H.1 Article 11: General safety requirements

Each Contracting Party shall take the appropriate steps to ensure that at all stages of radioactive waste management individuals, society and the environment are adequately protected against radiological and other hazards.

In so doing, each Contracting Party shall take the appropriate steps to:

(i) ensure that criticality and removal of residual heat generated during radioactive waste management are adequately addressed;

(ii) ensure that the generation of radioactive waste is kept to the minimum practicable;

(iii) take into account interdependencies among the different steps in radioactive waste management;

(iv) provide for effective protection of individuals, society and the environment, by applying at the national level suitable protective methods as approved by the regulatory body, in the framework of its national legislation which has due regard to internationally endorsed criteria and standards;

(v) take into account the biological, chemical and other hazards that may be associated with radioactive waste management;

(vi) strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation;

(vii) aim to avoid imposing undue burdens on future generations.

H.1.1 Regulatory requirements

H.1.1.1 The general obligations of licence holders

See section G.1.1.1.

H.1.1.2 Basic provisions and licence obligations

Basic regulatory requirements for radiation safety in association with licensed activities (SSMFS 2018:1) include general regulations for the management of radioactive waste from both nuclear and non-nuclear activities. These include requirements relating to:

- documentation of a radioactive waste management plan, based on an up-to-date evaluation of alternative management options, indicating how and when the waste will be taken care of,
- segregation at source of wastes with different properties so far as is reasonably practicable to enable their effective management,
- documentation and preservation of information regarding waste generation, providing information necessary to support their ongoing management,

– annual reporting of waste arising to the Swedish Radiation Safety Authority (SSM) in accordance with a specified schedule.

Regulations that apply to both spent fuel and radioactive waste from nuclear facilities are described in section G.1.1.2. Additional requirements that apply only to radioactive waste from nuclear facilities include the following.

Identification of radioactive substance content in nuclear waste
The radioactive substance content of nuclear waste that is to be transferred to a repository without further handling, or which is intended to be stored for a period of time exceeding two years, shall be identified through nuclide-specific measurement. In cases where this is neither feasible nor possible, the radioactive substance content may be determined in some other way. Prior to measurement and registration, the waste is to be classified into items corresponding to waste packages, components, containers or other units matching the material in question in order to enable reliable identification of the activity content.

Records of nuclear waste
A licensed facility must have records of the items of nuclear waste generated at the facility or present at the facility. To the extent that is feasible and possible, these records must be kept up to date. Each registered waste item is to be clearly marked for identity purposes. The records must also contain information about the management of each waste item that has left the facility. For each waste item, the records must provide information about:

– the waste item's identity (marking),
– the corresponding type description or separate description of the waste (when applicable),
– the origin of the nuclear waste or from which part(s) of the facility the nuclear waste has come,
– the nuclear waste's previous treatment, if any, and its present physical and chemical form,
– quantity,
– nuclide-specific content of radioactive substances, with reference date and uncertainty in terms of the nuclide content,
– external radiation level, with distance and reference date,
– position in the storage facility or repository, and
– the date of treatment performed: in the case of nuclear waste intended to remain at the facility for a period of time exceeding two years, the records must also provide information about the time schedule for the ongoing management.

Reporting
A report concerning the past calendar year must be submitted to SSM. This report is to comprise a summary account of the following:

– the amount of waste that has arisen or has by other means been brought to the facility;
– waste that has been transferred to a disposal facility or has been transported from the facility for treatment or storage in another facility, or that has been cleared;
– waste that at the turn of the year is present at the facility, the nuclide inventory of the waste and information on its location; and
– experiences from handling of the waste and a follow-up of established plans.

Discharges to air and water from a facility to the surrounding environment are regulated in accordance with SSMFS 2008:23, see section F.4.1.2.

Regulations relating to the clearance of nuclear and non-nuclear waste have been issued in the form of SSMFS 2018:3 (section L.1).

H.1.1.3 Criticality and removal of residual heat
See section G.1.1.3.

H.1.1.4 Interdependencies in waste management and minimisation of radioactive waste
– An up-to-date inventory of all radioactive waste on-site shall be available at all times (SSMFS 2008:1).
– Measures for the safe on-site handling, storage or disposal of waste shall be analysed and included in the safety report for the facility. The measures for on-site handling shall take into account the requirements for safety posed by the continued handling, transport and disposal of the waste. The safety report shall also include measures that need to be taken on-site to prepare for the safe transport to, or storage or disposal in, a nuclear waste facility (SSMFS 2008:1).
– Plans shall be drawn up providing a general description of management, including disposal, of all waste types that are likely to be generated while operating the facility. The plan for management of such materials shall also state the measures being taken to limit the quantity of nuclear waste and its content of radioactive substances. The plans must be reported to the authorities before the waste is generated (SSMFS 2008:1).
– As regards waste whose type or quantity deviates from that specified in the plans as stipulated above, all necessary measures for management of the non-conforming material must be explained and documented in a separate plan. The separate plan shall be reported to the authorities before the waste is handled (SSMFS 2008:1).
– Acceptance criteria shall be derived, stating the properties of the material that can be received for storage, disposal or some other management. Acceptance criteria shall, so far as is reasonably practicable, be formulated while taking into account safety and radiation protection throughout all stages of the ongoing management. Procedures must be in place for management of material that does not meet the acceptance criteria in that it is returned to the consignor or by taking measures to rectify identified deviations (SSMFS 2008:1).
– The possibility that limitation of discharges to the environment may imply increased radiation doses to personnel is to be taken into account through optimisation considerations as well as the consequences of other waste management arrangements (SSMFS 2008:23).

H.1.1.5 Protection of individuals, society and the environment
See section G.1.1.5.

H.1.1.6 Account of biological, chemical and other hazards
As noted in section H.1.1.2, above, SSM requires updated registers to be kept for all waste and spent nuclear fuel at a nuclear facility. The registers for every waste item (e.g. package or component) shall include information on, among other things, any treatment that has been applied and the physical and chemical form of the waste.

The question of chemical and biological hazards with regard to the long-term performance of a repository is addressed in the Swedish Radiation Safety Authority's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21).

Only packages approved by SSM are allowed to be transported to a repository. This approval presupposes compliance of the methods for waste management with the conditions and acceptance criteria stated in the safety report of the repository. Furthermore, the licensee must submit documentation showing that due regard has been taken to all relevant aspects, including biological, chemical and other hazards with regard to the long-term performance of the repository.

H.1.1.7 Striving to avoid impacts and undue burdens on future generations
See section G.1.1.7.

H.1.2 Measures taken by the licence holders

H.1.2.1 The general obligations of licence holders
Decisions on the premature closure of four reactors have affected the national action plan for low and intermediate level waste by bringing forward the need for interim storage of waste from facility dismantling as well as the need for decommissioning planning to be developed and concretised sooner (see also section F.6). The final repositories that SKB plans to establish for low and intermediate level waste include an extension of the SFR disposal facility to accommodate short-lived decommissioning wastes, and constructing the SFL deep geological repository for long-lived low and intermediate level waste.

RD&D programme 2019
The nuclear industry, through its co-owned company, SKB, has since the mid-1970s performed research on the long-term management of spent fuel and final disposal of radioactive waste. The formal requirement for an RD&D programmes to be submitted for regulatory evaluation was established in 1984 when the Act on Nuclear Activities was promulgated.

In September 2019, SKB submitted the twelfth RD&D programme to the regulator, SSM, for review and a public consultation, in preparation for the Government's decision concerning the licence holders' fulfilment of their legal obligations (SKB Report 2016, TR-19-24, December 2019, can be downloaded at www.skb.se). In RD&D Programme 2019, SKB presents its plans for research, development and demonstration during the period 2020–2025. The programme consists of three parts:

Part I SKB's activities and plan of action

Part II Waste and final disposal

Part III Decommissioning of nuclear facilities

The programme for low and intermediate level waste includes day-to-day management of waste generated during operation as well as work to realise the remaining parts of the system that are needed for the safe long-term management and disposal of low and intermediate level waste. The overall programme for the waste management system is primarily led by SKB, but in some respects also by the nuclear power companies, as well as actors such as AB Svafo and Studsvik Nuclear AB.

Applications were submitted in late 2014 under the Act on Nuclear Activities and Environmental Code for permission to extend the SFR repository for short-lived waste in order to accommodate decommissioning wastes. The licence applications are currently (at the time of preparing this report) with the Government for decision (see also section A.8.3.2 and K.1.2).

An evaluation of post-closure safety issues based on a conceptual design for the proposed SFL repository (the geological repository for long-lived low and intermediate level waste) was delivered in autumn 2019. The main results from the study were presented in conjunction with the twelfth RD&D programme. The RD&D programme also presents an analysis of siting factors and a proposed stepwise siting process for SFL. According to SKB's current plans, the SFL repository could be commissioned around 2045.

In the above-mentioned work, experience from the operation of SFR constitutes an important knowledge base for the development and construction of new repositories for low and intermediate level waste.

H.1.2.2 Basic provisions and licence obligations
Measures taken by the licensees regarding general safety requirements are discussed in sections H.3.2 (facility siting), H.4.2 (facility design and construction), H.5.2 (assessment of facility safety) and H.6.2 (facility operation).

Some of the nuclear power companies are arranging for temporary interim storage of short-lived decommissioning waste until the extension of SFR is commissioned. For example, Barsebäck Kraft AB has existing storage facilities

that can be used for interim storage, but the capacity needs to be increased to accommodate the short-lived waste that will be produced during decommissioning of Barsebäck Units 1 and 2. It is also expected that existing on-site storage capacity will also need to be increased to accommodate short-lived wastes from the decommissioning of Oskarshamn Units 1 and 2.

Long-lived wastes from decommissioning will be stored at the power plants or at suitable alternative locations, where these can be identified, until SFL is ready for operation. At Barsebäck, the plan is for the site to be cleared completely before SFL is due to be commissioned, so on-site storage of long-lived waste from dismantling is not currently an option.

AB Svafo currently operates an underground interim storage facility for long-lived low and intermediate level waste, which is use for storing not only its own long-lived waste, including legacy waste, but also waste from other licensees such as Studsvik Nuclear AB. This facility does not have capacity to receive more waste. AB Svafo is therefore planning to construct an additional building for interim storage of low and intermediate level waste arising from its ongoing decommissioning operations. This interim storage facility will be located at the Studsvik site, and constructed as an extension to an existing storage building. The intention is that it should be commissioned around 2021. A notification of the modification to operations covered by the existing nuclear licence was submitted to SSM in June 2019. An environmental permit for the interim storage facility was granted by the Land and Environment Court in January 2017.

AB Svafo is also currently studying the prospects for conditioning and re-packing legacy wastes from historical activities within the Swedish nuclear research programme. The study will analyse how different waste fractions are to be handled and what the possibilities are for management and final disposal. However, technical issues concerning how long-lived waste from AB Svafo, Studsvik Nuclear AB and Cyclife Sweden AB is to be treated and packaged for disposal can only be finally resolved when acceptance criteria for long-lived wastes at SFL are established.

H.1.3 Regulatory control

H.1.3.1 The general obligations of licence holders

Evaluation of the RD&D programme

In September 2019, SKB submitted the nuclear reactor licensees' twelfth programme for research, development and demonstration, RD&D Programme 2019, to SSM for review and broad consultation with national stakeholders. In March 2020, SSM submitted the results of its evaluation and a statement to the Government with a recommendation to approve SKB's programme.

In the light of the ongoing scrutiny by Government of SKB's licence applications for extension to the SFR disposal facility (see also section A.8.3.2 and K.1.2), the regulatory evaluation of the programme was constrained so as not to forestall an eventual licensing decision. The overall conclusion from the regulatory review as regards nuclear waste management in Sweden was, however, that the programme was assessed to be fit for purpose in relation to the research and development activity required to support a programme consistent with the licence holders' obligations under the Act on Nuclear Activities.

With regard to the safety evaluation for SFL, summarised in the RD&D report, SSM assessed that SKB's continued work with safety analysis need to be developed with regard to, among other things, methodology and assumptions, with the aim of reducing uncertainties and to ensure that the basic safety concept for the repository is fully reflected in the analysis of its protective capabilities. This, in turn, will support the development of preliminary acceptance criteria for long-lived low and intermediate level wastes, to guide decisions on future treatment, conditioning and packaging. SSM also agreed with SKB's conclusion that it is important to reduce uncertainties surrounding the forecast inventory for the waste that is planned to be disposed of in SFL, including legacy wastes from historical activities within the Swedish nuclear research programme.

SSM further noted that SKB's facilities for disposal of low and intermediate level waste are designed also to accommodate both nuclear wastes arising from nuclear activities other than commercial nuclear power (the specific obligation of the licence holders) and radioactive wastes from non-nuclear activities. The Authority therefore concluded that there is a need to ensure that SKB's development of a national system for the final management of all radioactive wastes is reflected in the way in which future RD&D programmes are described and reviewed.

H.1.3.2 Basic provisions and licence obligations

Regulatory control of specific measures taken by the licensees regarding general safety requirements is discussed in sections H.3.3, H.4.3, H.5.3 and H.6.3.

See also the description of the outcome of SSM's integrated evaluation of radiation protection and safety for SKB's facilities, contained in section G.1.3.2 (Inspections and Surveillance).

H.1.4 Conclusion

Sweden complies with the obligations of Article 11.

H.2 Article 12: Existing facilities and past practices

Each Contracting Party shall in due course take the appropriate steps to review:

(i) the safety of any radioactive waste management facility existing at the time the Convention enters into force for that Contracting Party and to ensure that, if necessary, all reasonably practicable improvements are made to upgrade the safety of such a facility;

(ii) the results of past practices in order to determine whether any intervention is needed for reasons of radiation protection bearing in mind that the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including the social costs, of the intervention.

H.2.1 Existing facilities

By the time the Joint Convention entered into force with regard to Sweden, the situation was satisfactory as regards the safety of radioactive waste management facilities.

The elements of the Joint Convention have long been implemented in the form of requirements imposed by the Swedish legal and regulatory framework, as well as being implemented in the management of radioactive waste in Sweden. The conformance of licensees' activities with the legal and regulatory requirements is nevertheless something that constantly needs reaffirming through inspection and review activities.

H.2.2 Past practices

H.2.2.1 Regulatory requirements

As described in section E.2.1.4, a funding mechanism is established in the legislation to cover expenses for liabilities originating from the establishment of a nuclear programme in Sweden. This special funding primarily contributes to the decommissioning of research reactors at Studsvik, the Ågesta reactor and clean-up activities at the former uranium mine in Ranstad.

H.2.2.2 Measures taken by the licence holders

The four utilities operating nuclear power reactors jointly own a special company, AB Svafo, to deal with management of the legacy waste and decommissioning of decommissioning of the research reactors at Studsvik and the Ågesta reactor.

H.2.2.3 Regulatory control

Decommissioning of the research reactors at Studsvik and the Ågesta reactor as well as management of decommissioning waste is subject to regulatory control. Regulatory review of these activities are part of SSM's baseline supervision which will continue until the facilities have been free released and the licensee exempted from any further responsibilities.

H.2.3 Conclusion

Sweden complies with the obligations of Article 12.

H.3 Article 13: Siting of proposed facilities

1. Each Contracting Party shall take the appropriate steps to ensure that procedures are established and implemented for a proposed radioactive waste management facility

(i) (to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime;

(ii) to evaluate the likely safety impact of such a facility on individuals, society and the environment;

(iii) to make information on the safety of such a facility available to members of the public;

(iv) to consult Contracting Parties in the vicinity of such a facility, insofar as they are likely to be affected by that facility, and provide them, upon their request, with general data relating to the facility to enable them to evaluate the likely safety impact of the facility upon their territory.

2. In so doing, each Contracting Party shall take the appropriate steps to ensure that such facilities shall not have unacceptable effects on other Contracting Parties by being sited in accordance with the general safety requirements of Article 11.

H.3.1 Regulatory requirements

H.3.1.1 Assessment of safety and environmental impact

See section G.3.1.1.

H.3.1.2 Public information and involvement

See section G.3.1.2.

H.3.1.3 Consulting contracting parties

See section G.3.1.3.

Information regarding the planned extension of the SFR disposal facility, currently the subject of the Government's licensing review process (see also section A.8.3.2 and K.1.2), will be submitted to the European Commission at the appropriate time in accordance with Article 37 of the Euratom treaty.

H.3.2 Measures taken by the licence holders

H.3.2.1 Repository for short-lived low and intermediate level waste from decommissioning

A summary account of the siting process and related consultations undertaken by SKB in respect of the development of a repository for short-lived radioactive waste from decommissioning was provided in Sweden's fifth national report, published in 2014. SKB's environmental impact statement in support of licence applications under the Environmental Code and the Act on Nuclear Activities was submitted in December 2014. As noted in Sweden's sixth national report, one consequence of consultation with the local municipality for the preferred site (as an extension to the existing SFR) was that SKB in May 2017 withdrew from the scope of its licence application a request for permission to temporarily store certain long-lived low and intermediate level wastes within the

proposed facility, pending the final repository for such wastes (SFL).

SKB's licence applications for extension to the SFR disposal facility currently (at the time of preparing this report) the subject of scrutiny ahead of a formal Government decision.

H.3.2.2 Repository for long-lived low and intermediate level waste (SFL)

As noted above, SKB's RD&D Programme 2019 included not only an evaluation of post-closure safety issues for the proposed SFL repository but also an analysis of siting factors and a proposed stepwise siting process for the facility.

SKB indicates that a future licence application should contain a systematic comparison of available alternative locations, taking account of key factors relevant to siting. The identified key groups of factors for determining a preferred site are based on those adopted in corresponding siting studies for the nuclear fuel repository and SFR. They include:

- safety and radiation protection after repository closure – a robust basis for meeting radiation safety requirements in the long term;
- technical feasibility – necessary conditions to enable technical implementation and operation of the facility;
- environment and health – limited impact on the environment and public health at a reasonable cost;
- societal aspects – societal acceptance at the chosen as well as the alternative site.

SKB then gives an account of the various factors that are included in each main group. According to SKB, the requirements relating to safety and radiation protection are similar, though not identical, to those for the spent fuel repository. Key differences are that the total rock volume required for SFL is considerably smaller and that heat generation from the wastes does not place any requirements on the potential host rock's thermal properties.

Information gained from investigations supporting siting of the spent fuel repository (but also knowledge from other facilities, including Clab, SFR and the Äspö laboratory, as well as rock cavern storage facilities at Studsvik and Oskarshamn) is considered to be relevant to building up basic knowledge of geoscientific factors relevant to siting SFL. SKB draws the conclusion that it is unlikely, especially given the relatively small size of the planned repository, that a meaningful ranking of alternatives can be based on geoscientific information alone.

SKB also highlights challenges in achieving societal acceptance – that it takes time to build up acceptance and that it can never be taken for granted. On the basis that several regions are potentially suitable from a geoscientific perspective, but that it is not considered feasible to rank the technical suitability of alternatives in the absence of site-specific geoscientific investigations, SKB therefore suggests that the selection process should in the first instance be based on those factors (e.g. protection of human health and the environment, land use, access to infrastructure, potential to obtain societal support) that are more easily determined at an early stage in siting, on condition that geological prerequisites can be met.

According to this model, the development of a siting process would be undertaken within the scope of an EIA consultation, starting from regions (at Forsmark and Laxemar/Simpevarp) where good geoscientific information already exists and that have previously been identified as being of national interest for geological disposal of radioactive waste. In a first stage, comparative studies would be made with other regions where relevant data have been obtained at appropriate geological depth or that have previously been highlighted as having potential advantages from a radiological safety perspective. Were such areas shown to have obvious benefits, they could then be included in the siting process if it were judged to be reasonably practicable. More detailed site investigations and consultations would then be undertaken to develop the necessary basis for selection of a preferred location.

H.3.3 Regulatory control

H.3.3.1 Repository for short-lived low and intermediate level waste from decommissioning

In its published assessment and statement to Government regarding SKB's licence application to extend the SFR facility to accommodate short-lived low and intermediate level waste from decommissioning, SSM shared SKB's assessment that the site is suitable and that there are obvious synergies to be gained from co-location. SSM noted further that the location under the sea bed (at least for the initial period after repository closure) had the advantage of providing a low hydraulic gradient, which would give rise to very slow groundwater flow in the surroundings of the repository. It also meant that the likelihood of intrusion would be very low during this period.

The site is considered by SSM to have advantages for limiting the release of radioactive substance, not only in terms of the relatively low groundwater flow rate, but also the chemically-reducing conditions that are expected to dominate the repository environment after closure. Even the proposed depth at which the repository extension would be construction was judged to be suitable given the hazard presented by the waste, estimates of potential future permafrost depth and possible future human actions.

SSM considered that the question of siting is to a large extent a balance between advantages for radiation safety during the first 1000 years or so after closure and time period afterwards (e.g. for an inland site with even lower groundwater flow). Since the facility is designed for an inventory of predominantly short-lived radionuclides, SSM considers the potential advantages of possible alternative locations to be very limited, to the extent that they would not justify the additional cost and inconvenience. Likewise, the Land and Environment Court, in its statement to Government on the conclusions of its scrutiny of SKB's licence application under the Environmental Code, did not question SKB's arguments for siting the repository as an extension to the existing SFR.

SSM noted that SKB had carried out a fairly extensive consultation process in relation to the siting of the facility, and its impacts on human health and the environment, although there was no detailed consultation on matters relating to design alternatives. The Land and Environment Court, in its corresponding assessment and statement to Government, concluded that the consultation process was acceptable in relation to expectations established in the Environmental Code.

H.3.3.2 Repository for long-lived low and intermediate level waste (SFL)

In its review of SKB's RD&D Programme 2019, SSM reviewed and commented on the identified siting factors and proposed stepwise siting process proposed for SFL. Other actors, including provincial government and local municipalities, as well as Luleå University and the Royal Academy of Sciences, also offered comments on SKB's proposals. SSM concluded that the proposed EIA-consultation to be led by SKB in the coming years was likely to be extensive, with many involved parties. It would also be necessary to ensure that the work was underpinned by concrete understanding of what is known, and what is not currently known, in terms of requirements for concept and technical development. Nevertheless, it was considered positive that SKB planned to start a consultation process and SSM recommended that the formal discussions should encompass both siting and technical alternatives.

H.3.4 Conclusion

Sweden complies with the obligations of Article 13.

H.4 Article 14: Design and construction of facilities

> Each Contracting Party shall take the appropriate steps to ensure that:
>
> **(i)** (the design and construction of a radioactive waste management facility provide for suitable measures to limit possible radiological impacts on individuals, society and the environment, including those from discharges or uncontrolled releases;
>
> **(ii)** at the design stage, conceptual plans and, as necessary, technical provisions for the decommissioning of a radioactive waste management facility other than a disposal facility are taken into account;
>
> **(iii)** at the design stage, technical provisions for the closure of a disposal facility are prepared;
>
> **(iv)** the technologies incorporated in the design and construction of a radioactive waste management facility are supported by experience, testing or analysis.

H.4.1 Regulatory requirements

As a result of the review of the industry's RD&D programme 2016, it was decided by the Government that consultation was needed between SSM and SKB regarding development of the design of a facility for long-lived waste. A mechanism has therefore been established whereby SSM can provide guidance to SKB on regulatory expectations relating to concept development for such a facility, and to ensure that post-closure safety and radiation protection issues are accorded due priority in a future siting process. Following publication in autumn 2019 of SKB's latest safety evaluation report for SFL, SKB has specifically requested that SSM undertakes a detailed review of the evaluation and underlying reports. See also section G.4.1.

H.4.1.1 Suitable measures to limit radiological impact

See section G.4.1.1.

H.4.1.2 Conceptual plans and provisions for decommissioning

See section G.4.1.2.

H.4.1.3 Technology provisions for closure of repositories

According to Section 14 of the Act on Nuclear Activities, licensees retain their obligations to dispose of the nuclear waste and nuclear material in a safe manner until these obligations have been fulfilled. In accordance with Section 16 of the Act on Nuclear Activities, SSM determines whether these obligations are fulfilled. With respect to a repository, this can be achieved only after SSM has approved the final closure of the repository. In this respect, final closure is defined to entail backfilling of tunnels and shafts up to ground surface level in a manner consistent with the safety analysis which, according to SSM's regulations concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21), must demonstrate how safety after closure is maintained through a system of passive barriers. This in turn means that technology provisions for closure need to be developed at the design stage, as part of a comprehensive design for the repository facility.

H.4.1.4 Technology supported by experience

See section G.4.1.3.

H.4.2 Measures by the licence holders

H.4.2.1 Suitable measures to limit radiological impact

The safety philosophy applied in the design of all Swedish nuclear facilities is based on the principles of defence in depth and of using multiple barriers to prevent the unplanned release of radioactive material to the environment. Facilities are designed to ensure that releases of radioactive material in normal operation are limited as far as is reasonably practicable.

This safety philosophy underpins the design and planned construction of the extension to SFR to accommodate short-lived low and intermediate level waste from decommissioning, as well as the conceptual designs under development for the SFL repository for long-live low and intermediate level waste. A specific example of how design and construction measures to limit radiological impact have been informed by experience from related facilities is provided in H.4.2.4, below.

H.4.2.2 Conceptual plans and provisions for decommissioning of radioactive waste management facilities

Current planning relating to new waste management facilities in Sweden is focused mainly on alternative storage and disposal solutions for long-lived wastes, including those arising from decommissioning of nuclear power plants as well as legacy wastes from past practices. Conceptual plans for decommissioning are taken into account as appropriate in facility design and in accordance with SSM's regulations (SSMFS 2008:1; see also G.4.1.2). These plans will be assessed by the regulator at the appropriate time when the relevant permissions are sought.

A recent very simple process working in practice is the development of decommissioning plans for the new interim storage facility for low and intermediate level waste, to be constructed by AB Svafo as an extension to an existing waste store on the Studsvik site (see section H.1.2.2). An outline description of decommissioning plans was originally submitted together with the licence application for the facility under the Environmental Code, which was approved in January 2017. Plans for decommissioning, dismantling and demolition of the facility, consistent with regulatory requirements, were subsequently examined as part of the PSAR for the proposed facility change in June 2019, when the licensee sought permission from SSM to begin construction.

In this particular case, however, since the new store is classed as an extension to an existing storage facility, the plans for decommissioning are addressed as a modification to the SAR for the combined facility. The simple nature of the facility means that there are no radiological safety challenges associated with planning for decommissioning at the design stage. This in turn will be reflected in an update to the overall decommissioning strategy for Svafo's operations on the Studsvik site.

H.4.2.3 Technology provisions for closure of repositories

An account of the current status of SKB's technological development programme relating to plans for closure of the spent nuclear fuel repository and SFR was provided in Sweden's fifth national report published in 2014.

Activities relating to the design, development and verification of plugs for closure of deposition tunnels in the spent fuel repository, including full-scale tests at the Äspö laboratory, are summarised in SKB's RD&D Programme 2019. SKB notes that the purpose of the plugs is to keep the backfill in the deposition tunnels in place while minimising leakage of oxygen from access tunnels during the repository operating period, until the adjoining main tunnel can be closed. The full-scale tests were conducted over a period of three years, demonstrating the feasibility of constructing the plug system that can withstand pressurisation using materials that conform to performance requirements for the repository barrier system as a whole. Reporting on gas transmissivity testing was published in 2018. Lessons learned from evaluating the construction and dismantling of the plug will be compiled into a basis for further studies on materials and methods for plug design and construction.

A simplified design for overall closure of the spent fuel repository has been proposed based on completed sensitivity analyses. It is noted that the size and function of closure components may ultimately have an impact on details of the repository design, which means that continued efforts are needed in this area. SKB's forward RD&D programme therefore incorporates the drawing up of an overall closure plan to yield more details with respect to the closure sequence as well as the required function and potential size of closure plugs.

Analyses in support of the proposed extension of SFR to accommodate short-lived wastes from decommissioning have resulted in updated requirements on the closure components for SFR as well as the development of a coordinated closure plan for the extended facility. Closure is currently described on the conceptual level, with the intention that knowledge concerning materials, design and installation should be improved prior to the completion of the PSAR. Separate studies of individual closure components (e.g. modelling of concrete plugs) have been carried out to develop an understanding of how properties are expected to evolve over time, with the aim of defining requirements in more detail. SKB is planning for continued technological development of concrete plugs with the aim of achieving a robust design that meets the relevant set of requirements and practical conditions for the repository.

H.4.2.4 Technology supported by experience

The principle of proven technology is broadly accepted and implemented in the design and construction procedures for Swedish nuclear facilities. The use of properly environmentally qualified equipment ensures functioning of safety-related systems and components under emergency conditions.

The development of engineered barrier designs for the planned extension to the SFR-facility reflects experience gained from design and operation of the existing facility. In particular, the vault for intermediate level wastes, known as 1BMA, has been demonstrated to exhibit design flaws that have given rise to cracks in the concrete structures that form the base and walls of the vault. SKB has since demonstrated, through modelling studies undertaken in response to an enforcement notice, that such cracks may not ultimately have a particularly significant impact on the flow of groundwater through the wastes. Nevertheless, lessons learned from the causes of the cracking have been taken into account in the design and construction methods for the corresponding vault in the extended facility. A prototype for the revised vault design has been installed at the Äspö laboratory to test the revised methods.

H.4.3 Regulatory control

In performing reviews of licence applications for both the KBS-3 final repository for spent nuclear fuel and the proposed extension of the SFR facility to accommodate short-lived low and intermediate level wastes from decommissioning (sections A.9.4.2, A.10.3 and K.1.2), SSM has given consideration to SKB's reference designs, including plans and provisions for final closure. In both cases, SSM has issued statements to Government based on the results of its comprehensive regulatory review of supporting material to the licence application, declaring that SKB will be able to meet regulatory requirements for operational and long-term safety of the disposal facilities. The Authority has also identified during its reviews a range of issues that need to be addressed as the repository design and construction work progress in detail and underlying safety analyses are updated ahead of future decision stages in programme implementation.

In its review of SKB's RD&D Programme 2016, SSM emphasised the importance of SKB developing, as soon as it is feasible to do so, a sufficiently justified and detailed repository design concept as a robust starting point for the next phase in the development process. In this respect, SSM stressed the need to ensure that the outcomes of safety assessments are of sufficient quality to support guiding decisions about the direction of future activities (for example, with respect to requirements for barrier functions and their influence on concept development). The new safety evaluation study for SFL, submitted in support of RD&D Programme 2019, was judged by SSM to have gone some way in this direction, by highlighting certain critical factors affecting performance for this type of facility. However, as noted in section H.1.3.1, there remains a need to demonstrate how the selected barrier system design reflects the principles of minimising release from the facility so far as is reasonably practicable. Such information will potentially make an important contribution to defining preliminary acceptance criteria for wastes destined to be disposed of in the SFL facility.

H.4.4 Conclusion

Sweden complies with the obligations of Article 14.

H.5 Article 15: Assessment of safety of facilities

> Each Contracting Party shall take the appropriate steps to ensure that:
>
> **(i)** before construction of a radioactive waste management facility, a systematic safety assessment and an environmental assessment appropriate to the hazard presented by the facility and covering its operating lifetime shall be carried out;
>
> **(ii)** in addition, before construction of a disposal facility, a systematic safety assessment and an environmental assessment for the period following closure shall be carried out and the results evaluated against the criteria established by the regulatory body;
>
> **(iii)** before the operation of a radioactive waste management facility, updated and detailed versions of the safety assessment and of the environmental assessment shall be prepared when deemed necessary to complement the assessments referred to in paragraph (i).

H.5.1 Regulatory requirements

H.5.1.1 Assessment of safety, including post-closure safety

See section G.5.1.1.

H.5.1.2 Environmental assessment

See section G.5.1.2.

H.5.1.3 The licensing procedure

See section G.5.1.3.

H.5.2 Measures taken by the licence holders

Waste storage facilities

In 2016, AB Svafo submitted an environmental impact assessment to the Land and Environment Court in support of its licence application under the Environmental Code to construct a new interim storage building for low and intermediate level waste on the Studsvik site. Subsequently, in June 2019, AB Svafo submitted a preliminary safety report (PSAR) to SSM, describing the radiological safety implications of the store in terms of an extension to the licensee's existing above-ground storage arrangements on site. Both the environmental assessment and the PSAR were comparatively simple documents, appropriate to the nature of the hazard and reflecting the nature and purpose of the store, where the primary focus is on shielding to protect the workforce and ventilation to maintain a suitable environment for long-term storage of metallic waste containers.

Short-lived operational and decommissioning waste

In December 2014, SKB submitted parallel applications to SSM and the Land and Environment Court for permission to develop an extension of SFR. The purpose of the expansion is to accommodate disposal of additional short-lived LILW, including those generated by demolition of Swedish nuclear reactors. The licence application includes an environmental impact assessment and a comprehensive preliminary safety assessment report for the extended SFR facility as a whole.

The first preliminary safety analysis report (F-PSAR), submitted in support of SKB's licence application, will be further updated and detailed so that it can be submitted to SSM as a PSAR for approval prior to starting construction of the facility. The safety report reflects a systematic analysis of both operational and post-closure safety considerations for the disposal facility. An updated safety analysis report that is meant to reflect the as-built facility will then be prepared prior to trial operation. In the case of SFR, this means that the safety analysis report for the present disposal facility for operational LILW will, at this point, be replaced by the updated safety analysis report describing trial operation of the extended facility. Before the extended facility will then be allowed to begin routine operation, the safety analysis report must be supplemented with experience gained from trial operation.

Long-lived operational and decommissioning waste

A comparison of different design concepts for the repository for long-lived waste (SFL), including a qualitative assessment of alternative barriers and their long-term safety function, was presented by SKB in 2013. SKB has now (autumn 2019) completed an updated safety evaluation, based on its preferred conceptual design for SFL. The safety analysis is not yet at the stage where it can be considered appropriate as support for a permit to start construc-

tion. This was, however, not SKB's purpose of the safety evaluation. According to SKB's current planning schedules it is not expected that the SFL repository will be commissioned before around 2045.

H.5.3 Regulatory control

Short-lived operational and decommissioning waste
At the time of preparing the Sweden's sixth national report (2017) SSM was continuing its examination of SSM's licence application, including F-PSAR, for the extension and continued operation of SFR as a disposal facility for both operational and decommissioning short-lived radioactive wastes. The Land and Environment Court's public hearings into SKB's licence application under the Environmental Code was held over a two-week period in September/October 2019. SSM and the Land and Environment Court submitted their findings to Government for consideration in October and November 2019, respectively.

Having submitted its findings to Government, SSM plays no further direct part in the decision over licensing of the extension to SFR under the Act on Nuclear Activities. Likewise, the Land and Environment Court, after submitting its findings to Government, plays no further part unless and until a determination has been made on the permissibility of SKB's plans according to the requirements of the Environmental Code.

SSM is now making preparations to review the documentation, including a PSAR covering operation and post-closure safety, which SKB needs to submit in support of an application to begin construction of the extension to SFR, if and when a licence is granted by Government.

Long-lived operational and decommissioning waste
At the time of preparing this report, SSM had just started its detailed review of the safety evaluation report published by SKB in autumn 2019 regarding the proposed SFL repository. As noted above, SKB's planning schedule suggests that it will be several years before a safety assessment is submitted in support of a licence application, and even more before an application to start construction and operation. In the meantime, SSM expects to continue in dialogue with SKB during pre-licensing with the aim providing guidance on regulatory expectations for future safety analyses and licence applications.

H.5.4 Conclusion

Sweden complies with the obligations of Article 15.

H.6 Article 16: Operation of facilities

Each Contracting Party shall take the appropriate steps to ensure that:

(i) the licence to operate a radioactive waste management facility is based upon appropriate assessments as specified in Article 15 and is conditional on the completion of a commissioning programme demonstrating that the facility, as constructed, is consistent with design and safety requirements;

(ii) operational limits and conditions, derived from tests, operational experience and the assessments as specified in Article 15, are defined and revised as necessary;

(iii) operation, maintenance, monitoring, inspection and testing of a radioactive waste management facility are conducted in accordance with established procedures. For a disposal facility the results thus obtained shall be used to verify and to review the validity of assumptions made and to update the assessments as specified in Article 15 for the period after closure;

(iv) engineering and technical support in all safety-related fields are available throughout the operating lifetime of a radioactive waste management facility;

(v) procedures for characterisation and segregation of radioactive waste are applied;

(vi) incidents significant to safety are reported in a timely manner by the holder of the licence to the regulatory body;

(vii) programmes to collect and analyse relevant operating experience are established and that the results are acted upon, where appropriate;

(viii) decommissioning plans for a radioactive waste management facility other than a disposal facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body;

(ix) plans for the closure of a disposal facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility and are reviewed by the regulatory body.

H.6.1 Regulatory requirements

See section G.6.1.

H.6.1.1 Initial authorisation

See section G.6.1.1.

H.6.1.2 Operational limits and conditions

See section G.6.1.2.

H.6.1.3 Established procedures

See section G.6.1.3.

H.6.1.4 Engineering and technical support

See section G.6.1.4.

H.6.1.5 Procedure for characterisation and segregation of waste

All waste to be disposed of in SFR, which is described in detail in section D.1.4.5, must conform to predefined waste acceptance criteria. The characteristics of each waste type are documented in a Waste Type Description (WTD). The WTDs are prepared by the waste producer in close contact with the licence holder of SFR (SKB). The completed WTD is sub-mitted to SSM for approval. SSM reviews the WTD and may issue specific conditions for the disposal of a particular waste type. To ensure consistent and comparable WTDs, guidelines have been issued for the structure and content of the WTDs. Wastes that are to be disposed of in shallow land burials are specified and described in the licences (see section D.1.4.2). The licensee must notify SSM at least three months in advance of each such disposal campaign and must then provide information about each waste package.

H.6.1.6 Reporting of incidents in a timely manner

See section G.6.1.5.

H.6.1.7 Programmes for collecting and analysing operating experience

See section G.6.1.6.

H.6.1.8 Decommissioning plans

See section G.6.1.7.

H.6.1.9 Plans for closure of disposal facilities

SSM's regulations contain several requirements relating to safety and radiation protection after closure (see sections G.3.1 and G.4.1). There are no specific requirements concerning the closure of repositories for spent nuclear fuel or radioactive waste; however, as noted earlier (section H.4.1), licensees retain their legal obligations for safe management until they are judged to have been fulfilled, which in practice entails approval by SSM of the final closure of the repository. This, in turn, means that the plans and technical provisions for closure need to be developed at the design stage and updated during the operational lifetime of the disposal facility.

In the case of the SFR facility, the existing repository for short-lived low and intermediate level operational waste, requirements relating to closure planning are issued as a licence condition. According to this licence condition, SKB is required to have a developed plan for the future closure of the facility. The requirement is important as future closure could ultimately entail the imposition of restrictions on the operation of the facility, such as on the mechanical performance, physical dimensions or chemical characteristics of the waste and waste containers. The closure plan should be held under continuous review and may be modified as long as all relevant requirements are still met.

H.6.2 Measures taken by the licence holders

No radioactive waste disposal facilities have been commissioned in Sweden since 1988, when the repository for radioactive operational waste (SFR) was licensed for operation. As noted previously, in addition to the repository for spent fuel, two additional final disposal facilities need to be constructed and taken into operation: a repository for short-lived low and intermediate level decommissioning waste, and a repository for the disposal of long-lived low and intermediate level waste.

The general regulations concerning safety in nuclear installations (SSMFS 2008:1) contain legally binding requirements relevant for all obligations of Article 9. These requirements are summarised in section G.6.2.

H.6.2.1 Initial authorisation

SKB anticipates that authorisation to start operations of its planned disposal for low and intermediate level waste will follow the procedures specified in SSM's regulations. A full commissioning programme will be developed during the course of facility construction, and will be submitted to SSM for approval alongside the safety report for the completed facilities, taking into account results from inspection and any relevant non-active tests.

SKB submitted parallel applications to SSM and the Land and Environment Court in December 2014 regarding development of an extension to SFR, see also section A.8.3.2 and K.1.2. The purpose of the expansion is to accommodate disposal of additional short-lived wastes including those generated during decommissioning of Swedish nuclear reactors. According to current plans, it is anticipated that construction can start in 2023, with operation commencing in 2029.

Also according to SKB's current plans, outlined in the RD&D programme for 2019, it is anticipated that licence applications for the repository for long-lived low and intermediate level waste (SFL) can be submitted around 2030. This presupposes that a suitable siting process, in consultation with SSM and affected municipalities and other interested parties, results in the identification of a preferred location by the end of the 2020s.

Wastes that will ultimately be consigned to SFL are currently stored at Studsvik, are being produced via the decommissioning of nuclear power plants and other facilities, and in some cases are being stored as in the fuel storage pools at Clab. Conditioning and packaging facilities will need to be developed to meet identified waste acceptance criteria for SFL before disposal can take place. Additional interim storage arrangements are also likely to be required, for example to accommodate long-lived wastes from reactor decommissioning (including core and other internal components) as well as future wastes arising from research, industry and medical applications.

H.6.2.2 Operational limits and conditions (OLCs)

See section G.6.2.2.

H.6.2.3 Established procedures

See section G.6.2.3.

H.6.2.4 Engineering and technical support

See section G.6.2.4.

H.6.2.5 Procedure for characterisation and segregation of waste

See section H.6.1.5.

H.6.2.6 Reporting of incidents in a timely manner

In late 2012, SKB informed SSM that it was suspected that errors could have been made in documentation relating to the material contents of a specific type of waste package from Studsvik that had been accepted at the SFR disposal facility for short-lived low and intermediate level waste. Regulatory consent for disposal of this type of waste package was originally granted in 1994. The ISO waste containers contain concrete-grouted wastes in 200 litre drums, while the content of individual drums varies considerably in content depending on the original source, which included institutional waste producers (both civil and military) as well as nuclear licensed activities.

In total 75 waste containers of this type were disposed of between 1994 and 2005, containing an estimated 2,800 waste drums. Subsequent to their disposal, non-destructive examination of similar, though mostly older (and therefore not fully representative) drummed wastes remaining in storage at Studsvik had given rise to suspicions that the content of a significant fraction might not comply with conditions for acceptance at the disposal facility. SKB reported its intention in 2013 to retrieve the waste at an appropriate time, but noted that a decision would be taken only after further investigations had been undertaken. At first it was considered that the liquid content of the wastes might be the most significant anomaly and that non-compliance, rather than a significant hazard to the workforce or the environment, was the primary consideration. However, subsequent analyses, ordered by the regulator to guide the analysis of available options, revealed that a fraction of the packages were likely to contain very large numbers of small Ra-226 sources (night sights from former military weapons).

The presence of such sources, and possibly other long-lived radionuclides, in the waste has potentially significant implications for long-term radiation protection, both in terms of the slow release of radionuclides from the undisturbed repository and the possible consequences to those directly exposed in the event of human intrusion. See also section G.6.2.5.

H.6.2.7 Programmes for collecting and analysing operating experience

The objective of the analysis and feedback programme concerning operating experience is to learn from one's own and others' experience and thus prevent recurrences of events, particularly those that might affect the safety of the facility. The operating experience feedback process consists of a wide variety of activities within the plant organisation as well as externally.

When SFR was built, the intention was that the facility would receive waste up until 2010. Due to the prolonged operating time of the nuclear power plants, SFR's operating phase will also be prolonged, which imposes new demands on the maintenance of the facility. In addition to remedial and preventive maintenance, the maintenance programme includes identification, handling and prevention of age-related deterioration and damage. In recent years, a number of maintenance projects have been carried out in SFR. These have included installation of a water-proofing membrane to protect barriers and waste in the rock vault for intermediate-level waste (1BMA) and the silo, as well as the addition of a sprinkler in the operations building. Within the parameters of renovation work, projects continue for replacement of fire alarms, evacuation alarms, fibre-optic networks, systems for monitoring and control (SCADA systems), and gates and doors in the underground area of the repository.

H.6.2.8 Decommissioning plans

As described in section G.6.1.7, the general regulations concerning safety in nuclear installations (SSMFS 2008:1) comprise requirements for preparation of decommissioning plans for all nuclear facilities. The degree of detail in such a plan increases as the time for decommissioning approaches.

A preliminary decommissioning plan for the extended SFR facility has been prepared for the application under the Act and under the Environmental Code for authorising the extension and continued operation of SFR.

H.6.2.9 Plans for closure of disposal facilities

According to the current plans, closure of repositories will not take place for at least 30 to 60 years. Closure is thus still part of SKB's RD&D programme and an item for future safety assessments. Planning for closure has been undertaken for SFR and is reported as part of the supporting material for the licence application to extend the facility.

H.6.3 Regulatory control

H.6.3.1 Operational limits and conditions

SSM routinely reviews applications from licensees for changes in the OLCs at licensed facilities, as well as for temporary exemptions from the authorised OLCs. Based on the application and supporting information provided by the licensees, together with associated safety analyses, assessments are made regarding how the proposed changes or exemptions contribute to the risk profile of the facility.

H.6.3.2 Procedures

Operational and maintenance procedures are normally not reviewed by SSM. Only in connection with event investigations would SSM request that a procedure be submitted for review.

H.6.3.3 Engineering and technical support

SSM has also continued to carry out follow-up reviews of SKB's plans for engineering countermeasures relating to degradation of the structural concrete in the BMA vault at SFR, but has yet to take a final decision regarding the proposals that have been submitted.

H.6.3.4 Characterisation and segregation of waste

As described in section H.6.1.5, all waste types must be approved by the regulator before disposal. Compliance with regulations is verified by inspections carried out both at the waste producer and the operator of the disposal facility, e.g. SFR or shallow land burials. These inspections for instance cover administrative routines, documentation, equipment and radiological measurements.

One specific area that has been a matter of some attention in recent years has been the disposal of certain operational waste streams to the 1BMA vault for intermediate level waste at SFR. In particular, SSM has raised concerns regarding the swelling of bitumen-solidified ion-exchange resin and its potential implications for the integrity of the engineered barrier. In this case it is important to know if the waste may swell and, if so, how large the swelling pressure of the waste may be. Experiments conducted at the Äspö underground repository have shown that the matrix associated with the bituminised waste form is not sufficiently tight to prevent the ion exchange resin from swelling. SSM has underlined in an enforcement notice the importance of updating and harmonising the definition of waste acceptance criteria for SFR, with particular emphasis on the disposal of bituminised wastes.

H.6.3.5 Incident reporting

As described in section H.6.2.6, SKB in 2012 informed SSM about potential errors in documentation relating to the material contents of a specific type of waste package from Studsvik that had been accepted for disposal in the SFR.

SSM issued in March 2015 an injunction requiring SKB to report to SSM to present an account of its plans in the light of several key questions relating to the nature and timing of intervention. SKB reported to SSM in October 2015. In its review statement in March 2019, SSM supported SKB's decision to retrieve the waste, but questioned whether SKB's preferred option to retrieve the waste in the 2030s (i.e. after commissioning of the planned SFR-extension) was in fact optimal. SSM therefore issued in March 2019 an injunction requiring SKB to report a plan for when the waste should be retrieved, with reference to potential degradation of the waste containers. SKB submitted a revised analysis of options in February 2020, giving explicit consideration to SSM's concerns regarding degradation of the waste packages in situ within SFR, but not significantly changing its previous conclusions regarding the optimum time for retrieval. At the time of preparing the present report, SSM had not yet taken a final decision position regarding SKB's plans. See also section G.6.2.5.

H.6.3.6 Experience feedback analysis

See section G.6.3.4.

H.6.3.7 Decommissioning plans

Regulatory requirements (section G.6.1.7) specify that updates of the decommissioning plan should be reported to SSM and reviewed by the regulatory authority alongside related updates of, and supplements to, the facility's safety analysis report. The revised safety analysis report must be reviewed and approved by SSM before dismantling and demolition are allowed to commence. However, no final decision on dismantling and demolition is expected for several decades in respect of SKB's disposal facilities or other waste treatment facilities.

H.6.4 Conclusion

Sweden complies with the obligations of Article 16.

H.7 Article 17: Institutional measures after closure

Each Contracting Party shall take the appropriate steps to ensure that after closure of a disposal facility:

(i) records of the location, design and inventory of that facility required by the regulatory body are preserved;

(ii) active or passive institutional controls such as monitoring or access restrictions are carried out, if required; and

(iii) if, during any period of active institutional control, an unplanned release of radioactive materials into the environment is detected, intervention measures are implemented, if necessary.

H.7.1 Record keeping

The regulations on information archiving at nuclear facilities (SSMFS 2008:38) contain requirements for record management, under which specified documents concerning location, design and inventory of waste are required to be kept in archives for more than 100 years. Moreover, the general advice to the regulations SSMFS 2008:37, which concern protection of human health and the environment in connection with final management of spent nuclear fuel and nuclear waste, states that the implementer should produce a strategy for preservation of information so that appropriate measures can be undertaken before closure of the repository. Examples of information that should be taken into consideration include information about the location of the repository, its content of radioactive substances, and its design. Relevant records are to be transferred to national and regional official archives when facilities are decommissioned or closed.

SSM is currently considering which specific regulatory requirements (rather than general advice) on record keeping, if any, may be appropriate to a disposal facility for radioactive waste. This involves consideration of the purpose of such record-keeping and its contribution to overall radiation safety, as opposed to, for example, a more general desire to convey particular information to future generations. It is recognised that a disposal facility operator will need to be aware of any such requirements from an early stage in order to ensure that appropriate measures are in place.

H.7.2 Measures taken by the licence holders

Generally, licence holder organisations are responsible for the development and management of records, and they carry out the necessary RD&D on these subjects. The RD&D activities performed by SKB as a basis for the design work on repositories are based on the fact that the design is to be such that the safety of a closed repository is not dependent on surveillance or monitoring, even though it may be expected that some institutional controls – such as safeguards for nuclear materials – need to be in place after closure.

Monitoring programmes, covering both geoscientific and ecological parameters, were already initiated at the time of the site investigations of the proposed site for the reposi-

tory for spent fuel and at the SFR site. A similar programme is envisaged for the planned repository for long-lived low and intermediate level waste (SFL). With a few exceptions, these programmes have continued after the completion of the surface-based site investigations, and will continue both during construction and operation of the repositories.

As construction and operation proceeds there will be a need to regularly reassess the selection of monitoring parameters, monitoring objects and measurement frequencies. If judged useful, long-term experiments carried out underground to explore impacts on key barrier functions may be included.

A quality control programme will be developed prior to excavation with the objective of ensuring fulfilment of the design premises and other requirements for the construction work and for the operations. Safeguards control will be implemented to the degree needed. The control programme with its quality documentation is the basis for assessing whether the construction and operational work conform to the safety-related requirements as expressed in stated design premises and requirements for efficiency and quality. The objectives and content of the control programme will be defined prior to the underground construction work, but will evolve and be adjusted in response to experience gained.

Repository closure is a stepwise process, from consecutively closing a deposition tunnel to closing one or several deposition areas before the entire repository is closed. Monitoring is planned to continue until all waste has been emplaced and closure of the repository facility is commenced. At closure, monitoring systems that are accessible only from underground will be decommissioned successively. The extent to which the closure process itself needs to be monitored must be considered at that time.

A surface-based monitoring system may in principle be in operation even after repository closure. The extent of the post-closure monitoring programme will essentially be determined by decisions made at, or shortly before, closure. It is appropriate that any decisions on requirements for post-closure monitoring are taken by the decision-maker at the time of closure with full consideration of their wider implications. If monitoring after closure, or any other measure to facilitate the retrieval of disposed materials, or to make access to the repository difficult, is prescribed, its potential implications for disposal system performance must be considered (SSMFS 2008:21).

H.7.3 Institutional control

Requirements for institutional control after closure of a waste repository are neither established nor formally decided. The general regulations concerning safety in nuclear installations (SSMFS 2008:1) stipulate that a facility for the disposal of nuclear waste shall be designed so that the barriers provide the required safety without monitoring or maintenance after the disposal facility is closed. This is specified further in the regulations concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21), in which it is stipulated that safety after closure of a disposal facility shall be maintained through a system of passive barriers. Also, the regulations for protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste (SSMFS 2008:37) require that the long-term performance of a disposal facility should not rely on any active measures.

The four shallow land burials for short-lived very low-level waste (at Oskarshamn, Forsmark, Ringhals and Studsvik) are located within the premises of the power plant or licensed industrial facility at that location. Therefore, access restrictions for the repositories are maintained through the access restrictions that apply for the entire facility. Institutional control in this case is requested for a period of up to 50 years after closure of the burial, primarily in order to minimise the potential for inadvertent disturbance of the wastes while the contamination is above clearance levels. It is the task of the owner and operator of the disposal facility to demonstrate how the requirement for institutional control can be maintained over that period. For longer periods of time, it is foreseen that the environmental hazard and risk are principally of a non-radiological nature. Prolonged requirements for institutional control may be issued by county or municipal administrations. The municipalities' detailed development plans are also of importance, by providing conditions concerning future use of the land. All nuclear facilities, including shallow land disposal facilities, are within areas where detailed development plans have been established.

H.7.4 Intervention measures

As described above, SSM's regulations (SSMFS 2008:1, SSMFS 2008:21) stipulate that a facility for disposal of nuclear waste must be designed so that safety after closure of a disposal facility is provided by a system of passive barriers. Prior to disposal facility closure, the final safety assessment must be renewed and approved by the regulatory authority. Based on a regulatory review, the Government makes a decision on final closure of the disposal facility and whether the licence holder may be relieved from its responsibilities and obligations. Thus, if intervention measures need to be taken after the licence is surrendered, these will be the responsibility of the State.

H.7.5 Conclusion

Sweden complies with the obligations of Article 17.

Section I – Transboundary Movement

I.1 Article 27: Transboundary movement

1. Each Contracting Party involved in transboundary movement shall take the appropriate steps to ensure that such movement is undertaken in a manner consistent with the provisions of this Convention and relevant binding international instruments.

In so doing:

(i) a Contracting Party which is a State of origin shall take the appropriate steps to ensure that transboundary movement is authorized and takes place only with the prior notification and consent of the State of destination;

(ii) transboundary movement through States of transit shall be subject to those international obligations which are relevant to the particular modes of transport utilized;

(iii) a Contracting Party which is a State of destination shall consent to a transboundary movement only if it has the administrative and technical capacity, as well as the regulatory structure, needed to manage the spent fuel or the radioactive waste in a manner consistent with this Convention;

(iv) a Contracting Party which is a State of origin shall authorize a transboundary movement only if it can satisfy itself in accordance with the consent of the State of destination that the requirements of subparagraph (iii) are met prior to transboundary movement;

(v) a Contracting Party which is a State of origin shall take the appropriate steps to permit reentry into its territory, if a transboundary movement is not or cannot be completed in conformity with this Article, unless an alternative safe arrangement can be made.

2. A Contracting Party shall not licence the shipment of its spent fuel or radioactive waste to a destination south of latitude 60 degrees South for storage or disposal.

3. Nothing in this Convention prejudices or affects:

(i) the exercise, by ships and aircraft of all States, of maritime, river and air navigation rights and freedoms, as provided for in international law;

(ii) rights of a Contracting Party to which radioactive waste is exported for processing to return, or provide for the return of, the radioactive waste and other products after treatment to the State of origin;

(iii) the right of a Contracting Party to export its spent fuel for reprocessing;

(iv) rights of a Contracting Party to which spent fuel is exported for reprocessing to return, or provide for the return of, radioactive waste and other products resulting from reprocessing operations to the State of origin.

I.1.1 Regulatory requirements

There are four different enactments that must be considered in order to obtain a complete picture of the Swedish regulatory requirements regarding transboundary movement of spent nuclear fuel and radioactive waste:

- the Radiation Protection Act (2018:396);
- the Act (1984:3) on Nuclear Activities;
- Council Regulation (EC) No 428/2009; and
- the Act (2000:1064) on the Control of Dual-use items and Technical Assistance.

Sweden has implemented Council Directive 2006/117/ Euratom of 20 November 2006 on the supervision and control of shipments of radioactive waste and spent fuel in the national legislation, i.e. the Radiation Protection Act and the Act on Nuclear Activities.

In summary, and as specified in the Radiation Protection Act, a licence to export spent nuclear fuel or radioactive waste from Sweden cannot be granted if the destination is:

i. south of latitude 60 degrees south;

ii. a State party to the Fourth ACP-EEC Convention which is not a member of the European Union;

iii. a State that has forbidden the import of spent nuclear fuel or radioactive waste; or

iv. a State that, in the opinion of the responsible Swedish authorities, does not have the technical, legal or administrative resources to safely manage the spent nuclear fuel, or administrative resources to safely manage the spent nuclear fuel or radioactive waste.

I.1.2 Regulatory control

Sweden follows the administrative procedures set forth in Directive 2006/117/ Euratom in order to ensure that states of destination and states of transit have the opportunity to give their prior consent, and are notified as is stated in the directive.

I.1.3 Experience of transboundary movements

Cyclife Sweden AB carries out volume reduction of radioactive waste on a commercial basis by incinerating combustible waste and melting scrap metal. The activities are to a certain extent based on services to companies abroad, and Cyclife Sweden AB imports radioactive waste and scrap metal for the purpose of volume reduction. Remaining radioactive waste is returned to the country of origin. Approximately two hundred transboundary shipments of this kind are carried out each year.

I.1.4 Conclusion

The Swedish party complies with Article 27.

Section J – Disused Sealed Sources

J.1 Article 28: Disused sealed sources

1. Each Contracting Party shall, in the framework of its national law, take the appropriate steps to ensure that the possession, remanufacturing or disposal of disused sealed sources takes place in a safe manner.

2. A Contracting Party shall allow for re-entry into its territory of disused sealed sources if, in the framework of its national law, it has accepted that they be returned to a manufacturer qualified to receive and possess the disused sealed sources.

J.1.1 Regulatory requirements

The management of disused sealed sources is covered by the Radiation Protection Act (2018:396). According to the Act, anyone who has conducted activities involving sealed sources must ensure the safe management, including disposal if needed, of the disused sealed sources. The Radiation Protection Act allows the re-entry of disused sealed sources into Sweden.

Detailed requirements for the management of disused sealed sources are found in regulations issued by SSM, see Annex L.1.1. SSMFS 2018:1 incorporates the provisions on high activity sealed sources from the Basic Safety Standards Directive 2013/59/Euratom. Before issuing an authorisation for practices involving high-activity sealed sources, SSM must ensure that adequate arrangements exist for the safe management of sources, including when they become disused sources. This may provide for the return of disused sources to the supplier or to the recognised waste management facility Cyclife Sweden AB. Financial provision must have been made to cover the cost of management of the disused sources safely should the licence holder become insolvent or go out of business.

In addition to the regulations, SSM can also issue licence conditions concerning the management of disused sealed sources. For sealed sources incorporated into electrical or electronic equipment, there is producer responsibility established through the Ordinance (2014:1075) on Producer Responsibility for Electrical and Electronic Equipment.

J.1.2 Measures taken by the licence holders

J.1.2.1 Disused sealed sources

Licence holders are required to keep records of all sources in their possession and report to SSM when a practice involving sealed sources ceases, when the ownership of a particular sealed source has been transferred to another licensee, and when a disused sealed source is either returned to a manufacturer or supplier, or sent for disposal.

Since one of the fundamental principles of radioactive waste management is that radioactive waste generated in Sweden shall be disposed of in Sweden, disused sealed sources that are to be disposed of can be sent to the only recognised radioactive waste management facility in Sweden, Cyclife Sweden AB, for treatment and storage before disposal. However, Cyclife Sweden AB is not required to accept disused sealed sources. The company operates on a commercial basis. If Cyclife Sweden AB for some reason does not accept disused sealed sources for treatment, the licence holder will have to store the source on site unless it is possible to return the source to the supplier or send it for reuse or recycling. When Cyclife Sweden AB accepts receiving a disused sealed source for treatment and disposal, the company also assumes the ownership of the sealed source which includes the financial liability.

At Cyclife Sweden AB the disused sealed sources are treated and stored pending disposal in either the disposal facility for short-lived low and intermediate level waste, SFR, or the disposal facility for long-lived low and intermediate level waste, SFL. During storage, the sources are retrievable. Cyclife Sweden AB receives approximately 250-300 disused sealed sources on a yearly basis, not counting a number of discarded ionising smoke detectors.

J.1.2.2 Orphan sources

Licence holders are required to take all the measures necessary so as not to allow for sealed sources to fall outside of regulatory control. Nevertheless, on rare occasions, orphan sources are found, usually at scrap metal recycling facilities. If the licence holder responsible cannot be identified, the State will provide financial resources for the management and disposal of the orphan source. This is made possible through a special governmental funding arrangement that allows SSM to cover the costs up to a certain amount for the management and disposal of orphan sources and legacy radioactive waste. The funding at the moment is SEK 3.0 million per year.

Several orphan sources are recovered every year, using the financial resources provided by the State. To date, no orphan high activity sealed sources have been found. The finder of an orphan source is required to contact SSM and apply for funding for the safe management and disposal of the source. SSM commissions Cyclife Sweden AB to manage and dispose of the orphan source. In connection with Cyclife Sweden AB accepting the responsibility to manage and dispose of orphan sources, the company assumes the ownership of the sources. The orphan sources are transported to the Studsvik site, where they are treated, conditioned and stored pending disposal. Short-lived disused sealed sources, including orphan sources, can be disposed of in SFR. Disused sealed sources must meet the same criteria as any item of short-lived LILW in order to be disposed of in SFR. The majority of disused sealed sources, including orphan sources, are long-lived. These sources are stored at the Studsvik site until SKB's planned disposal facility for long-lived low and intermediate level waste, SFL, is in operation. Should Cyclife Sweden AB choose not to accept to manage an orphan source, the source has to be stored by the finder pending a solution.

J.1.3 Regulatory control

SSM plans and performs inspections regularly at establishments in the non-nuclear sector. When it comes to research centres and hospitals, the entire practice is inspected, including routines for treatment of waste and the facilities where radioactive waste and disused sealed sources are stored. Handling of disused sealed sources and back-end issues in general are usually brought to the attention of SSM in connection with inquiries made by licence holders about these issues.

J.1.4 Conclusion

Sweden complies with the obligations of Article 28.

Section K – General Efforts to Improve Safety

K.1 Measures taken to address suggestions and challenges at previous review

K.1.1 Complete licensing for construction of an encapsulation plant and a spent nuclear fuel repository

Since the Joint Convention Review meeting in 2018, the review process for the Swedish Nuclear Fuel and waste Management Co. (SKB's) licence applications for construction and operation of an encapsulation plant and a deep geological repository for spent fuel has been completed. In January 2018, both the Swedish Radiation Safety Authority (SSM) and the Land and Environment Court submitted final review statements to the Government for licensing decisions. SSM recommended the approval of SKB's application for a licence to possess, construct and operate an encapsulation plant and a final repository under the nuclear activities act. However, the Court stated that SKB would need to present further documentation clarifying the long-term protective function of copper canisters, for the repository to be considered permissible in accordance with the provisions of environmental legislation.

Upon request from the Government, SKB submitted supplementary information on these issues related to the copper canister in April 2019. After a renewed public consultation and a thorough technical review of the new material, SSM reiterated its earlier statement to the Government that SKB's preferred site is suitable, the disposal concept is feasible and the safety case fulfils strict regulatory requirements. SKB's licence applications are now awaiting licensing decision by the Government. For more detail see sections A.9.4.1 and A.10.2.

K.1.2 Complete licensing of the extension of the SFR repository for low and intermediate-level waste

Since the Joint Convention Review meeting in 2018, the regulatory review process for SKB's application, to extend the SFR repository for short-lived low and intermediate level operational waste to receive decommissioning waste, has also reached the point of governmental decision. In 2019 SSM finalised its review and participated in the Land and Environment Court's public hearing and consultation process. SSM's final review statement, recommending the approval of SKB's proposed extension and continued operation of the facility, was sent to the Government in October 2019. A month later the Land and Environment Court submitted its review statement to the Government and concluded that extension was permissible according to the Environmental Code. SKB's licence applications are now awaiting licensing decision by the Government (see sections A.9.4.2 and A.10.3).

K.1.3 Addressing issues arisen from shutdown of several nuclear power reactors

The progress made in preparing for decommissioning in Sweden since the previous national report and the sixth review meeting, is recognised as a strong feature in the effective implementation of a national strategy for the immediate decommissioning of reactors in Sweden, see section K.3.1.6.

Decommissioning of nuclear reactors is also addressed in sections A.9 and A.10 from a waste management systems perspective and described in more detail in section F.6 with regard to measures to ensure the safety of decommissioning of nuclear facilities. Decommissioning is also addressed in section K.2.2 as a measure for safety with

regard to the development of waste acceptance criteria for long-lived waste, and in section K.3.1.1 with regard to continuity in the waste management programme as a strong feature in establishing repositories for decommissioning waste.

K.1.4 Competence for nuclear safety and radiation protection

K.1.4.1 Long-term competence provision

On December 2016, SSM received a government assignment regarding the provision of long-term competence. Two main background factors are given that describe this government assignment:

- International requirements regarding the provision of relevant education programmes and national competence in the area, together with the findings of international peer review (IRRS follow-up mission), conducted in 2016, which showed that Sweden does not fully comply with IAEA standards for maintaining competence in radiation protection and nuclear safety.
- The decisions of the nuclear power industry to shut down four nuclear power reactors up to and including 2020, comprising changed circumstances that may have an impact on knowledge management not only in the nuclear power sector, but also in relevant educational programmes.

In September 2018 SSM submitted its report to the Government. Some conclusions from the report are as follows:

- the national competence supply system in the field of nuclear safety and radiological protection needs to be strengthened to meet today's requirement for competence and needs in coming years;
- there is need for a national strategy and cooperation in order to increase the efficiency of the system for the provision of skills (competence);
- an increase in financing of critical research environments is required. A better, formal liaison between state actors involved in financing research is necessary;
- there is also a need to secure vital educations in areas of importance to nuclear safety and radiological protection, so that objectives of these educations remain clear and up-to-date and that quality in teaching is up-held; and
- outreach activities in order to attract students to select education and careers in areas relevant for radiation protection and nuclear safety are necessary.
- The continued measures taken on behalf of both the nuclear industry and the state, are addressed in the following sub-sections.

K.1.4.2 Measures taken to improve competence provision

SSM

Within SSM a project has started to develop a systematic and effective system to compile annual updates of the current status of the knowledge management framework. There are also plans to initiate the earlier reference group contributing to the above mentioned Government assignment from 2016. The reference group consists of some seventy institutions: CEOs; research managers; staff managers; professors and associate professors in the field of nuclear technology and radiation protection; regional authorities (county councils); various interested parties from the health care; the Swedish Research Council, the Government Research Council for Sustainable Development; the Swedish Foundation for Strategic Research; representatives from licensees and the Ministry of the Environment. SSM will also continue to have a dialogue with the central government research councils.

SKB and the nuclear industry

As described in section F.2.2.1, SKB requires competence within many areas, especially within natural science and technology, and SKB thus works actively with competence management in both the short term and the long term.

Generally, the national trends with a declining interest for technical and scientific education poses challenges for SKB and for Swedish industry as a whole. SKB works together with its owners to increase the attractiveness of the nuclear industry. For example, SKB collaborates with companies and schools, primarily at the locations where SKB is active, and participate in labour market days, fairs and various industry events. In order to secure competence in the country in the longer term, collaboration with universities and university colleges is strategically important.

In general, and in a long time perspective, SKB expects most of the need for personnel to be satisfied by personnel with basic education, who are then further trained by SKB for the company-specific applications. In addition, there is a need for a smaller number of persons with in-depth competence, for example postgraduates, combined with long experience of areas important for SKB.

In summary, SKB has developed strategic competence management plans and analysed the risks that may arise, and considers potential problems to be manageable, if identified actions are successfully implemented.

Within the nuclear power industry recruitment campaigns has been implemented. Further a network for future competence supply has been established between Vattenfall, Uniper in Sweden and TVO in Finland.

Educational system

Regarding the educational system, Uppsala University has restarted in the fall of 2019 a previously discontinued nuclear educational programme. The programme is partly funded by Vattenfall. In addition, Chalmers University of Technology has launched education on distance aiming to maintain competence in, reactor physics and nuclear chemistry. The training is a part of the EU-programme Horizon.

Investigation of the need for future research

In December 2019 SSM was asked by a government assignment to describe and clarify the need for research in the Authority's areas of activity in the future and what sources of funding should be used to maintain a national competence supply within the Authority's areas of competence that follow EU directives, conventions and IAEA standards.

SSM reported back on this task in March 2020. SSM has earlier identified critical and vulnerable research areas. To increase research funding for the critical areas identified in the previous SSM report on long-term competence provision (see section K.1.4.1), the authority now proposes that the Government raises SSM's research grants to SEK 130 million and requires Swedish research funding organisations such as the government Research Council for Sustainable Development (Formas), Sweden's Innovation Agency (Vinnova), the Swedish Research Council and the Swedish Energy Agency to make research calls within the identified research areas to an ambition level corresponding to about SEK 50 million per year. SSM has also suggested how the research funding should be shared between the Swedish state and the licensees.

K.1.5 Management of non-conformities of waste disposed at the SFR facility

As described in section H.6.1.5 and F.3.2, all waste types must be approved by the regulatory function before disposal. Compliance with regulations is verified by inspections carried out both at the waste producer and the operator of the disposal facility, e.g. SFR or shallow land burials. These inspections for instance cover administrative routines, documentation, equipment and radiological measurements.

In late 2012, SKB informed SSM that errors could have arisen in documentation relating to the material content of a certain type of waste package from Studsvik that had been accepted for disposal at SFR. The following year, SKB reported its intention to retrieve the waste (up to 2,800 barrels in 75 containers) at an appropriate time, but that a decision would be taken only after further investigations had been undertaken. Although SSM accepted that the wastes did not represent an immediate hazard to the workforce or wider environment, the regulator ordered in March 2015 that SKB provide an analysis of available options and the rationale for the actions SKB intended to undertake. When producing the requested reports, it was discovered that the waste also included large quantities of Ra-226-sources from previous military use (night aiming devises). The presence of these sources in the waste significantly affects the long-term radiation protection both in terms of dose consequences from the undisturbed repository, as well as the dose consequences in the event of human intrusion. In the review statement in March 2019, SSM supported SKB's decision to retrieve the waste. However, in the review SSM identified factors that could point to an earlier retrieval compared to SKB's preferred option to retrieve the waste in the 2030s after the extension of the SFR is expected to be in operation. SKB presented the comparison of the different options in February 2020. At the time of preparing the present report, SSM had not yet taken a final decision regarding SKB's plans. See also section H.6.2.6 and H.6.3.5.

K.1.6 Complete implementation of actions arisen from the follow-up IRRS mission

K.1.6.1 After the 2016 IRRS follow-up

A full scope IAEA IRRS mission to Sweden was performed in 2012. The outcome of the 2016 follow-up mission was that two of 22 recommendations remained open. See also section 8.12. 'Follow-up of the 2012 IRRS review mission' in Sweden's Eighth National Report under the Convention on Nuclear Safety, Ministry Publication Series, Ds 2019:16, 2019. In general, the IRRS team was satisfied with the approach of Sweden to address findings and the work in closing recommendations. Some progress after the 2016 follow-up is described below.

K.1.6.2 Competence for nuclear safety and radiation protection

See section K.1.4.

K.1.6.3 Operational experience and dissemination of significant experience

The second open recommendation was R4: *"SSM should systematically evaluate operational experience from non-nuclear facilities and radiation protection events and activities, and should establish and implement guidance for the dissemination of all significant operating experience lessons learned to all relevant authorised parties".*

In order to improve the evaluation of operational experience of non-nuclear facilities and radiation protection events and activities, SSM has implemented several measures. These include improving the dissemination of incident reports, exchanging information between the regulatory authority, the licensees, and other national and international organisations, and making more information on events available on SSM's website. A procedure for assessing reports from licensees, including deciding on how to disseminate information they contain, is established. It contains guidance on the management and assessment of incident reports in health and dental care, and the management of events in other practices and industries and research.

K.1.6.4 Outlook

Sweden has invited an IRRS-mission to Sweden in autumn 2022 followed by an ARTEMIS mission in spring 2023. Before this, about a year earlier, a self-assessment will be performed. In this context the two open recommendations will be re-evaluated and any additional actions will be taken, as appropriate.

K.2 Other measures taken to improve safety

K.2.1 Preparing for a decommissioning phase

The progress made in preparing for decommissioning in Sweden since the previous national report and the sixth review meeting, is recognised as a strong feature in the effective implementation of a national strategy for the immediate decommissioning of reactors in Sweden, see section K.3.1.6.

Steps and measures to ensure the safety of decommissioning of nuclear facilities are described in more detail in section F.6.

K.2.2 Development of waste acceptance criteria for long-lived waste

At present there is a considerable amount of long-lived waste in the waste producers' storage facilities and additional long-lived waste will arise during the continued operation and decommissioning of the nuclear facilities. In order to avoid that future transportation and disposal is impeded, it is important to clarify how the long-lived waste is to be managed and characterised and which requirements may be imposed on the waste today. There is thus a need to specify preliminary waste acceptance criteria for the planned geological repository for long-lived radioactive waste (SFL).

In their latest RD&D programme from 2019, SKB presented the results from an evaluation of the post-closure safety of the proposed repository concept for SFL. This evaluation, which was done during 2015–2019, provides some guidance for future acceptance criteria for the waste. The assumptions regarding waste form and packaging used in the safety evaluation have been based on the management of the waste to date. The results of the safety evaluation may therefore be used in the continued work to provide answers to how the present and former management affects the conditions for future disposal. In addition to requirements related to the post-closure safety of the repository, requirements related to the construction, transportation and handling during operation will serve as a basis to further define waste acceptance criteria. As the details of the repository design are finalised, it will be possible to establish waste acceptance criteria. It should be noted that waste producers should not commence final conditioning of waste until a verified repository concept exists.

K.2.3 Periodic Safety Reviews (PSR)

Since the previous Joint Convention review process, PSRs have been carried out for the Westinghouse nuclear fuel factory (WSE), in Västerås, in 2019. The regulatory review of the PSR concluded that the facility is operated in line with regulatory requirements but that there are room for improvements as regards full compliance with all requirements. SSM requested WSE to present an action plan to address outstanding issues by 31 January 2020, which has been reported to the regulatory authority. SSM also requested WSE to report the next PSR not later than 1 July 2024.

PSRs have also been carried out for the disposal facility for short-lived LILW (SFR) in Forsmark as well as for the interim storage facility for spent fuel (Clab) in Oskarshamn, in 2020, both facilities operated by SKB. The regulatory review of the PSRs concluded that both facilities are operated in line with regulatory requirements and are expected to be operated safely until the next PSR. SSM will follow up findings from the PSR within the regular inspection programme.

K.2.4 Safety implications of long term management of spent fuel

Due to the decisions to decommission both Oskarshamn units 1 and 2, and Ringhals units 1 and 2, there is an increased demand to receive spent fuel at Clab to accommodate the complete unloading of the reactors in a timely manner. An uprating of the cooling capacity for the storage pools at Clab has been made, by a modification to the existing residual heat cooling system. The uprating is also made in preparation of a planned increase of the storage capacity of spent fuel from 8000 tonnes to 11000 tonnes, pending the completion of the licensing of the KBS-3-system.

Based on the initial review of the licence application for an encapsulation plant for spent fuel to be collocated with Clab, SSM identified areas of improvement relevant for the safety analysis report of Clab. As a result, SSM issued an injunction to SKB to update the safety analysis report in areas relating to safety requirements, safety analysis and safety classification. SKB has since modernised the safety analysis report for Clab in several steps between 2016 and 2020. The safety analysis has been supplemented with a probabilistic safety assessment, including a human reliability analysis of all safety-related manual actions. The basic safety concept of Clab relies on passive and inherent safety with extensive grace periods before any action is needed to avoid adverse conditions. The human reliability analysis strengthens the safety case for relying on manual actions to achieve a safe state in case of incidents or accidents in the facility. The safety demonstration has also been extended to include a more comprehensive risk assessment of beyond design basis accidents. The assessment, based on IAEA and WENRA guides for design extension conditions, demonstrate that there are sufficient margins in the design of the facility such that sequences leading to significant fuel degradation are practically eliminated.

K.2.5 Development of SSM's regulatory framework

K.2.5.1 Major review and revision of SSM's Regulatory Code

SSM has conducted a major review and update of its Regulatory Code of Statutes (SSMFS). The first parts of the new Code were finalised, issued and entered into force in June 2018. Some remaining parts regarding regulations on the management of nuclear waste (see section K.2.5.2) and nuclear power reactors will gradually be completed and come into force between 2021 and 2022.

Experience has demonstrated the need to clarify and broaden the regulations in order to create more predictability for the licensees and to improve the regulatory support. Other reasons for this revision are the IPPAS mission reports to Sweden in 2011 and 2017 (follow-up report) and the IRRS mission reports to Sweden in 2012 and 2016 (follow-up report). The 2012 IRRS mission report concluded that Swedish regulations for nuclear facilities have, historically, emerged as the need for regulation arose.

Moreover, the Swedish Government has, through government assignments, ordered SSM in 2012 and 2013 to review the regulations concerning nuclear power reactors, to ensure that appropriate requirements are in place for potential new nuclear power plants, taking into account the experiences of events and accidents that have occurred and new international safety standards. In 2015, the government assignment was amended and expanded to include a general review of regulations on the safety of nuclear power reactors.

Below is a general outline of how SSM has managed some challenges in the process of review and revision of its Code.

Guidelines

As one of the results of the IRRS mission conducted in 2012 SSM decided to develop guidelines to its regulations. So in parallel with the work of reviewing and updating the Authority's Regulatory Code (SSMFS), guidance text has been prepared for each of the provisions in the various regulations.

The purpose of the guidance text is to gain better understanding and thus fulfilment by the licensees of the provisions by putting them into a context where the purpose, background, considerations of the provision and how they are intended to be applied. For each provision, the guide also specifies the international requirements, guidelines and recommendations upon which it is based (e.g. issued by Euratom, IAEA, ICRP, WENRA).

These guidance texts are only digital. The idea is that they can be easily updated as new experiences arise from supervision or if a provision is appealed and the judicial proceedings give precedents on how the provision is to be interpreted.

Hierarchical structure

A new hierarchical and more transparent structure of SSMFS has been implemented. This has been achieved by bringing together in one and the same regulations all provisions that are common to all types of activities with ionising radiation. This measure replaced seven earlier regulations.

The hierarchical order of the regulations is divided into the following levels.

- Level 1; one regulation (SSMFS 2018:1, see section L1) containing all basic and common requirements for activities with ionising radiation requiring a licence (medicine, research, industry and in the nuclear area). The regulation specifies requirements in the Radiation Protection Act and the Act on Nuclear Activities and has considered other international requirements and documents published by the International Commission on Radiological Protection (ICRP), the European Union (EU), the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA).
- Level 2; at this level there are several regulations clarifying some of the basic provisions of Level 1, adapted to the substantive issues to which the provisions of Level 2 regulations apply. In addition, certain provisions specify general requirements in law. The regulations on level 2 regulate issues that are of significance to different activities separately and are adapted to each type of facility.
- Level 3; at this level the regulations specify design and operational parts, where some of the provisions at levels 1 and 2 are more detailed in various respects.

K.2.5.2 Proposal for regulations on the management of nuclear waste

The purposed regulations on the management of nuclear waste aim to ensure a radiation safe handling and final disposal of nuclear waste. Radiation safe treatment means all measures taken with regard to radiation protection and safety. Handling means all measures from the generation of waste until it has been released or placed in a final repository and it final closure. An important prerequisite for radiation safe treatment is a careful and comprehensive planning of the entire treatment process.

The regulations constitute development of, and replacement of large parts of, section 6. SSMFS 2008: 1 (see section L1 about SSMFS 2008:1). The regulations will be sent on a broad referral in autumn 2020 and are scheduled to take effect in early 2022.

K.2.5.3 Pre-study on the need for update of regulations for final repositories

Currently there are two regulations, issued in the 1990s, on spent fuel and nuclear waste disposal (see section L1). The regulations need to be updated to better reflect national and international requirements. In the pre-study it is also considered to merge the requirements into one single regulation.

K.2.5.4 Pre-study on the need for regulations for nuclear activities other than nuclear power plants

At present, a number of regulations apply to both nuclear power plants in operation and other nuclear facilities. The experience from supervision shows difficulties in applying the same requirements to such different operations (as nuclear power plants and other nuclear facilities) with fundamentally different risks linked to the operations.

A study was initiated within SSM to address this issue. The study recommends that specific regulations be developed specifically for non-nuclear-power-plant nuclear facilities. In this way, the requirements can be better adapted to the specific risks associated with these facilities. These regulations are proposed to regulate construction, analysis, operation, decommissioning and final closure (of a geological repository). However, the preparation of such regulations awaits a formal decision in spring 2020.

In this context it should also be noted that extensive work is underway to update regulations for analysis, design and operation of nuclear power plants.

K.2.5.5 Preparation of licence conditions for interim storage and a future encapsulation facility

Ahead of the planned expansion the existing interim storage facility for spent nuclear fuel (Clab) and the construction of a planned new encapsulation plant (combined with Clab), SSM has developed a proposal with a set of licence conditions for those facilities. When the facilities are merged they will be regarded as one and the same facility as they will be combined with shared technical systems. The combined facility will also be considered as a new facility (Clink).

The purpose of the proposed conditions for Clab is to specify certain aspects of construction work and safety analysis for the planned expansion based on existing regulations. The purpose of the proposed conditions for the encapsulation facility (which is expected to be constructed at a later stage) is to supplement or replace those decided for Clab. The conditions focus on acceptance criteria, evaluation thereof and optimisation of the construction of the plant. Using a graded approach, requirements that are considered reasonable for new nuclear reactors, such as WENRA's Safety Reference Levels, will be applied to Clink.

In the spring of 2020, the licence conditions were sent on referral to SKB.

K.3 Strong features, major challenges and areas for improvement identified by the Contracting Party

K.3.1 Strong features

In its fifth and sixth national reports under the Joint Convention, Sweden reported on strong features relating to continuity of the waste management programme, allocation of responsibilities, the functions of the regulatory authority and a stepwise licensing process with provisions for stakeholder involvement. These strong features have been central for Sweden's progress in the licensing of a deep geological repository for spent fuel, identified as a Good Practice at the previous review meetings, and are still relevant as summarised below.

At the sixth review meeting, the decommissioning of nuclear reactors in Sweden was addressed as a challenge for future development. The progress made since the previous national report in the development of regulatory requirements, dialogue with operators, decommissioning planning and preparation, and the review and authorisation leading to the commencement of large scale dismantling activities, is recognised and summarised below as a strong feature in the effective implementation of a national strategy for the immediate decommissioning of reactors in Sweden.

K.3.1.1 Continuity in the waste management programme

Building public confidence and acceptance in the management and disposal of radioactive waste and spent nuclear fuel strongly benefits from a national system based on consistent and long-term strategies and planning. In Sweden, financial arrangements have been in place and performing successfully for over three decades in parallel with the continuous progress of a research and development (RD&D) programme for waste management, decommissioning and disposal.

Strategies are being implemented, for example with the establishment of the central interim storage for spent fuel (Clab) and disposal facility for LIL-SL operational waste (SFR) in the mid-1980s. Licence applications for an encapsulation plant and deep geological repository for spent fuel as well as for an extension of the SFR facility to accommodate decommissioning waste, have been submitted to the regulatory authority SSM, subsequently reviewed and are currently pending Government licensing decisions. SSM in 2020 reported to the Government on SKB's twelfth RD&D programme, with a specific focus on decommissioning waste management and the establishment of a future repository for long-lived LILW.

K.3.1.2 Stepwise licensing process with early regulatory involvement

Starting in the beginning of the 1980's, the regulatory authorities have every three years reviewed the nuclear industry's mandatory RD&D programme, developed by its implementing organisation SKB. This long-term regulatory engagement in the pre-licensing process of siting and development of disposal options has included broad public consultations and subsequent review statements to the Government as a basis for approval and strategic decisions on the continued direction of the programme. The formalised pre-licensing process has enabled the authorities to monitor SKB's siting process, perform pilot safety assessments, take part in pre-licensing consultations, participate in international projects and carry out independent research on geological disposal.

Following the pre-licensing phase, a key element in Sweden's regulatory framework is the clearly defined and stepwise licensing process. A licence application for the construction, possession and operation of a nuclear facility is reviewed by the regulatory authority, SSM, and the Land and Environment Court, and decided on by the Government. Following a Government approval, SSM in a stepwise process authorises the start of construction, the start of trial operation, the start of routine operation, and the eventual decommissioning or closure of the facility. A Government decision is again needed for the de-licensing and exemption from responsibilities. The Authority reviews the application to ensure that all obligations and licensing conditions have been fulfilled.

K.3.1.3 Clear division of roles and responsibilities

The division of responsibilities is clear in the regulatory framework, with an effective separation between the functions of the regulatory body and those of the nuclear energy industry. The nuclear licensees have prime responsibility for the safe operation of their facilities and transports as well as the safe disposal of spent fuel and radioactive waste. Swedish nuclear power plant licensees also have a common obligation to conduct research and development of disposal solutions (the RD&D programme) and to carry out cost estimates as a basis for payments to the Nuclear Waste Fund.

The legislation provides the regulatory authority with a strong mandate as well as extensive supervisory and enforcement powers. As a regulator, SSM is authorised to issue legally binding requirements regarding all aspects of nuclear activities and radiation protection. SSM supervises SKB, the power plant operators and other licensees of nuclear activities in fulfilling their responsibilities for safe operation of facilities and transports as well as in planning for decommissioning and disposal.

K.3.1.4 Independence and competence of the regulatory authority

SSM is the national regulatory body with a clear mandate in the areas of nuclear safety, radiation protection, nuclear security and nuclear non-proliferation. SSM is provided with the adequate authority, competence and financial and human resources to fulfil its assigned responsibilities. SSM's regulatory independence in its decision making according to the legal mandate is underpinned by Swedish legislation (see section E.3), but it is also a matter of public service culture and values. As a strong, independent and fully accountable national authority, SSM is confident and trustworthy in upholding high safety standards. The integrity of the regulator has become increasingly crucial with the progression of the licensing review of SKB's application for a spent fuel repository.

K.3.1.5 Provisions and actions taken for transparency and stakeholder involvement

The legal framework for licensing nuclear activities contains provisions governing transparency, openness and public participation. The licensing review for a spent fuel repository in Sweden has strongly benefited from the provisions for a transparent and predictable siting and licensing process, with an active involvement of stakeholders.

SKB's siting of a spent fuel repository has engaged local communities in open dialogue. The concerned municipalities have been involved on a voluntary basis and with the possibility to withdraw at all stages, from the initial feasibility studies to the detailed site investigations. This voluntary participation has also benefited from the understanding that an eventual host municipality ultimately has the right to veto a Government decision for a nuclear installation.

Preceding the licence application that was submitted in March 2011, SKB conducted a number of consultation meetings with stakeholders to inform about the planned activities and to obtain comments on issues that needed to be addressed in the formal Environmental Impact Assessment (EIA). The experiences from the RD&D review process and the participation by the regulatory authority in these meetings contributed to building public and local communities' confidence in the regulator's independence and in the overall licensing process.

To enable an active public participation during the licensing process, host municipalities, regional authorities and certain environmental organisations have also received financial support through the Nuclear Waste Fund. These stakeholders were involved in the pre-licensing process, are well informed and have over time built a good capacity for constructive dialogue.

In order to support the initial review and analyse the quality of SKB's application, SSM arranged for an international peer review of the post-closure safety case, organised by the OECD Nuclear Energy Agency. Results were made available and communicated by the review team to the public and stakeholders in meetings at SSM and the host municipality in 2012.

SSM also distributed SKB's license applications according to the Act on Nuclear Activities as part of a broad national consultation. During the continued licensing review, all relevant documents, including detailed supporting documentation to the licence application, supplementary information requests by SSM together with SKB's responses, external experts' technical review reports and SSM's review statements, have been successively published on SSM's website. These have also included minutes from dialogue meetings between SSM and SKB, and the publication by SSM of preliminary results between June 2015 and March 2016.

Swedish official documents are publicly available and the right to anonymously request or access a public document is protected. This applies unless a decision has been made to classify them under the Public Access to Information and Secrecy Act (2009:400). Reasons for secrecy might include interests of national security, international relations, commercial relations, or individuals' right to privacy. SSM provides information services to the public concerning its regulatory activities and regularly publishes reports to inform interested parties and stakeholders. The SSM website is used to provide information on current events and authority decisions. SKB report series are made public as well and can be downloaded from www.skb.se.

In parallel with the licensing review and being the competent regulatory authority on nuclear activities, SSM participated in the Land and Environment Court's consultation process under Sweden's environmental legislation. This included submitting a consultation statement in June 2016 and giving independent testimony in a five-week public court hearing in September to October 2017.

In January 2018, both SSM and the Court submitted final review statements to the Government. Preceding the licensing decision, the Government has an obligation to consult with the host municipalities.

The key contributing features to a successful stakeholder engagement in the licensing process for a spent fuel repository in Sweden can be summarised as follows.

- The nuclear industry's shared obligation for the development of waste management and disposal solutions, manifested in SKB's RD&D programme, together with associated regulatory review, public consultations and Government approvals every three years.
- The financial provisions, including the re-calculation of fees to be paid to the Nuclear Waste Fund every three years, as well as continuous reimbursements for the RD&D programme progress, including spent fuel management.
- The clear allocation of responsibilities between nuclear power plant licensees and their implementing organisation SKB, the independent regulatory authority and the political decision level.
- The local municipalities' voluntary participation in the siting process and right to veto a decision by the Government to grant a licence for a nuclear installation.
- The plan for the formal process of consultation with stakeholders that a prospective licensee is required to submit in accordance with the requirements of the Environmental Code as part of the development of an environmental impact assessment (EIA).
- The open access to public information and dialogue with stakeholders in the licensing review under the nuclear activities act.
- The financial support provided to stakeholders through the Nuclear Waste Fund, which has made it possible for local host municipalities and certain environmental organisations to build their capacity to take an active part in formal consultations.

In practice, these provisions have been very beneficial to the overall quality and public confidence in the licensing process for a spent fuel repository. However, maintaining public trust and stakeholder confidence have been challenging at critical decision points during the licensing phase. For further information on measures taken to complete the licensing since the previous review meeting, see section K.1.1.

K.3.1.6 Effective regulatory review of decommissioning of nuclear reactors

Twelve commercial reactors were commissioned at the Ringhals, Forsmark, Oskarshamn and Barsebäck sites in southern Sweden between 1972 and 1985. The twin BWR units Barsebäck 1 and 2 were shut down permanently in 1999 and 2005. In 2015, the utilities decided to shut down the four oldest reactors at Oskarshamn (BWR units 1 and 2) and Ringhals (BWR unit 1 and PWR unit 2) before 2020, i.e. ahead of their estimated operating time. The Ågesta PHWR was permanently shut down in 1974.

The decommissioning strategy is immediate dismantling and operational as well as the regulatory control activities are financed through the National Nuclear Waste Fund.

Since the previous review meeting, SSM has arranged two workshop seminars a year on the various technical and regulatory issues of decommissioning, with between 80 and 100 industry participants. These meetings, with group discussions on selected topics and presentations by recognised experts, have greatly supported the dialogue, building of knowledge and adherence to regulatory requirements that is necessary for the safe and efficient decommissioning of Swedish reactors.

Essentially, a comprehensive regulatory system for decommissioning of nuclear facilities was already in place. However, certain adaptations and amendments to the requirements had to be made by SSM in order to facilitate for the operators to prepare their applications for decommissioning and supporting documents. SSM achieved this by issuing additional licensing conditions for the seven units which are permanently shut down or which will be shut down in the near future.

In 2017, and updated in 2018, SSM issued specific licence conditions for the decommissioning of the Barsebäck, Oskarshamn, Ringhals, and Ågesta reactors. These complement the provisions of SSM's general regulations concerning allowed preparatory decommissioning activities and the content of the safety documentation. SSM has also developed its regulations for the clearance of materials, building structures and sites. The licence conditions and enhanced regulations have facilitated the licensee's efficient preparation of safety reports and supporting documents for dismantling and demolition.

Preparatory decommissioning activities at the Oskarshamn and Barsebäck units and the Ågesta reactor have included the segmentation of reactor internals and radiological characterisation. In late 2019, all five reactors had received environmental licences for decommissioning from the Land and Environment Court, as well as authorisation from SSM to start large scale dismantling and demolition activities.

SSM's authorisation for the start of dismantling and demolition activities is based on regulatory review of the safety documentation and the environmental monitoring programme. The safety documentation basically consists of the safety report, the operational limits and conditions, the waste management documentation, and supporting documents such as the final decommissioning plan and the decommissioning strategy.

K.3.2 Challenges and areas of improvement

K.3.2.1 Management of radioactive waste from outside of the nuclear fuel cycle

The radioactive waste management system that has been established in Sweden throughout the years is primarily focussed on spent nuclear fuel and radioactive waste arising from the operation and decommissioning of nuclear power reactors. The general attitude regarding radioactive waste from hospitals, educational and research facilities and non-nuclear industries has been that the volumes and activities are so low that it can be managed within the system created for the management of spent nuclear fuel and nuclear waste. This is reflected in the one-off compensation payment that the Government in 1984 agreed to the predecessor of Cyclife Sweden AB, Studsvik Energiteknik AB, to cover future costs for disposal in SFR of radioactive waste originating from non-nuclear activities.

A holder of non-nuclear radioactive waste therefore relies on commercial solutions where waste management companies on a voluntary basis agree to manage and dispose of the waste. The companies involved have no obligation to receive non-nuclear radioactive waste for treatment, storage or final disposal. Holders of non-nuclear radioactive waste pay Cyclife Sweden AB to treat, store and dispose of radioactive waste. When Cyclife Sweden AB accepts to receive the waste, the company also assumes the responsibility for the waste. Cyclife has agreements with SKB for the disposal of radioactive waste in SFR, in the planned extended SFR and in the planned SFL.

By and large, this system has worked over the years. However, there are shortcomings which can make it a challenge for holders of non-nuclear radioactive waste to fulfil their statutory responsibility for the waste, both in the present and in the future:

- Cyclife Sweden AB is the only recognised radioactive waste management facility in Sweden for managing non-nuclear radioactive waste. It operates on a commercial basis and is not obliged to accept non-nuclear radioactive waste for management and disposal. Hence, if Cyclife for some reason denies to receive radioactive waste, the holder of the waste has no other waste management company to turn to.
- There are no designated storage facilities available, so a holder of non-nuclear radioactive waste which is denied by Cyclife Sweden AB has to store the waste on-site until further notice which in many cases is not an ideal situation.
- Long-lived radioactive waste typically cannot be disposed of in SFR, thus it has to be stored until SFL is in operation which will be in 2045 at the earliest. Because SFL is not yet constructed, the final costs for disposal in the repository are very difficult to determine today. Cyclife Sweden AB has indicated that it might be too much of a financial risk for them to assume responsibility for long-lived non-nuclear radioactive waste. Also, even though SKB has entered into agreements on final disposal of non-nuclear radioactive waste with both Cyclife and ESS for instance, these agreements do not mean that SKB will accept waste for disposal without reservation. SKB has no obligation to receive non-nuclear radioactive waste.
- Non-nuclear activities will continue to generate radioactive waste for many years to come, after both SFR and SFL have been closed. This has become particularly pronounced with the planning and construction of the ESS facility (see section A.8.1.8). The ESS facility is expected to produce considerable amounts of long-lived radioactive waste, both from operation and from decommissioning which will need to be disposed of in SFL. According to the timetable ESS will cease its operation in 2065, whereas SKB plans to have SFL closed by 2055.

K.3.2.2 Management of human resources and maintaining knowledge

The time horizon for the Swedish nuclear industry's current waste management plans extend until the latter part of the 21 century. This poses big challenges on the long-term planning of competence management and provision of human resources for the regulatory authority, the nuclear industry and the national educational system. The issue of complying with international requirements on the terms of relevant education programmes and national competence in the areas of radiation protection and safety was also a specific recommendation in the IRRS report of 2016.

In addition, the Swedish nuclear and waste management programme is currently moving into a phase of nuclear reactor decommissioning and step-wise implementation of disposal solutions. This transition involves challenges in securing the provision of relevant competence both in the short and long term.

Section K.1.4 describes the strategic planning and measures taken by the Swedish Government, the regulatory authority, the nuclear industry and educational institutions to address the above challenges.

K.4 Policy and plans for international peer review missions

As a Member State of the European Union, Sweden is required to periodically, and at least every 10 years, arrange for self-assessments to be made and invite international peer reviews of its national framework, competent regulatory authority, and/or national programme with the aim of ensuring that high safety standards are achieved in the safe management of spent fuel and radioactive waste. SSM has the task of submitting proposals to the Government on the appropriate time schedule for such assessments and international peer reviews. As described in section K.1.6, a follow-up IRRS mission was carried out in Sweden in 2016. Sweden is now planning for a new full-scope IRRS mission to be carried out in autumn 2022 and an ARTEMIS in spring 2023.

K.5 Actions to enhance openness and transparency in the implementation of the obligations under the Convention

The legal framework for the licensing and supervision of nuclear activities in Sweden also stipulates provisions on transparency, openness and public participation. As an example, the regulatory review of SKB's and the power plant licensees' triannual RD&D programmes, as well as SKB's and the authorities' consultation with stakeholders in connection with the licence applications for a spent fuel repository, provide opportunities for broad public participation in the development of a Swedish system for managing spent fuel and radioactive waste.

The siting and development of a spent fuel repository in particular has benefited from the provisions for an open, transparent and predictable pre-licensing and licensing process, with the active involvement of stakeholders. These provisions and the actions taken are described as strong features of the Swedish waste management system in section K.3.1.5.

Furthermore, according to the Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452), SSM is required to ensure that a current national plan is in place for the management of spent fuel and radioactive waste corresponding with the content required under Article 12 of Council Directive 2011/70/Euratom. In the process of developing or amending this plan, SSM should give appropriate representatives of relevant agencies, local authorities, the public and industry an opportunity to comment.

SSM publishes and makes the Swedish national reports of the Joint Convention publicly available on SSM's official website. SSM is also planning to publish questions and comments received from other contracting parties, including the responses to these questions. All documentation filed that relates to the production of each national report from Sweden is obtainable from SSM upon request in accordance with the Swedish principle of public access to official records.

Section L – Annexes

L.1 Summary of applicable regulations

A brief description is provided below of the Swedish Radiation Safety Authority's (SSM) regulations with relevance to the safe management of spent fuel and radioactive waste, presented by main areas of application. As considerable work has been carried out on revising the content and overall structure of SSM's Regulatory Code (see also sections A.6.5 and K.2.5).

L.1.1 General radiation protection safety regulations

L.1.1.1 Regulations on basic requirements on activities involving ionising radiation requiring permit (SSMFS 2018:1)

These regulations contain all basic and common requirements for activities with ionising radiation requiring a licence (in medicine, research, industry, and in the nuclear area). The regulation specifying requirements in the Radiation Protection Act and the Act on Nuclear Activities and has considered other international requirements and documents published by the International Commission on Radiological Protection (ICRP), the European Union (EU), the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA).

To each of the paragraphs there are a guidance explaining the purpose, background, considerations, application of the provision and references to the provisions.

The regulation contains basic provisions on e.g.:

- Risk Analysis
- Physical protection
- Emergency preparedness
- Management system
- Protection of workers
- Protection of the public and the environment
- Radioactive sources intended for exposure
- Radioactive waste
- Discharge of radioactive substances
- Decommissioning

L.1.1.2 Regulations on activities requiring notification (SSMFS 2018:2)

These regulations include activities that only need to be notified. This is an application of the principle of graded approach according to art. 24.1 Council Directive 2013/59/Euratom.

The regulations apply to the following activities; sealed and unsealed sources below certain activity levels, orthodontic and veterinary x-ray diagnostics, cabinet x-ray equipment, technical devices for measurement, control, analysis and laboratory use, microwave drying, medical solariums and professional trade in radiation sources, etc.

Basically the regulations have the same requirements as in SSMFS 2018: 1 but in a less extensive application.

L.1.1.3 Regulations and general advice concerning safety in certain nuclear facilities (SSMFS 2008:1)

These general regulations are primarily worded to apply to nuclear power reactors. However, because the application of the regulations is subject to a graded approach, the regulations are also applicable to all licensed nuclear facilities. This is regardless of the size or type of facility, i.e. research or materials testing reactors, fuel fabrication plants, facilities for handling and storage of spent nuclear fuel, and facilities for handling, storage or disposal of nuclear waste.

The purpose of the regulations is to specify the measures needed for preventing and mitigating radiological accidents, preventing illegal access to nuclear material and nuclear waste, and conducting efficient supervision. The regulations cover the following areas:

- Application of multiple barriers and defence in depth
- Response to detected deficiencies in barriers and the defence in depth
- Organisation, management and control of activities significant for safety
- Actions and resources for maintaining and developing safety
- Physical protection and emergency preparedness
- Basic design principles
- Assessment, review and reporting of safety
- Operations of the facility
- On-site management of nuclear materials and waste
- Reporting to SSM of deficiencies, incidents and accidents
- Documentation and archiving of safety documents
- Final closure and decommissioning
- For most of the requirements, general advice on their interpretation has been issued.

L.1.1.4 Regulations on radiation protection managers at nuclear power plants (SSMFS 2008:24)

According to these regulations, a licence holder is required to appoint a radiation protection manager at the facility in order to implement radiation protection conditions issued by the authorities and to supervise compliance with these conditions.

L.1.1.5 Regulations on filing at nuclear power plants (SSMFS 2008:38)

These regulations apply to filing of documentation that has been drawn up or received in connection with the operation of nuclear power plants. Certain documentation must be filed. If the practice ceases, the archives are required to be transferred to the National Archives of Sweden.

L.1.2 Regulations on final disposal

L.1.2.1 Regulations concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21)

These regulations, in force since 2002, contain specific requirements for design, construction, safety analysis and safety reporting of disposal facilities in view of the period after closure of the facility. For the period before closure, the general safety regulations (SSMFS 2008:1) apply.

The regulations concerning long-term safety for disposal of spent nuclear fuel and nuclear waste specifically cover:

- qualitative requirements for the barrier system
- scenario definitions and classifications
- timescales for the safety assessment (as long as barrier functions are needed to isolate and/or to retard dispersion of radionuclides, but for at least 10,000 years)
- topics to be covered in the safety report

L.1.2.2 Regulations and general advice on the protection of human health and the environment in connection with the final management of spent nuclear fuel and nuclear waste (SSMFS 2008:37)

These regulations apply to the disposal of spent nuclear fuel and nuclear waste. They are not applicable to landfills for low-level nuclear waste. The basic requirement is that human health and the environment shall be protected from detrimental effects of ionising radiation, during operation as well as after closure. Another important requirement is that impacts on human health and the environment outside Sweden's borders are not permitted to be more severe than those accepted in Sweden.

The regulations contain provisions on areas such as BAT and optimisation, the risk criterion and most exposed group, time periods for the risk analysis and demonstration of compliance for different time periods.

L.1.3 Regulations on or related to non-nuclear radioactive waste

L.1.3.1 Regulations on smoke detectors for domestic use containing radioactive sources (SSMFS 2008:47)

These regulations stipulate that the discarded units are to be collected and shipped for disassembly.

L.1.3.2 Regulations on smoke detectors for industrial use containing radioactive sources (SSMFS 2008:44)

These regulations stipulate that the disused units should be handled as radioactive waste and returned to the supplier or manufacturer.

L.1.4 Regulations on discharges and protection of workers and the public

L.1.4.1 Regulations on the protection of human health and the environment from discharges of radioactive substances from certain nuclear facilities (SSMFS 2008:23)

These regulations contain provisions on releases of radioactive substances from nuclear facilities during normal operation based on optimisation of radiation protection. Compliance is to be achieved by using the best available technique (BAT). The optimisation of radiation protection shall include all facilities located within the same geographically delimited area. The effective dose to an individual in the critical group of one year of releases of radioactive substances to air and water from all facilities located in the same geographically delimited area shall not exceed 0.1 millisievert (mSv).

L.1.4.2 Regulations on radiation protection of workers exposed to ionising radiation at nuclear power plants (SSMFS 2008:26)

These regulations contain provisions on limitation of exposures as far as reasonably achievable while having taken into account societal and economic factors. For this purpose, the licence holder must ensure that goals and needed actions for control are established and documented and that the needed resources are available.

L.1.5 Regulations on emergency preparedness, physical protection and safeguards

L.1.5.1 Regulations on emergency preparedness at certain nuclear facilities (SSMFS 2014:2)

These regulations apply to the planning of emergency preparedness and radiation protection measures in the event of an emergency or a threat of an emergency at nuclear facilities.

The regulations contain provisions on planning of emergency preparedness, alarm criteria and alarms, premises, assembly stations, iodine tablets, personal protection equipment, evacuation, education and training, radiation surveillance, filtration, meteorology data, etc.

Additional provisions on emergency preparedness are stipulated in the regulations (SSMFS 2008:1) of the Swedish Radiation Safety Authority concerning safety in nuclear facilities.

L.1.5.2 Regulations on physical protection of nuclear facilities (SSMFS 2008:12)

These regulations contain requirements on organisation of physical protection, clearance of staff, tasks for security staff, central alarm station, perimeter protection, protection of buildings, protection of compartments vital for safety, access control for persons and vehicles, protection of control rooms, communication equipment, searching for illegal items, handling of information about the physical protection, and IT security. Design details about the physical protection are to be reported in a classified attachment to the SAR of the facility.

L.1.5.3 Regulations on the control of nuclear material, etc. (SSMFS 2008:3)

These regulations apply to the measures required to meet the obligations resulting from Sweden's agreements in order to prevent proliferation and unauthorised dealing with nuclear fuel, spent nuclear fuel placed in the final repository, nuclear equipment and related software and technology.

L.1.6 Regulations on clearance and exemption

L.1.6.1 Regulations on exemptions from the Radiation Protection Act and on clearance of materials, building structures and areas (SSMFS 2018:3)

These regulations contain provisions on the clearance of materials, rooms, buildings and land that have been used in practices involving ionising radiation.

L.1.7 Regulations on shipments and reporting

L.1.7.1 Regulations on the control of transboundary shipments of radioactive waste and spent nuclear fuel (SSMFS 2009:1)

These regulations apply to transboundary shipments of radioactive waste and spent nuclear fuel within the European Union as well as from or to the European Union, provided that Sweden is the country of origin, country of destination or country of transit.

The regulations, which implement Council Directive 2006/117/Euratom, require prior authorisation for moving radioactive waste and spent fuel across borders if the item is being sent from, through, or to an EU country.

L.2 List of acronyms

ALARA	As Low As Reasonable Achievable (a principle applied in radiation protection)
ATB 1T	Waste container for transportation of long-lived low and intermediate level waste
AM	Interim storage for low and intermediate level waste (Studsvik site)
AU	Storage facility for radioactive waste (Studsvik site)
AV	Swedish Work Environment Authority
BAT	Best Available Technique
BFA	Rock Cavern for Waste (Oskarshamn site)
BKAB	Barsebäck Kraft AB
BLA	Rock vault for low level waste (part of the SFR facility)
BMA	Rock vault for intermediate level waste (part of the SFR facility)
BSS	Basic Safety Standards
BTF	Rock vault for concrete tanks (part of the SFR facility)
BWR	Boiling Water Reactor
Clab	Centralt Lager för Använt Bränsle (central interim storage facility for spent fuel)
Clink	Integrated central interim storage facility and encapsulation plant
ConvEx	IAEA Convention Exercises
ECURIE	European Community Urgent Radiological Information Exchange
EIA	Environmental Impact Assessment
ENSREG	European Nuclear Safety Regulators Group
EU	European Union
FOI	Swedish Defence Research Agency
FR0-A	Treatment facility for radioactive non-nuclear waste (Studsvik site)
HA	Incineration facility (Studsvik site)
HCL	Hot Cell Laboratory (Studsvik site)
HELCOM	The Helsinki Commission
HERCA	Heads of European Radiation Control Authorities
HRL	Hard Rock Laboratory
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IGD-TP	Implementing Geological Disposal of radioactive waste Technology Platform
INES	International Nuclear Event Scale
INEX	OECD/NEA International Nuclear Emergency Exercises
INRA	International Nuclear Regulators' Association
IRRS	Integrated Regulatory Review Service
ISO	International Standard Organisation
KBS-3	Proposed method for disposal of spent nuclear fuel
KTH	Kungliga Tekniska Högskolan (Royal Institute of Technology)
LER	Licensee Event Report
LILW	Low and Intermediate Level Waste
LLW	Low Level Waste
MOX	Mixed oxide fuel
MSB	Swedish Civil Contingencies Agency
MTO	Interaction between Man, Technology and Organisation
NBHW	National Board of Health and Welfare
NEA	Nuclear Energy Agency within the OECD
NESA	National Expert Council on Remediation
NGO	Non-Governmental Organisation
NORM	Naturally Occurring Radioactive Materials
NORMAN	Nordic manual for cooperation between the respective regulators in the five Nordic countries of Denmark, Finland, Iceland, Norway and Sweden in response to and preparedness for nuclear and radiological emergencies and incidents
NPP	Nuclear Power Plant (including all nuclear power units at one site)
OECD	Organisation for Economic Cooperation and Development
OKG	Oskarshamns Kraftgrupp AB
OLC	Operational Limits and Conditions
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PHWR	Pressurised Heavy Water Reactor
PSAR	Preliminary Safety Analysis Report/Preliminary Safety Report
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
QA	Quality Assurance
R0-A	Treatment facility for radioactive non-nuclear waste (Studsvik site)
RadGIS	Radiation Geographical Information System software for reporting, storing, extracting and visualising radiation monitoring data and environmental samples collected during an emergency
RANET	Response and Assistance Network
RD&D	Programme for Research, Development and Demonstration
RN-MEG	Nuclear Medical Expert Group
RO	Reportable Occurrence
SAR	Safety Analysis Report/Safety Report
SFA	Swedish Food Agency
SFL	Disposal facility for long-lived low and intermediate level waste
SFR	Disposal facility for short-lived low and intermediate level waste
SKB	Swedish Nuclear Fuel and Waste Management Company
SKI	Swedish Nuclear Power Inspectorate
SMA	Melting facility (Studsvik site)
SMHI	Swedish Meteorological and Hydrological Institute
SNAB	Studsvik Nuclear AB
SR-Site	Long-term safety assessment for the spent fuel repository
SSI	Swedish Radiation Protection Authority
SSM	Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority)
SSMFS	SSM's Regulatory Code
STUK	Finnish Nuclear and Radiation Safety Authority
SVJ	Swedish Board of Agriculture
TSO	Technical Support Organisation
USIE	Unified System for Information Exchange in Incidents and Emergencies
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association
VLLW	Very Low Level Waste
WSE	Westinghouse Electric Sweden AB
WTD	Waste Type Description

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Figure L1 This report has been produced by a working group of representatives from the Swedish Radiation Safety Authority (SSM) and with the support of the Swedish Nuclear Fuel and Waste Management Company (SKB). The team collaborates while keeping distance to avoid the spread of covid-19.

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