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Swedish Radiation Safety Authority

2015:32

Safe and responsible management of spent nuclear fuel and radioactive waste in Sweden

Notification of the Swedish National Programme under the Council Directive 2011/70/Euratom (National Plan)

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Authors: Flavio Lanaro (project leader), Erica Brewitz, Jon Brunk,
Nicklas Carlvik, Bengt Hedberg, Björn Hedberg, Anna Mörtberg,
Helena Ragnarsdotter Thor, Helmuth Zika

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Foreword

Under the Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452), the Swedish Radiation Safety Authority, or SSM, is responsible for implementing and keeping an up-to-date national plan for management of nuclear materials not intended to be reused, nuclear and other radioactive waste. This plan must contain the accounts necessary under Article 12 of Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

The present national plan report provides an overall account of Swedish policy, the organisational and legal framework, in addition to the strategies governing management of spent nuclear fuel and radioactive waste occurring in Sweden, today and in the future. The national plan is considered to be in accordance with the requirements of the Directive for national frameworks and national programmes and encompasses Sweden's reporting of all the items stated in Article 12 of the Directive. The national plan, with its main references, constitutes the established Swedish National Programme under the Council Directive 2011/70/Euratom.

For a more detailed description of the objectives, milestones, strategies and plans, please refer to the underlying reports produced on a regular basis within the frameworks of the national environmental objectives system, the programme for research, development and demonstration activities from the nuclear power industry (the RD&D Programme), and the financing system (Plan Cost Estimates) for the area of nuclear waste management.

A presentation is made in the national plan covering quantities of spent nuclear fuel and radioactive waste produced in Sweden, as well as estimated quantities for the future. The intention is to carry out yearly updates and making available current statistics of movements of waste in not only the nuclear engineering sector, but also non-nuclear activities.

In the work on production of the national plan, the Authority provided opportunities for representatives of the relevant central and local government authorities, the general public and the business community to forward their viewpoints. A draft version of the national plan was made available on the Authority's website on 9 March 2015. Viewpoints could be submitted directly to SSM by 30 April 2015 or, alternatively, in connection with a public seminar held at SSM's premises on 26 March 2015. The seminar was attended by around 50 representatives of 36 organisations.

The national plan was produced by officers Flavio Lanaro (project manager), Erica Brewitz, Jon Brunk, Nicklas Carlvik, Bengt Hedberg, Björn Hedberg, Helena Ragnarsdotter Thor and Helmuth Zika, in addition to Senior Legal Adviser Anna Mörtberg. The English translation was carried out by Anders Moxness.

The steering group for the project comprised Department Director Johan Anderberg, Heads of Section Elisabeth André Turlind, Svante Ernberg, Ansi Gerhardsson and Christer Sandström, and Chief Legal Officer Ulf Yngvesson.

SWEDISH RADIATION SAFETY AUTHORITY

Johan Anderberg
Department Director

Stockholm, 20 August 2015

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Summary

Assignment

The Swedish Radiation Safety Authority (SSM) is responsible for the maintaining of an up-to-date national plan for management of nuclear material not intended to be reused, and nuclear and other radioactive waste. This plan must contain the accounts necessary under Article 12 of Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.

The present national plan provides a comprehensive account of established general principles in Sweden (*national policies*), the organisational and legal framework (*national framework*) in addition to the strategies (*national programme*) governing management of all kinds of radioactive waste occurring in Sweden, today and in the future. A presentation is also made covering quantities of spent nuclear fuel and radioactive waste as well as estimates of future quantities. The national plan, with its main references, constitutes the established Swedish National Programme notified under the Council Directive 2011/70/Euratom.

Waste from activities and practices involving radiation

Since the early 1970s, Sweden has used nuclear power produced by Swedish reactors as part of the national energy mix. Nuclear power companies are obliged to bear both the costs linked to radioactive residual products as well as management of their waste.

Today, Sweden has an effective system for taking care of this nuclear waste. Since the mid-1980s, facilities have been in operation for final disposal of short-lived operational waste (SFR) and interim storage of spent nuclear fuel (Clab). Since the 1970s, the Swedish Nuclear Fuel and Waste Management Company (SKB) has also worked on development of a method for safe handling, management and disposal of spent nuclear fuel over long spaces of time. In March 2011, a licence application was submitted by SKB concerning a system to deal with encapsulation and final disposal of spent nuclear fuel. The application is being examined by SSM and the Land and Environmental Court in preparation for the Government of Sweden's decision concerning permissibility of the disposal system under the Swedish Environmental Code and granting a licence under the Act on Nuclear Activities. The authorities have plans to submit their statements to the Government in 2017. In December 2014, SKB also submitted a licence application for permission to extend SFR for final disposal of waste from decommissioning and dismantling of nuclear facilities.

Radioactive waste is not solely generated when producing electrical power. It is also generated during different stages of industrial, agricultural, medical and research activities. There are thousands of operations and activities in Sweden that use unsealed and sealed radiation sources. Under the Radiation Protection Act, the activities that deal with radiation sources are also responsible for final management of the produced waste. Most sealed radioactive sources to be treated as waste are either returned to the manufacturer or managed by Studsvik Nuclear AB. For certain

kinds of radiation sources, either unsealed or sealed, there is presently no effective national system in Sweden established for their treatment and final disposal.

Policies for waste management

The fundamental principles for management of spent nuclear fuel and radioactive waste have evolved in pace with the emergence of the Swedish nuclear energy programme. Against the background of the 1970s' nuclear energy debate, several decisions in principle were taken on the political course and amendments were implemented in the legislation.

These are the key fundamental principles implemented in the legislation:

- A party that has generated spent nuclear fuel and radioactive waste is also required to bear the costs for managing these residual products,
- The main responsibility for safety in connection with management and final disposal of spent nuclear fuel or radioactive waste rests with the licensee of the facility that generated the waste,
- The State has the ultimate responsibility for management of spent nuclear fuel and radioactive waste generated in Sweden, and
- Each country is to be responsible for the spent fuel and radioactive waste generated from nuclear activities in that country. The disposal of spent nuclear fuel and nuclear waste in a foreign country is not allowed in Sweden other in exceptional cases.

Implementation of these fundamental principles for management and final disposal of spent nuclear fuel and radioactive waste in the Act on Nuclear Activities and Radiation Protection Act also implies fulfilment of the leading principle of the Environmental Code, which states that any party that gives rise to environmental damage must also bear the cost of the necessary measures for preventing or dealing with the detriment (the 'Polluter Pays Principle').

The political orientation vis-à-vis management of spent nuclear fuel is direct final disposal without being preceded by reprocessing. Thus, the spent fuel is in practice dealt with as radioactive waste and not viewed as a resource in the Swedish system.

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 and which are not intended to be reused are safely managed and disposed of in a repository. This obligation signifies an extensive commitment on the part of a licensee until a final disposal facility for this waste has been ultimately closed. When all obligations have been performed and discharge from liability has been approved by the Government of Sweden, the long-term liability will rest with the State.

Parties licensed to own or operate a nuclear power reactor are subject to a particular obligation to carry out the following in consultation with other licensees of nuclear power reactors:

- Preparing a programme for the comprehensive research, development and demonstration work and the other measures necessary for safe management of nuclear waste and spent nuclear fuel, in addition to safe decommissioning and dismantling of nuclear facilities (i.e. the RD&D Programme), and

- Preparing a cost estimate as input for calculating the fees to be payable to the Nuclear Waste Fund for management of these residual products from nuclear activities (i.e. the Plan Cost Estimates).

In order to fulfil these obligations, the reactor licensees established SKB as the company to be in charge of preparing and submitting to the Authority the nuclear power industry's joint RD&D programme and cost estimate. Today, SKB is also the licensee responsible for all handling, management, transports and interim storage of spent nuclear fuel and nuclear waste outside the nuclear power facilities, including operations of the facilities Clab and SFR.

SKB's application for a spent nuclear fuel repository is based on the conceptual design of a deep geological repository having passive safety systems. The method chosen is to fulfil SSM's regulatory requirements implying that a repository must have a design minimising impact on the surrounding environment. The radiation risk per year is not allowed to exceed one-hundredth of the human exposure risk posed by natural radiation in the environment. The repository's design must have resilience against conditions, events and processes that can lead to contamination by radioactive substances. This is to be achieved in the form of a system comprising several passive barriers whose function is to contain, prevent and impede contamination by radioactive substances prior to and after closure of the repository.

By means of communication and transparency, SSM contributes towards public insight into all operations encompassed by the Authority's mandate. The general public's opportunities for effective participation as part of the decision-making process for management of spent nuclear fuel and radioactive waste are, for instance, ensured by their potential involvement in a consultation procedure required within the Authority's review of the RD&D programme and cost estimates. This means that special interest groups are involved in the pre-licensing phase of nuclear facilities. Furthermore, an environmental impact assessment (EIA) must be produced. It must contain a formal plan and an account of the consultation process with relevant interested parties prior to a licence application. A special-purpose solution for financing also ensures that non-profit associations can actively take part in the consultation process for a spent nuclear fuel repository. This has contributed immensely to the level of quality, openness and insight in the licensing processes. What's more, the right of municipal authorities to exercise a veto at community level means that local residents can prevent the establishment of undesired nuclear activities in their area. This factor is of great significance when it comes to the general public's confidence in the licensing process.

Nuclear activities must be run in a way so that the quantity of nuclear waste and its content of radioactive substances are limited as far as reasonably possible. Optimisation and applying best available technique are to characterise final management of spent nuclear fuel and nuclear waste. Non-nuclear activities are subject to the provisions of the Swedish Environmental Code on promoting sustainable development, reuse and recycling, as well as other conservation of materials, commodities and energy.

The national framework

The role of central government authorities in the democratic Swedish system is to implement political decisions and to ensure compliance with legislation and rules. Swedish authorities have an independent role and extensive powers to determine how their own tasks are to be performed. The authorities are also autonomous as part of their exercise of public power in relation to individuals and in the context of

applying legislation. This independence is a crucial component of the Swedish model, which contributes towards public administration that is efficient, effective and follows the rule of law.

SSM is the Government's administrative authority responsible for areas concerning the protection of human health and the environment against the harmful effects of ionising and non-ionising radiation, for issues concerning safety, security and physical protection in nuclear and other activities involving radiation and also for matters concerning nuclear non-proliferation. SSM's tasks include the following: a) promoting radiation safety in society; b) working for prevention of radiological accidents; c) ensuring safe operation and waste management as part of nuclear activities; d) minimising the risks posed by radiation used in medical applications and optimising these outcomes; e) minimising the risks posed by radiation used in products and services, or which arise as a side effect when using products and services; f) minimising the risks posed by exposure to naturally occurring radiation; and g) improving radiation safety internationally.

SSM is also tasked with working for achievement of the generational goals for environmental work and the environmental quality objectives laid down by the Riksdag (i.e. the Swedish Parliament) and, as required, proposing measures for development of the environmental work and coordinating follow-ups, evaluations and reporting relating to the environmental quality objective 'A Safe Radiation Environment'.

SSM's fundamental values are based on a vision of a society safe from the harmful effects of radiation: its mission statement on working proactively and preventively in order to protect people and the environment from these effects, in addition to the Authority's three key values of reliability, integrity and openness. *Reliability* means pursuing this work on the basis of facts. *Integrity* means the Authority taking responsibility and maintaining its independence. This implies avoiding undue influence when it comes to the exercise of public power. *Openness* means that the work of the Authority is transparent to the outside world, which the general public has insight into its operations and that SSM clearly and proactively provides information about its work, standpoints and decisions.

Several other central government authorities, also Swedish courts, County Administrative Boards and local municipal authorities, have tasks and roles that pertain to activities and practices involving radiation.

The framework of Swedish legislation in the areas of waste management, nuclear safety and radiation protection consists of five principal enactments with appurtenant ordinances:

1. The Act on Nuclear Activities (1984:3),
2. The Radiation Protection Act (1988:220),
3. The Swedish Environmental Code (1998:808),
4. The Act on Financing of Management of Residual Products from Nuclear Activities (2006:647; also referred to as the 'Financing Act'), and
5. The Act on Financing of Management of Certain Radioactive Waste, etc. (1988:1597; also referred to as the 'Studsvik Act'.

The general principles governing safety and radiation protection are defined in the Act on Nuclear Activities, Radiation Protection Act and Environmental Code. The

provisions contained in these enactments are supplemented by ordinances and official regulations containing more detailed provisions.

The Act on Nuclear Activities contains the fundamental conditions pertaining to safety in connection with nuclear activities, and encompasses not only management of nuclear materials and nuclear waste, but also operation of facilities. The stipulated objective of safety work is to as far as possible eliminate the risk of a radiological accident and thus, ultimately, the loss of life and property. This is why the Act on Nuclear Activities has been formulated to give licensees a virtually strict liability when conducting nuclear activities. The Act contains the key provisions governing management and final disposal of spent nuclear and fuel nuclear waste.

The purpose of the Radiation Protection Act is to protect people, animals and the environment against harmful effects of both ionising and non-ionising radiation. It is a general safety enactment that basically encompasses all operations relating to aspects of radiation protection, such as medical services, research work and other non-nuclear industry. Thus, the Act also regulates important aspects of radiation protection in connection with work in the field of nuclear energy. The Radiation Protection Act is a key enactment for protection of workers engaged in operations involving ionising radiation. Parties conducting activities involving radiation are also responsible for ensuring that the radioactive waste occurring in their operation is managed and disposed of in a way that is satisfactory from the standpoint of radiation protection. This responsibility includes covering costs related to management, storage and disposal of this waste.

The purpose of the Swedish Environmental Code is to protect the environment and human health against environmentally hazardous activities and to promote sustainable development implying that present and future generations are ensured a healthy and sound environment. Nuclear facilities and certain complex facilities whose work involves radiation are to be viewed as operations that are environmentally hazardous and thus subject to the rules of the Code. Under the Code, SSM is the supervisory authority when it comes to detriment due to ionising and non-ionising radiation from nuclear activities and practices involving radiation that also require a licence according to the Code's rules. SSM is also tasked with giving guidance as part of County Administrative Board and municipal supervisory work relating to areas contaminated by radioactive substances.

The Financing Act contains provisions on defraying future costs for disposal of spent nuclear fuel as well as decommissioning, dismantling and demolition of nuclear power plants and other nuclear facilities. A party licensed to own or operate a nuclear facility must pay fees to the State, which reserves the assets in the Nuclear Waste Fund. Licensees also have an obligation to pledge assets as collateral for costs not covered by the fee payments. The purpose is to, as far as possible, minimise the risk of the State being forced to bear the types of costs encompassed by the licensees' payment liability.

Under the Studsvik Act, this financial responsibility applies to final management of legacy waste and facilities whose origin is related to the emergence of the Swedish nuclear power industry. Under the Act, an entity licensed to own and operate a nuclear power reactor is liable to pay a fee to the State in order to defray costs related to this kind of management. The Studsvik Act will, in accordance with current legislation, cease to apply at the end of 2017.

Under the Act on Nuclear Activities or Radiation Protection Act, a licence is required for conducting nuclear activities or extensive operations involving radiation, in addition to a permit under the Swedish Environmental Code. In other words, this implies that an activity undergoes a review in two stages. A nuclear licence is only applicable for the purpose and application deriving from the licensing decision. The Government of Sweden, or in certain cases SSM, examines matters concerning licences. Licensing reviews include application of the Environmental Code's general rules of consideration and provisions on environmental impact assessments. In cases where an activity is subject to Government approval, SSM processes the matter on the behalf of the Government. During its preparation of the matter, the Authority needs to consider whether the activity is likely to be sited, designed and conducted in a way fulfilling requirements imposed for safety, radiation protection and physical protection.

As a rule, activities involving radiation require a licence. The Radiation Protection Act contains provisions regulating the general obligations of parties conducting activities involving radiation. Applications seeking permission to conduct activities and practices involving radiation are considered by SSM. The licensing work of the Swedish Radiation Safety Authority on the part of complex non-nuclear facilities must primarily be of the same scope and orientation as licensing work on the part of nuclear facilities.

The processes of designing, constructing and commissioning nuclear facilities and other complex installations where ionising radiation is used take a long time to complete. This is also the case for major modifications to existing facilities of these types. Depending on the type of facility, detailed design documents are not usually available by the time applications are submitted. Also, conceivable design solutions can change over time. Problems can also arise during the construction or facility modification phase, leading to other necessary adjustments. This is why a review process in steps is needed; this is also in compliance with international practice. A continued review process after a licence has been issued for construction, owning and operating a facility encompasses approval granted in steps prior to construction, test operation, routine operation and decommissioning. Each step involves reviewing the safety analysis report that is to be updated and kept up-to-date for the respective step.

Together, the Act on Nuclear Activities and Radiation Protection Act give SSM a mandate to exercise regulatory supervision in terms of radiation safety in Sweden, i.e. nuclear safety, radiation protection, physical protection, security and non-proliferation control. Both Acts also empower SSM to impose sanctions when exercising this supervision. SSM is the supervisory authority, as stipulated by the Swedish Environmental Code, as far as concerns nuclear activities and activities involving radiation that require a licence under the Code, and for this reason has the powers to issue sanctions in accordance with the Code.

A prerequisite for ensuring that all steps as part of the management chain for handling and final disposal of spent nuclear fuel and nuclear waste are coordinated and compatible with the planned solution for disposal is that licensees of facilities where spent nuclear fuel and nuclear waste occur produce plans for waste management. These plans must cover all the subsequent steps of this process up until final placement in a repository that is ultimately closed. These plans are to serve as the basis of the licensees being allowed to establish during a step-wise process the criteria for waste receipt and the processes required to enable a system of control to ensure that spent nuclear fuel and nuclear waste leaving a licensee's

facility fulfil the requirements imposed for receipt criteria at the facility to which the spent nuclear fuel or radioactive waste is delivered.

There is an established national emergency response plan that has a special focus on the role and approach of authorities in Sweden as regards impact management following a release and covering decontamination waste in both the short and long term after a radiological or nuclear accident. The emergency response plan defines how to deal with an accident at a Swedish facility, or one outside Sweden that has an impact on Sweden's territory.

Main references to the national programme

The comprehensive national systems, whose regimes of control and content can, in the assessment of SSM, meet the Council Directive 2011/70/Euratom's requirements for a national programme, mainly comprise:

- The System of Environmental Objectives
- The programme for research, development and demonstration (the RD&D Programme),
- The cost estimates (the Plan Cost Estimates)

SSM is the national authority in Sweden responsible for the environmental quality objective 'A Safe Radiation Environment', which implies that human health and biological diversity must be protected against the harmful effects of radiation. Besides annual follow-ups of achievement of objectives, around every fourth year, an in-depth evaluation is made as input for the Government of Sweden's environmental policy bill. This follow-up assesses whether today's means of control and measures are sufficient for achieving the objectives and proposes additional actions as necessary. The most recent in-depth evaluation is from 2012. A new in-depth evaluation of the environmental quality objectives will be presented in 2015.

In the tenth and most recent RD&D programme (the RD&D Programme 2013), SKB accounts for the continued research work and technical advances needed to enable design, development and operation of planned facilities, also for the purpose of maintaining safe operation of existing facilities. According to SSM's statement to the Government of Sweden on the RD&D Programme 2013, this programme's orientation meets the requirements imposed by the Act on Nuclear Activities. SSM has established that the presentation of the programme pertaining to disposal of long-lived radioactive waste, in addition to decommissioning plans and dismantling studies, have demonstrated good development in relation to previous RD&D programmes, but that the presentation should be developed further in terms of decommissioning of facilities. In November 2014, the Government took its decision about approving the programme as recommended and proposed by the Authority.

In the same way, SSM performs reviews of SKB's Plan Cost Estimates within the framework of the financing system. SSM has reviewed Plan Cost Estimates issued in 2013 and, in a statement to the Government, proposed the fees to be paid by the reactor licensees to the Nuclear Waste Fund in addition to the guarantees to be provided by these licensees for costs not yet covered by the payments made to date. The decision of the Government, which is as proposed by the Authority, implies that the fee payable by the nuclear power industry to the Nuclear Waste Fund is increased from today's average rate of 2.2 öre per kilowatt hour (kWh) of nuclear power produced to 4.0 öre per kWh for the period 2015-2017.

Other tools used for following up and improving the comprehensive national systems include reviews of safety analysis reports, self-evaluations of the Swedish system, international peer reviews, international co-operation and further development of national rules.

Waste quantities and forecasts

Sweden has a waste classification scheme for radioactive waste that has been developed by the nuclear power industry (SKB). This scheme's platform is based on the final destinations of the waste.

The following quantities are currently in storage as defined by SKB's waste classification scheme as for year 2013:

- 21,717 m^3 of short-lived, very low level waste present in shallow land disposal facilities for nuclear waste or awaiting placement in this kind of facility,
- 17,734 m^3 of short-lived, low level waste in the SFR repository's sections BLA and BTF, or present at Swedish nuclear facilities awaiting final disposal in SFR,
- 24,159 m^3 of short-lived, intermediate level waste in the SFR repository's sections BTF, BMA and Silo, or present at Swedish nuclear facilities awaiting final disposal in SFR,
- 8400 m^3 of long-lived, low and intermediate level waste at the nuclear facilities awaiting final disposal in the planned repository for long-lived waste (SFL), and
- 6,296 tonnes U of high level waste that is in interim storage (spent nuclear fuel).

The projected future quantities of waste that will be in storage in the year 2076 (within the parameters of the present reactors' lifetimes) are as follows:

- 68,000 m^3 of short-lived operational waste in the SFR repository,
- 84,000 m^3 of waste from dismantling and demolition of the extended section of SFR,
- 16,000 m^3 of long-lived low and intermediate level waste in SFL, and
- 12,000 tonnes U of high level waste in the repository for spent nuclear fuel.

1. Introduction

1.1. **Background**

As a consequence of Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, the Swedish Radiation Safety Authority (SSM) has a mandate from the Government of Sweden for ensuring the maintaining of an up-to-date national plan for management of nuclear materials not intended to be reused, nuclear and other radioactive waste. Such plan must contain the accounts necessary under Article 12 of the Directive.

An additional factor is that in 2009[1], within the framework of the System of Environmental Objectives and a Government assignment, SSM produced a national plan for safe management of all radioactive waste up until 2020. This plan provided overall accounts of the entire waste management system, inventories of waste, waste streams, stakeholders and allocation of responsibility, as well as specific measures proposed for managing non-nuclear radioactive waste. The present report has been developed further from the previous plan in terms of fulfilling the requirements imposed for reporting stated by Council Directive 2011/70/Euratom.

In its work involving drawing up or updating this plan, SSM is to provide suitable opportunities for representatives of the relevant central and local government authorities, the general public and the business sector to submit their viewpoints. SSM is mandated to notify the content of the Swedish National Programme to the European Commission. The present national plan, with its main references, constitutes the established Swedish National Programme that is notified under the Council Directive 2011/70/Euratom.

1.2. **Council Directive 2011/70/Euratom**

The aim and objective of Council Directive 2011/70/Euratom is to establish a Community framework for ensuring responsible and safe management of spent fuel and radioactive waste for the purpose of avoiding any undue burden on future generations. According to the Directive, Member States must provide for appropriate national arrangements for a high level of safety in spent fuel and radioactive waste management to protect workers and the general public against the dangers arising from ionising radiation. Member States must also ensure the provision of necessary public information and participation in relation to decision-making on spent fuel and radioactive waste management while having due regard to security and proprietary information issues.

[1] SSM report 2009:29, 2009. *Nationell plan för allt radioaktivt avfall* [Swedish national plan for the management of all radioactive waste], Swedish Radiation Safety Authority (SSM)

Each Member State shall establish and maintain a *national policy*. SSM interprets these national policies as generally worded principles and objectives, according to which Member States are to carry out their work. Furthermore, under the Directive, each Member State is required to establish and maintain a *national framework* for spent fuel and radioactive waste management. This framework comprises a legal, regulatory and organisational system allocating responsibilities and establishing liaison between the relevant appointed bodies. Lastly under the Directive, Member States must have *national programmes* for the implementation of national policy. SSM has interpreted this as strategies and programmes for enabling implementation of national policies in practice.

The Directive reinforces three principles: the principle of national responsibility, the principle of prime responsibility of the licence holder for the safety of spent fuel and radioactive waste management, also the principle of the role and independence of the competent regulatory authority. The main proportion of the Directive's requirements at the time of this Directive's implementation was deemed to be fulfilled through pre-existing provisions contained in Swedish legislation.[2] Amendments to the legislation owing to implementation of the Directive are limited to prescribed authorisation for final disposal of Swedish spent fuel or radioactive waste in a foreign country.

1.2.1. Requirements on national programmes

Under Article 5 of Council Directive 2011/70/Euratom, the national framework is required to encompass national programmes for implementation of the national policies directed at safe and responsible management of spent fuel and radioactive waste.

Under Article 12 of Council Directive 2011/70/Euratom, national programmes are required to contain all the elements a) to i) below. For each element there is a reference to the relevant Chapters of the present report:

a) The overall objectives of the Member State's national policy in respect of spent fuel and radioactive waste management (Chapter 2);

b) The significant milestones and clear timeframes for the achievement of those milestones in light of the overarching objectives of the national programme (Chapters 4, 5 and 7);

c) An inventory of all spent fuel and radioactive waste and estimates for future quantities, including those from decommissioning, clearly indicating the location and amount of the radioactive waste and spent fuel in accordance with appropriate classification of the radioactive waste (Chapter 6);

d) The concepts or plans and technical solutions for spent fuel and radioactive waste management from generation to disposal (Chapters 4, 5 and Section 7.2);

e) The concepts or plans for the post-closure period of a disposal facility's lifetime, including the period during which appropriate controls are retained and the means to be employed to preserve knowledge of that facility in the longer term (Sections 2.2 and 7.2);

[2] *Genomförande av Rådets direktiv 2011/70/Euratom* [Implementation of Council Directive 2011/70/Euratom], SSM2012-1246, Swedish Radiation Safety Authority (SSM)

f) The research, development and demonstration activities that are needed in order to implement solutions for the management of spent fuel and radioactive waste (Sections 7.2);

g) The responsibility for the implementation of the national programme and the key performance indicators to monitor progress towards implementation (Chapters 3 and 8);

h) An assessment of the national programme costs and the underlying basis and hypotheses for that assessment, which must include a profile over time (Sections 7.2 and 7.3);

i) The financing scheme(s) in force (Chapter 3 and Section 7.3);

j) A transparency policy or process as referred to in Article 10 (Sections 2.11, 3.4 and 7.2);

k) If any, the agreement(s) concluded with a Member State or a third country on management of spent fuel or radioactive waste, including on the use of disposal facilities (Section 2.4).

According to the Directive, national programmes may, together with the national policy, be reported on in a single document or as part of several different documents.

1.3. **The national plan and programme**

The present national plan 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 management of spent nuclear fuel and all kinds of radioactive waste occurring in Sweden – today and in the future.

The national plan, with underlying reports (main references) that are referenced to in Chapter 7, constitute the materials to be notified to the European Commission as Sweden's established national programme under Article 13 of Council Directive 2011/70/Euratom.

1.3.1. Main references to the National Programme

The comprehensive national system, whose regimes of control and contents are, in the assessment of SSM, capable of meeting the Directive's requirements for a *national programme*, mainly comprises:

- The System of Environmental Objectives
- The programme for research, development and demonstration (the RD&D Programme)
- The financing system and cost estimates (the Plan Cost Estimates).

In regularly recurring Government Bills on environmental policy, the Government and Riksdag (i.e. Swedish parliament) adopt a standpoint on the analyses and proposed measures and strategies produced as part of work on the environmental quality objectives and in the regularly recurring in-depth analyses of public authorities in charge of the respective objectives. SSM is the national authority in

Sweden responsible for the environmental quality objective 'A Safe Radiation Environment'.

Swedish reactor licensees are, under the Act on Nuclear Activities (1984:3), under an obligation to present every third year a joint research, development and demonstration programme (the RD&D Programme) for management of spent nuclear fuel and nuclear waste. The principal aim of the RD&D Programme is to serve as a tool and means of control for translating the overarching principles and strategy for managing residual products from production of nuclear power in Sweden into defined objectives, activities, organisations and facilities. Waste streams from nuclear and non-nuclear activities in Sweden make use of shared and integrated solutions for management, storage and disposal, which are accounted for in the RD&D Programme.

The Swedish Nuclear Fuel and Waste Management Company, or SKB, a company owned jointly by the licensees of nuclear power reactors, is in charge of this programme. SSM reviews the RD&D Programme and may propose conditions for the ongoing RD&D process. The Government of Sweden decides on the extent to which the RD&D Programme is fit for purpose in line with the State's overarching principles and strategies.

In the same way, within the framework of the financing system, SSM performs reviews of cost estimates (Plan Cost Estimates) produced on a regular basis by the reactor licensees and SKB for managing spent nuclear fuel and nuclear waste, in addition to estimates for future dismantling of nuclear power plants under the Financing Act. SKB's Plan reports serve as input for the Authority's calculations of fees and guarantees as decision guidance documents for the Government when it sets the fees to be paid by reactor licensees to the Nuclear Waste Fund, in addition to the guarantees to be provided by these licensees for costs not yet covered by the payments made to date.

1.3.2. Waste quantities, forecasts and definitions

The national plan also encompasses a summary account of the radioactive waste quantities generated and managed as part of the Swedish system, as well as estimates of future quantities.

In this context, *spent nuclear fuel and radioactive waste* is defined as follows:

- Waste from the nuclear fuel cycle: uranium extraction, operation and decommissioning of nuclear facilities, reprocessing of nuclear fuel and spent fuel, that is, the kind of material defined by the Act on Nuclear Activities as nuclear waste or nuclear material,
- Waste generated by non-nuclear activities, such as at hospitals, industries and research institutes as a consequence of using radioactive material in the operations. The waste consists of sealed radioactive sources such as level gauges, smoke detectors, calibration sources, radioactive sources and unsealed sources in the form of discarded products and other materials that for example contain radioactive substances from laboratory work,
- Waste containing raised levels of naturally occurring radioactive material arising as byproduct of non-nuclear activities in which large quantities of natural resources are managed, such as in the processing industry and at

water treatment plants. In this report, this waste is referred to as NORM waste (Naturally-Occurring Radioactive Material). Council Directive 2011/70/Euratom does not apply to NORM waste,

- Waste in the form of ash containing caesium-137 spread in the environment following the Chernobyl accident and ash from burning of peat or wood fuel by biofuel facilities and heating plants. Council Directive 2011/70/Euratom does not apply to this kind of waste or decontamination waste following a radiological accident.

1.3.3. Stakeholder consultation

A draft version of the present national plan was made available on the Authority's website on 9 March 2015 offering the opportunity of forwarding viewpoints directly to SSM by 30 April 2015 or, alternatively, in connection with a public seminar held at SSM's premises on 26 March 2015. The seminar, which also was webcast, was attended by around 50 representatives of competent authorities, municipal authorities, the public and the business community. Written comments were submitted by 17 organisations.

Information about SSM's administration of comments and viewpoints submitted is available from notes taken and memoranda from the seminar, in addition to a separate summary account of the consultation procedure. An example of a significant change made to the report thanks to the proposals, comments and viewpoints submitted is more clear-cut communication of the objectives and principles of environmental legislation having a bearing on spent nuclear fuel and radioactive waste. Areas relating to alternative sites and methods as part of licensing reviews, waste hierarchies, public insight and safeguards are also described in more detail in the updated report.

1.3.4. Strategic environmental assessments

Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment is applicable to some plans and programmes within the framework of Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (SEA).[3] Strategic Environmental Assessments are performed for plans and programmes that risk having a significant environmental impact at the time when they are being prepared and before they are adopted. According to Article 13 (3) in the SEA Directive, the general obligation referred to in Article 4(1) shall apply to the plans and programmes of which the first formal preparatory act is made before 21 July 2004.

The plans and programmes that are potentially subject to a required strategic environmental assessment are stated in Articles 2 and 3 of the SEA Directive. This mainly applies to plans and programmes, as well as changes to them, that are prepared and adopted by a public authority, or drafted for implementation by means of a legislative procedure. Secondly, this applies to plans and programmes required under law or some other enactment. The third aspect is the precondition that the plan or programme may be assumed to imply a significant environmental impact.

[3] Preamble (11), Council Directive 2011/70/Euratom.

An environmental assessment shall be carried out for programmes made for waste management, if the programmes set the framework for future development consent (Article 3.2). An environmental assessment is also required for other programmes, if they are likely to have significant environmental effects (Article 3.4).

Under the provisions of the Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452), the national plan shall contain the requirements under Article 12 of Directive 2011/70/Euratom. The present national plan, which is also the Swedish National Programme according to Article 12 of Directive 2011/70/Euratom, provides an overall account of today's national objectives and principles, a summary account of current legislation and official mandates, in addition to a summary description of the main references. These main references are produced on a regular basis within the framework of the national System of Environmental Objectives, the nuclear industry's programme for research, development and demonstration (the RD&D Programme) as well as the financing system (Plan Cost Estimates). A presentation is also made in this national plan covering quantities of spent nuclear fuel and radioactive waste produced in Sweden, as well as estimates of future quantities.

The national plan does not specify any mandatory conditions for future licences and does not constitute a framework within which future licences shall be examined. The plan contains pre-existing information; no new decisions or strategies were produced when compiling the report (see above on the SEA Directive's applicability according to Article 13 of the same Directive). Furthermore, future licences will be reviewed according to relevant legislation, such as the Environmental Code.

In view of this, the Swedish Radiation Safety Authority, does not consider the national plan to be such a plan or program likely to have significant environmental effects nor for which a strategic environmental assessment needs to be carried out.

2. General principles

The general principles for management of spent nuclear fuel and radioactive waste have evolved in pace with the emergence of the Swedish nuclear energy programme, particularly as a result of the 1970s nuclear energy debate in Sweden, with subsequent decisions in principle and legislations. Fundamental provisions on management of radioactive waste and the obligation to take care of this waste are currently part of the Act on Nuclear Activities, Radiation Protection Act and Environmental Code. The Act on Nuclear Activities regulates radioactive waste generated by a nuclear facility, whereas the Radiation Protection Act also encompasses other radioactive wastes. The Swedish Environmental Code regulates both kinds of waste. As the administrative authority in charge of this area, SSM has issued regulations specifying in detail the approach to management of this waste and the requirements for administrative procedures that must be fulfilled. The regulatory framework is described more fully in Chapter 3.

The key general principles implemented in the legislation are as follows:

- A party that has generated spent nuclear fuel and radioactive waste is also required to bear the costs for managing these residual products,
- The main responsibility for safety in connection with management and final disposal of spent nuclear fuel or radioactive waste rests with the licensee of the activity or facility that generated the waste,
- The Swedish State has the ultimate responsibility concerning the management of spent nuclear fuel and radioactive waste that has been generated in Sweden, and
- Each country is to be responsible for the spent fuel and radioactive waste generated from nuclear activities in that country. The disposal of spent nuclear fuel and nuclear waste in a foreign country is not allowed in Sweden other in exceptional cases.

Implementation of these fundamental principles for management and final disposal of spent nuclear fuel and radioactive waste in the Act on Nuclear Activities and Radiation Protection Act also implies fulfilment of a leading principle of the Environmental Code, which states that any party that gives rise to environmental damage must also bear the cost of necessary measures for preventing or dealing with the detriment (the ‘Polluter Pays Principle’).

The leading principles contained in the Environmental Code on sustainable cycles and natural conservation have however not had their full impact in the areas of radioactive waste and spent nuclear fuel. In many cases, the waste is sent for direct disposal without attempting recycling or reuse.

Management of spent nuclear fuel is, as mentioned above, largely dependent on political standpoints specifying direct disposal of the spent fuel without being preceded by reprocessing. However, Swedish legislation does not prohibit reprocessing. In practice, spent nuclear fuel is managed as radioactive waste and not as a resource, although the legal definition of spent fuel means that it is viewed as nuclear waste only once the spent fuel has been placed in a final repository facility.

2.1. **A historical perspective**

2.1.1. Activities that generate waste

The concept of radiation protection arose in the late 1800s when the radioactive element radium and X-ray machines began to be used in Sweden for treating tumours and for medical diagnostics. The first cancer clinic in Sweden was Radiumhemmet, which was founded in 1910 in an apartment in Stockholm. One early discovery was that injuries similar to burns formed on areas of skin exposed to excessive radiation. At the second international radiologists' congress, held in Stockholm in 1928, the International Commission on Radiological Protection (ICRP) was established with the mission of studying the correlation between radiation exposure and risks, and advising on how to deal with ionising radiation in order to avoid unacceptable risk levels. Unsealed and sealed radioactive sources came to be used at an early phase of industrial and research applications.

Sweden's nuclear history began just after the Second World War. In 1945, the Government of Sweden appointed the 'Atomic Committee', whose task was to study the possibilities and consequences of nuclear energy. That same year, the supreme commander of the Swedish Armed Forces assigned the Defence Research Establishment (FOA) to conduct research on use of nuclear weapons. In 1947, AB Atomenergi was established as a kind of joint venture between the Swedish State, technical institutions of higher education and industry. AB Atomenergi was to work on research and development of peaceful uses of nuclear power. FOA's task was to be in charge of developing military applications of nuclear energy.

In the 1950s, peaceful uses of nuclear energy showed very rapid technological development. The first Swedish nuclear reactor was R1, a research reactor operated by AB Atomenergi between 1954 and 1970 in central Stockholm.

In the late 1950s, AB Atomenergi began construction of a nuclear facility for research and training purposes at Studsvik, outside Nyköping Municipality. In 1960, the first two research reactors, units R2 and R2-0, were commissioned. These reactors were for example used for irradiation and testing of nuclear fuel and materials for reactors, as well as for manufacturing of radioactive isotopes for hospital applications and the pharmaceutical industry. The reactors were shut down in 2005 after the owner decided to terminate their operations.

At the facility at Studsvik, Studsvik Nuclear AB currently works with waste treatment and management of waste from nuclear power plants and other industries that use radiation in their operations. The company also conducts different kinds of materials testing. The collocated AB SVAFO is in charge of decommissioning of facilities used during Sweden's early research and development period and manages waste from these facilities.

Sweden's first commercial nuclear reactor, Ågesta, produced district heating in Farsta, a suburb south of Stockholm, during the period 1963-1974. This facility, a pressurised heavy water reactor (PHWR), also produced ten megawatts of electrical power during its period of operation.

A plant in Ranstad, between Falköping and Skövde, was built as part of national plans to reduce Sweden's dependence on uranium imports. Between 1965 and 1969, some 200 tonnes of uranium were extracted from the uranium-rich alum shales of

Billingen for the Swedish nuclear energy programme. In the 1990s, the open-cast mine was restored, the industrial area cleaned up and some buildings were demolished. Waste from leaching processes was treated and covered. Winding up remaining sections of the facility is in progress, with completion planned for 2016.

In 1966, ASEA commissioned a fuel fabrication plant in Västerås. This plant, now a part of Westinghouse Electric Sweden AB, manufactures nuclear fuel, control rods and other components not only for Swedish nuclear reactors, but also for global customers.

On a few occasions between the late 1950s and early 1960s, radioactive waste from Sweden was dumped at sea – both in Swedish territorial waters and in the Atlantic. This waste originated from operation of the R1 reactor as well as from different institutes and hospitals. The waste's radiation levels were generally low. Since the early 1970s, Sweden is a contracting party to several international conventions that prohibit dumping at sea. This ban has been implemented in Swedish law in Chapter 15 of the Swedish Environmental Code, which prescribes a general ban on dumping of waste in Swedish territorial waters, in Sweden's economic zone as well as from Swedish marine vessels and aircrafts in international waters.

The first commercial nuclear power reactor for energy production in Sweden was Oskarshamn 1 (O1), which was commissioned in 1972. Until 1985, O1 was followed by an additional eleven reactors at four locations in southern Sweden: Barsebäck, Oskarshamn, Ringhals and Forsmark. Of the twelve reactors in total, nine are boiling water reactors (BWR) designed by ASEA ATOM, and three reactors are pressurised water reactors (PWR) of Westinghouse design. Barsebäck's reactors (B1 and B2) were shut down permanently in 1999 and 2005 respectively following a Riksdag decision. Dismantling is planned for 2020 at the earliest.

On 31 July 2012, Vattenfall AB submitted a licence application to SSM on constructing, owning and operating up to two new nuclear power reactors substituting its current ones. Moreover, the owner companies, Vattenfall and Eon, have begun preparations for consultations regarding future decommissioning of reactors O1, O2, R1 and R2 after 50 years of operation.

In 1985, the Swedish Nuclear Fuel and Waste Management Company (SKB) commissioned Clab, an interim storage facility for spent nuclear fuel at Oskarshamn. SFR, a repository for low and intermediate level waste in Östhammar, was commissioned in 1988. In 2009, SKB selected Forsmark in Östhammar Municipality as the site for a spent nuclear fuel repository, and on 16 March 2011, the company submitted applications to SSM and the land and environmental court for authorisation to build this repository in the municipality. In December 2014, SKB also applied for permission to extend the SFR facility at Forsmark so that it has capacity to receive decommissioning and dismantling waste from Swedish nuclear power plants.

2.1.2. Political and legal developments

The Atomic Energy Act (1956:306) was adopted by the Riksdag in 1956. This Act supplemented the concession rules under the radiation protection act of 1941, which at the time also regulated licensing in the nuclear energy field. The Atomic Energy Act contained fundamental regulations on the construction and operation of nuclear energy reactors. The Act also contained provisions on regulatory control of

activities. The supervisory authority had the powers to require access to the information and documents necessary for regulatory control. The authority also had the powers to issue regulations as needed for the purpose of ensuring compliance with conditions issued as per the Act.

That same year, a reactor facility safety committee was set up to look into safety conditions at nuclear energy facilities. The Swedish Radiation Protection Authority, or SSI, was founded in 1965 for regulatory control of all activities and practices involving radiation. In 1974, the Swedish Nuclear Power Inspectorate, or SKI, was also founded and the reactor facility safety committee was incorporated by SKI.

A more restrictive approach to exploitation of nuclear energy emerged in the mid-1970s. There was great emphasis on hazards in conjunction with management and final disposal of spent nuclear fuel and nuclear waste. Against this background, the A special act on permission to charge nuclear reactors with nuclear fuel, the Nuclear Power Stipulation Act (1977:140) was implemented in 1977. Special charging permission from the Government of Sweden should be granted for this purpose and only if the reactor owner could reliably demonstrate planning for safe management of spent fuel in the form of reprocessing and/or entirely safe final disposal. The first decisions on charging permission taken under the Stipulation Act had a complete focus on reprocessing spent nuclear fuel. Between the 1970s and early 1980s, contracts on reprocessing were signed with BNFL in England and Cogéma in France. A small proportion of the spent nuclear fuel was reprocessed. However, since 1982, Swedish policy is completely oriented towards direct disposal of spent fuel without reprocessing. Here, the main rationale is non-proliferation of nuclear weapons.

In 1978, an amendment made to the Atomic Energy Act implied compulsory authorisation for constructing, owning and operating a facility for treatment, storage or retention of spent nuclear fuel or radioactive waste generated by nuclear power reactors. Up until this time, waste management was not mentioned by the Atomic Energy Act.

In the early 1980s, the Riksdag decided on separate financing of costs for safe future management of spent nuclear fuel as well as safe decommissioning and dismantling of nuclear power reactors. Based on the Swedish nuclear power industry's cost estimates, the Government now decides every third year (previously each year) on the fee to be payable by each owner of a nuclear power reactor per delivered kWh of power, in addition to guarantees to be provided for costs of management not covered by previous fee payments. The present Act on Financing of Management of Residual Products from Nuclear Activities (2006:647; the 'Financing Act') contains provisions on this form of financing.

Today's Act on Nuclear Activities entered into force in 1984, replacing the Atomic Energy Act and Nuclear Power Stipulation Act. Questions concerning final disposal became subject to targeted regulations, including requirements on reactor licensees to be in charge of conducting the comprehensive research, development and demonstration work necessary for performing safe final disposal of residual products from the nuclear power industry. The concept of nuclear waste was introduced to the new Act, implying that waste generated in connection with nuclear activities became subject to particular, and stricter, regulation than regulation of radioactive waste under the Radiation Protection Act. Using the Radiation Protection Act as a model, a rule was introduced requiring licensees to take all the measures necessary to maintain nuclear safety.

As a consequence of the new legislation, the nuclear energy company Svensk Kärnbränsleförsörjning AB (SKBF) was reorganised. This company, a purchaser of uranium and enrichment services on the global market, was renamed the Swedish Nuclear Fuel and Waste Management Company, or SKB, with the business concept of conducting research and development work in the area of management and disposal of spent nuclear fuel and nuclear waste. SKB was also tasked with being in charge of industry cost estimates under the Financing Act.

On 1 January 1987, a new provision entered into force in the Act on Nuclear Activities. It implied a ban against granting a licence for construction of new nuclear power reactors. This ban clearly defined the Riksdag decision to phase out nuclear power in Sweden by 2010. On 1 January 1998, the Act on Nuclear Power Phase-Out (1997:1320) entered into force. The Act for example implied closure of the Barsebäck nuclear power plant and avoiding determination of a year for shutting down the last reactor in Sweden. This meant that the Government of Sweden could decide on the point in time for when the right to operate a nuclear reactor should cease to apply. An amendment to the Act on Nuclear Activities was made in 2006 lifting the ban on carrying out preparatory measures for construction of new nuclear power reactors.

On 1 July 2008, the Swedish Radiation Safety Authority, or SSM, was established following a merger of the former Swedish Radiation Protection Authority (SSI) and former Swedish Nuclear Power Inspectorate (SKI).

In 2010, the Riksdag repealed the Act on Nuclear Power Phase-Out and decided to allow construction of new nuclear reactors provided that they only replace existing ones at a site already with reactors in operation. The Riksdag also decided that licensees were to have greater liability to pay damages in connection with an accident and clarification was made implying that the State was prohibited from subsidising new nuclear power investments.

2.2. **The State's ultimate responibility**

The Riksdag has on several occasions established that the Swedish state has a comprehensive responsibility for spent nuclear fuel and nuclear waste.[4] The long-term responsibility for a waste facility for spent nuclear fuel or other radioactive waste should, in accordance with statements by the Riksdag, be assumed by the State. One rationale is the fact that once a final disposal facility has been closed, some kind of responsibility for the facility and regulatory supervision of the facility's safety over a considerable timespan should be maintained. According to a Government statement, it is self-evident for the State to have the ultimate liability for operations, even over an extreme timespan, until all obligations under the legislation have been met.[5]

The Swedish State has also, by ratifying the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (i.e. the Waste Convention), undertaken to assume the ultimate responsibility for final

[4] See e.g. Government Bill 1980/81:90, Appendix 1, p. 319, Government Bill 1983/84:60, p. 38, Government Bill 1997/98:145, p. 381, Government Bill 2005/06:183, in addition to Committee on Industry and Trade Reports 1988/89:NU31 and 1989/90:NU24

[5] Government Bill 1997/98:145, p. 381.

disposal of spent nuclear fuel and nuclear waste in a case where there is no existing licensee in charge. Here, the State has a comprehensive responsibility to ensure arrangements for final disposal. The State's ultimate responsibility does not in itself imply any limitation of the nuclear power industry's liability under the Act on Nuclear Activities. It is also in the light of this situation that a special-purpose financing system has been set up.

In 2011, an inquiry presented a proposal on cohesive legislation in the fields of nuclear safety and radiation protection.[6] The proposal, which is undergoing deliberation by the Government, implies clear definition of the State's responsibility in Swedish legislation.

2.2.1. Responsibility after closure of a final repository

The long-term responsibility for a closed waste disposal facility for spent nuclear fuel or other radioactive waste should, in accordance with statements by the Riksdag, be assumed by the State. One rationale is the fact that once a disposal facility has been closed, some kind of responsibility for the facility, and maintaining regulatory supervision or monitoring of its safety and security over a considerable timespan after its closure, should be required. One line of reasoning is for a central government authority to be capable of taking over the responsibility for closed repositories.[7] There are also requirements for long-term retention of information about the facilities' sites, design, layout and inventories of waste.

Post-closure safety and security of disposal facilities must be maintained through a system of passive barriers. This is why no requirements are imposed for post-closure security or control measures once a repository has been closed. Before a final disposal facility is permanently closed, however, a final safety and security assessment is conducted. Following approval by the competent authority's review, the licensee may be relieved from liability as decided by the Government. If control measures or other forms of action are deemed necessary after this point, the State assumes responsibility.

The IAEA has declared in its Policy Document[8] that safeguards remain in effect after a repository has been closed, provided that international agreements on non-proliferation control are in force.

The existing four Swedish shallow land disposal facilities for very low level waste are subject to official regulations on facility owners maintaining control over a 30 year period following final sealing. After this stage, the waste is to be considered safe in terms of radioactivity. The period of time for maintaining control may be extended by a municipal authority or County Administrative Board.

[6] Swedish Government Official Report SOU 2011:18, *Strålsäkerhet – gällande rätt i ny form* [Radiation safety: About law in a new form].
[7] Swedish Government Official Report SOU 2011:18, *Strålsäkerhet – gällande rätt i ny form* [Radiation safety: About law in a new form], p. 495.
[8] IAEA Safeguards Manual SMR 2.15 Policy Paper 15: Safeguards for Final Disposal of Spent Nuclear Fuel in Geological Repositories.

2.3. **Responsibilities of the operators**

Many different entities have licenses under the Act on Nuclear Activities or Radiation Protection Act. As far as concerns radioactive waste that is not nuclear waste, the Radiation Protection Act requires producers of radioactive waste to be in charge of management and final disposal. They must also bear related costs. However, there are a number of activities exempt from the authorisation requirement which nevertheless generate radioactive waste. All these entities are subject to the principle of requiring all organisations that generate radioactive waste to manage it as well.

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 and which will not be reused are safely managed and disposed of at a waste repository facility. This obligation (waste producer responsibility) implies a long-term commitment for a party carrying out an activity. Even if a licence is revoked or has expired, there is still an obligation on the licensee to not only safely manage and dispose of spent nuclear fuel and nuclear waste, but also decommission, dismantle and demolish the facility.

The responsibility of the licensee remains in effect until all obligations have been performed and discharge of liability has been granted by the Government. These obligations are not performed until a final disposal facility has been closed permanently. Figure 1 provides a schematic illustration of licensee responsibilities.

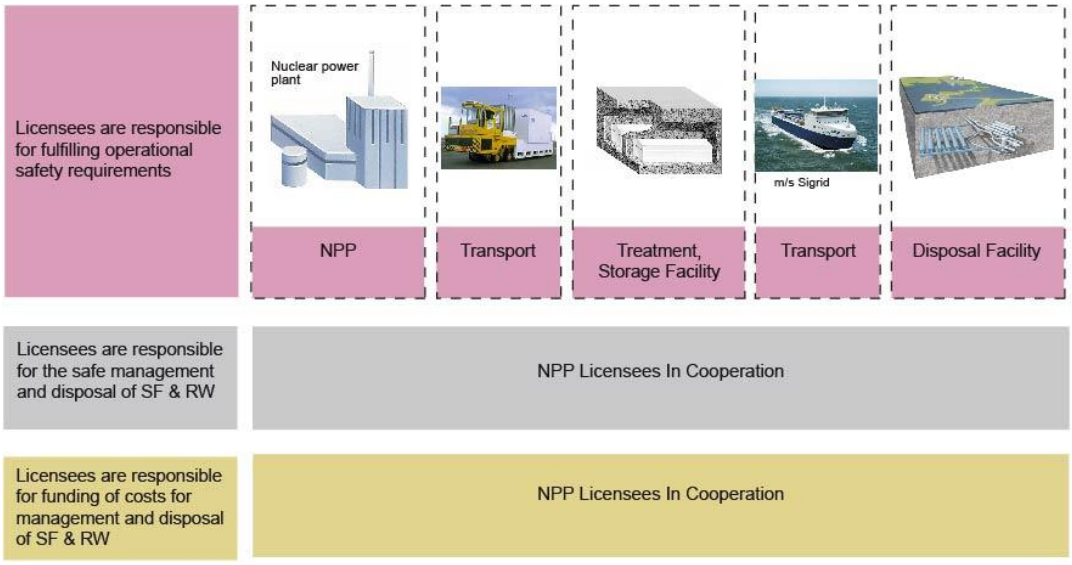

Figure 1. Licensee responsibilities and obligations.

These general requirements are supplemented by more detailed regulations issued by SSM in addition to licence conditions imposed by the Authority or the Swedish Government on a case-by-case basis.

Parties licensed to own or operate a nuclear power reactor are subject to a particular obligation to carry out the following in consultation with other licensees of nuclear power reactors:

- Preparing a programme, either in-house or by a third party, for the comprehensive research, development and demonstration work and the other measures necessary for safe management of nuclear waste and spent nuclear fuel, in addition to safe decommissioning and dismantling of nuclear facilities (i.e. the RD&D Programme), and
- Preparing a cost estimate as input for calculating the fees to be payable to the Nuclear Waste Fund for management of residual products from nuclear activities (i.e. the Plan Cost Estimates).

In order to fulfil the above obligations, the reactor licensees established a joint company, SKB, as the entity to be in charge of preparing and submitting to the Authority the nuclear power industry's joint RD&D programme and plan. SKB is not only responsible for planning, constructing and operating the facilities required for management and final disposal of spent nuclear fuel and radioactive waste, but also for needed research and development for these areas. SKB liaises prerequisite investigations as input for calculating future costs for the areas, including reactor decommissioning. Today, SKB is also the licensee responsible for all handling, management, transports and interim storage of spent nuclear fuel and nuclear waste outside the nuclear power facilities, including operations at the Clab and SFR facilities.

2.4. Safe management and final disposal of radioactive waste

SSM's regulations contain requirements for ensuring that radioactive waste management and construction of disposal facilities are carried out to minimise impact on the surroundings.

Waste management is to be carried out in a way achieving the safety and protection of workers, the general public and the environment against harmful effects of radiation. Protection of people and the environment against radiation arising from radioactive waste management is achieved by applying regulatory control, monitoring and measures based on radiation protection principles (see Section 2.9). Nuclear safety in connection with waste management is achieved through nuclear facilities' fulfilment of radiation safety requirements and their protection against aspects such as sabotage and human intrusion to prevent nuclear fuel and other fissionable material from being misplace or falling into the wrong hands.

The radiation risk per year from a disposal facility for radioactive waste is not allowed to exceed one-hundredth of the human exposure risk posed by natural radiation in the environment. The annual risk is based on international guidelines (including those issued by the International Commission on Radiological Protection, or the ICRP, and the IAEA). The risk criterion is in line with other countries' requirements for safety in connection with disposal of radioactive waste. A repository's design must have resilience against conditions, events and processes that can lead to contamination by radioactive substances. This is to be achieved in the form of a system comprising several passive barriers whose function is to contain, prevent and impede contamination by radioactive substances prior to and after closure of the repository. Regulations also prescribe competence and capability on the part of the organisation operating the final disposal facility.

The nuclear power industry's programme for research, development and demonstration (the RD&D Programme) has, since the first issue was produced in the early 1980s, been based on the conceptual design of a deep geological repository with passive safety systems as the safest and most sustainable option for final disposal of spent nuclear fuel. This proposed conceptual design has since then become more established through public sector review work, consultation with special interest groups and Government standpoints in relation to the programme and its continued orientation and approval every third year. This process culminated in SKB choosing in March 2011 to submit a licence application for owning, constructing and operating a repository for spent nuclear fuel at Forsmark with a partner encapsulation facility at Oskarshamn. SKB has an existing repository for short-lived low and intermediate level waste at Forsmark for which it has applied for an extension in 2014.

2.5. **Radioactive waste to be disposed of in the originating country**

All spent nuclear fuel and radioactive waste from nuclear activities in Sweden must, as a main rule, be dealt with safely in this country. Following its treatment, foreign radioactive waste treated at Swedish facilities is to be transferred outside the country within the timeframe for treatment specified by the Swedish regulator. Only small quantities of waste may be exempted from this prohibition. This presupposes a Government decision.

Radioactive waste is not only generated when producing electrical power. It is also generated by industrial operations, the agricultural sector, medical operations and research work. Thousands of operations in Sweden use unsealed and sealed radioactive sources. Operations that work with sources of radioactivity are, under the Radiation Protection Act, also responsible for their final management. Most sealed radioactive sources to be managed as waste are either returned to the manufacturer (Swedish or foreign), or taken care of by Studsvik Nuclear AB. For certain kinds of radioactive sources, both unsealed and sealed, there is currently no effective national system for this waste's treatment and final disposal.

Against the background of the fact that Council Directive 2011/70/Euratom, under certain conditions, allows derogation from the main rule of radioactive waste generated by a Member State to be disposed of in that State, amendments to the Act on Nuclear Activities and Radiation Protection Act have been made implying a compulsory licence for foreign disposal of nuclear material that is not intended to be reused, as well as for nuclear waste and other radioactive waste. Certain requirements have been imposed as conditions for this kind of licence. Among other things, an agreement must be in effect between Sweden and the other country, and the advantages of final disposal in the other state must, from the perspectives of nuclear safety or radiation protection, clearly outweigh the advantages of final disposal in Sweden.

The required separate licence does not apply to waste and materials which, after treatment or reprocessing in Sweden, are to be disposed in the state where the waste was generated or the radioactive materials originated. Nor does the licence obligation apply to shipments of spent fuel from research reactors to a state to which fuel for research reactors is delivered or where it is manufactured, or discarded sealed radioactive sources to be returned to a supplier or manufacturer of this kind of radiation source.

After direct disposal in a repository, spent nuclear fuel from Sweden is viewed as nuclear waste under the Act on Nuclear Activities, and thus not as a resource.

2.6. **Transboundary shipments**

The guiding principle of Council Directive 2011/70/Euratom is for transboundary shipments of waste to take place under government regulatory control. In this area, SSM cooperates internationally with sister authorities and other competent authorities both in the EU and in third countries.

In 2006, Council Directive 2006/117/Euratom was issued on the supervision and control of transboundary shipments of radioactive waste and spent fuel. The Directive has the aim of public authority regulation of movements of waste across borders, not only between EU Member States, but also to and from third countries. This was deemed necessary as some Member States of the European Union previously lacked legislation to regulate these flows, or had insufficient legislation in the area.

In Sweden, the Act on Nuclear Activities and Radiation Protection Act already had this function, though through implementation of the Directive in Swedish legislation, these movements of waste are now completely regulated in the form of the Swedish Radiation Safety Authority's regulation, SSMFS 2009:1. The system is based on approval of applications for transboundary shipments by all the states involved, transit countries included.

2.7. **Agreements with other countries**

Sweden currently has no agreements concluded with any Member State or third country concerning management of spent fuel or radioactive waste, including use of disposal facilities needing to be accounted for under Article 12 of Council Directive 2011/70/Euratom.

Studsvik Nuclear AB has permission from the Government since 1994 for receiving and treating nuclear waste from abroad. In connection with treatment of foreign waste, Studsvik Nuclear also has a current licence for disposal in Sweden of approximately 200 kg of nuclear waste and 200 kg of spent nuclear fuel over a ten-year period. The licence covers nuclear waste and spent nuclear fuel transferred to Sweden up to and including year 2024.

Authorisation for receiving waste from foreign countries is regulated in the form of licences granted under the Act on Nuclear Activities or the Radiation Protection Act. Council Directive 2006/117/Euratom on transboundary shipments has been implemented in these Acts, in addition to regulation SSMFS 2009:1. The latter regulates the consultation procedure between the relevant countries, which is carried out on a case-by-case basis. An agreement concluded between the parties involved in the exchange of waste is a requirement prior to the shipment taking place.

2.8. **International commitments**

Spent fuel management must always fulfil the obligations deriving from Sweden's agreements whose purpose is to prevent proliferation of nuclear weapons and unauthorised dealing with nuclear materials. This means that this management must meet the requirements imposed by the International Atomic Energy Agency, the IAEA, for the purpose of verifying that Sweden is in compliance with the Non-Proliferation Treaty. Another requirement is management complying with the Euratom Treaty and agreements concluded between Euratom and third countries on peaceful uses of nuclear material from these countries. These agreements, for example concluded with Australia and Canada, might imply certain restrictions for (for instance) reprocessing of spent nuclear fuel.

International cooperation between unions and cooperation on legal issues are key factors for achieving globally accepted and sustainable management of spent fuel and radioactive waste.

Sweden has signed international agreements that influence the system for radioactive waste management. Some agreements are based on established international principles to which Sweden has successively adapted its national legal framework. Examples include the 1994 Convention on Nuclear Safety (SÖ 1995:71) and the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (SÖ 1999:60). Both Conventions were drafted under IAEA supervision and define the regulatory framework for a system to ensure nuclear safety and safe management of radioactive waste.

The IAEA's safety standards comprise fundamental principles, requirements and guidelines. These documents are not legally binding, but they lay the foundation for fulfilment of requirements defined under the Conventions.[9]

In 1976, an agreement was concluded between the Nordic countries on guidelines for communicating safety concerns pertaining to nuclear energy facilities located in close proximity to factors such as these countries' shared borders. The agreement refers to as Note Exchange between Sweden, Denmark, Finland and Norway. The principle of consultation with neighbouring countries is codified in the Swedish Environmental Code.

Sweden has, through SSM, agreements concluded with the following countries on cooperation and exchange of information with competent authorities in the area of management and final disposal of spent nuclear fuel and radioactive waste:

- Canada (Canadian Nuclear Safety Commission, CNSC)
- Finland (The Radiation and Nuclear Safety Authority, STUK)
- France (Nuclear Safety Authority of France, ASN)
- United Kingdom (Office for Nuclear Regulation of Great Britain, ONR)
- United States (U.S. Environmental Protection Agency, U.S. EPA; U.S. Nuclear Regulatory Commission, U.S. NRC).

[9] IAEA Safety Standards, The Global Reference for Protecting People and the Environment from Harmful Effects of Radiation, IAEA.

2.9. **Radiation protection principles**

Radiation protection in Sweden is based on the ICRP's internationally recognised principles:

- *Justification:* All activities involving radiation, or measures to change an exposure situation, shall imply benefit to an individual or society outweighing the detriment implied by the activity or measure. In this context, an activity is the nuclear activity, or activity or practice involving radiation, that generated waste. The principle of justification is difficult to apply to pre-existing waste. Pre-existing waste produced owing to earlier decisions must be managed by licensees according to the provisions of the Radiation Protection Act and Act on Nuclear Activities.
- *Optimisation:* Radiation protection is to be designed so that the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept "As Low As Reasonably Achievable", taking into account economic and societal factors. This is often referred to as the ALARA principle.
- *Dose limits*: The total dose to any individual should not exceed the appropriate limits specified for the particular circumstances. The total dose to workers and the general public, other than from medical exposure, should not only fall below the appropriate limits, but also be kept to a minimum through the process of optimisation. The process of optimisation makes use of several tools, such as dose constraints for a planned operation and reference levels for existing exposure situations, emergency response planning work and diagnostics.

2.10. **Principles of the Swedish Environmental Code**

The purpose of the Swedish Environmental Code is to promote sustainable development implying that present and future generations are ensured a healthy and sound environment. This for example means that human health and the environment are to be protected against damage and detriment, also that use of natural resources, raw materials and energy is to be based on good management and conservation over the long term.

The general rules of consideration are aspects of key importance in the Code. The rules are legally binding and are to be applied in connection with both regulatory supervision and licensing reviews. A party that applies for authorisation, conducts an activity or takes a measure is under an obligation to demonstrate compliance with the rules of consideration.

The following aspects of the rules of consideration are viewed as relevant to waste management, either in connection with supervisory work or review processes for facilities:

- *The knowledge requirement*: Persons who pursue an activity or take a measure, or intend to do so, must possess the knowledge that is necessary in view of the nature and scope of the activity or measure to protect human health and the environment against damage or detriment.
- *The precautionary principle and best available technology:* Persons who pursue an activity or take a measure, or intend to do so, shall implement 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 or measure. For the same reason, the best possible technology is to be used in connection with professional activities. Precautions shall be taken as soon as there is cause to assume that an activity or measure might cause damage or detriment.

- *The conservation principle*: Persons who pursue an activity or take a measure shall conserve raw materials and energy and reuse and recycle them wherever possible. Preference shall be given to renewable energy sources. The preparatory work of the Swedish Environmental Code mentions energy recycling from waste as an option for conservation.
- *Site selection*: In cases of activities or measures requiring utilisation of a land or water area, a suitable site shall be selected in such a way as to make it possible to achieve their purpose with a minimum of damage and detriment to human health and the environment.
- *Considering reasonability*: The above-mentioned rules of consideration apply to the extent it cannot be deemed unreasonable to fulfil them. When considering what is reasonable, particular consideration is to be given to the benefits of protective measures and other precautions in relation to the costs for taking these measures.
- *Responsibility for environmental damage*: Persons who pursue or have pursued an activity or taken a measure that causes damage or detriment to the environment shall be responsible, until such time that the damage or detriment ceases, for remedying it to the extent deemed reasonable pursuant to the provisions of the Code concerning polluted, contaminated and environmentally damaged areas. Damages may also be claimed.
- *Final considerations*: If an activity or measure is likely to have the potential to cause significant damage or detriment to human health or the environment, even where protective measures and other precautions are taken as required by the Environmental Code, the activity or measure may only be undertaken provided that the Government considers that special circumstances prevail as per Chapter 17, Sections 1, 3 or 4 of the Environmental Code. Conditions may be attached to this decision in order to safeguard a public interest.

2.11. **Minimisation of waste**

Principles for waste minimisation are not expressly regulated by Swedish legislation and regulations governing non-nuclear activities. The purpose of the provisions of Chapter 1 of the Swedish Environmental Code is nevertheless to promote sustainable development, implying that present and future generations are to be ensured a healthy and sound environment. The Code is to be applied to promote reuse, recycling and other conservation of materials, commodities and energy to achieve a sustainable waste management system.

Nuclear activities must be run in a way so that quantities of nuclear waste and its content of radioactive substances are limited as far as reasonably possible (regulation SSMFS 2008:1).

Extensive regulatory work is in progress at SSM. One area is development of basic provisions to regulate activities and practices involving radiation. These regulations will apply to nuclear and non-nuclear wastes and will impose requirements for waste minimisation in the form of optimisation and applying best available technology.

2.12. **Openness, transparency and insight**

The Swedish right of public access to official records implies insight into public authority work by the general public and mass media. This right gives everyone, including Swedish and foreign residents, access to official documents, provided they are not subject to secrecy. Civil and local government servants are also entitled to disclose what they know to a third party to the extent they need not observe duty of confidentiality.

SSM's mandate under its Instructions from the Swedish Government includes, by means of communication and transparency, contributing towards public insight into all operations encompassed by the Authority's areas of responsibility. These efforts have the aim of promoting health and preventing illness, preventing acute radiation injuries and reducing the risk of delayed injuries as a consequence of radiation exposure. Moreover, the Authority is to provide advice and other information about radiation, its properties and areas of application, as well as about radiation protection. SSM's work in other respects to promote openness, transparency and insight into its organisation and operations based on the shared values of Swedish public administration is described in Section 3.1.1.

The general public's opportunities for effective participation in the decision-making process for management of spent nuclear fuel and radioactive waste are, for instance, ensured through the following:

- A compulsory consultation procedure as part of the Authority's reviews of RD&D Programmes and Plan Cost Estimates, also calculations of fees and guarantees. Over an extended period of time, this has brought about the involvement of interested parties in the pre-licensing phase for nuclear facilities.
- Compulsory consultation in accordance with the Swedish Environmental Code. An environmental impact assessment (EIA) must provide an account of the consultation process with stakeholders, referred to as a consultation report.
- Referring proposals for consideration and court proceedings during licensing reviews comprise a different process involving the interests of society.
- Special-purpose funding ensures the potential for non-profit associations to actively take part in a consultation procedure in accordance with the Environmental Code, with a financing system through the nuclear power industry's payments to the Nuclear Waste Fund; these areas include a review process performed by the Authority. Over time, these organisations have built up a level of expertise and capacity for monitoring the evolution of final disposal methods, thus contributing extensively to the standard, openness and transparency of, and insight into, this process.
- The municipal right to exercise a veto, as well as efforts to improve awareness and provide information. This is a key aspect for gaining

confidence in the licensing process, where local residents are given the right to reject the establishment of an unwanted nuclear activity in or near their community.

Local safety boards have been set up in municipalities with nuclear power plants for the purpose of giving the public insight into nuclear activities and provide them with information about these operations. The role of local safety boards is to enable insight into safety and radiation protection matters at the facilities and emergency response planning, and also communicating these areas to the general public.

The transparency of operations such as SKB (the Swedish Nuclear Fuel and Waste Management Company), a key stakeholder when it comes to management of spent fuel and radioactive waste in Sweden, is not only achieved by means of SSM's regulatory supervision of its activities and facilities, but also in the form of consultation procedures involving the general public as per the Environmental Code's provisions on consideration of permissibility and licensing reviews. Transparency is also promoted via reviews of SKB's RD&D Programme and Plan Cost Estimates. This gives insight into SKB's work in the form of consultation procedures and opportunities for the public to be heard about these programmes.

3. The National Framework

3.1. **Competent authorities**

In Sweden, the Riksdag (the Swedish Parliament) has the supreme legislative power, takes decisions on taxation and sets the central government's budget. The Government of Sweden rules the country by enforcing decisions of the Riksdag and by initiating new legislation or amending existing legislation. For assistance in its work, the Government turns to the Government Offices and central government authorities. The Government lays down rules in the form of ordinances. The Riksdag and Government have also assigned certain central government authorities with the powers to issue regulations in their respective mandates and areas of operation.

The role of central government authorities in the democratic Swedish system is to implement political decisions and to ensure compliance with legislation and rules. The Government mainly directs the work of central government authorities by issuing ordinances, particularly in the form of official instructions. Annual appropriation directions serve as a supplement to the instructions in the form of financial control, also as needed by defining additional Government assignments and through management by objectives. Swedish authorities have an independent role and extensive powers to determine how their own tasks are to be performed. The authorities are also autonomous as part of their exercise of public power in relation to individuals and in the context of applying legislation. This independence is a crucial component of the Swedish management model, which contributes towards public administration that is efficient, effective and follows the rule of law.

As of 1 January 1995, Sweden is a Member State of the European Union (the EU), and consequently party to the European Atomic Energy Community (Euratom).

3.1.1. Swedish Radiation Safety Authority

The Swedish Radiation Safety Authority, or SSM, was established on 1 July 2008 following a merger of the former Swedish Radiation Protection Authority (SSI) and former Swedish Nuclear Power Inspectorate (SKI).

Mandate and assignments

The Ordinance with instructions for the Swedish Radiation Safety Authority (2008:452) stipulates that SSM is an administrative authority responsible for areas concerning the protection of human health and the environment against harmful effects of ionising and non-ionising radiation, issues concerning safety, security and physical protection in nuclear and other activities involving radiation, and also issues concerning nuclear non-proliferation.

SSM's task is to work proactively to maintain a good level of radiation safety in society while, in its areas of operation, striving to:

- Prevent radiological accidents and ensure that nuclear activities are characterised by radiation safety in terms of their operation and waste management,
- Minimise the risks associated with radiation and optimise its effects in medical applications,
- Minimise risks associated with radiation used in products and services or which arise as a hazard when using products and services,
- Minimise risks associated with exposure to naturally occurring radiation, and
- Improve the level of radiation safety globally.

SSM is also tasked with working for achievement of the generational goal for environmental work and the environmental quality objectives laid down by the Riksdag and, as required, proposing measures for development of the environmental work and coordinating follow-ups, evaluations and reporting relating to the environmental quality objective 'A Safe Radiation Environment'.

SSM administers matters related to financing in terms of management of residual products from nuclear activities (see also below).

SSM is the authority responsible for the National Metrology Laboratory for ionising radiation. The Authority also keeps national records (Svedos) of radiation doses that workers are exposed to, or might be exposed to, in connection with activities involving radiation. SSM also issues personal certificates and dose passports for radiation monitoring of the workers.

SSM is also tasked with contributing to development of national competence within the Authority's areas of operation by taking initiatives for research, education and study purposes, in addition to conducting situational and scenario analyses and other development and improvement work. Also, by means of communication and transparency, SSM contributes towards public insight into all operations encompassed by the Authority's mandate. These efforts have the aim of promoting health and preventing illness, preventing acute radiation injuries and reducing the risk of delayed injuries as a consequence of radiation exposure. Moreover, the Authority is to provide advice on and information about radiation, its properties and areas of application, and also communicate on radiation protection.

Several of SSM's tasks derive from Sweden's international commitments. The Authority exercises supervision to ensure that Swedish nuclear material and Swedish nuclear equipment are used in the manner they have been declared in accordance with Sweden's international commitments, and in the areas of nuclear non-proliferation, including export control, is tasked with striving to ensure that such material and equipment are not used to produce nuclear weapons. SSM is also tasked with the following:

- Responsibility for preparatory national work deriving from the 1994 Convention on Nuclear Safety and the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management,

- A particular functional responsibility as a competent authority under the International Atomic Energy Agency's (IAEA) Conventions on assistance and early notification in the case of a nuclear accident or radiological emergency,
- Serving as the point of contact referred to in Article 5.1 of the Convention on the Physical Protection of Nuclear Material,
- Serving as the national point of contact for the International Atomic Energy Agency's database for illicit trafficking and other illegal handling of nuclear material and radioactive substances (Incident and Trafficking Database, or ITDB),
- Performing the specific tasks related to shipments assigned to a competent authority under Council Regulation (Euratom) No 1493/93 on shipments of radioactive substances between Member States and under Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel,
- Performing the specific tasks and observing the principles assigned to a competent authority and stipulated in Council Directive 2003/122/Euratom on the control of high-activity sealed radioactive sources and orphan sources in addition to those contained in the IAEAs Code of Conduct on the Safety and Security of Radioactive Sources, or IAEA/CODEOC/2004,
- Every third calendar year, compiling and forwarding to the European Commission a report on implementation of Council Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations, also a report on implementation of Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste,
- Proposing to the Government the appropriate point in time for the self-assessments and international peer reviews that are to be performed at least every 10 years under Article 9.3 of Council Directive 2009/71/Euratom and under Article 14.3 of Council Directive 2011/70/Euratom, presenting the outcomes from the self-assessments and peer reviews performed and, as necessary, proposing measures owing to these outcomes, and
- Responsibility for ensuring implementation of an up-to-date national plan and programme for management of nuclear material not intended to be reused, and nuclear and other radioactive waste, where such plan must contain the presentation necessary under Article 12 of Council Directive 2011/70/Euratom.

SSM is to give guidance on supervisory work in certain matters relating to environmentally hazardous activities as per the Swedish Environmental Code in cases where these matters are regulated by the Radiation Protection Act or Radiation Protection Ordinance (1988:293).

Otherwise within its areas of operation, the Authority participates in the work pursued by the Government of Sweden in the European Union and internationally, and assists the Government by providing documentation, input and expert support.

Within its areas of operation, SSM also pursues cooperation and development work with neighbouring countries and other states, involving public bodies and non-governmental organisations in the countries determined by the Government; at the present time, this involves nuclear security and radiation protection in Eastern

Europe, as well as international environmental and nuclear security cooperation with Russia. In recent years, the cooperation with Eastern Europe has encompassed projects in the areas of reactor safety, nuclear non-proliferation, radiation protection, emergency preparedness and radioactive waste management in Ukraine, Georgia and Moldova. The cooperation with Russia encompasses management of radioactive and nuclear waste, nuclear non-proliferation activities, emergency preparedness contacts (including environmental monitoring) between Sweden and northwest Russia, in addition to decommissioning issues related to nuclear power plants in close proximity to Sweden.

Within the national preparedness for nuclear and radiological emergencies, SSM liaises the necessary emergency preparedness and response measures for preventing, identifying and detecting nuclear or radiological incidents that can cause damage to human health or the environment.

Organisation and management

SSM is a unitary authority, which means that its Director General is solely responsible for the work and answers directly to the Ministry of the Environment and Energy. The Director General has been appointed by the Government of Sweden. A Director General is in charge of the organisation and work vis-à-vis the Government and is responsible for ensuring that the public authority is run efficiently and effectively in compliance with applicable law and the obligations deriving from Sweden's membership in the European Union, while also seeing to it that the work of the organisation is fairly and reliably accounted for and reported, and that the authority wisely manages and conserves the State's funding and resources. SSM has an advisory council, comprising a maximum of ten members. The council, which has been appointed by the Government, is to have insight into SSM's operations and provide the head of the Authority with advice.

SSM was founded through a merger between the Authority's predecessors, the Swedish Nuclear Power Inspectorate (SKI) and the Swedish Radiation Protection Authority (SSI). One of the rationales behind this merger was stronger supervision of nuclear and non-nuclear activities relating to nuclear safety and radiation protection. Other rationale behind the merger were improved coordination, efficiency and effectiveness when reviewing licence applications from the nuclear power industry in the areas of methods and siting of spent nuclear fuel repositories. When SSM was founded, the predecessor authorities' regulations were reissued as the Swedish Radiation Safety Authority's Regulatory Code, 'SSMFS'.

Councils and committees

Several councils and committees are linked to the Authority. The delegation for financing of management of residual products from nuclear activities (the Financing Delegation) is an advisory body of SSM in areas related to preparing proposals for the fees and guarantees payable by fee-liable licensees to the Nuclear Waste Fund. The Delegation is led by the Director General and its members are appointed by the Government.

The committee for matters relating to radioactive waste and spent nuclear fuel (the Radioactive Waste Committee) provides the Authority with advice in areas relating to waste management, rules and regulations, and also provides advice prior to high-profile decisions and statements. The Reactor Safety Committee has the task of assisting the Authority in the form of advice, recommendations and viewpoints prior to official decision-making, in addition to providing advice in matters of nuclear

safety. The Research Committee's task is to assist the Authority with situational and scenario analyses and evaluations of the Authority's research and development work in the fields of nuclear safety, nuclear non-proliferation and radiation protection. The Authority is required to have these committees, as stipulated by SSM's Instructions from the Government. The members are appointed by the Director General.

The Authority also has three scientific councils in these fields: ultraviolet radiation (UV), electromagnetic fields (EMF) and ionising radiation in medical applications (oncology). These councils have the task of monitoring scientific developments in their respective fields and compiling an annual report for the Authority on the present situation in terms of technical expertise. The councils also provide guidance for adopting standpoints in issues requiring scientific consideration of different opinions or perspectives. The members are appointed by the Director General.

Securing human resources and professional skills

As of 1 January 2015, SSM had 321 employees with an average age of 47 years. The staff turnover rate, excluding retirements, was 5 %. SSM works continuously on long-term planning to identify recruitment needs and competence requirements. As a result of the many specialised areas and fields encompassed by the Authority's area of responsibility, SSM's employees have a relatively high level of education compared with many other Swedish public authorities. More than 30 per cent of SSM's employees have a university education, many with postgraduate degrees.

The Authority performs systematic professional skills assessments and gap analyses for providing SSM's senior management with input on the competence required by the Authority in both the short and long term. In spring 2012, SSM launched a continuous professional development programme for skilled supervision. The objective is for all employees involved in regulatory supervision to have the same basic skills for performing consistent supervisory work regardless of the area or licensee that is the focus of this supervision.

Management system

SSM's model for management and control is based on a process-oriented and integrated management system for all official work, certified to the standards for quality (ISO 9001), environmental management (ISO 14001) and occupational health and safety (OHSAS 18001). Another management system for information security (LIS) is integrated in the overall management system, though it is not certified.

SSM's management processes (see Figure 2) are identified on the basis of flows of tasks that the Authority needs to perform in order to meet its remit. Departmental application of these processes as part of their work performance, also the approach to development, follow-ups and evaluations of the processes, are described in internal steering documents.

Ensuring efficient and effective operations involving continual improvements is realised on an ongoing basis through internal and external audits of the management system. Contracted external auditors are accredited by SWEDAC, the Swedish Board for Accreditation and Conformity Assessment.

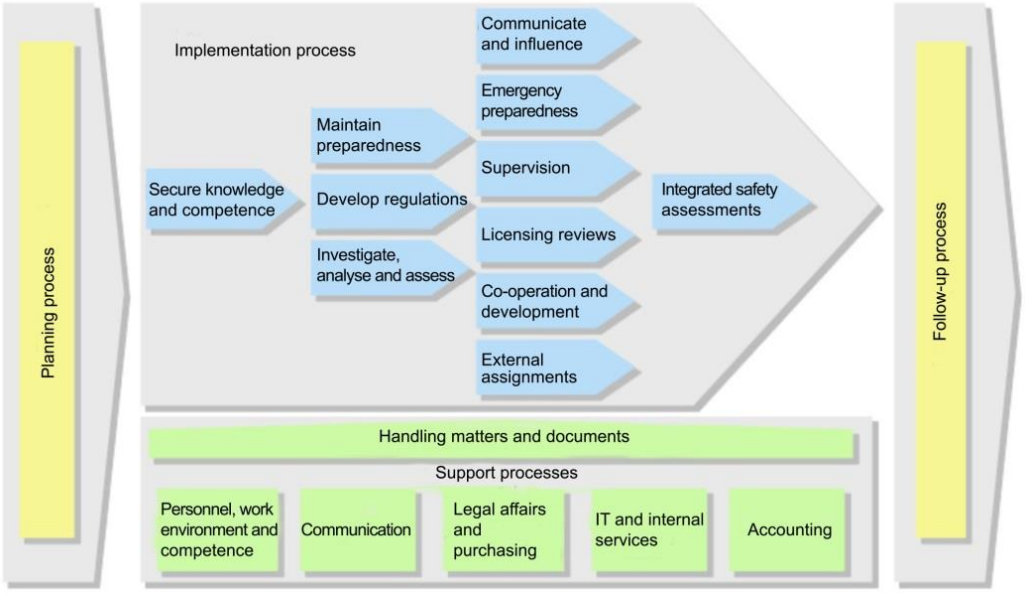

Figure 2. SSM's main management processes.

Financial resources

SSM's main source of funding is a central government appropriation comprising two items: for administration and for research. This appropriation is largely funded by fees recovered from the licensees. Other appropriation items are at the Authority's disposal: for international cooperation with Russia, for nuclear security and radiation protection in Eastern Europe, also for management of orphan sources within the parameters of the appropriation for decontamination and restoration. SSM also utilises fee revenues for licensing under the Act on Nuclear Activities, certain review processes under the Radiation Protection Act, the calibration work of the National Metrology Laboratory for ionising radiation, and for the Radon Laboratory.

Following a decision by the Government of Sweden, some regulatory supervision and licensing reviews of nuclear power industry management and final disposal of spent nuclear fuel, as well as decommissioning of nuclear power plants and related areas, are financed through contributions from the Nuclear Waste Fund. Certain measures to increase emergency preparedness that have no direct link to preparedness for nuclear energy emergencies also imply contributions to SSM from the Swedish Civil Contingencies Agency (MSB) via an appropriation for nuclear emergency preparedness. For certain international assignments, SSM receives contributions from Sida (the Swedish International Development Cooperation Agency); also, for certain radiation protection research, SSM receives contributions from FORMAS, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning.

The main principle defining SSM's sources of funding is all licensing reviews and all supervision of licensees being covered by fees. Nuclear activities are also subject to the strict principle of prohibiting central government subsidies of businesses. Activities where there are no licensees are funded through the relatively small proportion of SSM's appropriation that is based on tax revenues. This for example applies to work in the areas of ultraviolet radiation, electromagnetic fields and certain aspects of emergency preparedness work outside of preparedness for nuclear energy emergencies.

The appropriation item for research may be used for basic and applied research work on developing national competence in the Authority's areas of operation, also for supporting and developing the Authority's regulatory supervision. Research work is mainly carried out by external experts and researchers engaged by the Authority.

SSM's total budget for its 2014 operations was approximately SEK 506 million, of which SEK 76 million earmarked for research and SEK 71 million sourced from the Nuclear Waste Fund.

Research and technical assistance

The purpose of SSM's research is sustaining and developing professional skills of importance for radiation safety work, both in-house on the part of the Authority's employees and on a national level. For these reasons, SSM provides funding not only for basic and applied research, but also for development of methods and processes that lead to improved national competence in the Authority's areas of operation. This also underpins and improves SSM's regulatory supervision.

SSM provides funding for several research projects and research positions at Swedish universities for the purposes of professional development and maintaining expertise and teaching skills. Areas of key importance include reactor physics, severe accidents and non-proliferation. SSM also provides funding for high level research positions in fields such as radiation biology, radioecology and dosimetry. The availability of research funding is also announced in the form of public invitations to apply for funding in the areas of radiation protection and waste management research.

Research in the areas of final disposal of spent nuclear fuel and decommissioning of nuclear facilities is financed through the Nuclear Waste Fund. Funding is for example awarded to research projects on canister corrosion, biosphere processes, bentonite and backfill, geosphere processes, fuel processes and consequence/impact analyses. The purpose of this research is to provide input for ongoing and future reviews, including impending review elements as part of the step-wise licensing processes that Swedish disposal facilities are subject to. The research funding also has the aim of longer term maintenance of know-how, skills and continuity in areas, fields and disciplines relating to final disposal of radioactive waste. Alongside the funding for research projects, the Authority provides funding to researchers at institutions of higher education.

Over the past three decades, SSM and its predecessors have carried out extensive research programmes with the aim of developing independent expertise in geological repositories and tools in this area. Research here has been carried out by in-house personnel and through a network of external experts engaged via several international initiatives in these areas: hydrogeology (INTRACOIN and HYDROCOIN), model validation (e.g. INTRAVAL), radionuclide transport, rock mechanics modelling (DECOVALEX), biosphere modelling (BIOMOVS) and environmental protection (ERICA). Also, two independent assessments of nuclear safety and radiation protection over the long term in connection with spent fuel management in accordance with the KBS-3 method were conducted ('Project-90' and SKI's 'SITE-94').

In addition to technical research, a research programme was carried out on dialogue with interested parties such as environmental organisations, other non-governmental organisations and municipal authorities affected by SKB's programme for siting a

spent nuclear fuel repository. This project has contributed towards the development of methods and fora for conducting dialogue with the stakeholders affected and for improving awareness of stakeholder roles and needs (VALDOR and RISCOM).

For the licensing reviews for the spent nuclear fuel repository application, external technical experts are engaged to a considerable extent. Up to 70 per cent of this group is made up of international experts. In the part of the licence application relating to the environmental impact assessment (EIA) and the geological repository's long-term safety, agreements have been concluded with around 40 suppliers within four review areas: safety analysis, technical barriers, Forsmark as a candidate site and EIAs. Since 2012, around 70 technical reports have been published within the framework of this review work.

Openness, transparency and insight

SSM embraces the fundamental values held by Swedish public administration based on the platform of democracy and human rights while continually striving to follow the rule of law, maintain efficiency and effectiveness and have a citizen's perspective.

SSM's fundamental values are based on a vision of a society safe from the harmful effects of radiation: a mission statement on working proactively and preventively in order to protect people and the environment from harmful effects of radiation, in addition to the Authority's three key values of *reliability*, *integrity* and *openness*. Reliability means pursuing this work on the basis of facts. Integrity means the Authority taking responsibility and maintaining its independence. This implies avoiding undue influence when it comes to the exercise of public power. Openness means that the work of the Authority is transparent to the outside world, that the general public has insight into its operations and that SSM clearly and proactively provides information about its work, standpoints and decisions.

SSM uses its website (www.ssm.se) as a source of information about relevant current events and official decisions, and as a means of communicating to the general public as well as to occupational users whose work involves radiation. SSM gives advice and recommendations and provides information in the event of a nuclear energy accident or other incident involving radiation via the Authority's website and through social media.

The Swedish right of public access to official records not only gives the public and mass media the right to gain insight into SSM's organisation and its work, but also the right to access the Authority's official documents, provided they are not subject to secrecy. SSM's online register (e-registry), which contains details about the Authority's registered items of business, is available from the website. All reports issued by SSM may be ordered. Most of them are downloadable from the SSM website. An emergency website linked to SSM's public website can be activated during an event or accident with a radiation hazard.

SSM maintains constant emergency preparedness around the clock to enable emergency response to a severe accident, serious incident or other urgent situation. This service has a link to SOS Alarm, which in its turn alerts SSM's radiation protection expert, who can give recommendations and decide on actions to be taken (officer on duty for emergency preparedness).

Independence

As a central administrative authority, SSM has an independent role and extensive powers to decide on how official tasks are to be performed. The Authority is independent in relation to the Swedish Riksdag and Government in its exercise of public power towards individuals and matters relating to application of legislation. As evident from the above, integrity is one of the Swedish Radiation Safety Authority's key values.

Due to SSM's role as a supervisory and regulatory authority, and consequently very high integrity standards, experts and specialists engaged by the Authority must account for any circumstances that might have a bearing on their objectivity or impartiality in the matter in question or on an assignment from the Authority. Corresponding requirements are imposed when the Authority procures services and recruits employees. SSM applies a waiting period, which means that new employees are not allowed to be in charge of supervisory work or to participate in decision-related drafting or processing work vis-à-vis their former employer during the first two years of their employment by SSM.

Each year, the Authority undergoes an annual audit by the Swedish National Audit Office, an independent control body of the Riksdag.

Responsibility in the financing system

The Ordinance on Financing of Management of Residual Products from Nuclear Activities ('Financing Ordinance') and what is known as the 'Studsvik Ordinance' together regulate the financing system for residual products from nuclear activities in addition to final management of radioactive legacy waste and facilities with a link to the emergence of the Swedish nuclear power industry. SSM's tasks in the financing system are described below.

Every third year, SSM reviews the reactor licensees' cost estimates and proposes the nuclear waste fee to be payable by each of these licensees to the Nuclear Waste Fund over the next three years. SSM also prepares proposals for guarantees (financing amounts and supplementary amounts). After SSM has given a reactor licensee, the relevant government agencies, local authorities and associations an opportunity to submit a consultation response to the proposal, SSM submits the proposal to the Government of Sweden for decision-making.

Similarly, SSM performs a review every third year of all fee-liable licensees that do not have reactors and proposes for each licensee the nuclear waste fee to be payable over the next three years. SSM also prepares proposals for the guarantees (financing amounts). After SSM has given a licensee the opportunity to comment on the proposal, the Authority sets the nuclear waste fee and financing amount. If the matter concerns a nuclear power reactor permanently shut down after 31 December 1995, or if the matter is of principal importance or otherwise of special significance, the proposal is to be forwarded to the Government for decision-making. This for example means that proposals relating to the reactors at Barsebäck must be forwarded to the Government for decision-making.

SSM performs annual reviews of cost estimates and calculates the level of the nuclear waste fee as per the Studsvik Act and notifies the Government of needed changes to this fee in accordance with the Act.

SSM decides on certain types of disbursements from assets of the Nuclear Waste Fund and performs checks to ensure that payments from the Fund were used for the intended purpose. SSM has the powers to issue regulations and decide on certain types of injunctions and exemptions under the Financing Ordinance and Studsvik Ordinance.

Besides SSM, the Nuclear Waste Fund, which also is a government authority, and the Swedish National Debt Office bear responsibility in the financing system.

3.1.2. Nuclear Waste Fund

The task of the Nuclear Waste Fund is to receive and manage fee payments from nuclear power companies and other fee-liable licensees of nuclear facilities following decision-making by the Government or by SSM. These fees must for instance cover financing of future costs for the management and final disposal of spent nuclear fuel and other residual products. The Nuclear Waste Fund is led by a board of governors appointed by the Government of Sweden. Two of the board members are appointed as nominated by the licensees that must pay a nuclear waste fee. Administrative work is managed by Kammarkollegiet (Legal, Financial and Administrative Services Agency).

The main task of the Nuclear Waste Fund is to manage its capital to achieve a good return on fee payments. The Nuclear Waste Fund's capital investments are subject to the assumptions defined by the Financing Ordinance and by the investment policy decided on by the Fund's board of governors.

The Nuclear Waste Fund also manages payments from the Fund following a decision by the Government or by SSM.

3.1.3. Swedish National Debt Office

The Swedish National Debt Office is the State's central financial management authority. The Debt Office's mandate includes serving as the State's internal bank, issuing loans, managing central government debt and providing government guarantees and credit. The Debt Office also has assignments with the aim of promoting consumer protection and stability in the financial system by bearing responsibility for deposit insurance and investor protection, and dealing with central government assistance to banks.

The Debt Office manages and assesses the guarantees to be provided by fee-liable licensees to the Nuclear Waste Fund and takes certain decisions in this area. These guarantees are ordinarily provided by the parent company of licensees of the nuclear activity. The Debt Office assesses the value stability of the pledged assets from the perspective of their potential exercise several decades into the future. After each review every third year, the Swedish National Debt Office submits a statement to the Government on the assessed creditworthiness of the companies providing guarantees.

3.1.4. Swedish Civil Contingencies Agency (MSB)

The Swedish Civil Contingencies Agency, or MSB, is a central government authority whose task is to develop the capability of society to prevent and deal with accidents, crises and emergencies. MSB is in charge of comprehensive coordination efforts to protect the population and is responsible for rescue services as per the Civil Protection Act (2003:778). MSB coordinates nuclear emergency preparedness outside nuclear facilities, and assists and monitors planning of the relevant parties in charge: municipal authorities, county councils, government agencies and other organisations. MSB also evaluates outcomes of emergency exercises and launches educational initiatives.

3.1.5. Swedish Work Environment Authority

Employers have the main liability for workers' occupational environments. The mandate of the Swedish Work Environment Authority, as a supervisory authority, is to enforce compliance with work environment and working hours legislation. The objective is to reduce the risk of occupational illnesses and accidents and to improve work environments from a holistic perspective, which means from physical, mental and work organisation aspects. The Authority is also responsible for statistics on occupational environments and occupational injuries in Sweden.

The tasks of the Swedish Work Environment Authority include enforcing compliance with work environment legislation among stakeholders that use ionising radiation or that carry out nuclear activities.

3.1.6. Swedish Environmental Protection Agency

As an administrative authority in environmental work relating to climate science and air, land, biological diversity, contaminated sites, ecocycle, waste management, environmental surveillance and environmental research, the Swedish Environmental Protection Agency monitors the state of the environment and the evolution of environmental work. The Swedish Environmental Protection Agency has a key role in environmental work with its mandate implying proactive, supportive and coalescing efforts in implementation of environmental policy. The Agency also has the task of coordinating, following up and evaluating work to achieve Sweden's environmental objectives.

One of the Swedish Environmental Protection Agency's missions is to provide guidance to Swedish public authorities having a responsibility in the environmental objectives system and to coordinate follow-ups of these objectives. Each year, when following up the environmental objectives, the Swedish Environmental Protection Agency publishes a comprehensive report on the authorities' respective follow-ups and forecast trends in relation to the environmental quality objectives, and regularly conducts an in-depth evaluation of the potential for achieving the generational goal and environmental quality objectives. The Agency forwards a report to the Government giving an account of the overall situation from the authorities' evaluations.

In other respects, the Swedish Environmental Protection Agency has these specific mandates in its area of responsibility:

- Having a central role in terms of supervisory guidance,
- Liaising with County Administrative Boards for achievement of efficient and effective supervisory work,
- Monitoring general and public environmental protection interests in legal cases and official matters subject to the Swedish Environmental Code,
- Taking part in environmental licensing processes in matters of principle or of key significance for the environment,
- Providing guidance to central government authorities in their environmental management work,
- Developing, following up and evaluating application of benefit-cost analysis as part of the System of Environmental Objectives,
- Developing, following up and coordinating environmental reporting work and being in charge of overarching administrative liaison of environmental assessment work,
- Being in charge of national coordination and prioritisation for rectifying the kind of contamination and severe environmental damage referred to in Chapter 10 of the Environmental Code, and
- Striving for waste management capacity and methods to be efficient and effective for the needs of society and straightforward for consumers.

3.1.7. Other central public authorities

Several central public authorities have tasks as expert authorities in the areas of natural or environmental sciences with links to radiological matters, such as the Geological Survey of Sweden, Public Health Agency of Sweden, National Food Agency and Swedish Agency for Marine and Water Management. The National Board of Health and Welfare has expertise in medical care and nursing and has capability to carry out supervision of operations regulated by the Radiation Protection Act and Act on Nuclear Activities. As part of the national systems for nuclear and radiological emergency preparedness and physical protection against antagonistic threats, SSM liaises with police, security services, Swedish Customs, Svenska Kraftnät (Swedish National Grid) as well as with other public authorities.

The Surgeon General is responsible for regulatory supervision of the Swedish Defence Materiel Administration, Swedish Fortifications Agency and National Defence Radio Establishment. Their work is mainly of a military nature and is for this reason not encompassed by the present report.

3.1.8. Swedish National Council for Nuclear Waste

The Swedish National Council for Nuclear Waste was established in 1992 as an independent scientific advisory body. It is linked to the Ministry of the Environment and Energy. The task of the Swedish National Council for Nuclear Waste, under committee terms of reference 2009:31, is to carry out studies of issues related to

nuclear waste and decommissioning of nuclear facilities, and to advise the Government and other public authorities in these areas.

The Government has authorised the Minister for the Environment to appoint the chair and a maximum of ten other members of the Council. The Council's budget is set by the Government and funding for its work is provided by the Nuclear Waste Fund. Members of the Council are independent experts in different disciplines of importance for disposal of radioactive waste; not only in engineering and the natural sciences, but also ethics and the social sciences. The mission of the Swedish National Council for Nuclear Waste shall be deemed completed when the Government has decided on a repository for spent nuclear fuel and high level nuclear waste in Sweden.

Within the parameters of its mandate, the Swedish National Council for Nuclear Waste carries out the following activities:

- Assessing SKB's programme for research, development and demonstration (the RD&D Programme), evaluating licence applications and reviewing other reports of relevance for disposal of spent nuclear fuel and radioactive nuclear waste,
- No later than nine months after SKB has reported on its RD&D programme, as per Section 12 of the Act on Nuclear Activities, presenting to the Government an independent assessment of the research, developments and other measures presented in this programme,
- Monitoring activities conducted in the area for decommissioning and dismantling of nuclear facilities,
- No later than February of each year reporting to the Government on its work over the previous year and giving its independent assessment of the situation in the area of nuclear waste management,
- Investigating and shedding light on important aspects of nuclear waste management, for instance through seminars and public hearings, and creating optimal assumptions for the advice it provides to the Government,
- Monitoring the evolution of other countries' programmes for disposal of spent nuclear fuel and radioactive nuclear waste; also, the Swedish National Council for Nuclear Waste should also keep abreast of, and, as necessary, take part in the efforts of international organisations related to final disposal of spent nuclear fuel and radioactive nuclear waste.

3.1.9. Local safety boards

Since the early 1980s, the five municipalities in Sweden with nuclear power plants (Östhammar, Oskarshamn, Kävlinge, Varberg and Nyköping) have official boards as per a Government decision. The local safety boards consist of members appointed by the Government following nomination by the respective municipality. These boards were set up to guarantee insight into the nuclear power plants' safety work and emergency preparedness, also to ensure important communication to the general public and local residents.

Public insight and the tasks of local safety boards are regulated by the Act on Nuclear Activities and by Ordinance 2007:1054 containing instructions for the local safety boards of nuclear facilities. A party that holds a licence to operate a nuclear

power or research reactor, or a facility for the production, management, processing, storage or disposal of nuclear material or nuclear waste, is under an obligation to provide the local safety board with insight into the safety and radiation protection work at the facility.

The tasks of local safety boards are to monitor, obtain information about and communicate to the general public and local authorities the nuclear safety and radiation protection work at a facility, in addition to planning for nuclear emergency preparedness work. A local safety board is allowed to commission the investigations necessary to enable the board to assess the significance of measures taken or planned on the part of nuclear or radiation safety at the relevant nuclear facility. However, the tasks of the board exclude regulatory supervision; local safety boards also do not impose requirements for measures to raise the level of safety nor prescribe such measures.

The Swedish Radiation Safety Authority and representatives from County Administrative Boards regularly take part in local safety board meetings.

3.1.10. Courts

Land and environmental courts

Land and environmental courts' main task is to process cases and matters as stipulated by the provisions of the Environmental Code, Real Property Formation Act (1970:988) and Planning and Building Act (2010:900). These courts were established on 2 May 2011. They were formed by merging the predecessor property courts and environmental courts. Land and environmental courts are part of Swedish general courts located in Umeå, Östersund, Nacka, Växjö and Vänersborg.

Under the Environmentally Hazardous Activity and Health Protection Ordinance (1998:899), a licence is required as per the Environmental Code for facilities that treat, store or remove spent nuclear fuel, nuclear waste and/or radioactive waste. A licence is also required under the Code for decommissioning of nuclear reactors. A land and environmental court is the first instance court for examining licensing matters relating to this kind of activity. A land and environmental court may issue a licence under the Code for a shallow land disposal facility, including conditions, without seeking approval from the Government.

Judgements and decisions made by these courts may be appealed to the Land and Environmental Court of Appeal, and its judgements may be appealed to the Supreme Court. Certain decisions under the Radiation Protection Act and Act on Nuclear Activities may be appealed to the Government.

Administrative courts

Swedish administrative courts comprise three instances: administrative courts, administrative courts of appeal and the Supreme Administrative Court. The courts settle disputes, first and foremost between individuals and public authorities. Appeals in specific cases under the Radiation Protection Act may be lodged with a general administrative court. Certain decisions by local safety boards under the Act on Nuclear Activities may also be appealed to an administrative court.

3.1.11. County Administrative Boards

County Administrative Boards are liaising public authorities in 21 Swedish counties. The governor of the respective county heads each County Administrative Board. County governors are appointed by the Government. Under Ordinance 2007:825 with instructions for the County Administrative Boards, each Board is in charge of tasks that belong to conservation and environmental protection efforts, regional development, sustainable social planning, civil protection, emergency preparedness, civil defence, peacetime crisis management and rescue services.

A County Administrative Board is an important stakeholder as part of the Swedish crisis management system. County Administrative Boards' responsibility for rescue services is regulated by the Act (2003:778) and Ordinance (2003:789) on civil protection. In the event of a serious incident, the local County Administrative Board is the public authority that is in charge of the situation in the county and, for example, heads rescue services or decontamination efforts following a nuclear accident. A County Administrative Board is among other things also in charge of providing information about health protection measures to the affected population in an emergency situation posing a radiation hazard.

In the process of preparing environmental impact assessments (EIA), an applicant is required to confer with the County Administrative Board at an early stage and to an appropriate extent before submitting an application for authorisation in accordance with the Environmental Code and preparing the environmental impact assessment.

County Administrative Boards, or municipal environment committees, carry out regulatory supervision of waste facilities where radioactive and cleared waste may be disposed of. A County Administrative Board is also the supervisory authority for large-scale facilities for interim storage of hazardous waste in the form of electrical and electronic products containing radioactive sources, such as fire alarms and smoke detectors.

3.1.12. Municipal authorities

On a local level, municipal authorities carry out regulatory supervision as per the Environmental Code on the part of relevant use of a site, buildings or facilities that might bring about detriment to the surroundings due to ionising or non-ionising radiation and where such use does not require a licence under the Code.

Under Chapter 17, Section 6 of the Environmental Code, the Government may permit nuclear facilities only provided that the municipal council of the municipality planned for siting of a facility has given authorisation for such facility. From a national point of view, if the case is extraordinarily urgent for establishment of the operation, the Government has the possibility of granting an exemption from, and thus overriding, a municipal veto to facilities for the interim storage or disposal of nuclear material or nuclear waste. Municipal environmental boards carry out regulatory supervision of waste facilities where radioactive and cleared wastes may be disposed of.

Municipal authorities not only have the right to exercise a veto when considering the permissibility of a nuclear activity. They also work proactively on increasing awareness and communication on the part of their organisations and the general public, also other public authorities and licensees involved in decision-making processes at both national and international levels.

In parallel with a licensing review for a nuclear facility, the relevant municipal authority considers matters relating to the detailed development plan and building permit for the facility.

In the event of a non-nuclear accident involving radioactive material, such as an accident during transport or other accident or event involving radiation, municipal rescue services are primarily in charge.[10]

3.2. **The regulatory framework**

The general principles governing safety and radiation protection are defined in the Act on Nuclear Activities, Radiation Protection Act and Environmental Code. The provisions contained in these enactments are supplemented by ordinances and official regulations containing more detailed provisions. It is illegal for a nuclear facility to be owned or operated without a licence issued under the Act on Nuclear Activities and Environmental Code. Consequently, two separate licences are required, issued under two different enactments, to legally own and operate a nuclear facility. Complex sites that conduct activities involving radiation must be licensed under not only the Radiation Protection Act, but also the Environmental Code. In normal cases, however, the vast majority of activities involving radiation only require a licence under the Radiation Protection Act.

The framework of Swedish legislation in the areas of waste management, nuclear safety and radiation protection consists of five enactments with appurtenant ordinances:

- The Act on Nuclear Activities (1984:3),
- Radiation Protection Act (1988:220),
- Swedish Environmental Code (1998:808),
- Act on Financing of Management of Residual Products from Nuclear Activities (2006:647; also referred to as the 'Financing Act'), and
- The Act on the Financing of the Management of Certain Radioactive Waste, etc. (1988:1597; the 'Studsvik Act').

Significant regulation is also in place in parts of the Act on the Control of Dual-use Items and Technical Assistance (2000:1064) and legislation on nuclear liability and transports. Health and safety aspects, such as public interests stipulated by the Planning and Building Act (2010:900) in connection with work on planning and considering building permits, mean an additional review of activities and facilities for radioactive waste management beside the Swedish Environmental Code, though this work also must comply with the Code.

[10] Swedish Rescue Services Agency, 2008/Swedish Civil Contingencies Agency (MSB), 2015. *Den svenska beredskapen för radiologiska och nukleära olyckor 2015* [Emergency preparedness in Sweden for radiological and nuclear accidents, 2015], p. 15.

3.2.1. The Act on Nuclear Activities

The Act on Nuclear Activities is the fundamental enactment regulating nuclear safety. The Act contains fundamental conditions pertaining to safety in connection with nuclear activities, and governs not only management of nuclear material and nuclear waste, but also operation of facilities.

The Act on Nuclear Activities focuses on safety compliance of nuclear activities and meeting Sweden's commitments in the area of nuclear non-proliferation, as well as regulatory supervision of these nuclear activities and insight into them. The stipulated aim of the Act on Nuclear Activities when it comes to safety work is to as far as possible eliminate the risk of a radiological accident and thus, ultimately, the loss of life and property. This is why the Act on Nuclear Activities has been formulated to give licensees a virtually strict liability when conducting nuclear activities (i.e. waste producer responsibility).

The Act on Nuclear Activities has the nature of a framework enactment, which is given its tangible content through the Nuclear Activities Ordinance and official regulations. The Act contains key definitions and provisions that regulate management and disposal of nuclear waste and spent nuclear fuel.

Moreover, the Government has authorised SSM to issue regulations and provisions under the Act on Nuclear Activities and has given SSM a mandate as a supervisory authority. SSM also has the powers to decide upon licence conditions deemed necessary by the Authority for the purpose of maintaining safety.

The Act on Nuclear Activities obligates a licensee to not only comply with the conditions and regulations issued by the Government or SSM, but also to work independently on performing all the measures needed for these purposes:

- Maintaining nuclear and radiation safety,
- Enabling the safe management and disposal of generated nuclear waste and nuclear material that will not be reused, and
- Enabling the safe decommissioning, dismantling and demolition of a facility in which the operation will be discontinued.

These obligations imply that a licensee must take all the measures necessary to enable safe management and disposal of the nuclear waste generated and nuclear material that will not be reused, and that the facility where the activity will be discontinued is to be decommissioned and demolished in compliance with safety requirements. This also includes a responsibility to define the necessary measures and approach to the work. The requirements for management of spent fuel and nuclear waste must by definition be quite extensive for the purposes of nuclear safety and radiation protection. This is also the case when decommissioning a facility. This obligation includes complete dismantling and removal of (for example) a reactor and other components of the reactor unit. The responsibility that rests with a licensee of a nuclear activity includes bearing the waste facility’s actual and necessary costs.

On several occasions, the Swedish Riksdag has declared that Sweden supports, and will comply with, the principle of each nation managing and assuming responsibility for all spent nuclear fuel and radioactive waste generated by the nuclear activities in that state. All dealing with, even temporary storage, of foreign spent nuclear fuel and radioactive waste, is prohibited in Sweden. However, in extraordinary cases, the

Swedish Government may grant special permission to allow storage of a small quantity of foreign spent fuel or radioactive waste.

Under Section 10 of the Act on Nuclear Activities, a party that carries out nuclear activities is responsible for the requisite measures for safe decommissioning and dismantling of facilities; this responsibility includes safe management and final disposal of spent nuclear fuel and nuclear waste. Section 11 prescribes that a party holding a licence to operate a nuclear power reactor is responsible for the comprehensive research and development operations necessary to fulfil the obligations of Section 10. Under Section 12, a party that holds a licence to own or operate a nuclear power reactor must, in consultation with other reactor operators, prepare or arrange for a programme for the comprehensive research and development work and the other measures necessary for safe management of nuclear waste and spent nuclear fuel, in addition to safe decommissioning and dismantling of nuclear facilities (the RD&D Programmes). Every third year, this programme must be submitted to SSM for review and evaluation.

An important step of this review process is to arrange for a consultation procedure to collect viewpoints from a number of interested parties. These may include other central and local government authorities, environmental organisations, research institutes and universities. Following SSM's review, the programme and SSM's statement are forwarded to the Government, which considers the matter and decides whether or not to approve the programme. In conjunction with the review and evaluation, the Government may impose conditions considered necessary for continuing research and development work.

The Act on Nuclear Activities does not regulate aspects of radiation protection. These are regulated by the Radiation Protection Act. As far as concerns radioactive material and radiation, both of the Acts are to be applied in parallel as well as jointly.

The Act on Nuclear Activities does not lay down requirements on reversibility of disposed nuclear waste or potential for retrieval of nuclear waste that has been disposed of. However, it is stated in Section 8 of SSM's regulations (SSMFS 2008:21) concerning safety in connection with final disposal of nuclear material and nuclear waste that safety impact due to the kind of measures taken to facilitate monitoring or recovery of nuclear material disposed of or nuclear waste from the waste facility, or taken to hinder access to such facility, is to be analysed and reported to SSM.

3.2.2. The Radiation Protection Act

Radiation protection requirements are stipulated by the Radiation Protection Act, Radiation Protection Ordinance and regulations issued by the Swedish Radiation Safety Authority, SSM. The purpose of this legislation is to protect people, animals and the environment against harmful effects of radiation.

The Radiation Protection Act governs all activities that involve radiation. Consequently, this Act applies to radiation from nuclear activities and to harmful radiation – ionising and non-ionising radiation – regardless of source (medical, industrial, research, consumer products and NORM). The Act is not only key legislation in terms of protecting employees engaged in activities involving

radiation, but also the general public in the surrounding environment and persons exposed to medical radiological procedures.

A party that conducts an activity involving radiation is required to observe the necessary precautions. It is clear from the Radiation Protection Act that parties conducting activities involving radiation are also responsible for ensuring that the radioactive waste occurring in the undertaking is managed and disposed of in a way that is satisfactory from the standpoint of radiation protection. This responsibility includes covering costs related to both management and storage of this waste.

The Radiation Protection Ordinance contains detailed provisions defining the Radiation Protection Act. Also, the Swedish Government has given SSM the powers to issue regulations containing further provisions on general obligations, radioactive waste, external releases of radioactive materials and prohibition of activities involving certain materials, etc. SSM is the supervisory authority under the Radiation Protection Act. The Ordinance also states that certain provisions contained in the Radiation Protection Act are not applicable in cases where the level of activity is so low that it falls below certain limits.

The Government or SSM may also, as far as possible without circumventing the aim of the Act, prescribe exemptions from the Act or certain provisions of the Act concerning radioactive substances. Moreover, particular conditions may be issued for radioactive material or technical devices that can emit radiation and which otherwise would not be governed by the Act. SSM has issued regulations encompassing waste management and derogation from the Act on the part of certain materials (clearance). When it comes to nuclear facilities, the Radiation Protection Act and Act on Nuclear Activities are applied together.

3.2.3. The Swedish Radiation Safety Authority's regulations

With reference to its legal mandate, SSM issues legally binding regulations governing nuclear facilities and other activities and practices involving radiation. These regulations belong to the Swedish Radiation Safety Authority’s Regulatory Code (SSMFS). In addition to the regulations, SSM issues general advice for interpretation of provisions. The general advice is not legally binding. Measures are to be taken in accordance with the general advice or equivalent alternatives that are considered suitable. Through SSM’s regulations, large parts of EU Directives and international commitments have been implemented in Swedish legislation. SSM’s regulatory work takes into account the IAEA’s safety standards, ICRP publications, international recommendations, industry and other standards, as well as the regulations of other Swedish public authorities.

An account is provided below of provisions and regulations of relevance to waste management. Besides these regulations that to a large extent regulate waste management, there are provisions on managing discarded radiation sources that belong to the regulations (SSMFS 2012:2) on bearing binoculars, bearing compasses and night vision devices containing tritium, the regulations (SSMFS 2008:47) on fire alarms containing a source of radioactivity in the form of a radioactive material, the regulations (SSMFS 2008:44) on smoke detectors containing radioactive material, and the regulations (SSMFS 2008:9) on the control of high-activity sealed radioactive sources.

Regulations and general advice concerning safety in nuclear facilities (SSMFS 2008:1)

These regulations are mainly formulated for application at nuclear power plants. However, they govern all nuclear activities licensed under the Act on Nuclear Activities regardless of size or the kind of operation. For instance, the regulations apply to facilities for manufacture of fuel and facilities for management and storage of radioactive waste. The regulations strive to specify the measures necessary for preventing radiological accidents and illegal trade in nuclear material and nuclear waste, in addition to achieving efficient and effective supervisory work. The regulations apply to aspects such as decommissioning and management of nuclear material and nuclear waste.

Regulations and general advice concerning non-proliferation control, etc. (SSMFS 2008:3)

This regulation supplements Commission Regulation (Euratom) No 302/2005 on the application of Euratom safeguards (see Section 3.3.1) and mainly relates to facilities in operation. The regulation imposes requirements for procedures for accounting for nuclear material and for verification of spent nuclear fuel prior to being emplaced in copper canisters. A description of each facility is to be submitted to SSM. Documents or records relating to safeguards must be retained for the duration of a nuclear activity.

Regulations and general advice concerning safety in connection with the disposal of nuclear material and nuclear waste (SSMFS 2008:21)

These regulations, which entered into force in 2002, impose specific requirements for design, construction, safety analyses and safety analysis reports for disposal facilities, taking into account the period following closure of this kind of facility. One area encompassed by the regulations is quality requirements for the barrier system. The period prior to closure is subject to the general safety regulations (SSMFS 2008:1).

Regulations and general advice concerning the protection of human health and the environment in connection with final management of spent nuclear fuel and nuclear waste (SSMFS 2008:37)

These regulations apply to final management of spent nuclear fuel and nuclear waste. The fundamental requirement is to protect human health and the environment against harmful effects of ionising radiation, not only while taking the different steps as part of final management of spent nuclear fuel and nuclear waste, but also in the future. Final management must not cause more severe effects on human health and the environment outside the borders of Sweden than levels accepted within Sweden. The regulation also contains provisions on optimisation and use of best available technique, the risk criterion, time periods for risk analyses and compiling rationale for assessing compliance with the regulatory provisions.

Regulations concerning filing at nuclear facilities (SSMFS 2008:38)

The regulations concerning filing at nuclear facilities (SSMFS 2008:38) require records to be kept on the facility's site and design and its inventory of waste needing long-term storage (much longer than 100 years).

Regulations concerning management of contaminated ash (SSMFS 2012:3)

These regulations apply to the management of contaminated peat and wood fuel ash generated when producing energy at incineration facilities where more than 100 tonnes of ash dry matter are produced each year. The regulation contains preventive provisions on management of ash in the form of different options, such as recycling on forest land and recycling of ash for road projects or as a filler material. Contaminated ash having levels of activity exceeding the limits for recycling must be disposed of.

Regulations concerning naturally occurring radioactive material (SSMFS 2011:4)

These regulations contain provisions on clearance of naturally occurring radioactive material and exemptions from the licence obligation. The provisions cover areas such as building materials, water treatment filters and residues containing naturally occurring radioactive material.

Regulations concerning protection of human health and the environment in connection with discharges of radioactive substances from certain nuclear facilities (SSMFS 2008:23)

The regulations apply to all discharges of radioactive substances from nuclear facilities that are directly related to normal operating conditions at the respective facility. The limitation of discharges of radioactive substances from nuclear facilities is to be based upon optimisation of radiation protection while using the best available technique. Such optimisation of radiation protection includes all facilities located within the same geographical area. The effective dose to any individual in the reference group by a yearly discharge of radioactive substances to water and air from all facilities situated within the same geographical area must not exceed 0.1 millisievert (mSv).

Regulations concerning clearance of materials, rooms, buildings and land in practices involving ionising radiation (SSMFS 2011:2)

These regulations contain provisions on clearance of materials, rooms, buildings and land in practices involving ionising radiation. The regulations replace the previous regulations on clearance of goods and oil from nuclear power operations.

Regulations concerning radioactive waste management and releases from activities involving unsealed sources (SSMFS 2010:2)

These regulations apply to waste management and releases from activities in which unsealed sources are manufactured or used. The regulations apply to management of solid and liquid wastes from sources such as medical, laboratory and research activities.

3.2.4. The Swedish Environmental Code

The purpose of the Swedish Environmental Code is to protect the environment and human health against environmentally hazardous activities and to promote sustainable development implying that present and future generations are ensured a healthy and sound environment. This kind of development is to be based on the insight that nature is worthy of special protection and that the right of human beings

to alter and utilise natural resources is linked to a responsibility for ensuring sound conservation practices.

The Environmental Code stipulates the prerequisites for achieving the objectives of the Code. This means application of the Environmental Code to ensure:

- Protection of human health and the environment against damage and detriment regardless of whether they are caused by contamination or other impact,
- Protection and conservation of valuable natural and cultural environments,
- Preservation of biological diversity,
- Use of land, water and physical environments in other respects to achieve and maintain long-term and effective conservation from the perspectives of ecological, social, cultural and economic aspects, and
- Work to promote reuse, recycling and other conservation of materials, commodities and energy to achieve a sustainable waste management system.

The Environmental Code's area of application is thus quite broad. Its rules may be applied to all activities and all measures that affect the environment, from large-scale industrial projects to small individual actions by private persons.

It is evident from the Environmental Code that use of facilities that might imply detriment to human health or the environment is to be viewed as an environmentally hazardous operation. Nuclear facilities and certain complex sites whose work involves radiation are to be viewed as carrying out activities that are environmentally hazardous and thus subject to the rules of the Code. The Government issued the Environmental Supervision Ordinance (2011:13) to regulate mandates for regulatory supervision under the Environmental Code. Under the Code, SSM is the supervisory authority when it comes to potential detriment due to ionising and non-ionising radiation from nuclear activities and practices involving radiation that also require a licence according to the Code's rules. SSM is also tasked with giving guidance as part of County Administrative Board and municipal supervisory work relating to areas or sites contaminated by radioactive substances.

Under the Act on Nuclear Activities, the Environmental Code's general rules of consideration are to be applied to consideration of matters under the Act on Nuclear Activities. The provisions concerning environmental quality standards contained in the Code must also be applied. The same burden of proof applies here as in connection with consideration in accordance with the Code. The applicant has the task of demonstrating that the general rules of consideration contained in the Environmental Code are taken into account and that the applicant complies with radiation safety legislation.

The Act on Nuclear Activities also requires an environmental impact statement (EIA) as part of an application for a licence to construct, own or operate a nuclear facility. As far as concerns the procedure for preparing an EIA and its requirements, the Act on Nuclear Activities refers to the provisions of the Environmental Code. The purpose of an EIA is to lay a good foundation for decision-making. An EIA is a compulsory and key document for a licensing review. It must be included as part of the decision guidance documents and enable an overall assessment of a planned activity's impact on the environment, human health and conservation of natural resources.

Presenting alternatives is an important prerequisite for meeting the objective of an EIA. An EIA must include an account of alternative locations, if feasible, in addition to alternative designs together with justification for selection of a particular alternative. It must also provide a description of the consequences of an activity not being realised, what is known as the 'zero alternative'.

An omitted or a deficient EIA is a procedural hindrance, thus implying mandatory rejection of the application. The special status of an EIA as an underlying document for a licence application is underlined by the fact that the regulator is to consider its approval; that is, whether the EIA fulfils the Environmental Code's requirements.

Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives[11], as well as the Waste Ordinance (2011:927), both lay down the legal framework for waste management. These enactments not only define key concepts such as waste, recycling and removal, but also impose fundamental requirements for waste management. In particular, this applies to an obligation for parties carrying out an activity involving waste handling to have authorisation or be entered in a registry; Member States are also under an obligation to draw up plans for waste management. This also establishes several important principles, such as one's obligation to deal with waste in such a way to avoid a negative impact on the environment and human health, promoting use of the waste hierarchy, and the Polluter Pays Principle. The latter implies a requirement for licence holders or previous owners of waste, or manufacturers of products giving rise to wastes, to bear the costs of waste management. Departures from the waste hierarchy may be justified for technical, financial or environmental reasons. The Waste Ordinance (2011:927) also states that the waste hierarchy does not apply to spent nuclear fuel and nuclear waste regulated under the Act on Nuclear Activities, or radioactive waste regulated under the Radiation Protection Act.

3.2.5. The Planning and Building Act

Human health and safety belong to the public interests protected by the Planning and Building Act. These provisions are contained in Chapter 2 of the Act. Compliance with them is mandatory as part of all planning work. Application of parts of the present national waste plan will certainly be influenced by physical planning, for example, structure plans and detailed development plans for areas that can be used for management and storage of spent nuclear fuel and other radioactive waste, likewise for establishment of protective zones.

One of the Planning and Building Act's points of departure is considering siting in terms of the land and water areas' suitability for buildings and structures. The Planning and Building Act also imposes requirements in terms of design and characteristics of structures on the basis of safeguarding human health and ensuring safety. These public interests and considerations of these aspects are not only brought to the fore during planning work, but also when considering building permits for constructing, refurbishing and rebuilding the kind of facilities discussed in the national waste plan.

[11] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

The Planning and Building Act also requires consultation procedures in connection with planning work that is broader than required by the Environmental Code and which is relevant in the context.

3.2.6. The Financing Act

The financial liability governed by the 'Financing Act' (Act on Financing of Management of Residual Products from Nuclear Activities; 2006:647) applies to all licensees of nuclear activities. A party licensed under the Act on Nuclear Activities is liable to bear the costs for areas such as safe management and final disposal of residual products from its operations as well as safe decommissioning, dismantling and demolition of its facilities when the activities have ceased. The obligations remain in force until the measures have been performed, even if the licence is no longer valid.

The Financing Act requires funding to be set aside for the costs of licensees. This Act applies to all licensees of nuclear activities. The purpose of the financing system is to, as far as possible, minimise the risk of the state being forced to bear the types of costs encompassed by the licensees' payment liability.

Every third year, licensees must submit a cost estimate to SSM on total costs for management of all residual products and decommissioning of all facilities. SSM reviews the cost estimates and proposes the licensees' nuclear waste fees and guarantees. The Government decides on the nuclear waste fees and guarantees of reactor licensees for the next three-year period. Fee payments are made to a special fund, the Nuclear Waste Fund. Assets belonging to the Nuclear Waste Fund are to cover both present and future costs for the above measures.

3.2.7. The Studsvik Act

Under the Studsvik Act, the financial liability applies to final management of legacy waste and facilities whose origin is related to the emergence of the Swedish nuclear energy industry. An aspect that is shared by the facilities and operations subject to the Studsvik Act is that they have a link to the emergence of the Swedish nuclear energy programme of the 1950s and 1960s.

According to the Studsvik Act, an entity licensed to own and operate a nuclear power reactor is liable to pay a fee to the state in order to defray costs for areas such as decontamination and dismantling of certain nuclear facilities, as well as management and final disposal of nuclear waste, nuclear material and certain other kinds of radioactive waste.

SSM performs annual reviews of cost estimates, calculates the level of the nuclear waste fee as per the Studsvik Act and notifies the Government of needed changes to this fee in accordance with the Act.

The Studsvik Act will, in accordance with current legislation, cease to apply at the end of 2017.

3.2.8. Dual-use items

The Act on the Control of Dual-use Items and Technical Assistance (2000:1064) regulates these and other items which might have both peaceful and non-peaceful uses above a particular technical level. The Act contains supplementary provisions to 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.

Under the Ordinance on the control of dual-use items and technical assistance (2000:1217), an application for export of spent nuclear fuel from the EU must contain information about the material's final management. If the origin of the spent fuel is nuclear activities in Sweden, the licence application must also contain an affirmation stating that the exporter of the material will recover it if it cannot be managed as intended.

Provisions are also contained in the Military Equipment Act (1992:1300) and Act on Nuclear Activities.

3.2.9. Nuclear liability

The Riksdag has passed the Act on Liability and Compensation in the Event of Radiological Accidents (2010:950). It will replace the Nuclear Liability Act (1968:45) and enter into force upon ratification of the 2004 protocol to amend the Paris Convention, with the Supplementary Convention, on liability to pay damages in the area of nuclear energy.

Under the Nuclear Liability Act, owners of nuclear facilities have a strict liability to pay damages for detriment caused by a nuclear accident, apart from exceptional cases where a transporter is liable. This liability amounts to SEK 3.3-4.0 billion. The owner of a facility is required to be insured by 120 per cent cover of the liability amount.

When the Act on Liability and Compensation in the Event of Radiological Accidents enters into force, unlimited liability will be introduced. Owners of nuclear power reactors will be obligated to secure financing of this liability to pay damages, in the form of third party liability insurance or other financial security, at an amount up to EUR 1.2 billion (approx. SEK 12 billion). For nuclear facilities other than nuclear power reactors, the main rule will be for owners to secure financing for their liability for a maximum of EUR 700 million (approx. SEK 7 billion). The new Act will also raise the total guaranteed compensation from the state from SEK 6 billion to EUR 1.5 billion (approx. SEK 15 billion).

3.2.10. Transports

Sweden has a well-developed legal framework for transports of radioactive waste. International transport regulations that also apply to Sweden are the foundation of this regulation of waste transports, whereas special legislation such as the Act on Nuclear Activities imposes supplementary requirements for safety, radiation protection and physical protection of such material during shipment. The principle is waste transports subject to official regulatory control. This implies compulsory transport permits and checking compliance with requirements for waste packages and other prerequisites under transport regulations in the form of supervisory action by competent authorities.

Legal prerequisites applying to domestic transports are stipulated by the following:

- The Swedish Environmental Code,
- The Act on Transport of Dangerous Goods (2006:263),
- The Act on Nuclear Activities,
- The Nuclear Activities Ordinance,
- The Radiation Protection Act,
- The Radiation Protection Ordinance,
- Facility-specific license conditions issued by the Swedish Government or by SSM, and
- The Regulatory Code of SSM, the Swedish Radiation Safety Authority (SSMFS).

Transports of radioactive material require a permit under the Act on Nuclear Activities or Radiation Protection Act, and in certain cases, the Act on Transport of Dangerous Goods (2006:263). Regulatory supervision by SSM of transporters of radioactive material is performed together with supervision by other Swedish public authorities such as the Police, Coast Guard, Work Environment Authority and Customs.

Following processing, a transport permit may be granted for owners of nuclear facilities, research institutes, hospitals and the like. Transports of radioactive material are dually regulated activities, where detailed requirements imposed on transporters, packaging and other areas are stipulated by international modal regulations for transport of dangerous goods: ADR-S for road transport, the IMDG Code for marine transport and ICAO-TI for air transport. The modal regulations are in the form of official enactments issued by MSB and the Swedish Transport Agency; the enactments encompass all nine classes of dangerous goods.

SSM is the competent authority and supervisory authority as laid down by the Act on Transport of Dangerous Goods as described above. SSM carries out regulatory supervision to ensure that transports of Class 7 radioactive waste fulfil the requirements of international transport regulations (ADR, RID, IMDG, ICAO-TI).

Transport companies such as hauliers and shipping lines can have their own permits for transport, or in some cases operate as contractors on the behalf of holders of transport permits under the above-mentioned enactments. Transporters may be domestic or foreign companies.

3.2.11. New legislations and regulations

A proposal was presented in 2011 on changing the structure of the provisions contained in the Radiation Protection Act, Act on Nuclear Activities and Environmental Code.[12] This proposal, whose purpose is to collect the rules for radiation safety contained in the Environmental Code, has not yet led to any amendments to the legislation. At the same time, an extensive project is currently

[12] *Strålsäkerhet – Gällande rätt i ny form* [Radiation safety: About law in a new form], Swedish Government Official Report SOU 2011:18.

ongoing at SSM for the purpose of revising its official regulations. The regulations are to be adapted to enable application to new nuclear facilities with amendments being made in pace with international recommendations and EU Directives.

In consultation with the Nuclear Waste Fund and Swedish National Debt Office, SSM presented in 2013 a Government assignment on proposing amendments[13] to the Financing Act and Financing Ordinance. The purpose was to clarify the principles for calculating nuclear waste fees and managing assets in the Nuclear Waste Fund, while also reviewing provisions concerning use of guarantees for the purpose of improving the level of financial security on the part of the state. The background of this assignment was that since the present Act and Ordinance entered into force, the authorities have pointed out to the Swedish Government a number of unclear circumstances and problems relating to the present system of financing.

3.3. **International requirements**

3.3.1. The European Union

Euratom

The Treaty establishing the European Atomic Energy Community, Euratom, was signed on 25 March 1957, at the same time as the Treaty establishing the European Economic Community (EEC Treaty). Consequently, the Euratom Treaty is one of the European Union's founding treaties. Euratom's key function is to lay the necessary foundations for the nuclear power industry's rapid organisation and growth and thus contribute to a raised standard of living in Member States and development of links with other countries. Through the Treaty, Member States agree to a series of obligations on development of and shared control over production of nuclear power in the Community.

The Euratom Treaty constitutes part of Member States' legal systems; the Treaty applies to Sweden under Act 1994:1500 on the accession of Sweden to the European Union. EU regulations decided under Euratom are directly applicable in the Member States. This means that additional legislation is not needed in order for the Euratom Treaty and the EU regulations issued in pursuance of the Treaty to apply in Member States. On the other hand, supplementary legislation is needed in cases such as when the Treaty imposes requirements on Member States to take special action that is not regulated in detail by the Treaty. Also, rules are needed for implementing the provisions contained in Directives under Euratom.

The Euratom Treaty is of importance for the fields of nuclear engineering and radiation protection, primarily by stipulating uniform standards for radiation protection and by the Community supervising their application. The Euratom Treaty is also of immediate importance for disposal of radioactive waste, an area that encompasses final disposal of spent nuclear fuel and nuclear waste.

Under Article 37 of the Euratom Treaty, each Member State is obliged to provide the European Commission with general data relating to plans for the disposal of

[13] SSM report, Amendments to the Act on Financing of Management of Residual Products from Nuclear Activities (2006:647) and the ordinance on financing of this management (2008:715), SSM2011-4690.

radioactive waste. This information must enable the Commission to establish whether a plan's implementation could imply radioactive contamination of water, soil or air in another Member State. The Commission is to deliver its opinion on the plans within six months after consulting with the 'Article 37 group'. The Court of Justice of the European Union has established that Article 37 is to be interpreted as requiring the general data concerning a plan for disposal of radioactive waste to be provided to the Commission prior to authorisation being given to this disposal by the relevant Member State's competent authorities.[14]

The Commission has issued a more detailed Recommendation[15] specifying the kinds of facilities that may be affected by Article 37 and the kind of information that should be sent to the Commission. Under Article 37, 'disposal of radioactive waste' refers to all planned disposal and planned or unintentional releases into the environment of radioactive substances in the form of a gas, liquid or solid in connection with the following examples of activities:

- The operation of nuclear reactors,
- The mining, milling and conversion of uranium and thorium,
- The fabrication of nuclear fuel,
- The storage of irradiated nuclear fuel in dedicated facilities,
- The dismantling of nuclear reactors and reprocessing plants,
- The handling and processing of radioactive substances on an industrial scale,
- The processing or storage of radioactive waste arising from the above-mentioned activities, and
- The emplacement of radioactive waste above or under the ground without the intention of retrieval.

This implies that SSM requests underlying documents from the applicant and then sends them to the Ministry of the Environment and Energy, which in turn ensures that these documents are also received by the Commission.

Chapter 7 of the Euratom Treaty, 'Safeguards', contains general rules on this area. Anyone setting up or operating an installation for managing irradiated nuclear fuels must declare to the Commission the basic technical characteristics of the installation. The European Commission has the right to require operating records for ensuring that the safeguards are in place and to send inspectors to the facility to ensure that nuclear material is not used for purposes other than declared by the users, also ensuring that the regulations on supply are complied with, as well as all obligations agreed by the Community with a third state or an international organisation.

Chapter 7 also contains specific provisions on sanctions. Anyone who neglects their obligations can be issued a warning, have special benefits withdrawn, have their undertaking placed under administration, or in a worst case scenario, have nuclear material withdrawn. Member States are required to ensure enforcement of sanctions and, when applicable, ensure that a liable party pays compensation.

[14] Case no. 187/87(4) of 22 September 1987
[15] Commission Recommendation of 11 October 2010 on the application of Article 37 of the Euratom Treaty (2010/635/Euratom)

Euratom regulations

Commission Regulation (Euratom) No 302/2005 on the application of Euratom safeguards contains rules for this area applying to all facilities and installations in the European Union. This implies that the Regulation also applies to facilities for spent nuclear fuel and nuclear material that will not be reused. A facility is required to present a basic technical description no later than 200 days prior to expected receipt of the first shipment of nuclear material. Furthermore, the Commission is to receive a yearly framework programme (e.g. activity programme). The Regulation contains detailed requirements for nuclear material accountancy systems. Accountancy records must contain details about quantities, physical form and actual placement, etc. The measurement system upon which the accountancy records are based is required to fulfil the latest international standards.

The Euratom Treaty also contains rules applying to entry and transfers, or import and export, of spent nuclear fuel and radioactive waste. In this area, the Treaty is supplemented by Council Regulation (Euratom) No 1493/93 of 8 June 1993 on shipments of radioactive substances between Member States.

Euratom Directives

The fundamental Directive governing radiation protection is the Directive for protection of workers and the health of the general public,[16] the BSS Directive, updated most recently in January 2014.

There is also, since 2011, Council Directive 2011/70/Euratom,[17] which establishes a Community framework for management of spent fuel and radioactive waste. This Directive has been implemented in Swedish legislation in the form of amendments to both nuclear engineering and radiation protection legislation (Government Bill 2013/14:69).

Since 2009, there has also been a Directive on establishing a Community framework for the nuclear safety of nuclear installations; this Directive was updated first in July 2014. The Nuclear Safety Directive[18] has two express aims: a) to maintain and promote the continuous improvement of nuclear safety and its regulation, and b) to ensure that Member States provide for appropriate national arrangements for a high level of nuclear safety to protect workers and the general public against the dangers arising from ionising radiation from nuclear installations.

[16] Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.
[17] Council Directive 2011/70/Euratom establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste.
[18] Council Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations.

EU Directives

In contrast to Euratom Directives with their origin from the Euratom Treaty, European Union Directives originate from the Treaty on European Union and the Treaty on the Functioning of the European Union. The following EU Directives are relevant for the responsible and safe management of radioactive waste and nuclear waste:

- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment, and Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (Environmental Impact Assessments: EIAs).

- Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (Strategic Environmental Assessments: SEAs).

- Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC.

3.3.2. Requirements for international contacts in accordance with the Swedish Environmental Code

The Convention on environmental impact assessments in a transboundary context (SÖ 1992:1; the Espoo Convention) is an environmental protection convention for the EU, US and Canada on joint work to prevent adverse environmental impact across boundaries. The Convention requires informing neighbouring countries and the general public about planned activities that could potentially cause environmental impact. The Espoo Convention is implemented in Chapter 6, Section 6 of the Environmental Code, which regulates exchange of information and consulting with other countries. Here, it is stipulated that if an activity might have a significant environmental impact in another country, the Swedish Environmental Protection Agency must inform the competent authority in that country about the planned activity and give the country concerned and the residents who are affected the opportunity to take part in a consultation procedure concerning the licence application and environmental impact assessment. Such information shall also be supplied when another country which might be exposed to a significant environmental impact so requests it.

The responsibility of the Swedish Environmental Protection Agency under Chapter 6, Section 6 of the Environmental Code is described in Section 9 of the Environmental Impact Assessment Ordinance (1998:905). The Swedish Environmental Protection Agency must assess whether a new nuclear power plant or a power uprate of an existing nuclear power plant, or construction or modification of another kind of nuclear facility that requires authorisation, might be assumed to imply a significant environmental impact in another country, and in this case must provide information to the competent authority of that country. Moreover, the Swedish Environmental Protection Agency must allow the country that could be affected and its residents opportunities to participate in a consultation procedure concerning the licence application and environmental impact assessment.

Under Section 11 of the same Ordinance, central government authorities that become aware of an activity or a measure that might be assumed to imply a significant environmental impact in another country must notify the Swedish Environmental Protection Agency about this.

3.3.3. Transboundary shipments

Regulation of radioactive waste shipments in the EU and across borders to a third country encompasses nuclear substances, nuclear material, spent nuclear fuel, nuclear waste and other radioactive waste. These areas are mainly regulated by the below enactments and agreements:

- The Euratom Treaty,
- 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,
- Council Regulation (Euratom) No 1493/93 on shipments of radioactive substances between Member States,
- Commission Regulation (Euratom) No 302/2005 on the application of Euratom safeguards,
- Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel,
- Bilateral agreements with certain EU Member States and third countries, and
- Obligations under Codes of Conduct (CoC): reporting in accordance with the Joint Convention, i.e. the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management (SÖ 1999:60).

In connection with transboundary shipments, several aspects must be taken into account:

1. The recipient state must be informed in advance about the incoming shipment and have approved it,
2. Any transit countries must have consented to transit,
3. The sending state must have verified that the recipient country has the administrative, technical and infrastructure-related prerequisites for management of spent nuclear fuel and radioactive waste,
4. A sending country is not allowed to grant permission for shipping its spent fuel or radioactive waste for storage or final disposal to a destination south of latitude 60 degrees South, and
5. The sending country is required take appropriate action to permit return to its territory in the event a transboundary shipment is not carried out**.**

Authorisation under the Act on Nuclear Activities and Radiation Protection Act is given by the Swedish Government or by SSM. Under these Acts, permission is required for acquisition, possession, transfer, handling, processing, shipment of or other dealing with spent nuclear fuel, nuclear waste and radioactive waste. Entry to and exit from Sweden are also encompassed. Licenses are issued on the prescribed

standard forms in accordance with an established procedure having specified time limits.

Under Council Directive 2006/117/Euratom, Member States must every third year report to the Commission on the Directive's implementation status as well as provide an overview of licenses granted for transboundary shipments of spent nuclear fuel and radioactive waste.

3.3.4. Agreements with the IAEA under the Non-Proliferation Treaty

According to the Non-Proliferation Treaty, the NPT, non-nuclear weapon states are required to negotiate an agreement with the IAEA on international safeguards. Sweden has acceded to this kind of agreement together with the EU's other non-nuclear weapon states and Euratom.[19] The purpose of the international safeguards is to verify that no nuclear material can be put to use in order to manufacture nuclear explosives. The IAEA also requires basic technical descriptions of facilities in addition to information about quantities, physical and chemical form of the nuclear material, etc. IAEA inspectors must be allowed access to the facilities as well as the documentation required for non-proliferation control. The inspectors also need to be able to perform measurements, assemble monitoring equipment and place seals. One of the Additional Protocols to the Agreement[20] strengthens the IAEA's powers to also pay visits to installations other than nuclear facilities, obtain information about exports/ imports and transfers of nuclear equipment and be informed about research related to the nuclear fuel cycle as well as other aspects.

IAEA inspectors' right of access to places and documentation is regulated by Section 17 of the Act on Nuclear Activities.

3.3.5. Other international agreements

SSM sends licence applications for radioactive waste management facilities, the relevant environmental impact assessments and reports that provide a summary account of the application documents to the competent authorities of another country where the facility might be assumed to imply a significant environmental impact.

In 1976, an agreement was concluded between the Nordic countries with the intention of communicating safety concerns to each other pertaining to nuclear energy facilities located in close proximity to these countries' shared borders. These are referred to as Notes Exchange between Sweden, Denmark, Finland and Norway concerning guidelines for maintaining contact on cross-border nuclear safety issues. Under this agreement, the respective authority of the constructing country is to provide "messages containing relevant material" to the neighbouring countries' respective authorities, for instance concerning licences for operation of nuclear power plants or changes to licence conditions. According to Section 2 of the agreement, "messages containing associated and relevant material are to be provided on a timely basis so that any comments and remarks from the neighbouring country can be taken into consideration prior to decision-making when the constructing country processes the application".

[19] Published as the IAEA's INFCIRC/193
[20] Published as the IAEA's INFCIRC/193/Add.8

Since 2005, Sweden has been a contracting party to the Aarhus Convention (Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters). The Convention was developed by the United Nations Economic Commission for Europe (UNECE). The Aarhus Convention links together environmental aspects and human rights. According to the Convention, satisfactory environmental protection is essential for human well-being and fundamental human rights. The Convention contains provisions for ensuring that the general public gains access to environmental information, has the right to take part in decision-making processes that have a link to environmental aspects and has access to due process in relation to environmental issues.

3.4. **Licensing reviews**

Under the Act on Nuclear Activities or Radiation Protection Act, a licence is required to be allowed to conduct nuclear activities or extensive operations involving ionising radiation, in addition to license under the Swedish Environmental Code. In other words, this implies that an activity undergoes a review in two stages. Nuclear activities reviewed under the Act on Nuclear Activities need no specific licence under the Radiation Protection Act for the operation. The Radiation Protection Act and its subsequent enactments are still in effect; also, SSM has the powers to impose conditions under the Act. It is stated by the Environmental Code that the Code must be applied in parallel to the other legislation regulating the activity, thus implying that the Environmental Code applies alongside the Act on Nuclear Activities and Radiation Protection Act.

The processes of designing, constructing, commissioning, decommissioning and potential closure of nuclear facilities and other complex installations where ionising radiation is used take a long time to complete. This is also the case for major modifications to existing facilities of these types. Depending on the type of facility, detailed design documents are not usually available by the time applications are submitted. Also, conceivable design solutions can change over time. Problems can arise during the construction or facility modification phase, leading to other necessary design solutions. This is why a review process in steps is needed, as recommended by the IAEA; this is also in compliance with longstanding international practice.

3.4.1. Licensing under the Act on Nuclear Activities

Nuclear activities are not allowed to be conducted without a licence. However, there are certain exceptions, for instance small-scale operations and scientific activities at universities and similar institutions. A licence is only valid for the purpose and method ensuing from the licensing decision; in other words, the nuclear activity specified by the licence. It is prohibited to conduct any nuclear activity beyond the permission granted by the licence. These rules are fundamental ones, as laid down by the Act on Nuclear Activities.

The Government of Sweden, or in certain cases SSM, examines matters concerning licences. In Section 16 of the Nuclear Activities Ordinance, the Swedish Government gives SSM, the Swedish Radiation Safety Authority, the mandate to consider certain licensing matters, such as shallow land disposal of low level nuclear waste. Other licensing matters are considered by the Government. In connection with this kind of consideration, provisions such as those contained in Chapters 2 and

6 of the Swedish Environmental Code concerning general rules of consideration and environmental impact assessments must be applied. In cases where an activity is subject to Government approval, SSM processes the matter on the behalf of the Government. This means that such application, together with the environmental impact assessment and suitable reports summarising the application documents, are to be sent to the relevant Swedish authorities as part of a consultation procedure. Statements of the views of special interest groups may also be sought.

Section 24 of the Nuclear Activities Ordinance stipulates that a licence application under Chapter 5 of the Act on Nuclear Activities must be made in writing and submitted to SSM for processing. The application documents must include an environmental impact assessment, which is a requirement under Chapter 6 of the Environmental Code. The Ordinance also states that if an application concerns an issue to be considered by the Government, the Authority must obtain the statements of views necessary, then provide its own statement attached to the documents belonging to the matter, and subsequently deliver them to the Government.

SSM determines the matter in accordance with the Act on Nuclear Activities on the basis of the fundamental safety requirements under this Act and the fundamental radiation protection requirements under the Radiation Protection Act, as well as regulations describing these requirements in detail. An assessment also needs to be made on fulfilment of the general rules of consideration as per Chapter 2 of the Swedish Environmental Code. Underlying documentation to be assessed includes the environmental impact assessment submitted in addition to an initial preliminary safety analysis report, together with technical and other reports concerning the planned facility and its operation. These must be attached to the application. During its preparation of the matter, SSM needs to consider whether the activity is likely to be sited, designed and conducted in a way fulfilling requirements imposed for safety as well as for radiation protection and physical protection.

SSM's assessment must be based on an in-depth review of the application documents, own investigatory reports and analyses as necessary, in addition to the formal statements and comments received in the matter. The scope and orientation of this work are defined by the nature of the matter, for example whether it involves modifications subject to authorisation on the part of an existing facility, construction of a new facility, or involves new and untested design solutions or proven solutions to be applied.

Using the requirements imposed on nuclear facilities as a basis, the following factors and aspects are to be accounted for to the extent applicable:

- Accounts of the planned facility's location, design and construction with its barriers and various kinds of functions,
- Analyses of facility barriers and safety functions' capability to prevent accidents that can lead to harmful effects of radiation (a radiological accident) and mitigate the impact of accidents should they take place nevertheless, as well as to prevent unauthorised access and sabotage,
- Information about the planned activity's releases and radiation impact from releases to the environment during normal and abnormal operating conditions as well as assumed accident sequences,
- Planned activity's system for radiation protection of workers,

- Planned management of nuclear waste and other radioactive waste generated by the activity in addition to plans for future decommissioning of the facility,
- Applicant's application of general rules of consideration,
- Design of the planned activity's physical protection against unauthorised access and sabotage in addition to protection against unauthorised dealing with nuclear material and nuclear waste,
- System for the planned activity's emergency preparedness for taking protective measures in the facility in the event of disruptions and accidents, or threats of the same, in addition to measures to return the facility to a safe and stable state,
- Applicant's organisation and financial and human resources in addition to competence for the purpose of maintaining safety, radiation protection and physical protection for the time period during which the obligations of the Act on Nuclear Activities remain in force,
- Applicant's planned management and control of the facility's construction, operation and physical protection activities in addition to non-proliferation control, and
- Applicant's third party liability insurance or other financial security to enable compensation to be made in the event of a radiological accident

According to Section 5b of the Act on Nuclear Activities, Chapter 6 of the Swedish Environmental Code concerning environmental impact assessments must be applied in connection with consideration under the Act on Nuclear Activities. This for example implies that the regulations concerning publication as stated in Chapter 6, Section 8 of the Environmental Code are to be complied with. The environmental impact assessment and application documents must subsequently be kept available to the general public, which is to have an opportunity to express opinions on them before the matter is formally considered. Notification of an environmental impact assessment having been conducted is to be published in *Post- och Inrikes Tidningar* (the Official Swedish Gazette) and in the local newspaper(s) decided by the Authority. Such notification is to state that written objections concerning the environmental impact assessment must be forwarded to SSM within a specified period of time, no later than four weeks following publication of the notification in the Gazette. The same procedure applies to licensing work for activities to be decided by SSM under Section 3a of the Nuclear Activities Ordinance in addition to Section 20 of the Radiation Protection Act; also, where the Authority has decided that the application documents must include an environmental impact assessment.

Based on performed reviews of application documents, possible own investigations and analyses, in addition to statements of views received in a matter, SSM is to adopt a standpoint as to whether the activity is likely to be located, designed and conducted in a way so that the requirements imposed for safety and radiation protection, as well as the general rules of consideration, can be fulfilled. This standpoint is subsequently documented as part of an assessment report and statement of views together with the justifications behind the Authority's final assessment. This statement must also include an opinion as to whether the environmental impact assessment conducted by an applicant as part of the matter fulfils the requirements imposed by the Environmental Code.

If SSM approves the licence application and proposes Government approval under the Act on Nuclear Activities, it might also be suggested in this kind of matter that the Government issue licence conditions requiring consent from SSM prior to allowing construction, test operation, routine operation and decommissioning of the facility as part of the continued step-wise licensing process.

The statement of its views and assessment report serving as the basis for SSM's decision are subsequently handed over to the Government, via the Ministry of the Environment and Energy, together with the licence application, related documents and statements of views from public authorities, other relevant organisations and the general public, as well as the Commission in cases where the matter relates to Article 37 of the Euratom Treaty.

When a nuclear activity ceases, the facility is to be decommissioned once permission has been granted by SSM. In the case of a waste disposal facility, this implies its permanent closure. The responsibility of the licensee remains in effect until all obligations have been performed, discharge of liability has been granted and the licence has been terminated by the Government.

The step-wise licensing process, with the licence from the Government and permission from SSM, is illustrated by Figure 3.

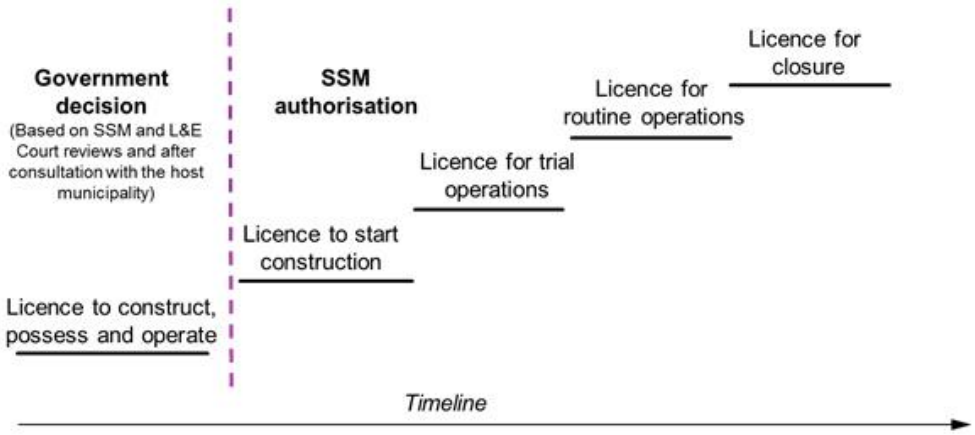

Figure 3. The step-wise licensing process, with Government license under the Act on Nuclear Activities and permission from SSM.

3.4.2. Licensing under the Radiation Protection Act

As a rule, activities and practices involving ionising radiation require a licence. Exemptions may be granted for activities involving small quantities of a low level of activity, as per the Radiation Protection Ordinance. Even if an activity is exempt from the licence obligation, the general rules of consideration apply under the legislation.

Sections 6 to 14 of the Radiation Protection Act contain provisions regulating general obligations applying to parties conducting activities involving radiation. These parties must, while taking into account the nature of the activity and the conditions under which it is conducted, take all the measures and precautions necessary to prevent or counteract injury to people and damage to the environment. Furthermore, parties presently conducting, or that formerly conducted activities

involving radiation, are in charge of safe management and disposal of waste products and discarded radiation sources.

Applications seeking permission to conduct activities and practices involving radiation are considered by SSM. The licensing work of the Swedish Radiation Safety Authority on the part of complex non-nuclear facilities must primarily be of the same scope and orientation as licensing work on the part of nuclear facilities. Certain factors and aspects will nevertheless differ, both in terms of the nature of the activity and owing to differences in legal requirements. SSM has made available standard forms for many kinds of small-scale operations, which applicants can use when seeking permission. When considering non-nuclear matters, the Radiation Protection Act does not contain any compulsory provisions regulating environmental impact assessments. SSM may nevertheless in individual cases decide, under Section 14a of the Radiation Protection Ordinance, that an environmental impact assessment must be conducted and submitted in connection with a licence application.

When it comes to licences for facilities to be considered by SSM under Section 20 of the Radiation Protection Act, suitable reports summarising the application documents and, when applicable, the environmental impact assessment conducted as part of the matter, are sent to the relevant Swedish authorities.

Complex non-nuclear facilities requiring reviews in several steps involve SSM combining licensing decisions under the Radiation Protection Act with licence conditions. These are suitably worded in a way that is similar to that for nuclear facilities.

When a licence is issued, or has been issued under the Radiation Protection Act, SSM may impose conditions on a licensee. These conditions may be a prerequisite in terms of radiation protection. Similar conditions may also be imposed for an activity licensed under the Act on Nuclear Activities.

3.4.3. Licensing under the Swedish Environmental Code

It is evident from the Environmentally Hazardous Activity and Health Protection Ordinance (1998:899) that nuclear activities are illegal without a licence under the Environmental Code. Licensing matters subject to the Environmental Code in the area of nuclear activities are examined by a land and environmental court. The provisions contained in the Code thus imply a need for two separate licences for owning, constructing and operating a nuclear facility: one licence under the Act on Nuclear Activities, and another licence under the Environmental Code.

It is also evident from the ordinance concerning environmental impact assessments that a nuclear activity must always be presupposed to imply a potentially significant environmental impact. This situation is attributed particular significance in terms of the scope of an environmental impact assessment and the procedure for carrying this out. Besides detriment due to ionising radiation, the Environmental Code regulates facility safety, supervisory work and self-assessments of licensees. Activities subject to compulsory notification and subject to authorisation are regulated by the Environmental Code's ordinance on these organisations' self-assessments. Consequently, there are possibilities under the Code to intervene against all kinds of nuclear activity. However, the Environmental Code does not regulate work environment aspects.

A land and environmental court processes a licensing matter in accordance with the provisions of Chapter 22 of the Code. In the same way as for a matter subject to the Act on Nuclear Activities, the foundation comprises the general rules of consideration, the environmental impact assessment submitted, drawings and technical descriptions with information about site conditions, output, production quantity or similar information, in addition to consumption of raw materials, other input goods, radioactive materials and energy. SSM's role during reviews under the Code is to deliver an opinion on the licence application to the land and environmental court.

It is pointed out in Government Bill 2004/05:129 concerning more efficient environmental licensing proceedings that reviews under the Environmental Code and Act on Nuclear Activities relate to different areas. Reviews conducted under the Act on Nuclear Activities are mainly oriented towards safety matters. Reviews conducted by SSM also include consideration of radiation protection matters under the Radiation Protection Act. Reviews under the Environmental Code relate to more crosscutting areas, such as the location, nature and scope of facilities, as well as the impact of the activity on land use, the environment, energy and transport, etc. However, a land and environmental court is still free to also examine cases pertaining to nuclear safety and radiation protection.

The legal preparatory work for the environmental legislation proposed by Government Bill 1997/98:90 states that examination by a court under the Environmental Code is presupposed to take place in parallel with licensing work by SSM under the Act on Nuclear Activities and that the expert authority's assessment report from such consideration under the Act is available when considering matters under the Environmental Code. This statement mainly applies to situations where the nuclear activity is also subject to consideration of permissibility by the Government under Chapter 17 of the Environmental Code.

If the matter relates to a new nuclear activity whose permissibility must be considered under Chapter 17 of the Environmental Code, the activity is as a main rule only permissible if the municipal authority concerned has authorised this. The municipal authority's opinion in the matter is either obtained by the land and environmental court as part of consideration of the permissibility, or by the Government during a later phase.

3.5. The Swedish Radiation Safety Authority's regulatory supervision

The aim of supervision by the Authority is to assess the capability of entities to lead and manage their activities from the perspective of radiation safety. This implies that parties carrying out activities (i.e. licensees) must have a suitable management and governance, including self-assessments of a high standard, all giving the desired impact. SSM's supervision may be comprehensive, for example by checking management systems, or be conducted on a detailed level by e.g. supervising and inspecting particular practices.

3.5.1. Mandate for regulatory supervision

As a supervisory authority, SSM monitors the legal compliance of operations involving radiation and ensures that they take their responsibility for radiation safety. As an authority whose role is to provide assistance to other public authorities in terms of regulatory supervision, SSM supports the supervisory work of both central and local government authorities. Section 15 of the Radiation Protection Ordinance gives SSM a mandate to ensure compliance with the Radiation Protection Act, official regulations, as well as any conditions issued in pursuance of the Act

Section 22 of the Nuclear Activities Ordinance gives SSM a mandate to ensure compliance with the Act on Nuclear Activities and conditions and regulations issued in pursuance of the Act, also to supervise, check and inspect disposal facility operations.

The Environmental Supervision Ordinance regulates mandates for regulatory supervision under the Environmental Code. Under Chapter 2, Section 26, first paragraph of the Environmental Supervision Ordinance, SSM has a mandate in the area of detriment due to ionising and non-ionising radiation from environmentally hazardous activities subject to authorisation as per the Environmentally Hazardous Activity and Health Protection Ordinance (1998:899) and which is defined by the Radiation Protection Act as an activity or practice involving radiation.

Under Chapter 3, Section 14 of the Environmental Supervision Ordinance, SSM must also give guidance on supervisory work in certain matters relating to environmentally hazardous activities as per the Environmental Code in cases where these matters are regulated by the Radiation Protection Act or Radiation Protection Ordinance

The requirements which SSM needs to take into account as part of its regulatory supervision and consider in terms of fulfilment are mainly stipulated by the Act on Nuclear Activities, Radiation Protection Act and Environmental Code, in addition to ordinances and regulations issued in pursuance of these enactments. In some cases, licence conditions and decisions must also be taken into account as part of regulatory supervision. The enactments empower the Authority to impose sanctions when exercising this supervision.

One of SSM's tasks is to ensure that parties in charge of radiation safety under law, i.e. licensees, have the capability to fulfil their obligations and do so in practice. The Authority has a mandate for regulatory supervision that implies imposing requirements, checking compliance with requirements, giving impetus to radiation safety work and taking supervisory measures when weaknesses or deficiencies are identified. The aim of supervision is to verify that radiation safety is being maintained and improved.

3.5.2. Methods of regulatory supervision

When it is requested, a licensee must provide SSM with the necessary information and documents for SSM's supervisory work. SSM must also be given access to any facility or site where an activity is conducted for the purposes of investigations and taking of samples to the extent necessary to exercise this supervision.

This supervisory work gives SSM an awareness of a licensee's approach to radiation safety work. SSM's planned supervisory efforts in relation to a licensee over a 12-

month period are listed as part of a supervisory plan encompassing all steps of supervisory action in the form of the following methods of regulatory supervision:

- Compliance inspections,
- Surveillance activities,
- Reviews, and
- Follow-ups of events
- Integrated safety assessments.

SSM continually develops its methods of regulatory supervision, which are also documented as part of SSM's overarching system of management.

Compliance inspections

Compliance inspections involve site visits by SSM to look into how the licensees fulfil not only legislative and regulatory requirements, but also licensing and other conditions. SSM carries out this work by (for example) interviewing personnel, inspecting a facility or activity, and reviewing documents. SSM also performs unannounced supervisory actions.

Surveillance activities

SSM's surveillance activities involve compiling information about nuclear safety and radiation protection work at Swedish facilities. This includes accessing reports, applications and other documents, as well as paying visits to a facility or an operation. Dialogue is also conducted with the organisation's personnel and management team. The information gathered gives an understanding of the organisation's nuclear safety and radiation protection work. It may lead to additional inspections and reviews initiated by SSM.

Reviews

SSM's reviews involve analysing and assessing data, documents, reports, notifications and applications from facilities. Reviews might also be subject to particular conditions imposed by the Government or SSM in connection with authorisation issued for a certain activity, or other supervisory decisions. SSM may also initiate a review on its own accord.

Follow-ups of events

SSM follows up events that have occurred which licensees are under an obligation to report. SSM determines on a case-by-case basis if an event or a discovered deficiency implies that the Authority needs to take further action. SSM might for example choose to perform new compliance inspections or reviews, or follow up the event in some other way.

In connection with an event that has occurred, or following identification of a circumstance that might have a material impact on radiation safety on the part of a licensee, SSM performs what is referred to as a 'rapid investigation'. The aim of a rapid investigation is to, as soon as possible following an event, gather information on site to enable an independent interpretation of the occurrence..

Integrated safety assessments

The outcomes of all the elements of regulatory supervision of a licensee are evaluated as part of an integrated safety assessment. This kind of assessment is conducted each year on the part of nuclear power plants, and every other, or every third year, for other nuclear facilities depending on the risk picture of the activity. The purpose of integrated safety assessments is to identify tendencies in radiation safety work that might be difficult to detect in a short-term perspective or by means of individual supervisory actions.

SSM also performs integrated safety assessments of health and medical services, institutions of higher education and industries. These assessments provide a summary account of legal compliance, conclusions drawn from achieved fulfilment of requirements and an evaluation of the operation's radiation protection, level of safety and physical protection.

3.5.3. Reporting requirements

SSM's Regulatory Code requires extensive reporting from licensees. Requirements on reporting are for example imposed in the form of safety analysis reports, plans for physical protection of a facility, emergency response plans, waste plans, annual reports, reporting of deviations in nuclear material and nuclear waste, records for nuclear waste, reporting of weaknesses and deficiencies in repository barrier performance, periodic reviews of facility safety and radiation protection, as well as decommissioning plans for nuclear facilities.

Notifications, applications and reports from the facilities are examined by SSM. The Authority selects the documentation needing more extensive investigation by SSM's experts.

Besides reporting to SSM, an owner of nuclear material must report to the European Commission on the owner's holdings, submit an annual activity programme and account for its facility's design.

3.5.4. Regulatory supervision of nuclear facilities

As mandated by the Act on Nuclear Activities with subsequent enactments, SSM conducts recurring inspections and assessments of Swedish nuclear facilities. This is in order to evaluate their compliance with regulatory requirements and licence conditions, as well as to adopt a standpoint on a facility's further operation at the level of safety presupposed by the licence and which is to be accounted for in the safety analysis report (SAR).

The parameters of SSM's regulatory supervision of nuclear facilities encompass seventeen different defined areas (corresponding requirements are imposed by regulation SSMFS 2008:1). The ambition is for supervision to successively cover these areas, which are documented in a supervisory programme.

The areas reviewed and examined both as part of day-to-day regulatory supervision and within integrated safety assessments and periodic safety reviews of nuclear facilities encompass safety, radiation protection, physical protection, nuclear non-proliferation and emergency preparedness. This process takes place by assessing the following

1. Design and construction of the facility (including modifications),
2. Management, control and organisation of the nuclear activity,
3. Competence and human resources for the nuclear activity,
4. Operational activity, including management of deficiencies in barriers and defence in depth,
5. Core, fuel and criticality issues,
6. Emergency preparedness and response,
7. Management of maintenance, materials, inspections and control work, particularly taking into account degradation due to ageing,
8. Primary and independent safety reviews,
9. Investigation of events, operational experience and external reporting,
10. physical protection,
11. Safety analyses and safety analysis reports,
12. Safety programmes,
13. Management and retention of technical documentation concerning the facility,
14. Management of nuclear material and nuclear waste,
15. Safeguards, non-proliferation control, export control and transport security,
16. Radiation protection inside the facility, and
17. External releases of radioactive materials to the environment, environment checks and clearance of materials..

These areas are encompassed by the integrated safety assessments of licensees and the periodic safety reviews conducted by SSM every tenth year. This approach enables to SSM perform systematic evaluations of radiation safety and its evolution. When new evaluations are launched, it is possible to reuse previously performed and documented assessments of these areas for the purpose of painting a composite picture. The intention is to apply supervisory experiences and knowledge in a way that is efficient and effective.

Directive 2008/98/EC of the European Parliament and of the Council[21] has been implemented in Swedish legislation through the Waste Ordinance (2011:927), which does not apply to spent nuclear fuel and nuclear waste regulated under the Act on Nuclear Activities, or radioactive waste regulated under the Radiation Protection Act. SSM is nevertheless of the view that the principles of the waste hierarchy, which regulates the order of priority in legislation and national policy, is also relevant to questions of prevention and management of radioactive waste. These principles embrace the following: preventing waste generation, pre-planning for reuse, materials recycling, other recycling (e.g. energy recycling) and removal. Work is in progress for application of these principles when accounting for management of nuclear waste, which the licensees are liable to report to the Authority as part of their waste plans under regulation SSMFS 2008:1. The

[21] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives

outcomes of efforts to apply the principles in the waste hierarchy may be implemented in future regulations.

3.6. **Provisions on sanctions**

3.6.1. Mandate to impose sanctions

The Act on Nuclear Activities and Radiation Protection Act

The Act on Nuclear Activities and Radiation Protection Act give SSM the powers to impose sanctions as part of its regulatory supervision. As a regulator, SSM can also impose sanctions under the Environmental Code. A sanction can be described as a means for rectifying deficiencies that have been discovered when it comes to a supervisory subject's compliance with legal rules.

In the fields of nuclear safety and radiation protection, sanctions can be broken down into two groups: administrative sanctions and criminal sanctions. Administrative sanctions include different types of decisions concerning prohibitions, revocation of licences and other restrictions on operation, in addition to decisions concerning injunctions. Prohibitions and injunctions can both be combined with conditional fines. There are two kinds of criminal sanctions: a) fines, and b) imprisonment for a maximum of four years (the harshest penalty is for certain serious and intentional offences under the Act on Nuclear Activities. Under the Radiation Protection Act, the penalty is normally fines or imprisonment for a maximum of two years). One important difference between the types of sanctions is that SSM can take its own decisions on administrative sanctions, whereas criminal sanctions presuppose action by the Swedish Prosecution Authority and court system.

Alongside the rules governing sanctions, both Acts contain provisions requiring the subject of supervision to comply with a request from SSM to provide the information and documents needed for the Authority's regulatory supervision as well as to give the Authority access to facilities. The provisions described here are mentioned in order to shed light on the design and function of these sanctions.

The Swedish Environmental Code

Under Chapter 26, Section 1 of the Swedish Environmental Code, regulators are under an obligation to check compliance with the Code and the regulations and court and other decisions issued in pursuance of the Code, as well as to take requisite measures for achieving rectification.

Under the Environmental Code, regulators are under an obligation to report suspected offence to the police or Swedish Prosecution Authority. Provisions on environmental offences are collected in Chapter 29 of the Code. The penalty scale for minor environmental offences ranges from fines to imprisonment for a maximum of two years. The penalty scale for serious environmental offences ranges from imprisonment for a minimum of six months and a maximum of six years. It is also stated by Chapter 30, Sections 2 and 3 of the Environmental Code that supervisory authorities are under an obligation to decide upon an administrative sanction charge – an environmental sanction charge – if the conditions have been fulfilled. The specific violations leading to an environmental sanction charge are not expressly stated by the Environmental Code. Instead, these are defined by the Environmental

Sanction Charges Ordinance (2012:259). In the Ordinance, the Government has defined the violations for which an environmental sanction charge is payable, and the amounts. This charge is presently set at a minimum of SEK 1,000 and a maximum of SEK 1,000,000. These environmental sanction charges are a supplement to the penal provisions contained in Chapter 29. The principle is for environmental sanction charges to correspond to the violations not encompassed by Chapter 29. If in some case a violation is encompassed by both these systems and a party has been penalised in accordance with Chapter 29, this is a rationale for not imposing an environmental sanction charge.

A supervisory authority has the option of using different instruments for dealing with a violation. Depending on the circumstances of the offence, the Authority is under an obligation to file charges or impose an environmental sanction charge. The Authority may order measures to be taken or prohibit operations in order to prevent future deficiencies. For certain violations, the supervisory authority may seek a court order for/ provisional remedies. SSM might also order redress at the expense of the offender.

3.6.2. Administrative sanctions

An injunction is an order to carry out a type of action. The category of administrative sanctions may also include decisions to revoke licences (prohibition) and concerning rectification (redress) at the expense of the party in charge of the object. Rectification at the expense of the party in charge implies that if someone fails to take a measure required by legislation or a supervisory decision, the supervisory authority can – at the offender's expense – take this measure instead. To be sure, decisions concerning various licence conditions are a means for directing the subject of supervision, but as for decisions concerning injunctions, they are not sanctions in themselves. Legal references pertaining to injunctions, orders, prohibitions and rectification at the expense of the party in charge are contained in Section 18 of the Act on Nuclear Activities and Section 32 of the Radiation Protection Act. Revocation of licences is regulated by Section 15 of the Act on Nuclear Activities and Section 28 of the Radiation Protection Act. The most common sanctions applied in SSM's work are injunctions and prohibitions. As stated in the legislation, injunctions and prohibitions are used to enforce compliance with the Act on Nuclear Activities and Radiation Protection Act (including official regulations). Even if expressed in slightly different ways, both Acts make it possible to combine decisions concerning injunctions and prohibitions with conditional fines. SSM decisions on administrative sanctions may be contested by appeal.

3.6.3. Criminal sanctions

SSM's supervisory function involves an obligation to ensure that violations of regulations and conditions are met with appropriate action. If there is a clear suspicion that someone intentionally, or through negligence, is breaching provisions subject to a penalty under the Act on Nuclear Activities or Radiation Protection Act, or conditions or regulations issued in pursuance of these Acts, SSM is required to notify prosecutors. This also pertains to a suspicion by the Authority that an environmental offence under the Environmental Code has been committed. Both Acts – the Act on Nuclear Activities (see Sections 25, 25a and 27) and Radiation Protection Act (see Sections 35 to 37) – contain several penalty provisions. If the Authority has reason to suspect that these provisions have been violated, the

Authority must always consider filing charges. In this connection, SSM should not conduct its own investigation into the offence pertaining to intent or negligence, for example, but should only assess whether there are circumstances of the situation indicating a possible offence.

3.6.4. The sanction scale

The supervisory work of SSM, for example compliance inspections and reviews, usually culminates in an assessment of additional measures that SSM might need to take to give impetus to nuclear safety and radiation protection work. A sanction scale is presented below illustrating how various supervisory measures are interrelated and the sequence in which they are usually applied. The different supervisory measures, or sanctions, are usually used for disparate situations. Based on the degree of severity of these situations, the measures could be placed in the following sequence:

- Injunctions to take action,
- Prohibition against running the entire, or parts of, the activity until certain measures have been taken,
- Revocation of the licence, and
- Rectification at the expense of the party in charge of the object.

Measures such as comments, suggested improvements and issued licence conditions (which are not sanctions by definition) as well as indictments (that are not sanctions in a proper sense) are supervisory measures, not sanctions, at SSM's disposal. These measures may be taken separately or in connection with one of the sanctions on the sanction scale being considered or imposed.

3.7. **International supervision and control**

Under the international agreements mentioned previously,[22] the IAEA and European Commission carry out supervisory work pertaining to safeguards at Swedish facilities. Their regulatory control covers the same kinds of methods of regulatory supervision as described in Section 3.5.2.

Their regulatory control mainly involves physical verification of nuclear substances and facility design, in addition to reviews and audits of accountancy records, reporting and holdings of nuclear materials. The facilities selected also have security techniques, such as seals and cameras, in place for verification of accounting accuracy between safeguards inspections. Inspections are not only conducted on a routine basis in connection with yearly inventory, but also on short notice with the aim of checking Sweden's compliance with international agreements. A total of just over 50 international compliance inspections take place in Sweden each year.

SSM attends all IAEA inspections as the representative of the Swedish state. The European Commission also has the right to attend all inspections conducted by the IAEA, though with certain exceptions pertaining to inspections under the Additional Protocol.

[22] IAEA INFCIRC 153, IAEA INFCIRC 540, Euratom Regulation No 302/2005

The European Commission also performs inspections and surveillance activities independently of the IAEA. EU exports of nuclear substances are subject to the European Commission's surveillance inspections at the facilities in order to ensure that the necessary documentation is in place and to place seals on the nuclear material.

3.8. **Interdependencies between parties (licensees)**

3.8.1. Nuclear activities

Spent nuclear fuel and nuclear waste are primarily generated at Swedish nuclear power plants. Some wastes are generated by other nuclear facilities, for example at Clab, the interim storage facility for spent nuclear fuel, and at Studsvik Nuclear AB's facilities at Studsvik.

The entity that has the primary and comprehensive liability for management and final disposal of spent fuel and nuclear waste is the licensee whose activities give rise to the spent nuclear fuel or nuclear waste.

The process for management and final disposal of spent fuel and nuclear waste encompasses several steps. Different licensees are responsible for different links in the chain. The operational responsibility for management of spent fuel generated by nuclear power reactors rests with the licensee of each respective reactor. The operational responsibility for interim storage of spent nuclear fuel rests with the licensee of Clab. The operational responsibility for final disposal of spent nuclear fuel rests with the licensee of the waste facility. The operational responsibility for spent fuel shipments is the entity with a transport permit.

The management chain for nuclear waste may comprise additional steps. The waste generated more or less continually at nuclear facilities is conditioned (e.g. packaged in containers or embedded in concrete) at the relevant facility and is ready for direct shipment to a waste disposal facility. Certain other kinds of waste may be transported to dedicated facilities for management (for instance, melting, incineration or compaction) prior to final conditioning at the waste treatment facility.

A licensee has the operational responsibility for the activity conducted as well as for management and disposal of waste produced within the parameters of its individual licence.

Final disposal of spent nuclear fuel and nuclear waste is the last link in the management chain, which is why it is affected by earlier links in this chain. Consequently, it is important to ensure as far as reasonably possible that management of spent fuel and nuclear waste as part of previous steps in this process is compatible with the planned method of final disposal.

In order to as far as possible ensure that all steps as part of the management chain are coordinated, the legal framework imposes requirements on licensees of facilities where spent nuclear fuel and nuclear waste occur to produce plans for management of these wastes. These plans are to cover subsequent steps of this process after delivery to the entity in charge of the next link in the chain. Plans are to be produced at an early stage and encompass all subsequent steps of the process for management

of the spent nuclear fuel and nuclear waste up until their final placement in a waste disposal facility that is ultimately closed.

These plans are to serve as the basis of the licensees being allowed to establish during a step-wise process the criteria for receiving spent nuclear fuel and radioactive waste. The regulatory framework also requires licensees in the management chain to establish processes to enable a system of control for ensuring that spent nuclear fuel or nuclear waste leaving a licensee's facility fulfils requirements for receipt criteria at the facility to which the spent nuclear fuel or nuclear waste is delivered.

3.8.2. Non-nuclear activities

As for both waste management and nuclear activities, a corresponding framework applies to licensees generating non-nuclear radioactive waste. The framework implies these entities' primary and comprehensive responsibility for management and final disposal of this waste.

The system established for management of waste from non-nuclear activities usually implies that parties carrying out activities can deliver their waste to Studsvik Nuclear AB for further handling. When it comes to discarded radiation sources, licensees can choose between returning the radiation source to the manufacturer or supplier, or sending it to Studsvik Nuclear AB. Certain radioactive wastes from hospitals and similar operations can be cleared prior to incineration by municipal combustion plants. SSM has however pointed out certain waste categories lacking methods for treatment or final disposal, meaning that in these cases, licensees are required to keep the radioactive waste until further notice.

3.9. **Radioactive waste following a nuclear accident**

An accident in a nuclear facility implying an external release of radioactive materials has a large-scale impact on society, even if the release is small. Accidents at nuclear facilities outside the borders of Sweden might also give rise to contamination of Swedish territory where the residents demand decontamination of the area. An accident outside Sweden is to be managed in accordance with the same model applying to an accident in Sweden.

MSB, the Swedish Civil Contingencies Agency, had a joint Government assignment together with SSM and County Administrative Boards in the counties of Halland, Uppsala, Kalmar, Skåne and Västerbotten to produce a national emergency response plan for nuclear accidents.[23] The emergency response plan provides an account of the Swedish crisis management system for nuclear emergencies on an overall level and describes the roles and areas of responsibility of various stakeholders. Each public authority is required to make its own preparations to ensure its own organisation's compliance with official regulations.

[23] Swedish Civil Contingencies Agency (MSB), *Nationell beredskapsplan för hanteringen av en kärnteknisk olycka* [National emergency response plan for dealing with nuclear accidents], 2015

3.9.1. Decontamination

Decontamination following a release of radioactive material from a nuclear facility refers to measures to be taken by the state to make it possible to once again use land and water areas as well as facilities and other property contaminated by radioactive substances. The state is under an obligation to take this kind of measure only to the extent justified in consideration of the consequences of the release, the significance of the threatened interests, expense for decontamination work and the general circumstances.

A County Administrative Board is the central government authority responsible for decontamination work following an accident at a nuclear facility and for preparing a regional plan for these efforts.[24] A separate decision from the Swedish Government can give a County Administrative Board or other central government authority a mandate for decontamination work on the part of several counties. A County Administrative Board has the powers to restrict a third party's rights, including evacuation of areas, for the purpose of facilitating decontamination efforts. In these cases, the County Administrative Board must take a decision on wider evacuation in conjunction with termination of an emergency response operation. Areas that will not be decontaminated but are deemed hazardous for humans may be evacuated under the Public Order Act via a County Administrative Board decision

Decision-making on what to decontaminate and the approach is to involve weighing costs and benefits of the operation. A County Administrative Board is responsible for making prioritisations as part of decontamination efforts and needs input and data from several public authorities and other organisations, such as SSM, the Swedish Board of Agriculture, Swedish Transport Administration and MSB. As a rule, decontamination is not an emergency measure. It is carried out to enable reuse of a site. In the agricultural sector, however, quick countermeasures may be necessary in order to mitigate the consequences. On the whole, the time aspect nevertheless gives scope for well-grounded decisions that it should be possible to communicate in a clear and straightforward way.

3.9.2. Waste management

There are no finished plans for how to deal with contaminated waste following a nuclear accident. County Administrative Board programmes for rescue services are to cover decontamination methods, but no requirements are imposed for a waste management plan. One possible reason for this may be the difficulty of foreseeing the consequences of an accident and thus determining the need for waste management. Besides the quantities and kinds of waste, the choice of suitable storage methods also depends on the release's content of different radioactive material. MSB has issued a handbook for County Administrative Board response planning for nuclear accidents.[25] The handbook is undergoing revision (2015-2016). The new version will contain more advice on how to deal with the waste occurring

[24] Civil Protection Act (2003:778), Chapter 4, Section 6; Civil Protection Ordinance (2003:779), Chapter 4, Section 15

[25] *Sanering av radioaktiva ämnen, Planeringsstöd för länsstyrelser inför en kärnteknisk olycka* [Decontamination from radioactive substances, Nuclear emergency response planning assistance for County Administrative Boards] (available from www.msb.se)

Several of the decontamination methods used generate very large volumes of waste. Most of this waste will be contaminated. All radioactive wastes, such as soil or other material from scraped surfaces, sludge from treatment plants and ash from waste incineration, are encompassed by the general obligations. This implies the handlers of the waste needing to observe the necessary precautions. It is likely that separate regulations will have to be developed for managing different kinds of decontamination waste.

One key issue is transport of this waste. Transport routes other than the indicated routes for shipments of dangerous goods may need to be used. County Administrative Boards have the powers to issue local traffic regulations and can grant exemptions. The Swedish Transport Administration assists in rerouting work and assessing road suitability for such transports. SSM can grant exemptions under the Act on Transport of Dangerous Goods. MSB approves drivers for transporting these goods since ADR certificates are required for driving vehicles containing decontamination waste.

All contaminated waste occurring as a result of a nuclear accident is to be viewed as nuclear waste under the Act on Nuclear Activities.[26] Before decontamination waste can be disposed of in a waste facility, it will probably be put in interim storage. Under the Act on Nuclear Activities, the entity conducting the primary nuclear activity bears the responsibility for interim storage of decontamination waste. An interim storage facility is by definition a nuclear activity subject to the Swedish Radiation Safety Authority's nuclear regulatory control.

In its capacity as a leader of decontamination efforts, a local County Administrative Board takes decisions on management of this waste, following consultation with SSM and the Swedish Environmental Protection Agency. Licensing matters relating to management, processing, transport, direct disposal in landfills and final disposal are reviewed by SSM. SSM has the powers to issue regulations on exemptions following an assessment on a case-by-case basis, for example regulating management of low-level nuclear waste. This is the most likely kind of waste occurring after a nuclear accident. In these exceptional cases, however, authorisation is required under the Radiation Protection Act. Exemptions can also be granted under the Radiation Protection Act for radioactive material whose level of activity falls below the prescribed limit stated by the Radiation Protection Ordinance. The Swedish Environmental Protection Agency has a mandate in cases where waste management must comply with the Swedish Environmental Code, which fully applies alongside the Act on Nuclear Activities and Radiation Protection Act. SSM also has a mandate for regulatory control as per the Environmental Code in matters with a link to ionising radiation (see Section 3.5.1).

A nuclear accident leading to an external release of radioactive materials has an impact on society. This impact must be dealt with through coordinated efforts over a very long period of time. In the event of a release that is so extreme that it has an impact on other countries, there is also a need for coordinated actions across national borders.

Experience gained from earlier events has shown that long-term management takes several decades and it is probable that the organisations in charge will need to reserve special resources for this purpose. The radiation situation will necessitate follow-ups over an extended period of time after the accident, and special-purpose environmental monitoring programmes will need to be drawn up. The sites chosen

[26] Act on Nuclear Activities (1984:3), Sections 2 and 3b

for interim storage of the waste may require checks and inspections to ensure that radioactive substances are not leaking and contaminating the surroundings. The need to reduce the quantities of waste prior to final disposal may presuppose new research initiatives.

4. Nuclear activities

4.1. **Licensees**

Swedish regulations stipulate under the Act on Nuclear Activities, Radiation Protection Act and Environmental Code a clearly defined division of responsibility between licensees involved in management of radioactive material and regulatory authorities that issue licences and carry out supervision. A party that is licensed under the Act on Nuclear Activities is responsible for the safe management and final disposal of the waste generated. All the necessary measures and precautions for safe management of this waste are to be adopted by the waste producer.

The locations of existing Swedish nuclear facilities and a summary presentation about them are shown by Figure 4.

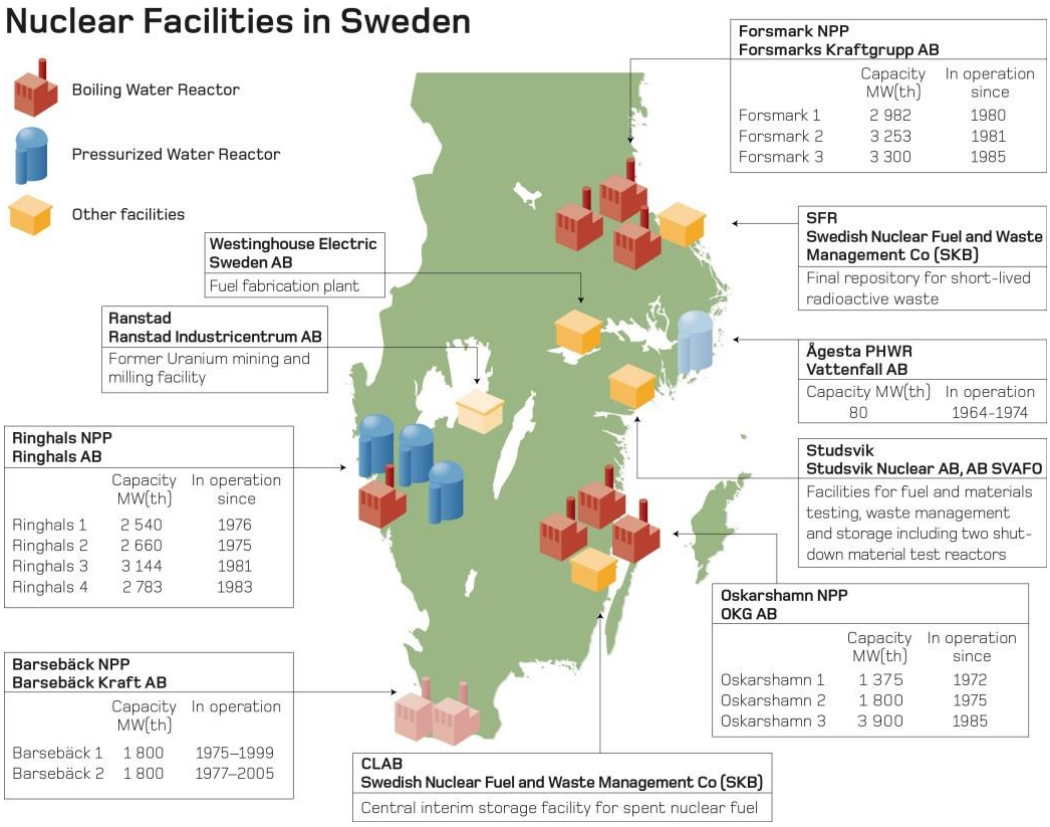

Figure 4. Nuclear facilities in Sweden.

4.1.1. Nuclear power plants

Ringhals AB

Ringhals AB (RAB) owns and operates the Ringhals nuclear power plant, situated at Väröbacka outside Varberg. Ringhals AB is owned by Vattenfall AB. Ringhals produces one-fifth of all electricity consumed in Sweden and is the largest power plant in the Nordic countries. The facility has four reactors that generate around 28 TWh of power annually. Reactor 1 (a boiling water reactor) and reactor 2 (a pressurised water reactor) were the first two reactors built, though not the first ones to be commissioned, in Sweden. They have been in commercial use since 1976 and 1975, respectively. The pressurised water reactors Ringhals 3 and 4 were commissioned in 1981 and 1983, respectively.

Ringhals AB's facility at Ringhals has a shallow land disposal facility for very low level waste.

OKG Aktiebolag

OKG Aktiebolag's (OKG AB) nuclear power plant is located on the peninsula of Simpevarp around thirty kilometres north of Oskarshamn. This is the location of three Swedish nuclear power reactors: Oskarshamnsverket 1, 2 and 3 (i.e. O1, O2 and O3), owned and operated by OKG. These reactors normally produce approximately ten per cent of Sweden's electrical power, which is why OKG is one of the largest suppliers of power to the Nordic power grid. OKG is a subsidiary of E.ON Sverige. The other part owner is the Fortum Corporation. The boiling water reactors O1, O2 and O3 were put in commercial operation in 1972, 1974 and 1985, respectively. OKG AB's facility at Oskarshamn has a shallow land disposal facility for very low level waste. This is also the site of OKG's rock cavern for waste, BFA, which is used for interim storage of discarded radioactive components, such as control rods, pipe systems and other components used in a reactor core.

Forsmarks Kraftgrupp AB

Forsmarks Kraftgrupp AB (FKA) owns and operates the Forsmarksverken nuclear power plant at Forsmark, located in Östhammar Municipality. Vattenfall AB, Mellansvensk Kraftgrupp AB and E.ON Kärnkraft Sverige AB own Forsmarks Kraftgrupp AB. The Forsmark nuclear power plant has three boiling water reactors, which were put in commercial operation in 1980, 1981 and 1985. Normally, Forsmark produces around 75 gigawatt hours (GWh) of power daily. One-sixth of the electricity consumed in Sweden is produced at Forsmark.

FKA's facility at Forsmark has a shallow land disposal facility for very low level waste.

Barsebäck Kraft AB

The Barsebäck (BKAB) plant is a closed nuclear power plant located on the west coast between Malmö and Helsingborg. Barsebäck 1 was shut down in 1999 following an agreement reached between the state, Sydkraft (presently E.ON Kärnkraft Sverige AB) and Vattenfall. Barsebäck 2 was shut down following a Government decision in 2005. E.ON Kärnkraft Sverige AB is the current owner of the facilities Barsebäck 1 and 2. Dismantling of the plant is financed by the Nuclear Waste Fund. Dismantling should be completed when the repository for dismantling and demolition waste is ready, preliminarily expected in the 2020s. BKAB is planning for construction of an internal components store for these parts prior to

transport to the repository at Forsmark. In late 2014, a building permit was granted for this temporary store.

Ågesta

Vattenfall is the licensee in charge of dismantling the reactor at Ågesta, which is expected to begin in 2020. AB SVAFO has sought permission to take over the licence from Vattenfall AB. This matter is being processed by SSM and a decision is expected in 2015.

4.1.2. Fuel manufacturers

Westinghouse Electric Sweden AB

Västerås is the location of a fuel fabrication plant belonging to Westinghouse Electric Sweden AB (WSE). Here, nuclear fuel is manufactured for nuclear power plants both in Sweden and abroad. This business was established in 1966 by what was then ASEA Atom.

The fuel fabrication plant manages the complete process, from enriched uranium hexafluoride to finished fuel elements. The uranium hexafluoride, provided by customers, is converted by Westinghouse into uranium dioxide, which is then compacted and sintered to form pellets. Then the pellets are inserted into fuel rods, that are in turn mounted together to form fuel elements. Westinghouse's fuel fabrication plant also manufactures control rods and other components for domestic and foreign nuclear reactors.

The plant has approximately 1,000 employees. Westinghouse's Västerås plant currently delivers nuclear fuel, components and electrical and control systems to customers in Europe, the United States, Asia and Africa. It is mainly the fuel fabrication plant's operations that are subject to SSM's regulatory supervision.

The Toshiba Group has been the main shareholder of the entire Westinghouse company since October 2006 and thus the Swedish facilities in Västerås.

Ranstad Industricentrum AB och Ranstad Mineral AB

Ranstad Industricentrum AB (RIC) owns a nuclear facility at the Ranstad plant. This plant was built for the purpose of extracting uranium from the uranium-rich alum shales of Sydbillingen, between Falköping and Skövde. The plant was built as part of national plans to reduce Sweden's dependence on uranium imports. Between 1965 and 1969, some 200 tonnes of uranium were produced for the Swedish nuclear power programme. As a result of changed assumptions and reduced profitability, the uranium mining operation was shut down in 1969.

In 1970, a new phase began at Ranstad: research and development related to extraction of uranium as well as other elements from the alum shales. The energy crisis in the mid-1970s spurred attempts to relaunch large-scale uranium mining. This project faced massive local resistance and all work was blocked since the Swedish Government rejected the licence application following vetoes against the project by the municipal authorities of both Skövde and Falköping.

In 1984, the licence for uranium mining expired and between 1990 and 1992, the open-cast mine was restored, the industrial area cleaned up and some buildings were

demolished. The entire area of waste from mining was covered with clay and gravel. The former open-cast mine is now a lake: Tranebärssjön.

Between 1984 and 2009, Ranstad Mineral AB (RMA) used part of the Ranstad plant for recovery of uranium from processing waste generated by manufacturing of reactor fuel. In other aspects, the facility has been undergoing decommissioning since 1984. RMA's licence expired at the turn of the year 2009/2010; since this point in time, the plant has been undergoing decommissioning. At the time, Ranstad Industricentrum AB, which owns the nuclear facility, performed a radiological survey of the buildings and developed a decommissioning plan for the Ranstad plant.

Demolition of certain buildings that were not contaminated by uranium started in 2011. Demolition of buildings which, following the survey, were established as contaminated by uranium, began in 2013 and will be completed in 2016.

4.1.3. Waste management companies

SKB

The Swedish Nuclear Fuel and Waste Management Company (SKB) is owned by the companies operating Swedish nuclear power plants. The company was set up with the aim of fulfilling the licensees' obligations relating to management of spent nuclear fuel and nuclear waste.

SKB is the licensee of the nuclear facilities at Forsmark (SFR) and at Oskarshamn (Clab). Its main office is located in Stockholm. SKB is licensed to transport spent nuclear fuel and radioactive waste. It owns a special-purpose marine vessel for this waste, the M/S Sigrid. This makes SKB the largest transporter of radioactive waste, measured by level of activity in Sweden.

SKB currently has around 500 employees. The company also collaborates extensively with external experts and contractors.

SKB is not only responsible for planning, constructing and operating the facilities required for management and final disposal of spent nuclear fuel and radioactive waste, but also for needed research and development for these areas. SKB's programme for low and intermediate level radioactive waste encompasses activities for management of this waste from operations and from dismantling and demolition of Swedish nuclear power plants. The nuclear fuel programme encompasses the KBS-3 system for taking care of spent nuclear fuel and for constructing the facilities required. SKB runs extensive research and development work to assist these operations, including the hard rock (Äspö), canister and bentonite laboratories at Oskarshamn.

SKB also liaises prerequisite investigations as input for calculating future costs for spent fuel and radioactive waste management, including reactor decommissioning.

SKB is planning for new facilities, which assuming granted licences, will be constructed and commissioned over the next few years. For this reason, SKB has a need to ensure the availability of expertise and to broaden the range of professional skills pertaining to operation of nuclear facilities. An important step in this direction was taken when SKB took over Clab's and SFR's operations in January 2007 and

July 2009, respectively. These operations were previously run on SKB's behalf under an agreement with OKG and FKA.

SKB has conducted research and development work for more than 30 years. These activities are currently broken down into three areas: natural science research, technical development and social science research. The objective of the natural science research is to increase awareness of changing conditions on the part of the different radioactive waste repositories over time and the impacts on safety over the long term. This is why SKB's research programme covers a spectrum of disciplines, such as geology, ecology and climate science.

Technical development includes ongoing work on design, manufacture, testing and refinement of all technical components of the repository system, as regards both spent nuclear fuel, and low and intermediate level waste. A great deal of the research and development work is conducted at the three laboratories at Oskarshamn: the Äspö Laboratory, Bentonite Laboratory and Canister Laboratory. The laboratories offer opportunities to test and demonstrate technologies and techniques on a full scale and in a realistic environment.

In 2004, SKB began to provide funding for research with links to the social sciences and humanistic aspects. This programme culminated in 18 research projects which have since then been concluded. Today's focus is on how to retain information about the spent nuclear fuel repository for future generations.

Every third year, SKB presents its planning for continuing research work and technical development, published as the RD&D Programme. The most recent programme was submitted to SSM in September 2013. It provides a detailed account of SKB's planning up until 2019.

SKB is in charge of the Swedish transport system for shipping spent nuclear fuel and nuclear waste from Swedish nuclear power plants to Clab interim storage facility and SFR final repository for operational waste located at Forsmark.

SKB's operations are financed via the Nuclear Waste Fund as well as directly by the owners, which bear the costs for operating SFR and managing operational waste.

Studsvik Nuclear AB

Studsvik Nuclear AB (SNAB) is a subsidiary of Studsvik AB. This company provides professional services within waste management, consulting in addition to fuel and materials technologies to the international nuclear power industry. SNAB performs testing of materials and reactor fuel in its own laboratories, supplies computer programs and consulting services that render nuclear power plant operations more efficient, and carries out work on site at customers' facilities in connection with maintenance, modernisation and decommissioning. SNAB also carries out treatment, stabilisation and volume reduction of low and intermediate level waste in its own facilities in Sweden. These operations are located at Studsvik, in Nyköping Municipality, and in Gothenburg, Stockholm and Västerås. The company has approximately 260 employees (2015).

SNAB's waste facilities treat low and intermediate level radioactive waste. Examples of this kind of waste include protective clothing, packaging material and scrapped components from nuclear power plants. The aim is to decrease waste volume, recycle materials, or to stabilise the radioactivity of this waste. Protective clothing and organic wastes are incinerated. Metal waste is decontaminated,

segmented and melted down in order to separate the radioactivity from the metal and minimise the quantity of radioactive residual waste. The radioactive content of metal is thoroughly checked. Much of this metal waste can be recycled.

When the waste has been treated at Studsvik, it is returned to the customer. Organic materials that have been incinerated are returned as ash. Some of the waste from operations in Sweden is instead sent to the repository at Forsmark, or stored at Studsvik pending future disposal solutions. Small quantities of spent nuclear fuel that have been examined at Studsvik are transported to Clab, the interim storage facility for spent nuclear fuel located in Oskarshamn.

Studsvik is also the site of a number of laboratories, where various kinds of materials are tested in order to determine how their properties are affected under different conditions. The kinds of materials studied include spent nuclear fuel and fuel cladding. SNAB measures cracking of materials and carries out corrosion studies on both radioactive and non-radioactive materials.

A new pyrolysis facility has been erected at this site for materials treatment within the framework of a 20-year contract with Westinghouse Electric. The facility has not yet started regular operation.

Low level waste is generated continuously by nuclear facilities. This kind of waste includes scrap metal, rags, filters and the like. Much of this waste can be incinerated, melted down or packaged directly intothe intended packaging materials and transported to the repository for short-lived operational waste (SFR) at Forsmark. The radioactivity in this kind of waste decays quickly. Studsvik is also used to store low level waste that must be conditioned for disposal. Intermediate level waste is managed at the treatment facility at Studsvik, built in the mid-1980s. This waste is largely long-lived, which is why it is destined for disposal in the future final repository for long-lived radioactive waste (SFL). For the time being, this waste is in interim storage in a rock cavern at Studsvik.

AB SVAFO

AB SVAFO carries out nuclear activities at Studsvik. This company is owned by the groups of companies operating Swedish nuclear power plants. SVAFO is in charge of decommissioning facilities built during the early research and development period of the 1950s and 1960s. The company also manages waste from these facilities.

At Studsvik, the company treats and stores radioactive legacy waste from former research and development operations conducted in Sweden. SVAFO also manages liquid radioactive waste generated at the Studsvik facilities.

One of the shut-down facilities located at Studsvik and which SVAFO is responsible for decommissioning is R2: a reactor facility from the early 1960s that was shut down in 2005. The R2 reactor was a research reactor, which actually comprised two reactors: R2 and R2-0. At the present time, all fuel has been removed from the R2 unit and decommissioning has begun. Decommissioning of R2 is expected to be finished in 2019.

SVAFO’s commissions also encompass metallic fuel from R1, a shut-down research reactor from 1970 located at the Royal Institute of Technology (KTH) in Stockholm. Most of this fuel has undergone treatment abroad. The residual waste has been returned to Sweden for interim storage until it can be placed in a waste facility. A small proportion of corroded R1 fuel has undergone treatment and is now in interim

storage in a rock cavern at Studsvik. Other waste includes remaining fuel from examinations of ordinary nuclear reactor fuel. This remaining fuel originates from research operations predating 30 June 1991. The spent fuel from the R2 research reactor has been sent to the United States in accordance with the reactor licence.

A rock cavern at Studsvik is also the location of SVAFO's interim storage facility for long-lived low and intermediate level waste (AM). SVAFO is currently carrying out a needs analysis of its interim storage capacity.

4.2. **Waste streams from generation to disposal**

In the Swedish system, nuclear waste is managed in different ways depending on radionuclide inventory, half-life and the waste's physical and chemical form. The strategy for managing waste generated is either disposal or, if this is feasible, clearance. Cleared materials may be reused, recycled or disposed of as conventional waste. This could also lead to a certain level of energy production to be taken advantage of. Principles and methods for managing nuclear waste are determined by the waste's physical and chemical properties. Waste may be in the form of a gas, liquid or solid and be classified as low, intermediate or high level, in addition to being either short-lived or long-lived waste. Volume reduction is basically applied to all kinds of waste, for example in the form of separation, decontamination, compaction and incineration. Figure 5 show the current streams of spent nuclear fuel and other nuclear waste, i.e. the origins of waste generation, management of the waste and sites for required final disposal.

As far as concerns short-lived waste, decay is one of the processes that can lead to clearance of the material or to permitted releases. Very low level waste and short-lived waste are mainly disposed of in a shallow land disposal facility. Other low and intermediate level and short-lived wastes are conditioned and disposed of at Forsmark's SFR facility. Low and intermediate level long-lived waste is for the time being put in interim storage at different nuclear facilities. The plan is for final disposal at SFL, though the exact location has not yet been decided. Research and development work is ongoing to improve existing waste management methods to achieve a higher level of radiation safety and lower costs, while working on alternative or new methods of waste management and final disposal.

The Swedish strategy when it comes to spent nuclear fuel is direct disposal without reprocessing. Spent fuel is dealt with as waste and not viewed as a resource in the Swedish system. Following interim storage in the fuel pools of the respective plant, the spent fuel is transported by ship to the central interim storage facility, Clab, located next to the Oskarshamn nuclear power plant.

As is described above, the Forsmark nuclear power plant is the location of SFR, the central underground repository for short-lived low and intermediate level operational waste. The nuclear power plants of Ringhals, Forsmark and Oskarshamn, in addition to the site of Studsvik, also have shallow land disposal facilities for very low level and short-lived waste. Other Swedish nuclear facilities include: the Westinghouse fuel fabrication plant, the facilities at Studsvik for management of both nuclear and non-nuclear waste, in addition to shut down research reactors, the closed uranium mining and milling facility at Ranstad and the Ågesta plant.

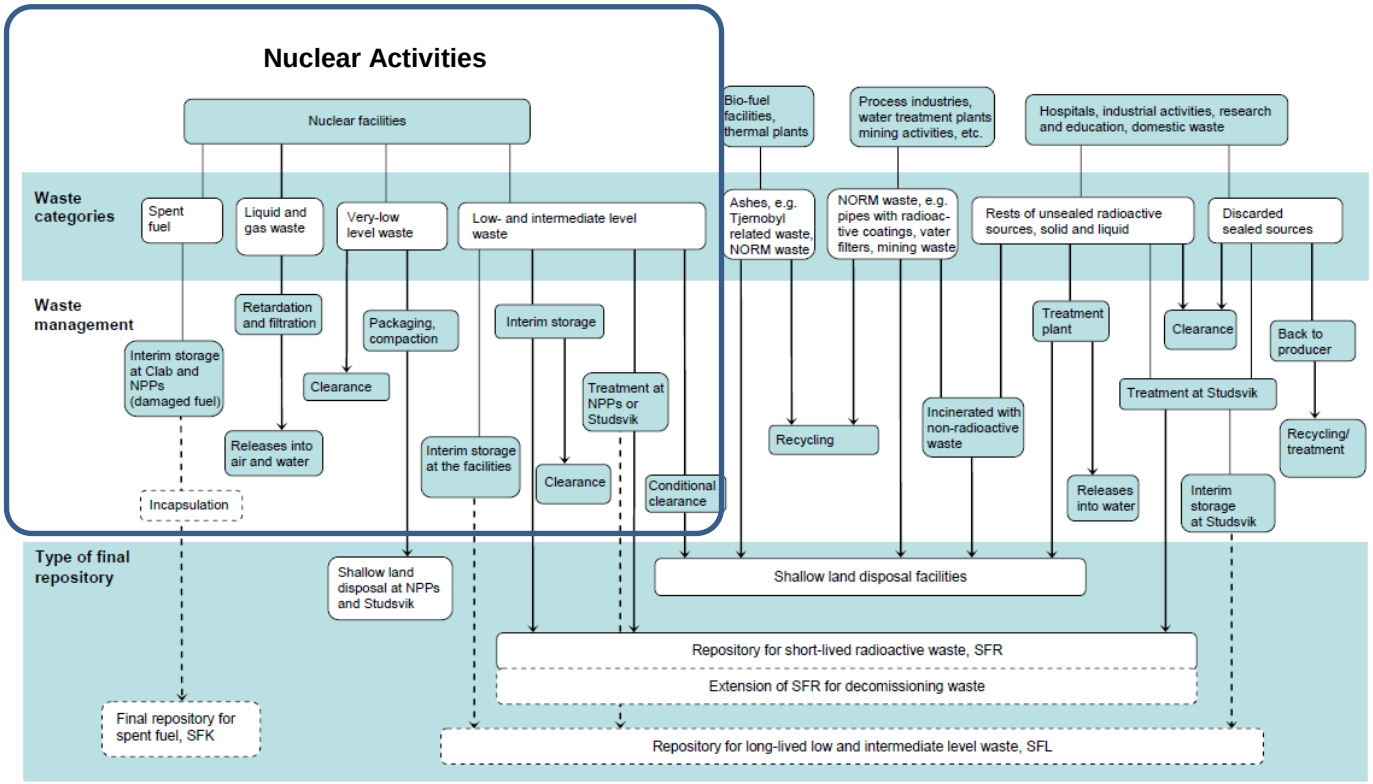

Figure 5. Current streams of spent nuclear fuel and other nuclear waste, i.e. the origins of waste generation, management of the waste and sites for required final disposal. The disposal facilities of SFK, SFL and the extended SFR repository are only in the planning stages, indicated by the dashed lines in the figure.

Besides the operational waste generated at nuclear power plants and other nuclear facilities, waste is also produced by hospitals, research institutes and industry, and generated by consumer products. Old research projects also generated some waste, which for the time being is in interim storage while awaiting a disposal method, or which has already been disposed of.

The Swedish nuclear power programme will generate a total of around 20,000 m^3 (12,600 tonnes) of spent fuel, 155,000 m^3 of short-lived low and intermediate level waste from operations and decommissioning, in addition to 15,000 m^3 of long-lived low and intermediate level waste (based on 60 years of reactor operation; this excludes Ringhals 1 and 2, which are expected to be in operation for 50 years. (Figure 5). Typical annual production of low and intermediate level radioactive waste at Swedish nuclear facilities is 1,000-1,500 m^3.

Most transports of spent nuclear fuel and (nuclear) waste are by marine vessel, as all Swedish nuclear power plants are situated along the coastline.

Transports of relatively small quantities of spent nuclear fuel as well as low-level nuclear waste may take place by road to and from the research facility at Studsvik. The marine transport system, run by the Swedish Nuclear Fuel and Waste Management Company (SKB), has been in operation since 1982. SKB has at its disposal a ship that is specially designed for this purpose. The ship transports spent fuel and waste in special-purpose transport casks that must fulfil international safety requirements of the IMDG Code for transport of dangerous goods by sea. The original ship, the M/S Sigyn, was replaced by the M/S Sigrid in early 2014. The International Maritime Organization (IMO) has given her the highest classification, Class INF 3, for marine vessels that transport radioactive waste.

Facilities that remain to be built include an encapsulation facility, a spent nuclear fuel repository, a repository for long-lived low and intermediate level waste, and an extension of SFR for waste from dismantling and demolition. SKB's RD&D Programme 2013 has a focus on these areas.

4.2.1. Facilities for spent nuclear fuel

Clab, the central interim storage facility for spent nuclear fuel

Spent fuel from Swedish nuclear power reactors is stored in a central interim storage facility, Clab (Figure 6), which is located adjacent to the Oskarshamn nuclear power plant. Around 100 employees work at this facility. The facility comprises an above-ground building for unloading spent fuel from transport casks and an underground area for storage, which is approximately 25-30 metres below ground.

The storage area consists of two rock caverns some 120 metres in length. Each one has five ponds for storage of spent fuel over a minimum of 30 years prior to its being encapsulated and placed in a repository. Construction of Clab began in 1980 and it was commissioned in 1985. The facility had an original storage capacity of 5,000 tonnes of spent nuclear fuel. An increase in its storage capacity in 2008 gives a current storage capacity of around 8,000 tonnes of spent nuclear fuel elements. At the end of 2013, a total of 5,740 tonnes was stored at Clab.

In early 2015, within the framework of the ongoing licensing reviews for the KBS-3 system, SKB supplemented its applications in the form of a request to increase the

interim storage capacity of the pre-existing ponds at Clab to 11,000 tonnes of uranium by using compact cassettes. Here, the rationale is an assessed delay in the time schedule for completion of a spent nuclear fuel repository so that it can receive spent fuel from an interim storage facility.

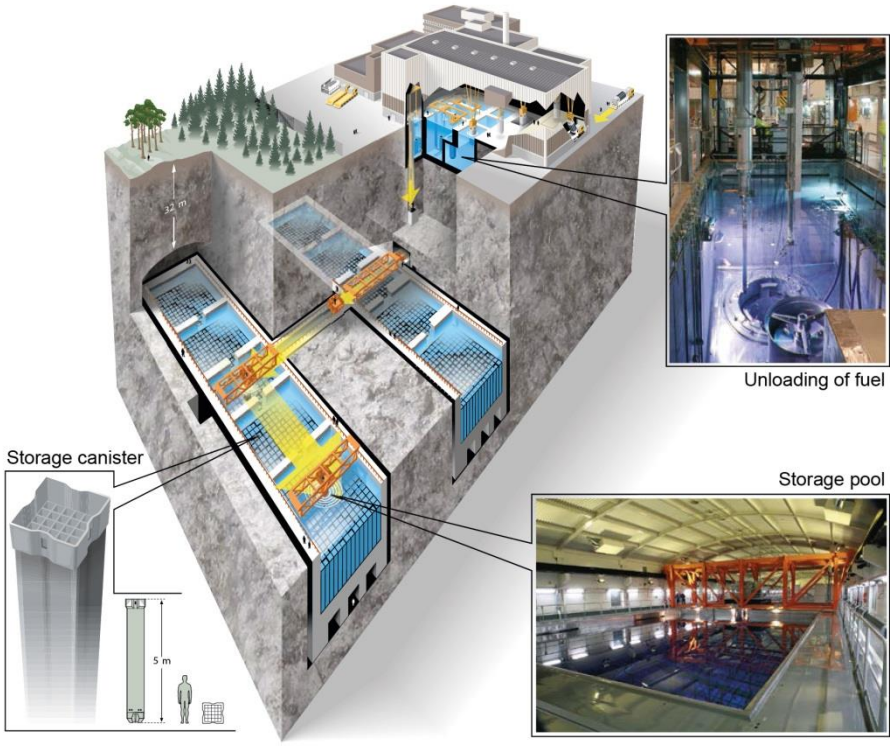

Figure 6. Clab, the central interim storage facility for spent nuclear fuel.[27]

4.2.2. Facilities for radioactive waste management

Nuclear power plants

Most low and intermediate level waste is conditioned (solidified, compacted, etc.) at the reactor facilities before being transported for disposal in the SFR repository. Certain items of waste are transported to the waste treatment facilities at Studsvik for incineration or melting down

Studsvik Nuclear AB (SNAB)

Studsvik Nuclear AB's facilities process low and intermediate level waste. Facilities at Studsvik process dry and metal waste mainly from nuclear installations in Europe by melting it down or incinerating it. The SMA melting facility separates radioactivity from other materials in the form of blasting and slag separation by melting the waste. Treatment at SMA generates large quantities of metal for clearance and recycling. Treatment of waste also achieves volume reduction and stabilisation of the waste prior to disposal. The HA incineration facility carries out volume reduction of waste by incinerating it and recycling the energy during this form of treatment. The ash produced from incineration has a lower level of chemical

[27] SKB, RD&D Programme 2013, Figure 1-5

reactivity than the unburnt organic matter. A new pyrolysis facility has also been built, which will enable recycling of uranium and other radioactive material that might be able to be leached from the pyrolysis ash.

Final repository for short-lived radioactive waste (SFR)

SFR is designed for disposal of short-lived low and intermediate level waste generated by Swedish nuclear power plants, from Clab, as well as similar waste from other industrial, research and medical applications. SFR is located around 140 kilometres north of Stockholm, in close proximity to the Forsmark nuclear power plant (Figure 7). This facility has approximately 40 employees.

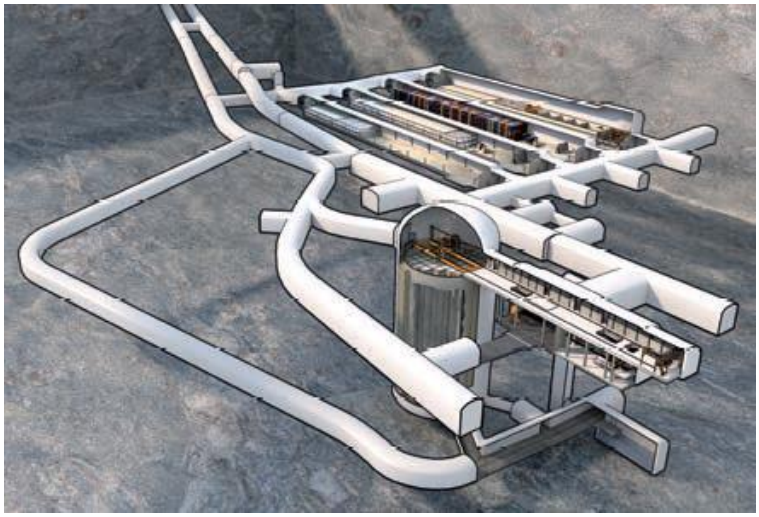

Figure 7. SFR, the final repository for radioactive operational waste located at Forsmark.[28]

SFR consists of four rock caverns and a silo, underground in bedrock, some 50 metres below sea level at a water depth of 5 metres. Its construction began in 1983 and it was commissioned in 1988. SFR's total capacity is 63,000 m^3, of which approximately 42,000 m^3 was used as at 31 December 2013. SKB is planning an extension of SFR to increase capacity for additional volumes of operational waste and waste from future decommissioning of nuclear power plants and other nuclear facilities. In December 2014, SKB submitted a licence application to SSM, with the operations expected to be launched in 2023.

Shallow land disposal facilities

The nuclear power plants of Ringhals, Forsmark and Oskarshamn (Figure 8), in addition to the site of Studsvik, have shallow land disposal facilities for solid low level, short-lived operational waste (<300 kBq/kg). Each site is allowed to have a total level of activity of 100-200 GBq. The highest level permitted by legislation is 10 TBq, of which a maximum of 10 GBq may constitute alpha-active material.

[28] SKB, RD&D Programme 2013, Figure 1-3

Figure 8. OKG's shallow land disposal facility at Oskarshamn.

Clearance

Materials may be cleared for unrestricted use or for disposal as conventional non-radioactive waste. In 2010, a total of 764 tonnes of melted down metal (<500 Bq/kg) was cleared for recycling, which is a representative level for the past ten years.

5. Non-nuclear activities

There are thousands of operations in Sweden that use ionising radiation for different purposes. Their activities generate radioactive waste. Radioactive sources are either 'unsealed' or 'sealed'. A sealed radiation source is defined as radioactive material that is either permanently sealed in a capsule or closely bonded and in a solid form that prevents spreading of the radioactive material during normal use. Consequently, an unsealed radiation source is radioactive material that is not permanently sealed in a capsule, nor firmly bonded and in a solid form that prevents spreading of the radioactive material. Unsealed sources may occur in the form of (for example) a gas, a solid or as a liquid.

Materials can become contaminated by coming into contact with radioactive powders, solutions or gases, and in this way having contaminated surfaces. A material can also have built up residues containing radioactive material, the possible result of long-term exposure to low levels of naturally occurring radioactive material. This can for example take place in pipes of flowing water. Material can become activated, for instance in accelerator operations. On the whole, non-nuclear activities comprise a very heterogeneous group that generates a broad range of different waste categories, in terms of nuclide content, activity content, physical and chemical form, etc.

5.1. **Parties within non-nuclear activities**

This Section gives an overall account of non-nuclear activities involving ionising radiation in which radioactive waste is generated and managed; these also include historical activities that gave rise to legacy radioactive waste. The majority of these activities are licensed under the Radiation Protection Act. There are some activities that are not subject to regulatory control, but which nevertheless generate radioactive waste. The following comprehensive descriptions are based on previous presentations.[29]

Industrial activities

Sealed radioactive sources are used in all kinds of industrial activities for different types of checking and quality control measures, analysis work and the like. The most common types of equipment are level, density, moisture, surface weight and thickness gauges, and the like. A broad range of industries use these gauges, such as steel mills, heating plants, paper mills, water treatment plants, the food industry and chemical companies. Other types of sealed radioactive sources include eliminators, which are used to eliminate static electricity, and EC detectors, which are for example used to analyse various chemical substances. These types of radiation sources are for instance used at car respray shops, by the auto industry, in analysis scales and at chemical companies. Material screening can in certain cases also be performed using sealed radioactive sources. Other examples of where radioactive material may be present are inside high-voltage switchgear, surge arresters,

[29] SSI-rapport 2001:15 Radioaktivt avfall från icke tillståndsbunden verksamhet (RAKET), SSI-rapport 2003:22 Kartläggning av radioaktivt avfall från icke kärnteknisk verksamhet (IKA), 2009:23 Kartläggning av fast avfall innehållande radioaktiva ämnen från icke kärntekniska verksamheter, 2009:29 Nationell plan för allt radioaktiv avfall.

transformers, laboratory scales, liquid scintillation counters, welding electrodes, zircon sand and coating materials.

Research and development work

Research is not only conducted at institutions of higher education, but also at pharmaceutical companies and in other industries. Research can be carried out in both laboratory and outdoor environments. In research work, ionising radiation is for example used to determine the effects of certain irradiation of cells and other material. In national Swedish university programmes and at research institutes, all types of radiation sources are used, even equipment designed in-house by the institute in cases where there is no possibility of purchasing a piece of equipment to meet the staff's needs. Radioactive sources, pieces of equipment and facilities can vary in size from very small to very large–in addition to their quantity. Institutions of higher education may also use radiation sources for teaching purposes. Corporate research is dominated by pharmaceutical companies. Tracer studies are carried out when analysing flows in biological, geological and technical systems. Education programmes up to upper secondary school level use radiation sources for teaching purposes. These are usually sealed radioactive sources with a low level of activity. Several schools also have unsealed sources, usually in the form of chemicals containing uranium or thorium, though they are not necessarily being used for teaching purposes any more.

There are currently two ongoing large-scale licensing reviews for research facilities in Lund: The MAX IV Laboratory, which is an accelerator facility at Lund University, and the ESS research facility, comprising a spallation neutron source to be located next to the MAX IV facility. The MAX IV Laboratory will study molecules and atoms using a particular kind of light source. According to the time schedule, the MAX IV Laboratory will be operational in 2015. European Spallation Source (ESS) is a pan-European research facility that will be used in several disciplines, such as materials science, structural chemistry, biology and geophysics. European Spallation Source is planned to be fully operational in 2025. The ESS research facility in particular will generate considerable quantities of radioactive waste compared to present quantities generated by non-nuclear activities.

Medical care

In medical services, by far the highest levels of activity of sealed sources are used in nuclear medicine for diagnostics and treatment purposes. Sealed radioactive sources with high levels of activity are mainly used for radiation treatment. Another medical application is blood irradiation devices containing high-activity Cs-137 sources. Depleted uranium is used where radiation shielding is necessary, for example in radiation shields, radioactive cobalt sources and transport containers for radioactive sources.

Radiography

Companies that work with industrial radiography use depleted uranium in transport containers, for instance for radioactive iridium sources.

Veterinary work

Unsealed sources are used in veterinary medicine for treatment and diagnostics.

Energy producers

Energy producers that burn peat or wood fuel can give rise to concentrations of radionuclides in the resulting ash. In certain parts of Sweden, forest land is

contaminated with cesium-137, which the trees absorb through their roots. This cesium is primarily a result of the Chernobyl accident and to a lesser extent from nuclear bomb testing in the atmosphere in the 1960s. The main problem areas are in southern and central Norrland. In some areas, peat land may have become enriched by naturally occurring radioactive material (NORM) in the groundwater. Peat containing NORM basically occurs throughout Sweden. In certain areas, there is a risk of the upper layer of peat also being contaminated with caesium-137 due to fallout from the Chernobyl accident.

Pit coal is used to some extent for producing energy. This means that it can generate considerable quantities of ash (including both bottom ash and fly ash captured in filters). All coal used in Sweden is imported and concentration of NORM (uranium and thorium) takes place in the burning process. The content in the ash is entirely dependent on the content in the coal burned.

Uranium prospecting

Prospecting that gives rise to small quantities of drill cuttings containing uranium is not classified as a nuclear activity. Instead, this work is considered to be an activity involving ionising radiation, which is regulated by the Radiation Protection Act. Presently, just under ten companies have licences for uranium prospecting under the Radiation Protection Act. Uranium prospecting in Sweden from the early 1950s up until 1986 resulted in collection of a large quantity of samples of radioactive mineralisations. To the extent that these samples are still around, most of them are in storage as specimens and drill cores at the drill core archives of the Geological Survey of Sweden (SGU), located in Malå.

Consumer products

Our homes contain a small number of products containing radioactive material. They are manufactured with materials of very low levels of activity, so using them does not pose any radiation hazard. Examples of consumer products containing radioactive material include ionising smoke detectors, compasses with a tritium light source, bearing compasses, bearing binoculars and night vision devices. These products are subject to licensing reviews under the Radiation Protection Act. Also, a licence is compulsory for their manufacture, entry and sale in the first stage. However, consumers' use of the products is exempt from the licence obligation. Other examples of consumer products containing radioactive material are those which are no longer manufactured but are still around in people's homes: glass and ceramic objects with uranium colouring, timepieces with luminous radium or tritium paint, and radium emanators that were long ago used to produce drinking water containing radon, which was once thought to be good for one's health.

Sweden has around 1.2 million permanent residents whose water comes from their own wells. Depending on their place of residence and their type of well, they may have problems with (for instance) excessive levels of naturally occurring radioactive material, iron, manganese or humus in their drinking water. Poor water quality is rectified by installing water filters, which in themselves do not contain radioactive material. On the other hand, there a risk of these filters–depending on their design–developing residues of excessive NORM concentrations after several years of use.

Processing industries and water treatment plants

Facilities that do not primarily use radioactive material in their operations, but which process large quantities of water, for example in pulp mills and water treatment plants, may over the years build up a concentration of NORM residues inside pipe

systems and water treatment filters. This might pose a problem when replacing the components.

Metal recycling industry

Steel mills and metal recycling companies risk receiving radioactive material with the scrap metal arriving to these facilities. The scrap metal might contain radioactivity due to several factors. Usually, the scrap metal has residues containing NORM. Scrap metal originating from the gas or oil industries or water treatment plants often have these kinds of residues. The scrap metal might also contain equipment or instruments having a radiation source that was used in industry, research or medical care for a large range of applications. The steel industry largely applies 'zero tolerance' regardless of whether or not the measured level of radioactivity is harmless. Large facilities today have portal radiation detectors at their entrances that sound the alarm if incoming freight has raised radiation levels. This means that the facilities are involuntary handlers of incoming radioactive material, which in many cases–usually when NORM is involved–leads to the material needing to be stored at the receiving facility. This is because Sweden has no definitive solution for management of NORM.

Recycling facilities and other companies that manage conventional waste

Under organiserade former kan privatpersoner lämna sina joniserande brandvarnare på återvinningscentraler i dag. Men återvinningscentraler kan även få in andra typer av radioaktivt material, utan personalens vetskap. Det kan till exempel röra sig om kemikalier som innehåller uran eller torium. I vissa fall upptäcks det radioaktiva materialet först när det transporteras till en metallåtervinningsanläggning som har en radiakportal. Även andra avfallsbolag som tar hand om konventionellt avfall kan råka ut för att radioaktivt material hamnar i deras system.

Legacy waste from manufacture of phosphoric acid and calcium phosphate

In the agricultural sector, phosphor is used in animal feed and as fertiliser. Phosphor is also a component of a wide range of products in the chemical industry. Phosphor is no longer manufactured in Sweden, though it used to take place at two sites over a long period of time. Manufacturing phosphor is a process of several stages, of which the first stage is manufacturing phosphoric acid. Manufacturing phosphoric acid generates phosphogypsum as a byproduct. The radium present in the raw material (calcium apatite) in addition to some of the uranium, precipitates in the phosphogypsum; however, most of the uranium is dissolved in the phosphoric acid.

Phosphoric acid was manufactured at the Supra AB factory in Landskrona starting in the 1940s, as well as at Boliden Kemi in Helsingborg. Waste from manufacturing of phosphoric acid is stored in connection with the factories. Phosphogypsum waste from Supra AB's operations is deposited on Vindön, an artificial island located a few hundred metres outside Landskrona. The island is 32 hectares in size, with its highest point at 15 metres. The island consists almost entirely of phosphogypsum waste totalling 4 million cubic metres. There are additional waste sites containing byproducts outside Landskrona. Phosphogypsum waste from Boliden Kemi's manufacturing of phosphoric acid and calcium phosphate totals around 6 million cubic metres. The waste is at a waste storage site located just outside Helsingborg's city.

Legacy waste from excavation and burning of alum shale

Alum shale was formerly excavated in some parts of Sweden, for instance at Kvarntorp in the 1950s and at Ranstad in the 1960s. The high content of uranium in the shale led to extraction of this element. Attempts were made in the 1920s to extract radium from uranium-rich anthracitic coal in Billingen. Burning of alum shale took place on a large scale in Sweden between the mid-1600s and the late 1970s for purposes such as burning limestone, manufacture of alum shale cement and alum shale-based lightweight concrete ('blue concrete') and manufacture of petroleum products. What above all remains from these legacy activities is a great number of heaps of the byproduct burnt alum shale, of which some exceed a half million cubic metres in size. The largest one is the Kvarntorpshögen heap, which is 40 million cubic metres in size.

Legacy waste from iron ore extraction

No known uranium mineralisations occur at any Swedish mines in operation today. On the other hand, there are heaps of spoil (waste rock having too low iron content to be classified as iron ore) at closed down mines that were sites of iron ore or siliceous iron ore extraction. In cases where the ores are associated with uranium mineralisation, this is usually only represented in a small proportion of the spoil and then most often individual pieces of waste rock consisting of uranium mineralisations. The mines in question are often small, or relatively small, and as mentioned, ore extraction ceased a long time ago. The fact that these mines are small also means that the volumes of spoil are limited. Another byproduct of iron production is represented by the slag heaps located nearby closed down blast furnaces that once melted uranium-rich iron ore.

Demolition waste containing 'blue concrete'

Lightweight concrete produced using uranium-rich alum shale–also called 'blue concrete'–was used as a building material in housing and other buildings from the late 1920s up until 1975. An estimated 300,000 buildings around Sweden contain alum shale-based lightweight concrete. In pace with these buildings and houses being demolished, the blue concrete enters the waste management system. This kind of lightweight concrete contains uranium and radium-226 in different concentrations depending on the alum shale used. Blue concrete emits radon gas and gamma radiation. Waste from demolished buildings containing alum shale-based lightweight concrete is not suitable for reuse as building materials or as fill material under buildings.

5.2. Waste streams from their generation to final disposal

The flows of radioactive waste currently occurring in Sweden are illustrated schematically by Figure 9, with a special focus on radioactive waste from non-nuclear activities: from the waste's generation to its being disposed. However, this figure does not illustrate shortcomings in the waste management system when it comes to handling of non-nuclear radioactive waste. Section 5.3 discusses the waste categories which at the present time do not fit into the Swedish waste management system.

Decay storage

Operations using unsealed sources with very short half-lives are permitted to store the radioactive waste until it has decayed sufficiently to allow for it to be handled as

conventional waste (it can be cleared). This waste can occur in solid (e.g. powder) or liquid form. Laboratories in the areas of medical care and research are the main sites of work activities involving unsealed sources and thus where this kind of management takes place. Decay storage of sealed radioactive sources also occurs to a limited extent in medical services, research and industry. The radionuclides used in sealed radioactive sources normally have a relatively long half-life and consequently cannot decay within a reasonable period of time to allow for this method of management.

Permitted releases

SSMFS 2010:2 contains provisions concerning external releases of radioactive materials to municipal sewerage systems. When the activity levels of solutions are below the prescribed levels, the party carrying out an activity (licensee) may freely empty these solutions into the municipal sewerage system, unless this is prohibited for other reasons. For instance, scintillation solutions containing organic solvents are not allowed to be poured down drains and must consequently be kept out of water treatment systems.

Clearance

Clearance implies that a material, including waste, is permitted to be managed or used without any restrictions from the point of view of nuclear safety and radiation protection. SSMFS 2011:2 implies general clearance on the part of radioactive material originating from all activities involving ionising radiation, including non-nuclear activities. Activities involving unsealed sources are subject to the provisions of SSMFS 2010:2 concerning clearance of solid radioactive waste subject to the precondition that it be destined for incineration; this is referred to as 'specific clearance'. The clearance levels stipulated by SSMFS 2011:2 are below those stated in SSMFS 2010:2, since the context concerns unrestricted use of the material. However, the general clearance levels may also be applied to laboratory waste if the party carrying out an activity decides not to apply the waste stream criteria defined by SSMFS 2010:2.

SSMFS 2011:4 contains provisions on clearance of naturally occurring radioactive material. These provisions cover building materials, water treatment filters from private households and residues containing naturally occurring radioactive material.

Radioactive waste that has been cleared in accordance with SSM's regulations is still encompassed by the provisions contained in the Swedish Environmental Code and Waste Ordinance (2011:927).

Reuse and recycling

A party carrying out an activity that no longer requires a radiation source is permitted to transfer it to another licensee that can continue using the source of radioactivity. Otherwise it is common for an agreement to be made already at the point of sale on return of the discarded radiation source to the supplier, or directly to the manufacturer abroad. Many manufacturers have developed methods enabling both reuse and recycling of returned sources of radioactivity. Some waste management companies abroad also have approved methods for reusing and recycling old sources of radioactivity.

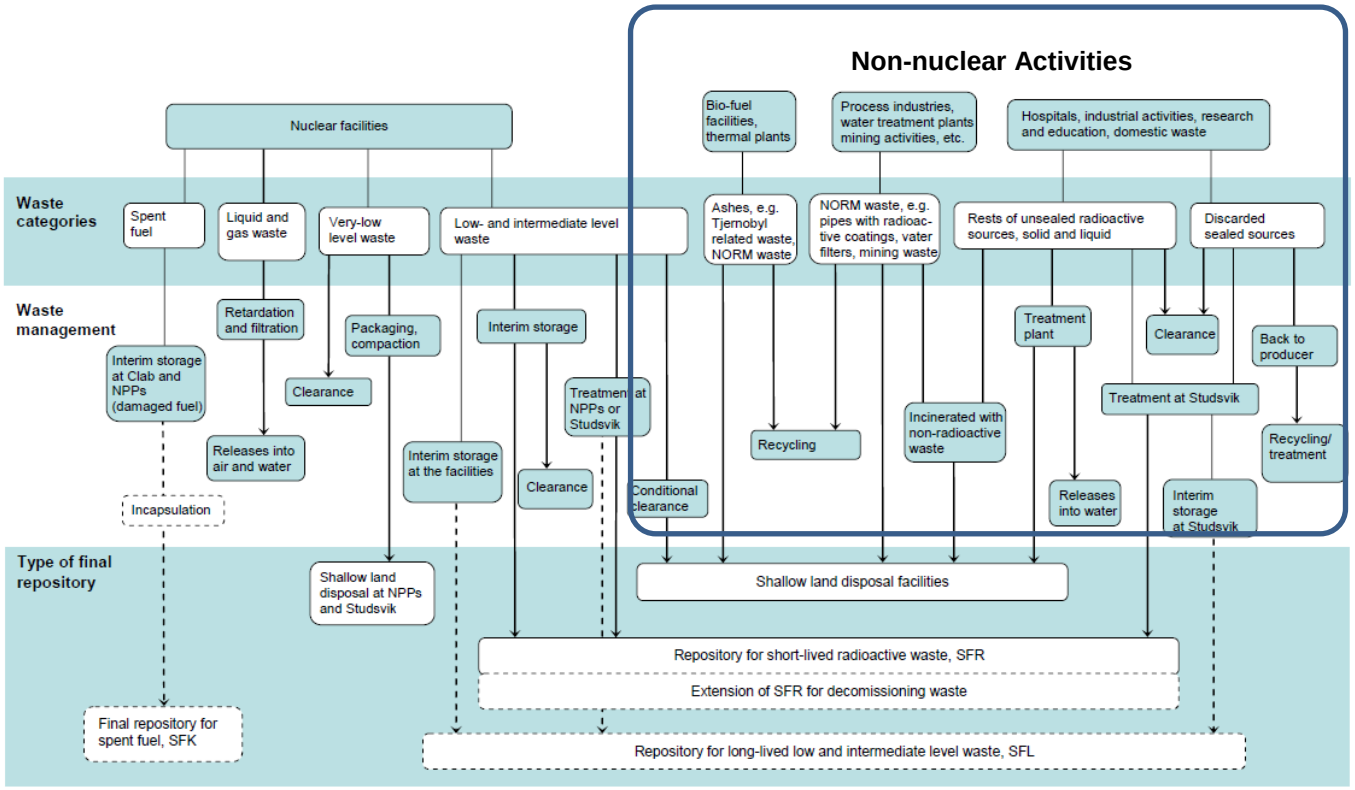

Figure 9. Schematic illustration of present flows of radioactive waste in Sweden with a special focus on non-nuclear activities: from the waste's generation to its being disposed. However, this figure does not illustrate shortcomings in the waste management system when it comes to management of non-nuclear radioactive waste. See Section 5.3 for a discussion of this area. The final disposal facilities of SFK, SFL and the extended SFR repository are only in the planning stages, indicated by the dashed lines in the figure.

Waste management and final disposal

Non-nuclear radioactive waste that cannot decay, be released, cleared, reused or recycled must be taken care of by a waste management company approved by SSM.

The radioactive waste generated by non-nuclear activities varies in terms of nuclide and activity composition and chemical and physical characteristics; however, as regards volumes, they are very small compared to the radioactive waste generated by nuclear activities. Sweden has no final disposal facilities designed specifically for disposal of non-nuclear radioactive waste. Instead, the Swedish Nuclear Fuel and Waste Management Company (SKB) has agreed to also dispose of non-nuclear radioactive waste in the nuclear power industry's waste management system. This was agreed in the 1980s in a contract with Studsvik Nuclear AB (SNAB) concerning final disposal of short-lived non-nuclear radioactive waste in SFR (a 1983 agreement concerning final disposal of intermediate and low level waste). This agreement also includes a declaration of intent in which SKB agrees to carry out planning and dimensioning of future waste facilities so as to encompass management of waste such as long-lived non-nuclear radioactive waste from SNAB. SNAB and SKB have commenced a process for designing an agreement concerning final disposal in SFL. SNAB also intends to reach an agreement with SKB on final disposal in the planned extension of the SFR repository.[30]

A precondition for disposal of radioactive waste is its treatment and conditioning, also the waste's storage over relatively brief or extended periods of time. Parties that have radioactive waste for final disposal are currently required to send it to SNAB for management. SNAB is the only waste management company in Sweden approved by SSM for management of non-nuclear radioactive waste. The fact that SNAB is a recipient of the radioactive waste also implies that the company assumes the responsibility for this waste.

The objective shared by all forms of treatment is to reduce the volume of waste to the furthest extent possible. The waste is (for instance) sorted as either combustible waste, material that can go directly into waste storage or material requiring further manual treatment. Pieces of equipment are disassembled in order to retrieve the radiation source. Low-level combustible waste is transported to the combustion plant. Some items of radioactive waste are simply repackaged. All radioactive waste is put in packaging and stored in SVAFO's rock cavern on the site before being transported to the SFR repository (or SFL), where final disposal of this waste takes place, see also Section 4.2.

5.3. Planned waste management methods

The existing system designed for management of nuclear waste and radioactive waste from Swedish nuclear power plants also deals extensively with non-nuclear radioactive waste. However, when it comes to certain categories of non-nuclear radioactive waste, their final disposal is unclear. In other words, a definitive treatment method and/or a solution for final disposal have yet to become established. This for example implies that metallic uranium, neutron radiation sources, tritium

[30] Studsvik Report N-10/238 Rev. 3, 2013. Radioaktivt icke kärntekniskt avfall, Redogörelse för hur IKA-avfall behandlas och hanteras i Studsvik i enlighet med gällande tillstånd [Radioactive non-nuclear waste: account of its treatment and management at Studsvik in accordance with the current licence], Studsvik Nuclear AB.

radiation sources, metals consisting of magnesium-thorium alloys and metal parts with residues containing raised levels of naturally occurring radioactive material cannot at the present time be satisfactorily taken care of in Sweden.

Studsvik Nuclear AB is presently reviewing some of these difficulties, since the company has in its ownership neutron radiation sources, tritium radiation sources and metallic uranium. For these problematic waste fractions, the company is required to produce plans for the waste's management and final disposal. SNAB is currently working on preliminary studies for method development aspects of treatment and final disposal of these waste fractions. The company expects to complete its preliminary studies by 31 December 2015 (see footnote [30]).

As far as concerns SKB's waste management system, a description of remaining facilities to be planned and constructed is provided in Section 7.2.

5.4. Time schedules with milestones up until closure of disposal facilities

The disposal facilities that are currently being considered for disposal of non-nuclear radioactive waste belong to SKB's waste disposal system. The period of operation for this waste disposal system is adapted in line with the planned periods of operation of the respective Swedish reactors and their decommissioning, see Section 7.2. Unless technological progress leads to the possibility of all radioactive material being replaced by something non-radioactive in all applications where they are currently being used, the non-nuclear activities will continue to generate radioactive waste for many years into the future, after both the SFR repository and SFL have been sealed. This situation will become obvious in connection with the European Spallation Source (see Section 5.1.2), which will generate considerable quantities of radioactive waste on a par with today's non-nuclear activities. The ESS facility is planned to be in operation for 40 years, starting in 2025. This implies, at least theoretically, that all radioactive waste from this facility requiring final disposal will not be ready for disposal in SKB's repository before its closure.

5.5. Plans for the period of time following closure

The disposal facilities that are currently considered for disposal of non-nuclear radioactive waste belong to SKB's waste disposal system. See Sections 2.2.1 and 7.2 for a more detailed account of planning principles for the period of time following closure of these final disposal facilities.

6. Waste quantities and forecasts

6.1. **Classification schemes**

There is no legally defined waste classification scheme in Sweden for nuclear or radioactive waste. There is, however, an established waste classification scheme used by the nuclear industry in Sweden. The classification scheme used in Sweden was derived from existing and future repositories (end points), see Table 1.

Table 1. Waste classification scheme developed by the Swedish nuclear power industry (SKB).[31]

	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 waste long-lived (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 shorter than 31 years; dose rate on waste package is shorter than 0.5 mSv/h. Long-lived nuclides with a half-life longer than 31 years can be present in restricted quantities.	Contains small amounts of short-lived nuclides with a half-life shorter than 31 years; dose rate on waste package (and unshielded waste) is shorter than 2 mSv/h. Long-lived nuclides with a half-life longer than 31 years can be present in restricted quantities.	Contains significant amounts of short-lived nuclides with a half-life shorter than 31 years; dose rate on waste package is shorter than 500 mSv/h. Long-lived nuclides with a half-life longer than 31 years can be present in restricted quantities.	Contains significant amounts of long-lived nuclides with a half-life longer than 31 years, past the restricted quantities for short-lived waste.	(Nuclear fuel) Typical decay heat >2kW/m3 and contains significant amounts of long-lived nuclides with a half-life longer than 31 years, past the restricted quantities for short-lived waste.
Other requirements	-	-	-	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 nuclear fuel

[31] SKB, Avfallshandbok - låg- och medelaktivt avfall, 1195328 Rev 4.0, 2015

Table 2. Comparison between different waste classification schemes.[32]

IAEA	Note	EU	Note	SKB	Note
Exempt waste (EW)		-	-	Exempt waste (EW)	
Very short-lived waste (VSLW)		Transition radioactive waste		-	-
Very low level waste (VLLW)				Very low level waste: short-lived (VLLW-SL)	T½<31 years < 0.5 mSv **Shallow land burial**
Low level waste (LLW)	Half-life must be taken into account; T½ less than about 30 years is considered short-lived	Low and inter-mediate level waste: short-lived (LILW-SL)	T½≤ Cs-137, Sr-90 (approx. 30 years)	Low level waste: short-lived (LLW-SL)	T½<31 years < 2 mSv SFR
Low level waste (LLW)		Low and inter-mediate level waste: short-lived (LILW-SL)		Intermediate level waste: short-lived (ILW-SL)	T½<31 years < 500 mSv Requires shielding **SFR**
Inter-mediate level waste (ILW)		Low and inter-mediate level waste: long-lived (LILW-LL)		Low and intermediate level waste: long-lived (LILW-LL)	T½>31 years SFL
High level waste (HLW)		High level waste (HLW)		High level waste (HLW)	Requires cooling Repository for spent nuclear fuel

It is not completely without its difficulties to use a waste classification scheme to compare waste between countries, since some waste conversions become somewhat distorted. Table 2 shows conversion of Swedish waste in accordance with the classification scheme defined by the European Union and the IAEA.

[32] SKB, *Avfallshandbok - låg- och medelaktivt avfall* [Waste manual: low and intermediate level waste], 1195328 Rev 4.0, 2015;
Commission Recommendation 1999/669/EC, Euratom, of 15 September 1999 on a classification system for solid radioactive waste.

When comparing SKB's waste classification scheme with that of the European Union, it is evident that SKB's classification scheme is somewhat more detailed. This implies that SKB's definition of short-lived low level waste, together with its definition of short-lived intermediate level waste, correspond to the classification LILW-SL. The same waste, in accordance with the IAEA's definition, would be classified as LLW. When it comes to long-lived waste, conversion does not lead to distortion between SKB and the EU; however, the IAEA definition implies that the same waste is classified as intermediate level waste. All three share the same classification for high level waste.

6.2. **Spent fuel and radioactive waste 2011-2013**

Radioactive waste is currently stored at the nuclear power plants in operation (FKA, OKG, RAB), the nuclear power plant undergoing decommissioning (BKAB), the fuel fabrication plant in Västerås (WSE), the waste management facilities at Studsvik (SNAB, SVAFO), the central storage facility for spent nuclear fuel (Clab), in addition to the repository for radioactive waste (SFR). Spent fuel is also stored in pools at the respective nuclear power plants in operation, as well as at Clab. Since some annual reports state the same kind of waste in different units, such as in m^3, kg and number of items, certain estimates have been necessary.

6.2.1. Quantities in accordance with SKB's classification scheme

Table 3 provides a summary account of waste quantities generated between 2011 and 2013 in accordance with SKB's classification scheme.

Table 3. Quantities of waste in accordance with SKB's classification scheme.[33]

		2011	2012	2013
Short-lived very low level waste (VLLW-SL)	m^3	8,541*	19,519	21,717
Short-lived low level waste (LLW-SL)	m^3	15,708*	16,237	17,734
Short-lived intermediate level waste (ILW-SL)	m^3	20,716*	22,388	24,159
Long-lived low and intermediate level waste (LILW-LL)	m^3	8,200**	8,300**	8,400**
High level waste (HLW)	tonnes U	5,404	5,577	6,296

* Insufficient data in several waste producers' annual reports.
** Insufficient data in several waste producers' annual reports, information is taken from SKBs' RD&D Programme 2013, see figure 11 below.

Table 4. Quantities of Swedish waste in accordance with the EU's classification scheme.[36]

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	44,965*	58,234	63,610
Long-lived low and intermediate level waste (LILW-LL)	m^3	8,200**	8,300**	8,400**
High level waste (HLW)	tonnes U	5,404	5,577	6,296

* Insufficient data in several waste producers' annual reports.
** Insufficient data in several waste producers' annual reports, information is taken from SKBs' RD&D Programme 2013, see figure 11 below.

[33] See references in Appendix 1.

6.2.2. Quantities in accordance with the EU's classification scheme

The waste quantities generated during the period 2011-2013, as summarised by Table 4, are accounted for in accordance with the EU's classification scheme.

6.3. **Forecasts for the period 2014-2076**

Waste forecasts are developed by the nuclear power industry (SKB) as a basis for dimensioning of future final disposal facilities. This work is carried out as part of the RD&D Programme developed every third year.

6.3.1. Repository for short-lived radioactive waste (SFR)

SFR is intended for disposal of short-lived low and intermediate level operational waste.

Quantities of short-lived operational waste

The quantity of short-lived operational waste that is planned to be deposited in SFR at its closure in 2076 is estimated today to be about 68,000 m^3 (SKB 2013a). The estimated volume is the sum of the volume deposited up to and including 31 December 2012 and the forecasted volumes for future operation.

Quantities of short-lived waste from decommissioning and demolition

The quantity of short-lived waste from dismantling and demolition that is planned to be deposited in SFR at its closure in 2076 is estimated today to be about 84,000 m^3 (SKB 2013a). The forecast is based on data from studies for decommissioning, decommissioning plans and data for the different facilities. In addition to the inventoried waste quantities, an estimate has been made of the quantity of secondary waste that might arise during dismantling and demolition.

Uncertainty in relation to waste volumes

The estimated quantity of waste that is intended to be deposited in the future is surrounded by numerous uncertainties. Some uncertainties are difficult to predict. Changes in laws and political decisions, operating conditions and the closure dates of the different nuclear power from what is currently assumed cannot be ruled out.

The forecast is based on operating experience and knowledge concerning how waste production has fluctuated in previous years. As regards waste from dismantling and demolition, uncertainties in the inventoried waste quantity are presented in the decommissioning studies. Aside from the inventoried waste – which includes iron/steel, concrete and sand – a certain fraction of secondary waste is expected to arise in conjunction with dismantling and demolition.

Another factor that can affect the future waste quantities is to what extent different types of after treatment are performed. This mainly concerns the waste from dismantling and demolition, since there are at present no established procedures for how it is handled. Examples of this are what packing degree can ultimately be attained and whether further volume reductions can be achieved by melting of low-level process systems. The waste quantities to SFR are also determined by the radiological clearance work and the use of near-surface repositories in the future. The option of depositing the very low-level waste from dismantling and demolition in near-surface repositories instead of in SFR would greatly reduce the waste

volume to BLA and thereby comprise the main alternative. At present, however, all material from dismantling and demolition that is not free-released and is classified as short-lived is included in the design volume for the extension of SFR. It is assumed that much low-level operational waste can continue to be deposited in near-surface repositories.

Design waste volumes

An evaluation has been done of how the forecasted waste volumes and identified uncertainties will be included in designing the capacity of the SFR extension. It has been decided that the design waste volume for the extension of SFR is 110,000 m^3 plus space for nine BWR pressure vessels. The decision is based on an attempt to balance the requirement of disposing of all waste that might arise against the risk of oversizing the facility. In addition to the basic forecasts of waste from operation as well as from dismantling and demolition, the design waste volume also includes some 15,000 m^3 to account for uncertainties.

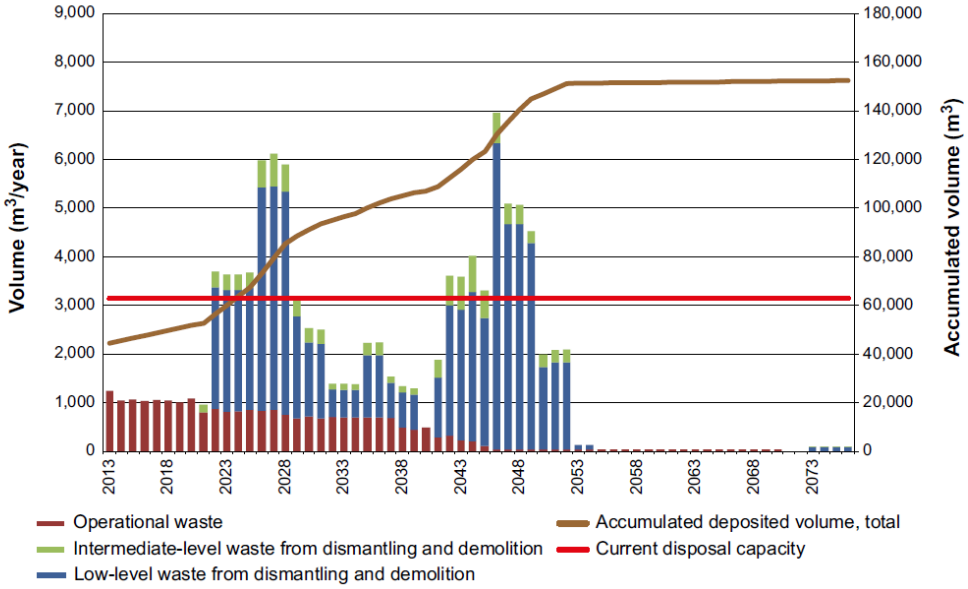

Figure 10. Forecast of volumes of short-lived waste from operation and from dismantling and demolition to SFR. The volume that arises during a year is read on the left-hand axis. The brown curve shows the accumulated volume of waste and is read on the right-hand axis (total about 155,000 m^3). Accumulated volume can be compared with current disposal capacity (red line, total 63,000 m^3).[34]

6.3.2. Interim storage of long-lived waste

Long-lived low- and intermediate-level waste is interim-stored today either wet in pools at Clab or at the NPPs, or dry in interim storage facilities at the NPPs. In addition, long-lived waste is stored in an interim storage facility on the Studsvik industrial site. This facility contains legacy waste that is managed by AB SVAFO and waste from Studsvik Nuclear AB's activities. The prospects for establishing a central interim storage facility for long-lived waste will be studied. One requirement imposed by SKB in terms of long-lived waste is that this waste must be potentially reconditioned for SFL.

[34] SKB, RD&D Programme 2013, Figure 5-1

In December 2014, SKB submitted an application to SSM seeking to extend the present SFR repository. The SFR extension will be designed to permit interim storage of long-lived waste (core components) from the nuclear power plants. According to a preliminary estimate, the greatest volume which the interim storage facility may have to hold is about 2,800 m^3. The interim storage facility will be designed with a view to the needs of the power companies and the date when SFL is planned to be ready to receive waste. Studies show that an interim storage facility in SFR is technically feasible. In the safety analysis report that will be included in the applications for an extension of SFR, the interim storage of long-lived low- and intermediate-level waste will be treated as a part of the operation.

6.3.3. Repository for long-lived radioactive waste (SFL)

Figure 11 below provides a general forecast of volumes of long-lived low level and intermediate level waste generated. The total volumes generated are estimated at approximately 16,000 m^3.

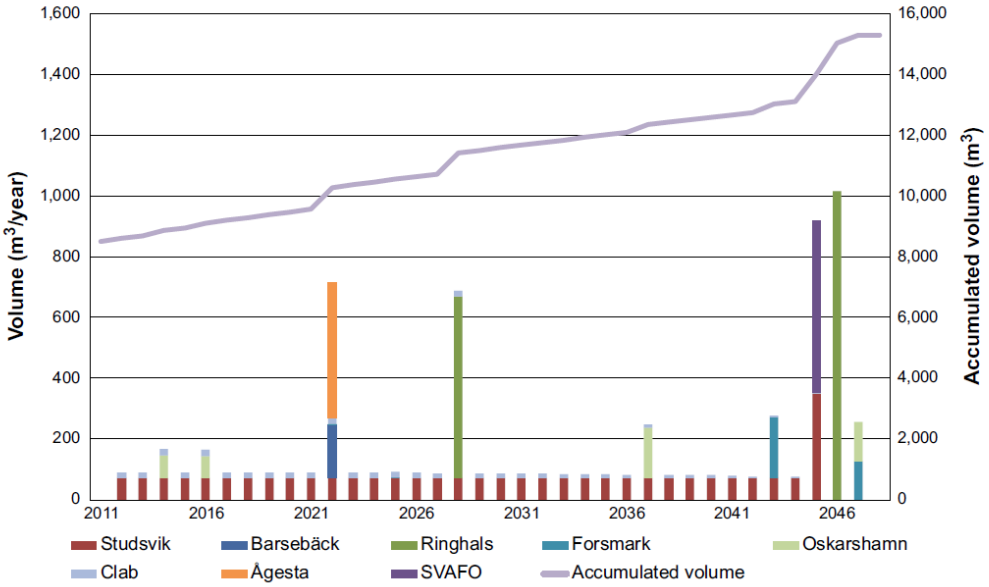

Figure 11. Overall timetable showing when long-lived low- and intermediate-level waste arises. The bars show the waste that arises per producer and year (left-hand axis). The curve shows the accumulated volume (right-hand axis). Data for Clab includes only interim-stored control rods and core components.[35]

The volumes have been estimated based on the following assumptions:

- Existing waste quantity is calculated from data reported by the waste producers and excerpts from the Draak database for interim-stored core components and control rods in Clab. In the future, this database will be combined with the Gadd database to include both short-lived and long-lived low- and intermediate-level waste.
- Forecasted waste volumes are based on data reported by the waste producers and assumptions concerning periodic replacements of control rods (operating time 15−20 years) and neutron detectors (operating time 10 years) for BWRs.

[35] SKB, RD&D Programme 2013, Figure 6-2

- Waste quantities from dismantling and demolition are taken from the decommissioning studies as well as volumes reported by Studsvik Nuclear and SVAFO.
- Studsvik Nuclear's forecast for operational waste extends up until 2045, so forecasted operational waste has been distributed evenly over the years up to and including 2045, when waste from dismantling and demolition of Studsvik Nuclear and SVAFO is also assumed to arise (even though the date for decommissioning of Studsvik Nuclear's facilities has not been determined).
- The disposal volume for core components and control rods has been calculated based on a packing degree of 1.1 tonnes per cubic metre, an expected inside volume of six cubic metres and an expected outside volume of 9.9 cubic metres, which is equivalent to the dimensions of a steel tank (including inner storage canister) with a wall thickness of 150 millimetres.
- Control rods from Ringhals PWRs are disposed of together with the spent nuclear fuel.
- Core components and RPVs from PWRs are segmented and deposited in the same way as core components from BWRs. The alternative of depositing the PWR pressure vessels whole (with or without core components) would reduce the total disposal volume by 400−800 cubic metres.
- Approximately 2,500 m^3 of radioactive waste from operation and decommissioning of the ESS research facility in Lund are expected to be disposed of at SFL, SKB's final disposal facility.

The issue of how to deal with waste from European Spallation Source is at the present time not fully resolved as regards an agreement between ESS AB and SKB, conditioning of waste and the method for final disposal.

6.3.4. Final repository for spent nuclear fuel

A repository for spent nuclear fuel is being planned. This facility is intended to be located at Söderviken, in close proximity to the Forsmark nuclear power plant. The repository has a planned depth of approximately 500 metres in bedrock and an expected capacity of some 12,000 tonnes of spent nuclear fuel elements. This repository is planned to be in operation from about year 2030 until around 2070 and consist of up to 60 kilometres of tunnels as part of a subterranean system with space for about 6,000 copper canisters containing spent nuclear fuel. The rock caverns required are an estimated four square kilometres.

6.4. **Future waste generated if new reactors are commissioned**

In 2012, Vattenfall AB submitted an application to SSM for a licence to replace one or two existing reactors with new ones. Licensing to build and commission one new reactor is a stepwise process that will take many years. A licence will be required from the Government. At this point, a plan for waste management will also be needed.

New reactors would entail that the total volume of waste could be much greater than has been assumed. It is not possible today to predict the size of the waste volumes that would result from generational changes of the reactors. These volumes depend above all on how future economic considerations affect the willingness to invest in new nuclear power. Current plans call for today's ten reactors to be taken out of service during the period 2025–2045. If new reactors are phased in at that time instead of the old one, the new scenario entails a total remaining operating time of nuclear power of up to 90 years, assuming the new reactors are utilized for 60 years.

It can be assumed that the new reactors will belong to what is usually called the third generation of nuclear power reactors. They are in many respects more technically advanced than today's reactors. But it is still a question of boiling or pressurized water reactors with the same fundamental technology as today's reactors, and they produce the same kinds of waste products. The relative composition of the waste may be different from todays. The radionuclide content of the spent nuclear fuel depends on, for example, what type of fuel is used, the operating conditions and the fuel's decay period. The composition of the fuel and the distribution between short- and long-lived radionuclides is determined by the fuel's burnup and the specific power.

The volume of radioactive operational waste will probably be lower per kilowatt-hour of electricity produced than that produced by the first- and second-generation reactors. The quantity of operational waste from today's reactors is already much smaller in relation to the electricity produced than had been expected when the reactors were put into operation. The reason is that the nuclear power companies have over the years improved the treatment and compaction of the waste for the purpose of minimizing its volume.

The spent nuclear fuel from the new reactors will have a higher average burnup than the nuclear fuel from today's reactors, considered over the entire life of the reactors. The higher burnup means that the nuclear fuel will need a longer period of interim storage before it can be encapsulated and disposed of. An interim storage period of about 60 years will be required. This, together with the new reactors' longer operating times, means that interim storage and encapsulation would need to continue well into the 22nd century. The fuel assemblies in the new reactors will probably be longer than those used in today's reactors. Clink will probably not be able to be used for fuels from new reactors. New facilities will then be needed for both interim storage and encapsulation. Well developed technology is available today for both wet and dry interim storage of spent nuclear fuel, and both techniques are thereby conceivable.

It is difficult to know at present whether the capacity of the Spent Fuel Repository will be sufficient for the new nuclear fuel as well. This requires new investigations. But tunnels and shafts could be kept open for the time required. The need for alterations in the Spent Fuel Repository is deemed small. The need for a new repository will thereby probably be determined by the available disposal capacity.

It is assumed below that all of today's ten reactors are replaced with new ones, but another conceivable scenario is that only some of the existing reactors are replaced. The net power capacity of the replacement reactors is assumed to be the same as that of today's reactors. For this a repository area of the same size as the one planned for the spent nuclear fuel from today's reactors is needed.

It should then be most advantageous in terms of both safety and economy to site the new repository areas adjacent to the Spent Fuel Repository. The advantages lie in good knowledge of the bedrock around the repository, reducing the need for new investigations, and in the fact that surface facilities, ramp and shafts can be used for the additional repository area as well. In order to meet the increased disposal requirement, SKB can investigate the possibility of building an additional level in the Spent Fuel Repository. This would enable the upper level to be closed after this generation of nuclear power plants, at which point operation of the lower level would commence.

Furthermore, a scenario with replacement reactors entails an additional need of disposal capacity for operational waste of roughly the same scope as SFR with the currently planned extension. Additional disposal rooms can be built adjacent to SFR, provided the bedrock is considered suitable, or as a separate facility on another site.

There will also be a need for additional disposal capacity in the final repository for long-lived waste, SFL. Construction of SFL would have to be commenced roughly as planned today in order to dispose of waste from today's reactors, but the facility needs to be kept in operation for a longer time.

6.5. **Radioactive waste from non-nuclear activities**

6.5.1. Waste stored at Studsvik and in the SFR repository

Non-nuclear radioactive waste taken care of in the established management system for nuclear radioactive waste is stored at the waste management facilities at Studsvik (Studsvik Nuclear AB, AB SVAFO) and disposed of at the SKB-owned SFR repository. Consequently, non-nuclear radioactive waste is included as part of the waste quantities presented earlier in this Chapter, though it is not reported separately. The non-nuclear radioactive waste received at Studsvik as of 1 July 1991 is the responsibility of Studsvik Nuclear AB, i.e. SNAB (radioactive waste generated at Studsvik prior to this belongs to AB SVAFO). Table 5 shows the quantities of non-nuclear radioactive waste sent by SNAB for disposal in the SFR repository, the quantities stored at Studsvik awaiting disposal in SFR and SFL, as well as the annual waste quantities generated.[33]

Table 5. Table showing non-nuclear radioactive waste already sent by Studsvik Nuclear AB to the SFR repository, as well as the quantities it plans to ship to SFR and SFL.

Waste fractions based on final disposal solution	**Volumes in SFR (m^3)**	**Volumes in SFL (m^3)**
Already sent to SFR as at 31 Dec. 2012	93	
Stored at Studsvik as at 31 Dec. 2012, planned repository: SFR	66–81	
Generated annually, planned repository: SFR	3.5–5.6	
Stored at Studsvik as at 31 Dec. 2012, planned repository: SFL		56
Generated annually, planned repository: SFL		1.4

SNAB has to date sent a total of 93 cubic metres of non-nuclear radioactive waste for disposal in the SFR repository. This waste was received by SNAB between 1

July 1991 and 31 December 2005 and during this period handled jointly with other nuclear waste. This waste consists of ash and non-combustible waste embedded in 200-litre concrete barrels.

SNAB has estimated that the non-nuclear radioactive waste stored at Studsvik destined for disposal in the SFR repository, as at 31 December 2012, had a total volume of 66–81 cubic metres. The estimated range reflects the kind of waste container that will be chosen for radiation sources from smoke detectors, which comprise a proportion of the waste stored. This fraction includes additional kinds of waste, both conditioned and unconditioned, from the period 1 July 1991–31 December 2005, in addition to SNAB's own operational waste.

Out of the discarded radiation sources and other non-nuclear radioactive waste currently received by SNAB, the company plans to only dispose of radiation sources from smoke detectors in the SFR repository. Each year, SNAB receives around 100,000 smoke detectors, which altogether correspond to 3.3-5.4 cubic metres of disposal volume in the SFR repository. SNAB is also planning to have its own operational waste, corresponding to 0.2 cubic metres per year, disposed of in the SFR repository.

SNAB has estimated that the non-nuclear radioactive waste stored at Studsvik destined for disposal in SFL, as at 31 December 2012, had a total volume of 56 cubic metres. This waste, which consists of radiation sources and various other kinds of radioactive waste, has to some extent been conditioned.

Apart from smoke detectors, non-nuclear radioactive waste currently received by SNAB is disposed of in SFL. This corresponds to 1.4 cubic metres of disposal volume per year.

SNAB also receives radiation sources containing Krypton-85. The intention is recycling of this gas. These radiation sources are shipped off as part of campaigns for recycling purposes abroad.

6.5.2. Residual products containing naturally occurring radioactive material (NORM)

A number of shut down operations have given rise to major deposits residual products containing naturally occurring radioactive material (NORM). This legacy waste occurs throughout Sweden, see Section 5.1 and Table 6. More detailed information is compiled in a number of reports issued by SSM.[1,36,37]

Today's activities and operations also generate residual products containing NORM. Although alum shale-based lightweight concrete ('blue concrete') is no longer manufactured, some 300,000 buildings throughout Sweden still contain this material. In pace with these buildings being demolished, this gives rise to thousands

[36] SSI report 2001:15, *Radioaktivt avfall från icke tillståndsbunden verksamhet* (RAKET) [Radioactive waste from non-licensed activities]; SSI report 2003:22, *Kartläggning av radioaktivt avfall från icke kärnteknisk verksamhet* (IKA) [Survey on non-nuclear radioactive waste]

[37] 2009:23, *Kartläggning av fast avfall innehållande radioaktiva ämnen från icke kärntekniska verksamheter* [Survey on solid waste containing radioactive substances from non-nuclear activities]

of cubic metres of demolition rubble per year. This waste contains uranium with daughter nuclides (0.5-3.5 kBq/kg).

Burning peat and coal to produce energy gives rise to kinds of ash containing uranium, thorium and their daughter nuclides in varying concentrations. Peat containing NORM basically occurs throughout Sweden. Depending on the activity concentration, the ash can either be reused or need to be disposed of. Around 30,000 tonnes of peat ash are generated each year. This ash is mainly transported to facilities for use as a filler material. Peat ash also contains Cs-137 from fallout. Around one million tonnes of coal ash are disposed of each year. This context also includes burning of wood fuel, though this is ash containing caesium-137, not NORM. Approximately 100,000 tonnes of wood fuel ash are generated each year, of which less than 10 per cent is disposed of. Ash that can be reused is for instance used for geotechnical construction purposes.

Table 6. Large deposits of residual products. This waste contains naturally occurring radioactive material (NORM) and occurs throughout Sweden.

Material	**Estimated quantities and occurrence**
Burnt alum shale (uranium + daughter nuclides, 2.5-5 kBq/kg)	Totalling millions of tonnes, often in great heaps. Skåne, Öland, Småland, Östergötland, Närke, Västergötland and Lidingö. The Kvarntorpshögen heap is the largest deposit.
Phosphogypsum (uranium + daughter nuclides, 0.6-2.5 kBq/kg)	Totalling millions of tonnes, of which the largest heap is located on the island of Vindön (Gipsön, or "gypsum island") just outside Landskrona.
Iron ore spoil heaps (uranium + daughter nuclides, 2.5-12 kBq/kg)	Totalling hundreds of tonnes. With a few exceptions, these heaps of spoil are mainly located in Bergslagen in connection with closed down iron ore mines. The heaps of spoil contain rocks with uranium mineralisation.
Iron ore slag (uranium + daughter nuclides, 2-10 kBq/kg)	Totalling a few hundred tonnes in slag heaps at a couple of closed down blast furnaces where uranium-rich iron ore was melted. In Närke, slag has also been used as a filler and building material.

Parts of certain processing facilities can have substantial NORM residues inside pipe and heat exchange systems. When these systems are replaced or dismantled, they are managed as ordinary scrap metal and transported for recycling via foundries. Thanks to the common occurrence of portal radiation detectors in the metal recycling industry, this kind of material is identified before it is melted. The contaminated system components are currently required to be stored at the facility that discovered the contamination. In the meantime, methods for dealing with the material are investigated. The activity concentration of these residues shows great variations. The volume of contaminated residue in relation to the volume of metal is negligible. It is not possible to provide an exact figure of present volumes at Swedish facilities nor of the incoming volumes per year. At the time of the latest inventory performed by the industry in 2009, it was established that at least 20 tonnes of metal components in the form of vessels and pipes containing NORM residues were present at these facilities.

6.5.3. Future waste quantities

The planned operations at the ESS facility in Lund will generate substantial quantities of non-nuclear radioactive waste requiring disposal, in relation to the present quantities generated. European Spallation Source's preliminary estimates show that the total quantities of radioactive waste from operations and decommissioning requiring final disposal may be equivalent to approximately 15 per cent of the planned space of SKB's final disposal facility SFL.

7. Main references of the National Programme

The comprehensive national system, whose regimes of control and content are, in the assessment of SSM, capable of meeting the Directive's requirements for a *national programme*, mainly comprises:

- The System of Environmental Objectives (Appendix 2),
- The programme for research, development and demonstration (the RD&D Programme) (Appendix 3)
- The financing system and cost estimates (the Plan Cost Estimates) (Appendix 4).

7.1. **The System of Environmental Objectives**

In 1999, the Swedish Parliament laid down fifteen national environmental quality objectives[38]. A few years later, in 2005, sixteenth environmental quality objectives were adopted concerning biological diversity39. Work on achieving these environmental quality objectives constitutes the basis for the Swedish national environmental policy and work.

The overall objective of the system is to hand over to the next generations a society that has solved the biggest environmental problems, without compounding environmental or health issues inside and outside the borders of Sweden. The environmental quality objectives define the level of quality and state of the environment that are deemed as sustainable over the long term, while also stating the ultimate target of Sweden's environmental work. The environmental objectives are not legally binding; however, they serve as guiding principles when following up the state of the environment and defining necessary measures for achieving the generational goal.

The environmental quality objectives undergo annual follow-ups[40] by the government agencies in charge of the respective objective. Their reports are compiled by the Swedish Environmental Protection Agency, which is the national authority in Sweden responsible for coordinating work on the environmental quality objectives[41]. SSM is the national authority in Sweden responsible for the environmental quality objective 'A Safe Radiation Environment'.

Around every fourth year, an in-depth evaluation is also made as input for the Swedish Government's environmental policy bill. In the follow-up, it is assessed whether current means of control and measures are sufficient for achieving the

[38] Committee Report 1998/99:MJU6, Environmental policy
[39] Government Bill 2004/05:150, A Rich Diversity of Plant and Animal Life
[40] Swedish Environmental Protection Agency, Report 6608, 2014. The environmental objectives – Annual follow-up of Sweden's environmental quality objectives and milestone targets 2014
[41] Environmental Objectives Portal: http://www.miljomal.se/sv/Environmental-Objectives-Portal/

objectives, and proposals for further action are made as needed. These must have been evaluated in terms of socioeconomic benefit in order to be taken into account. The environmental objectives are followed up using national indicators that track progress towards the objectives.

The latest in-depth evaluation was carried out in 2012[42]. A new in-depth evaluation of the environmental quality objectives will be presented in 2015.

7.1.1. A Safe Radiation Environment

The environmental quality objective 'A Safe Radiation Environment' implies that "human health and biological diversity must be protected against the harmful effects of radiation".

For the purpose of explaining the implications of this objective, four specially defined targets have been formulated on the work needed for achievement of the objective. These targets encompass radiation protection principles, radioactive materials, ultraviolet radiation and electromagnetic fields. The areas with a close link to waste management are radiation protection principles and radioactive material.

The 2012 evaluation of the environmental objectives[43] assessed that the forecast for the components of the environmental quality objective encompassing radiation protection principles and radioactive material showed a positive trend.

Specially defined target: Radiation protection principles

Human exposure to harmful radiation in occupational and other environments is to be limited as far as reasonably possible. This target is deemed as achievable by employing today's decided and planned means of control, in addition to measures and initiatives taken before the year 2020.

The defined target consists of limitation of all exposure to radiation in occupational and other environments. This for example implies that all activities and practices involving radiation must be justified, and radiation protection be optimised so that radiation doses are kept as low as reasonably achievable. Dose limits must not be exceeded and caution must be observed.

The licensees of nuclear facilities work continuously to optimise radiation protection and limit doses to workers. No dose limits have been exceeded at any Swedish nuclear power plants over the past ten years, and there is good potential for further reductions in doses in the future on the part of both workers and the general public.

In addition, a general improvement in regulatory compliance has been observed in SSM's supervision of medical services, as a result of completed supervisory work. In the area of health and medical services, SSM is planning to prioritise supervisory work and formulating more clear-cut requirements in the form of revised regulations.

[42] Swedish Environmental Protection Agency, Report 6500, 2012. Steps along the way: In-depth evaluation of the environmental objectives 2012
[43] Report 6500, June 2012, Swedish Environmental Protection Agency. *Steg på vägen – Fördjupad utvärdering av miljömålen 2012* [Steps along the way: In-depth evaluation of the environmental objectives 2012], p. 272.

Specially defined target: Radioactive materials

"Discharges of radioactive substances into the environment are to be limited so as to protect human health and biodiversity." This target is deemed as achievable by employing today's decided and planned means of control, in addition to measures and initiatives taken before the year 2020.

The defined target is limiting discharges of radioactive substances so as to protect human health and biodiversity. This for example implies that the maximum overall effective radiation dose that the general public is exposed to from activities involving radiation is not allowed to exceed one millisievert (1 mSv) per individual and year. SSM imposes a regulatory requirement on nuclear activities making use of Best Possible Technique (BMT) for the purpose of reducing external releases of radioactive materials into the environment as far as reasonably achievable. Licensees of non-nuclear activities are also responsible for ensuring that doses and releases from their activities are kept as low as reasonably achievable. Their work is followed up within the framework of SSM's day-to-day supervisory work. In the first instance, this work focuses on maintaining this situation, or improving it. This is why it is important to continue carrying out good supervision of existing operations while also carefully examining whether new activities and practices will be capable of fulfilling the environmental quality objective prior to granting a licence. A key means of control for this work is the Basic Safety Standards (BSS) Directive[19], a new EU Directive to be implemented in Sweden by 2018.

When it comes to management of spent nuclear fuel, the target is deemed as achieved owing to this area being encompassed by the RD&D Programme and ongoing licensing review of a final disposal system comprising a repository and encapsulation facility. As regards other radioactive waste from nuclear activities, approved or planned facilities are currently in place for short-lived operational waste and waste from decommissioning and dismantling. However, as far as concerns long-lived waste, no detailed proposal for a final disposal facility has been made; this is a prerequisite for enabling achievement of this part of the environmental quality objective.

The follow-up of the environmental objectives has established that there is an imbalance in management of radioactive waste depending on whether its origin is nuclear or non-nuclear activities: in other words, coming from medical services, research or industry. Radioactive waste from nuclear activities is subject to a clear division of responsibility under the legislation. In addition to this, plans for management and final disposal are required, as well as ensuring sufficient financial resources for management of this waste. Correspondingly, clearly defined requirements have not been established for all radioactive waste from non-nuclear activities. Today's management of radioactive waste from non-nuclear activities does not pose any radiation hazards to the general public; however, the long-term responsibility for management and final disposal of all kinds of radioactive waste needs to be defined and established.

Final management of certain categories of non-nuclear radioactive waste nevertheless remains unclear. There is no presently established method of treatment, nor is there a final disposal method implying that this waste can be satisfactorily dealt with in Sweden. This problem has been addressed by SSM[1] and SNAB is currently looking into treatment methods and/or final disposal facilities.

The Council Directive on high-activity sealed radioactive sources[44] (the HASS Directive) and Council Directive 2011/70/Euratom on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste require reserving sufficient funding on a national level to ensure safe management of radioactive waste and discarded radiation sources in cases where there is no owner. Of the appropriations of the Swedish Environmental Protection Agency, SSM has at its disposal SEK 2.0 million per year for decontamination and restoration work relating to management of orphan sources and certain legacy waste from non-nuclear activities. In recent years, the SSM has focused more actively on initiatives. For instance, funding of areas such as interim storage and final disposal of radiation sources from smoke detectors has been arranged, and a campaign has been launched on collection and management of disused teaching materials, comprising radioactive legacy waste from Swedish schools up to upper secondary school level.

7.2. Programme for research, development and demonstration (RD&D Programme)

As explained in Section 2.3, a licensee for a reactor is required to conduct the research and development work needed to ensure safe management and final disposal of residual products generated by reactor operations. Moreover, the licensees for reactors have agreed to task SKB, their jointly owned company, with taking the necessary measures for fulfilment of the obligations according to the Nuclear Act.

SKB is also tasked with preparing a programme for the comprehensive research and development work and other measures necessary for safe management of nuclear waste and spent nuclear fuel, in addition to safe decommissioning and dismantling of nuclear facilities (i.e. the RD&D Programme). The RD&D programme must contain an overview of all measures that may be necessary and specify in detail the measures intended to be implemented within six years. Every third year since 1986, SKB has submitted a successively updated RD&D programme. Over time, a comprehensive system for management and final disposal of spent fuel and radioactive waste generated by the nuclear power industry has evolved.

Final management of spent fuel and radioactive waste from reactor operation needs to be performed while taking into account the waste's relative level of hazard. The present classification scheme is based on the concept for final disposal expected to be applied to the respective category of residual product. The waste classification scheme is described in Section 6.1. Established and projected waste streams are schematically illustrated in Figure 12.

There are established methods for final disposal for the following kind of waste:

- *Very short-lived radioactive waste* is to be disposed of at shallow land disposal facilities, and
- *Short-lived low and intermediate level radioactive waste* is to be disposed of at the repository for short-lived waste: SFR.

[44] Council Directive 2003/122/Euratom on the control of high-activity sealed radioactive sources and orphan sources.

For the following kind of radioactive waste, established methods for final disposal have yet to be defined:

- *Long-lived low and intermediate level waste* is expected to be disposed of in a specially designed future repository for long-lived waste: SFL; and
- *Spent nuclear fuel* is expected to be disposed of in a specially designed future repository. For the time being, this spent fuel is in interim storage at Clab, a facility designed for this purpose.

Waste containing levels of radioactive material below the requirement limit for final disposal in the facilities listed above is released from regulatory control.

7.2.1. The programme's structure and content

In the RD&D Programme, SKB accounts for the research work and technical advances needed to enable designing, developing and licensing of planned facilities and also for the purpose of maintaining safe operation of existing facilities for management and final repository of radioactive waste. The structure and focus of this programme have varied over time. RD&D Programme 2013 encompassed the following five parts:

- *Part I, SKB's activities and plan of action,* which describes the comprehensive planning for the purposes of managing SKB's existing facilities and realising remaining components of the waste management system.
- *Part II, Low and intermediate level waste (the LOMA Programme),* which encompasses not only planned management of low and intermediate level waste generated from operation and decommissioning of Swedish nuclear facilities, but also other radioactive waste from industry, research and medical services.
- *Part III, Spent nuclear fuel (the Nuclear Fuel Programme),* which encompasses a presentation of the prerequisite technical advances for enabling planning work and developing and operating the repository system for spent nuclear fuel.
- *Part IV, Research for assessment of long-term safety,* which describes SKB's natural science research programme run on a needs basis from safety assessments in connection with final disposal of radioactive waste and spent nuclear fuel. This research covers comprehensive areas shared by several disposal systems as well as issues and matters relating to a specific disposal system.
- *Part V, Social science research,* which presents the outcome from the programme for social science research now concluded by SKB, and which addresses information retention over many generations.

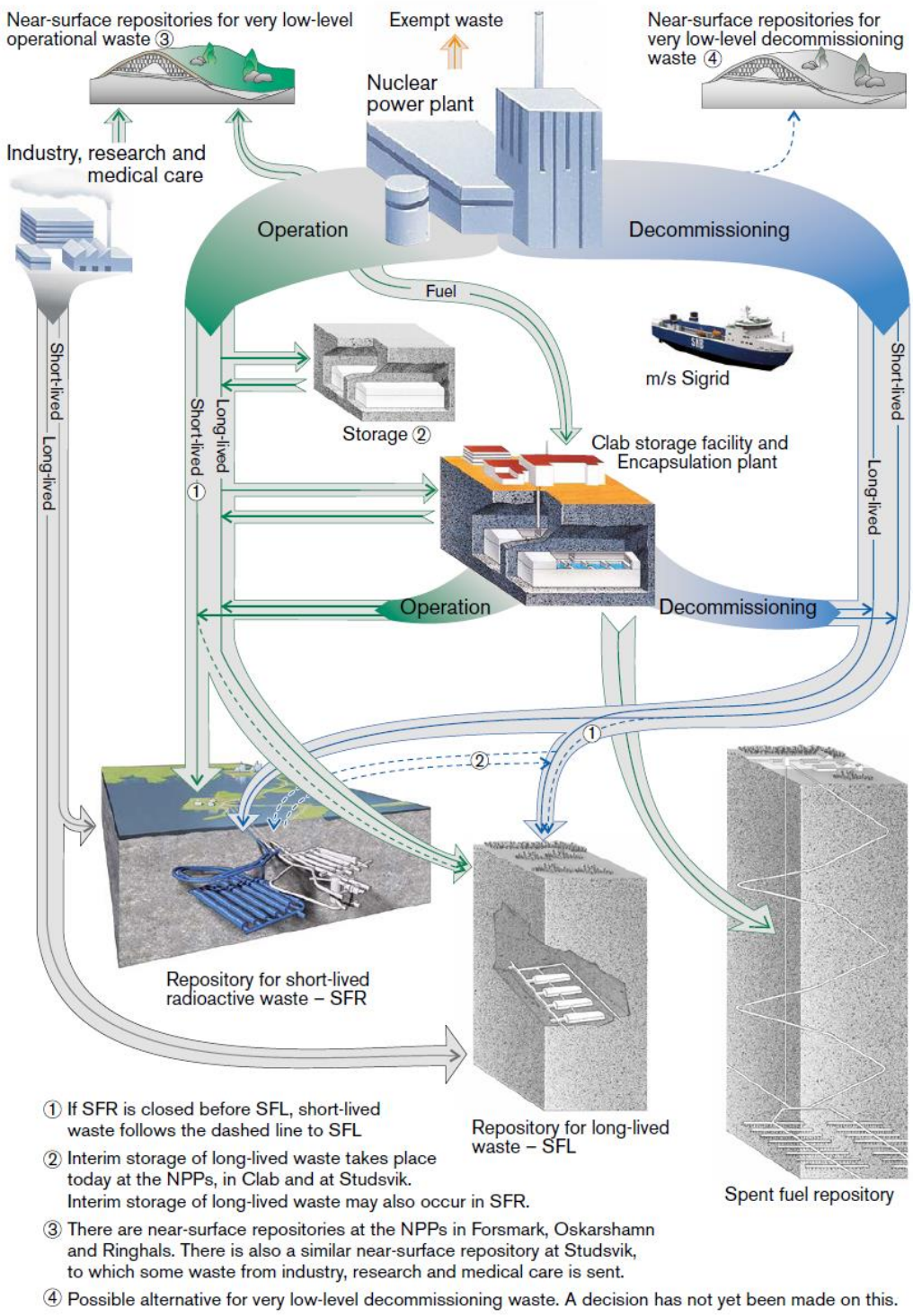

Figure 12. The system for management of Sweden's radioactive waste and spent nuclear fuel. Solid lines represent transport flows to pre-existing or planned facilities. Dotted lines represent alternative management paths.[45]

[45] SKB, RD&D Programme 2013, Figure 1-2

7.2.2. Research and demonstration facilities

SKB has set up research and demonstration facilities for assistance in its research and development work.

The Äspö Hard Rock Laboratory

This underground laboratory, located north of the Oskarshamn nuclear power plant, comprises a tunnel and shaft leading from the peninsula of Simpevarp, where this nuclear power plant is situated, to southern island of Äspö, down to a depth of 460 metres. The different experiments are performed in niches and in short tunnels branching out from the main tunnel. The laboratory is mainly used to investigate the performance of barriers in the repository for spent nuclear fuel (canister, buffer, backfill, rock grouting and bedrock) and their fulfilment of requirements.

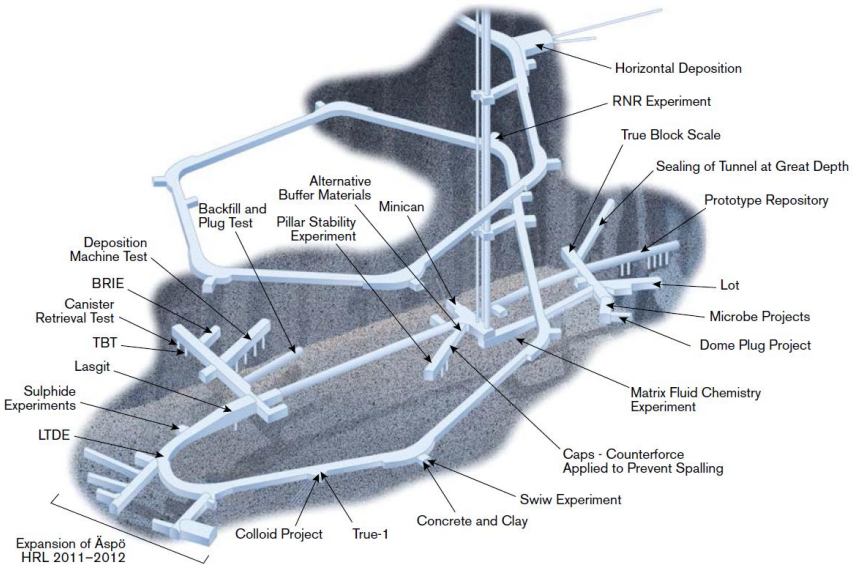

Figure 13. The Äspö Hard Rock Laboratory in Oskarshamn.[46]

The Canister Laboratory

The Canister Laboratory, located in the port area of Oskarshamn, is mainly used to develop the canisters' corrosion protection of copper. The main equipment developed there is for welding of copper lids and bottom plates of the canisters in addition to non-destructive testing of welding joints and the different canister components. The laboratory also tests and develops equipment and systems for handling and management of spent nuclear fuel.

The Bentonite Laboratory

The Bentonite Laboratory was established in 2007 and is located adjacent to the Äspö Laboratory. In this laboratory, SKB performs tests on the properties of bentonite clay as a buffer in the deposition holes where the copper canisters will be emplaced. The laboratory also develops methods for backfilling of repository tunnels and building plugs for sealing the deposition tunnels.

[46] SKB, RD&D Programme 2013, Figure 1-12

7.2.3. Reviews and evaluations

Every third year by 30 September, the RD&D Programme must be submitted to the Swedish Government or to SSM, the public authority appointed by the Government for reviewing and evaluating the programme. Within six months after the programme was submitted, SSM is required to forward the programme together with its own views to the Government. This statement is to cover a review and evaluation of the programme in these respects: i) planned research and development work; ii) presented research findings; iii) alternative management and storage methods; and iv) the measures planned to be taken. In connection with the statement, SSM also compiles a review report containing detailed comments and recommendations for SKB.

In conjunction with the review and evaluation, the Government may impose conditions considered necessary for continuing research and development work.

In the tenth and most recent RD&D programme (the RD&D Programme 2013)[47], SKB accounts for the continued research work and technical advances needed to enable design, development and operation of planned facilities, also for the purpose of maintaining safe operation of existing facilities. According to SSM's statement to the Government[48], this programme's orientation meets the requirements imposed by the Act on Nuclear Activities. SSM has established that the presentation of the Programme pertaining to disposal of long-lived radioactive waste, in addition to decommissioning plans and dismantling studies, have demonstrated good development in relation to previous RD&D programmes, but that the presentation should be developed further in terms of decommissioning of facilities. In November 2014, the Government took its decision[49] about approving the programme as recommended and proposed by the Authority.

7.2.4. Public insight

SSM distributes the RD&D Programme to a broad range of referral bodies, comprising approximately 70 organisations, for their viewpoints. These bodies include other public authorities, institutions of higher education and special interest groups. A compilation of the referral bodies' comments is presented in SSM's review report.

SSM's advisory committee for matters relating to radioactive waste and spent nuclear fuel (the Radioactive Waste Management Committee) holds meetings to consider the main elements of SSM's review of the RD&D programme.

[47] Swedish Nuclear Fuel and Waste Management Company (SKB), RD&D Programme 2013. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste, SKB TR-13-18.
[48] Swedish Radiation Safety Authority, SSM2013-2540-5, 2014. Statement concerning the RD&D Programme 2013
[49] The Government of Sweden, Ministry of the Environment, M2014/930, 1495/Ke, 2014. Government decision. Programme for research, development and demonstration relating to methods for management and final disposal of nuclear waste.

7.2.5. The programme for low and intermediate level radioactive waste (Loma Programme)

The time schedules, with milestones up until closure of disposal facilities in accordance with the plan of action for low and intermediate level radioactive waste, are illustrated in Figure 14.

Milestones of the programme for low and intermediate level radioactive waste

These are the most important milestones for the programme for low and intermediate level radioactive waste:

- 2014: Application seeking to extend the SFR repository to increase capacity for accommodating waste from decommissioning and dismantling,
- 2014: Conceptual design study for SFL repository is completed,
- 2018: Successful start of construction for the extension of SFR repository,
- 2023: Commissioning the extension of SFR repository,
- 2035: Start of construction for SFL repository, and
- 2045: Commissioning of SFL repository.

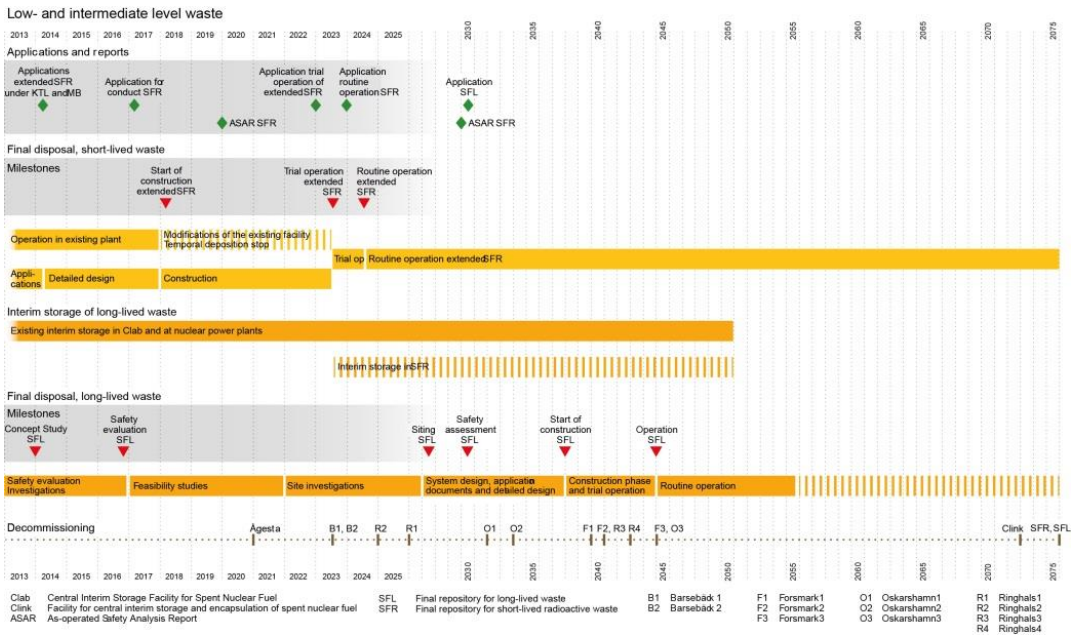

Figure 14. Time schedule for work on low and intermediate level waste as well as decommissioning of nuclear power reactors. The hashed bars represent uncertainty factors and flexibility as part of the planning.[50]

Repository for short-lived low and intermediate level waste from decommissioning and dismantling (the extension of SFR repository)

The extended SFR facility is where SKB plans to dispose of the waste from future decommissioning of nuclear power plants (see also Section 4.2). The planned

[50] SKB, RD&D Programme 2013, Figure 2-2.

extension will imply an increase in the facility's storage capacity by an estimated 140,000 m^3 from today's capacity of 63,000 m^3. In December 2014, SKB submitted a licence application and the operation of the facility is expected to be launched in 2023. Once the extension of the SFR repository is finished, it will be possible to dispose of low and intermediate level waste from decommissioning and dismantling there.

Repository for long-lived low and intermediate level waste (SFL)

Long-lived low and intermediate level waste mainly consists of waste from research work, industry, hospitals and certain internal components from nuclear power reactors. This waste is at the present time stored at Studsvik, the nuclear power plants and Clab. SFL's volumes will be relatively small compared with SKB's other facilities for final disposal. The total storage volumes are estimated at 10,000 m^3. During the period 2014-2016, the focus of work on SFL repository will be on the evaluation of long-term safety to be presented in 2016. According to the present plans, a licence application on construction of a repository for long-lived low and intermediate level waste (SFL) will be submitted in 2030. SFL is expected to begin routine operation in 2045.

Interim storage of long-lived waste

The applications concerning extension of SFR repository include SKB submitting a licence for interim storage in this repository. The storage is intended for long-lived waste from nuclear power plants. When SFL repository has been commissioned, the long-lived waste in interim storage at SFR will be transferred to SFL. A new transport container, ATB 1T, has been developed by SKB for transports of long-lived low and intermediate level waste. Delivery of the container is expected in 2015.

Decommissioning

Key points in time in terms of decommissioning, dismantling and demolition are illustrated by Figure 14. The decommissioning activities closest in time relate to the R2 research reactor at Studsvik, the two reactors at Barsebäck and the Ågesta plant. At all the facilities, the most radioactive parts consist of reactor vessels and internal components which largely constitute long-lived waste destined for final disposal in the repository for long-lived waste SFL. As SFL's establishment is not expected until around 2040, the possibility of interim storage of this waste is a requirement prior to beginning dismantling and demolition work.

The R2 reactors at Studsvik will undergo decommissioning in stages. Phase 1, which encompasses the reactor vassels, is projected to be in progress until 2016. Decommissioning of the reactor facility in its entirety is expected to be finished in 2019. SVAFO's existing interim storage facility, AM at Studsvik, will be used for interim storage of the long-lived waste.

BKAB is planning to begin dismantling and demolition of reactors B1 and B2 at Barsebäck in 2023, in conjunction with an anticipated licence to initiate disposal of waste from dismantling and demolition in the SFR repository. Certain pre-planned measures will be initiated prior to this. BKAB has plans to commence segmentation of internal components around 2018-2019 and build an interim storage for such components on the site before they can be transferred for interim storage at the SFR repository. BKAB expects the construction work for the interim storage of internal component to start in 2015 at the earliest.

In the decommissioning plan of the Ågesta plant, segmentation of the reactor vessel is presented as the main option; though one alternative scenario is disposing of the whole reactor vessel in a final disposal facility. Decommissioning and dismantling are expected to begin by the end of the year 2020. Earlier decommissioning of the Ågesta plant is deemed possible, though this situation would require additional room for interim storage.

7.2.6. Nuclear Fuel Programme

SKB's activities for present and future management of spent nuclear fuel, from interim storage at Clab via encapsulation destined for a final repository, is taking place within the framework of SKB's Nuclear Fuel Programme. This programme encompasses the licensing review process and designing, constructing and commissioning the encapsulation facility and repository for spent nuclear fuel (see Figure 15).

On 16 March 2011, SKB submitted a licence application under the Act on Nuclear Activities seeking to build a spent nuclear fuel repository, as well as a licence application under the Swedish Environmental Code concerning the KBS-3 system. The company has sought permission to build a repository for spent nuclear fuel at Forsmark and an encapsulation facility at Oskarshamn. A licence application under the Act on Nuclear Activities concerning the encapsulation facility was submitted in 2006. Supplementary material was submitted in 2009 and in connection with the repository application, submitted in March 2011.

The Land and Environmental Court is preparing this case and examining it under the Environmental Code. The court will also hold the main hearing. SSM is processing the matter under the Act on Nuclear Activities. The Government of Sweden will take the decision on a possible licence. The licensing review is currently in progress (spring 2015). SKB expects the start of construction of the repository for spent nuclear fuel and the encapsulation facility Clink to be 2019 and 2021, respectively. It is expected that these facilities will be commissioned in 2029.

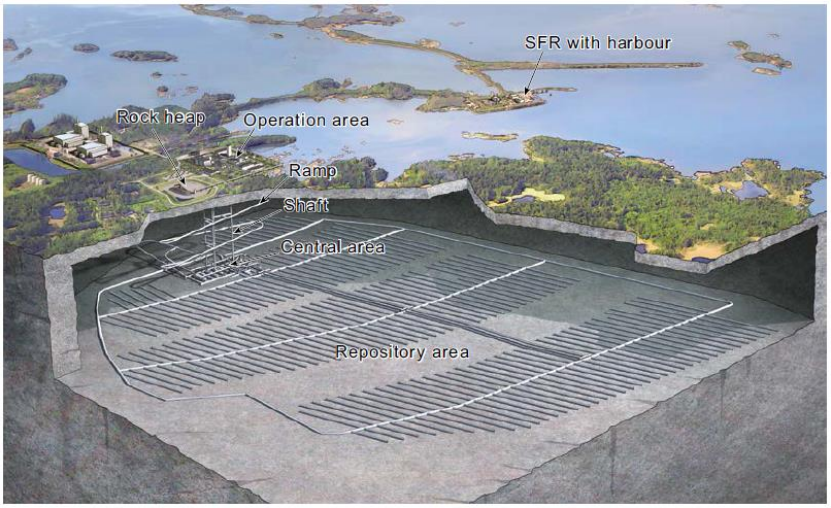

Figure 15. The repository for spent nuclear fuel at Forsmark.[51]

[51] SKB, RD&D Programme 2013, Figure 1-9.

Final repository for spent nuclear fuel

SKB is planning to site its geological repository for spent nuclear fuel at Forsmark (see Figure 16), located in Östhammar Municipality. SKB's time schedule for future activities linked to construction of the repository has the following milestones:

- 2011-2019: Review of the licence application carried out by SSM and the Land and Environmental Court, decision by the Swedish Government and completion of the PSAR,
- 2019-2028: Construction and commissioning,
- 2028: Submission of the application for trial operation,
- 2029-2030: Trial operation,
- 2030: Submission of the application for routine operation, and
- 2030: Routine operation.

Over the next few years, SKB will gradually prepare its organisation for construction of the spent nuclear fuel repository. Construction of the repository is currently planned to start in 2019. Each major stage of this work will be preceded by an evaluation of the programme from a holistic perspective. This will be done for the purpose of establishing a more detailed plan for the period of time up until the next stage.

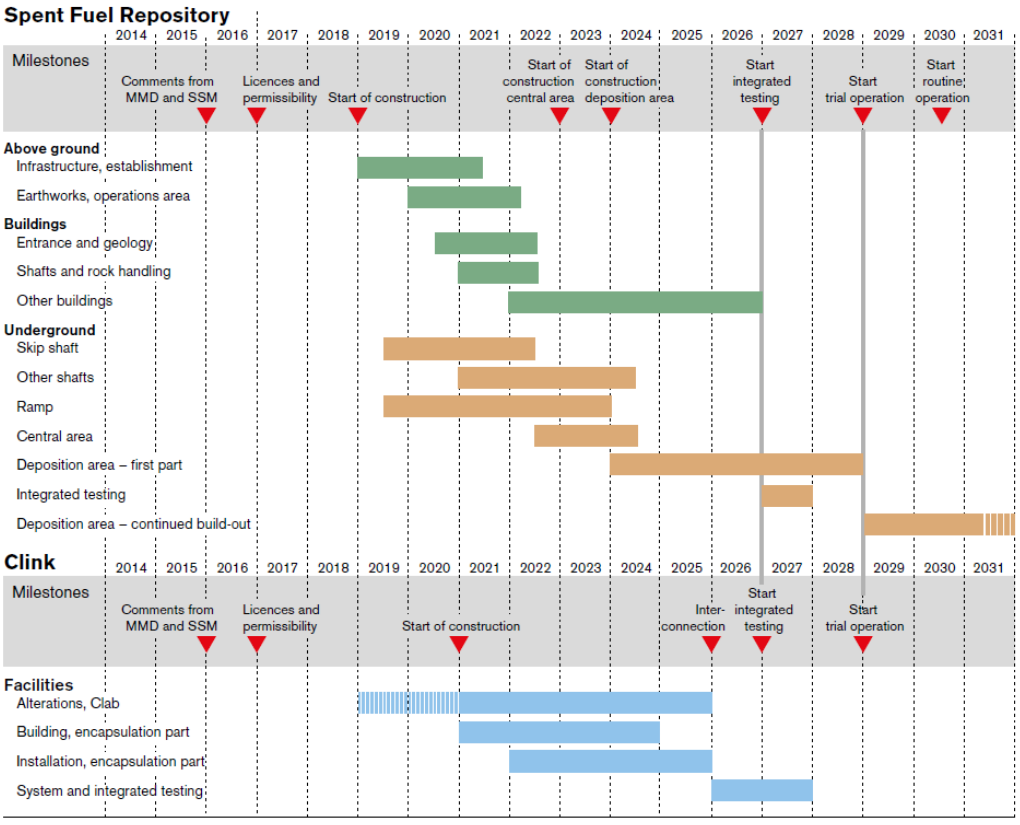

Figure 16. Time schedule for establishment and development of the final repository for spent nuclear fuel and encapsulation facility Clink.[52]

[52] SKB, RD&D Programme 2013, Figure 2-5.

Encapsulation plant for spent nuclear fuel (Clink)

During licensing and until starting construction of the encapsulation facility Clink in connection to Clab (see Figure 17), SKB will work on detailed design and procure for its construction. This is the design and procurement phase of the project and will be divided into four partially overlapping sub-phases: i) facility configuration; ii) system design; iii) detailed design; and iv) procurement of construction contractors.

Figure 17. The encapsulation facility for spent nuclear fuel, Clink[53], at Oskarshamn.

During the facility configuration phase, SKB plans to update the requirements for Clink identified during technology development and take measures based on the viewpoints expressed by SSM during licensing, also to modify the facility's preliminary layout as needed.

7.3. **The financing system**

7.3.1. Nuclear power reactor licensees

According to the Financing Act, a party that is licensed to own or operate a nuclear power reactor or other nuclear facility is required to pay a nuclear waste fee and pledge assets in order to finance future costs for areas such as management and final disposal of spent nuclear fuel and nuclear waste, in addition to decommissioning, dismantling and demolition of nuclear facilities. The fees also have the purpose of financing the research and development work needed for these measures, the state's costs for activities such as review processes, supervision and providing information in connection with these measures, as well as certain costs for municipal authorities (the municipalities of Östhammar and Oskarshamn) and non-profit associations.

The assets from fees are managed as part of a particular investment fund: the Nuclear Waste Fund. Assets belonging to the Nuclear Waste Fund are to cover both

[53] SKB, RD&D Programme 2013, Figure 1-7.

present and future costs for the measures. Each individual licensee reserves the funds needed for its share of the total costs. If fund payments made by a licensee are not needed, this money is repaid to the licensee. Licensees must pledge assets as security for cases where the costs are not yet covered by fee payments made to the Nuclear Waste Fund, also for expenses that might arise due to unforeseen events. The guarantee provided may be exercised if fee payments are insufficient. Detailed application of the Financing Act is regulated by the Financing Ordinance.

Cost estimates

Licensees of nuclear power reactors, that is, the parties that are licensed to own or operate a nuclear power reactor that has not been permanently shut down, must submit Plan Cost Estimates[54] to SSM every third year. This cost estimate is to take into account the total costs for managing all residual products and decommissioning of all facilities, and show how these costs are shared by the respective licence holder.

The reactor licensees cooperate as part of the financing system in the form of SKB, their jointly owned company. SKB submits the cost estimates, which serve as the basis of the licensees' respective nuclear waste fee. These calculations are to assume each reactor having a total period of operation of 40 years and a remaining period of operation of no less than six years. Consequently, this period of operation is used to estimate the quantities of residual products from the reactors. It is also within this period of time that the reactor licensees are required to pay the fees to cover the costs for their respective reactors.

Fees for the Nuclear Waste Fund

SSM reviews the reactor licensees' cost estimates and proposes nuclear waste fees. The fees are stated in Swedish öre (1/100 of a krona) per delivered kilowatt hour of electrical power. This means that a fee is based on how much power that each reactor licensee plans to produce during the period in question. Once the proposed fee has undergone a consultation procedure among the licensees of nuclear power reactors, competent authorities and other stakeholders, a final proposal is submitted to the Government of Sweden. The Government takes the decision on nuclear waste fees for the next three-year period. At the present time, the nuclear waste fee averages 4.0 öre per kilowatt hour of power produced.

Financing and supplementary amounts

The reactor licensees' cost estimates are also used to calculate financing amounts and supplementary amounts, which in turn determine the value of the guarantees to be provided. The financing amount corresponds to the difference between the Fund assets and the total amount to be paid into the Fund by the respective reactor licensee. The supplementary amount corresponds to an estimated safety margin for costs incurred as a consequence of unforeseen events. SSM prepares proposals for these amounts and forwards them to the Government for decision-making in conjunction with the fee proposal. Guarantees are assessed by the Swedish National Debt Office.

[54] Plan 2013 (Plan Cost Estimates), 2014. Costs from and including 2015 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2015-2017, Swedish Nuclear Fuel and Waste Management Co. (SKB)

Management of fund assets

Nuclear waste fees paid into the Nuclear Waste Fund are managed by the Swedish governmental authority bearing the same name. Each licensee has fund units in this investment fund. Assets in the Fund are invested in government bonds and covered bonds. The assets of the Nuclear Waste Fund currently amount to approximately SEK 56 billion. The approved guarantees are assigned to the Nuclear Waste Fund and managed by the Swedish National Debt Office. In 2014, the guarantees had a value equivalent to around SEK 19 billion.

Decision-making on use of fund assets

The licensees' use of money set aside in the Nuclear Waste Fund is subject to decisions taken by SSM. An application seeks approval for the measures to be taken and SSM considers whether they match costs serving as the basis of the fee calculation. SSM also considers applications from certain municipal authorities for information campaigns in connection with management and final disposal of spent nuclear fuel. In addition, the Authority considers compensation sought by non-profit associations for their taking part in the consultative process relating to facilities for the management and disposal of spent nuclear fuel. Compensation from assets of the Nuclear Waste Fund to SSM and other central governmental authorities is subject to consideration by the Government of Sweden.

Control over use of funds disbursed

Each year, parties receiving payments from the Nuclear Waste Fund are required to report on use of this money. They must also return funding that has not been used. SSM audits use of the funds disbursed.

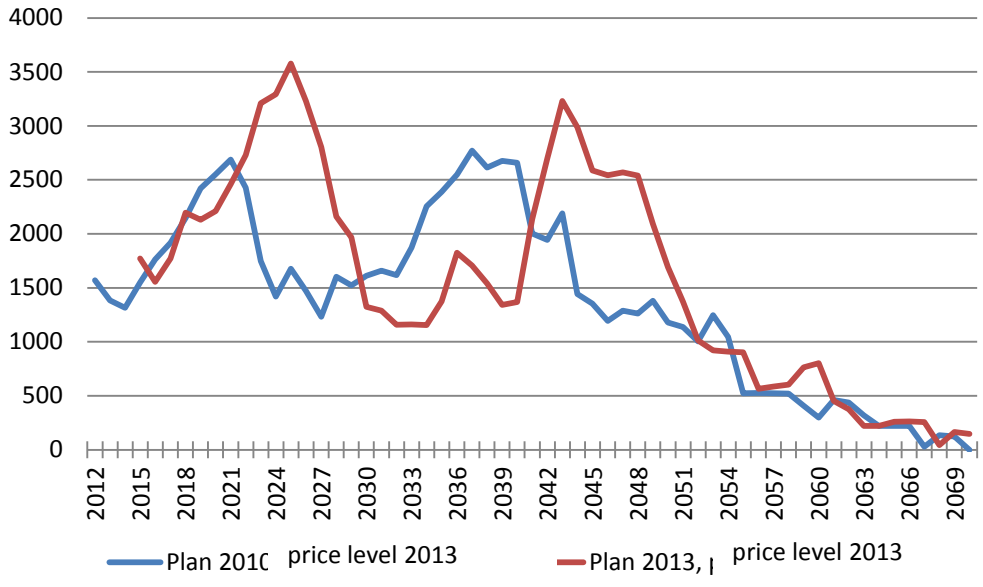

Figure 18. Remaining costs (reference costs) for the final disposal programme, in millions of Swedish kronor. The cost increase over the period 2018-29 is due to planned dismantling of the Barsebäck plant, the planned repository for spent nuclear fuel and for the waste generated from decommissioning, dismantling and demolition. It is evident here that these plans have both been delayed and risen in cost according to the most recent estimate, with the largest cost outcome taking place in 2015. Estimating a longer period of operation on the part of Swedish nuclear power reactors may also lead to decommissioning costs arising later than anticipated.

Nuclear waste fees and guarantees for 2015-2017

Based on its review of SKB's Plan Cost Estimates, SSM in a statement[55] to the Government of Sweden, issued in October 2014, proposed the nuclear fees and guarantees to be decided for the period 2015 to 2017. SSM in its statement announced that the nuclear waste fee should be raised from an average of 2.2 öre to 4.0 öre per kilowatt hour to ensure financing for safe decommissioning of the Swedish nuclear power and final disposal of the radioactive waste. The Government took a decision[56] on guarantees and the fee increase in December 2014. The main rationale behind the fee increase includes the following aspects:

- the projected costs reported by the nuclear power industry for decommissioning and final disposal have risen,
- the Nuclear Waste Fund's future return is expected to be low, partly due to low yields on Swedish bonds, and
- the fees paid were lower than was forecasted at the time of the previous fee proposal as a result of a lower level of reactor availability during the period.

7.3.2. Other fee-liable licensees

For fee-liable licensees that do not own a reactor, the nuclear waste fee is determined similarly as for reactor licensees. A cost estimate is submitted every third year and the fee is allocated over the expected remaining period of operation. As regards facilities that have been shut down, any remaining fee is to be paid over the next three years. Usually, SSM decides on the nuclear waste fee for these licensees. However, exceptions are made for nuclear power reactors shut down after 1995 (i.e. Barsebäck) and for matters of principal importance or particular prominence that must be forwarded to the Government of Sweden.

A financing amount is also calculated for these licensees and set by SSM. The guarantees are assessed by the Swedish National Debt Office. These licensees also have the possibility of seeking an exemption from the fee liability and instead provide guarantees on the part of all costs that the fees are to cover.

Management of fund assets, decisions concerning use of fund assets and control over use of disbursed funds are performed similarly to the description related to nuclear power reactors or other nuclear facilities.

[55] Swedish Radiation Safety Authority, SSM2013-6255-92, 2014. Statement concerning nuclear waste fees, financing amounts and supplementary amounts for the period 2015-2017 under the Act on Financing of Management of Residual Products from Nuclear Activities (2006:647)

[56] The Government of Sweden, Ministry of the Environment, M2014/2227/Ke, 2014. Nuclear waste fees, financing and supplementary amounts for the period 2015-2017.

7.3.3. Historical nuclear activities

Nuclear waste fees under the Studsvik Act

The Studsvik Act is designed somewhat differently than the Financing Act. Under the Studsvik Act, an entity licensed to own and operate a nuclear power reactor (which has not been permanently shut down) is liable to pay a fee to the state in order to cover the costs for decontamination and dismantling of nuclear facilities, as well as management and final disposal of nuclear waste, nuclear material and certain other kinds of radioactive waste. An aspect that is shared by the facilities and operations subject to the Studsvik Act is that they have a link to the emergence of the Swedish nuclear energy programme of the 1950s and 1960s.

This implies that reactor owners are required to pay fees to the Studsvik Fund although none of them are directly in charge of any of the residual products or any of the facilities regulated by the Studsvik Act, nor draw up the cost estimates serving as the basis of the fee. This is a result of the Swedish nuclear power industry having partly built up its know-how and activities by means of the development work performed at facilities such as at Studsvik up until 1991. For this reason, it is viewed as reasonable that costs for the measures encompassed by the legislation are to be borne by producers of nuclear power.

Licensees entitled to grants (holders of the nuclear licences in question) are required to prepare a cost estimate for their respective operations. Their cost calculations must include an estimate of total costs for all the measures that might be deemed necessary, in addition to costs for the measures planned to be taken within a time period of no less than three years. SSM reviews these cost estimates and develops proposed fee levels. SSM subsequently notifies the Government if the fee level needs to be changed.

The fee is currently 0.30 öre for each kilowatt hour of electrical power produced. The fee may be viewed as a tax; for this reason, it is specified in the Studsvik Act. The fee is laid down by the Riksdag and any excess payments as part of the Studsvik Fund are not repaid.

Detailed application of the Studsvik Act is defined and regulated by the Studsvik Ordinance. The Studsvik Act will, in accordance with a decision in the Riksdag, cease to apply at the end of 2017. The assets belonging to the Studsvik Fund will nevertheless still be used for the same purposes thereafter (until around 2050).

The Nuclear Waste Fund manages fee payments

Fee payments to the Nuclear Waste Fund are managed separately by the governmental authority with the same name as part of the ‘Studsvik Fund’ in accordance with the provisions contained in the Financing Ordinance. The assets of the Studsvik Fund currently amount to approximately SEK 1.3 billion.

Decision-making on use of Studsvik Fund assets

The licensees’ use of money set aside in the Studsvik Fund is subject to decisions taken by SSM. An application seeks approval for the measures to be taken and SSM considers whether they match the costs serving as the basis of the fee calculation.

Control over use of funds disbursed

Each year, parties receiving payments from the Studsvik Fund are required to report on use of this money. They must also return money that has not been used. SSM audits use of the funds disbursed.

7.3.4. Non-nuclear activities

Parties conducting activities involving ionising radiation, and whose operations generate radioactive waste, have under Section 13 of the Radiation Protection Act a liability to ensure that the radioactive waste is managed in a way ensuring radiation safety, including final disposal of the waste in cases where this is required. This responsibility includes ensuring the availability of funding for such management, even when this is not expressly stated in the wording of the Act. Consequently, this responsibility applies to all activities and practices involving ionising radiation: in medical services, industry, the agricultural sector, research, education and training programmes, etc., regardless of whether or not the operation requires a licence under the Radiation Protection Act.

The state bears the cost of final disposal

Parties with radioactive material to be managed as radioactive waste have only one entity in Sweden to turn to: Studsvik Nuclear AB. The fee payable to Studsvik Nuclear AB is to cover treatment, conditioning, storage, and in some cases, final disposal of this waste. As of the agreement[57] concluded between SKB and Studsvik Nuclear AB in the 1980s (see Section 4.1), the Government of Sweden agreed to compensate Studsvik Nuclear AB (Studsvik Energiteknik AB at the time) by a one-off expenditure amounting to approximately SEK 54 million. This amount was intended to cover areas such as future costs for final disposal of non-nuclear radioactive waste in SFR.[58] This implies that owners of non-nuclear radioactive waste, which may be disposed of in the SFR repository, only need to pay for Studsvik's management of the waste. The costs for transport to SFR and final disposal in this repository have already been borne by the state.

Owners of non-nuclear radioactive waste assessed as requiring final disposal in SFL must pay a charge for Studsvik Nuclear AB's present waste handling: for extended storage of the waste, possible future conditioning, as well as transport to and final disposal in SFL.

Financing management of high-activity sealed radioactive sources (HASS)

Under the HASS Directive (Council Directive 2003/122/Euratom of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources), it must be possible to track a high-activity sealed radioactive source throughout its lifetime, and SSM has an obligation to keep records on all such sources present in Sweden. Owners of high-activity sealed radioactive sources must already when

[57] Agreement concerning intermediate and low level waste, 28 September 1983, concluded between Svensk Kärnbränsleförsörjning AB and Studsvik Energiteknik AB.

[58] Government decision, Department of Industry, 28 June 1984; Application for approval concerning an agreement for final disposal of intermediate and low level radioactive waste, reg. no. 2093/83.

applying for permission, that is, before purchasing the radiation source, demonstrate that they are capable of financing its future management if the cost exceeds SEK 300,000. In this case, the licensee must be able to provide a financial guarantee. This financial guarantee may vary in form depending on the applicant. The requirement for financial guarantees on the part of high-activity sealed radioactive sources is contained in the HASS Directive and has been implemented in the Ordinance (2007:193) concerning producer responsibility for certain radioactive products and orphan sources.

When the applicant is part of a *public undertaking*, accounting for the financial guarantee may be as a signed affirmation about funds being available to cover the entire cost of managing the source of radioactivity when it has been disposed of.

When the applicant is part of a *commercial undertaking*, accounting for the financial guarantee may be as a bank guarantee or in the form of a blocked account; in either case with a Swedish bank. It must also be stated that these funds are available to SSM if the licensee should be insolvent, cease its activity or practice, or if the licensee is unable to fulfil the requirements imposed for safe management of the source of radioactivity when it has been disposed of. If a commercial undertaking chooses some kind of security other than a bank guarantee or blocked account, this entity will be charged a fee by SSM for review work in order to cover the cost of investigating issues such as solvency and the like.

Financing management of orphan sources

Under the Radiation Protection Act, a party that finds and takes care of an orphan source is also regarded as the owner, thus assuming the liability for its management. From the standpoint of the public interest, it could be viewed as unfortunate if the finder of a radiation source can be forced to bear the cost when the source is delivered for safe management, which implies a risk of these sources of radioactivity being left in place instead or discarded in the countryside.

Under the HASS Directive, each Member State is required to ensure that the competent authorities are prepared to resume control over orphan sources. In Sweden, this situation has been solved in the form of SSM having since 2006 the powers to utilise funding from the Swedish Environmental Protection Agency's appropriation for decontamination of land to enable safe management of orphan sources and certain radioactive legacy waste. In 2014, this appropriation was SEK 2 million. In cases where SSM is of the view that the material is an orphan source, the Authority will bear the cost of its management. This implies that the material is delivered to Studsvik Nuclear AB, which will manage it in accordance with its standard procedures.

In this context, it is worth noting that in cases involving radioactive material of a nature where there is either a lack of a treatment method or final disposal solution, it is not self-evident that Studsvik Nuclear AB will accept the material, despite the availability of financing. The orphan source must then be stored by the deemed owner while awaiting the choice of a suitable method.

8. Follow-ups, improvements and key performance indicators

A number of tools are implemented as part of the Swedish system for the purpose of following up the progress of national programmes in relation to the set and scheduled targets as well as developing the comprehensive organisational and legal framework.

The System of Environmental Objectives, the RD&D Programme and the Plan Cost Estimates comprise a subset of the Swedish framework and programme. They contain all the mechanisms for follow-ups, in addition to strategies, key performance indicators and measures to enable achievement of defined objectives (i.e. performance indicators). Additional tools include the Authority's review of each individual review step and changes to the safety analysis reports which the licensees are required to submit.

The Swedish framework also prescribes that authorities and licensees alike must perform self-assessments on a regular basis and mutual international evaluations for the purpose of harmonising the regulatory framework, developing good practices and learning from international experience. The tools for follow-ups described below contribute to keeping the national framework and program up to date, and improved as necessary. This is done by taking into consideration operating experience, technical and scientific advances as appropriate, in addition to recommendations and experiences communicated from national auditing and international peer reviews and evaluations.

8.1. **Follow-ups of environmental objectives**

The environmental quality objectives undergo annual follow-ups by Swedish government authorities in charge of the respective objective. Around every fourth year, an in-depth evaluation is also made as input for the Government of Sweden's environmental policy bill. This follow-up assesses whether today's means of control and measures are sufficient for achieving the objectives and proposes additional action as necessary. They must have been assessed for their socioeconomic benefit in order to be taken into account.[59]

Follow-ups of environmental quality objectives[60] are an outcome of close collaboration between the Swedish Environmental Protection Agency, the national authorities in Sweden responsible for the respective environmental quality

[59] Swedish Environmental Protection Agency, In-depth evaluation of potential for achieving the generational goal and environmental quality objectives, FU 2004, FU 2008, FU 2012.

[60] Swedish Environmental Protection Agency, report 6608, the environmental objectives: annual follow-up of Sweden's environmental quality objectives and milestone targets 2014

objectives, and County Administrative Boards. The authorities are tasked with performing follow-ups of the objectives. Each authority is in charge of reporting and assessments. Other liaising authorities and organisations contribute by providing input, documentation and their standpoints. The Swedish Environmental Protection Agency compiles the reports, conducts analyses and draws overarching conclusions.

It is likely that fourteen of the sixteen Swedish environmental quality objectives will not be achieved by 2020 through today's decided means of control. This is the same assessment as arrived at in the previous annual follow-up, as well as by the in-depth evaluation conducted in 2012. The environmental quality objective 'A Safe Radiation Environment' is one of the objectives assessed as achievable, provided that the decided measures are carried out.

8.2. **Reviewing the RD&D Programme**

The successively updated RD&D Programmes provide an overview of all the requisite measures for safe management and final disposal of spent nuclear fuel and nuclear waste; also for safe decommissioning and dismantling of facilities. The programme must also specify in detail the measures intended to be implemented within at least six years. These measures comprise operational, development, research and demonstration activities on the part of spent fuel and nuclear waste management. In conjunction with SKB also managing non-nuclear radioactive waste, the measures in the RD&D programme encompass large parts of the Swedish system for radioactive waste management.

The present procedure implies that the reactor licensees' joint RD&D programme is reviewed and evaluated every third year by SSM, which forwards its own statement together with the programme to the Government of Sweden for decision-making. This process gives the Government an opportunity to impose the conditions needed for the programme's continued orientation. More tangibly, this procedure means that the Government is given the option every third year to perform a particular evaluation of planned measures over the next six years as part of a robust, yet at the same time, flexible process in which the conditions are not deemed likely to change dramatically over time.

In its statement to the Government, SSM assesses whether SKB's presentation has met obligations under the Act on Nuclear Activities. The Government of Sweden decides on the RD&D programme and may impose conditions. Normally, the decision states that the reactor licensees' and SKB's future presentations are to take into account the collected assessments and viewpoints contained in the Authority's review report.

8.3. **Reviewing cost estimates**

Every third year, SSM reviews the reactor licensees' cost estimates and proposes nuclear waste fees and guarantees (the financing amount and supplementary amount) for next three-year period. This proposal is referred to the reactor licensees, competent authorities and organisations for consideration and comment prior to SSM forwarding its statement to the Government for decision-making on the fees and guarantees. The guarantees provided are assessed by the Swedish National Debt Office.

Every third year, SSM also reviews the cost estimates of other fee-liable licensees and proposes nuclear waste fees and guarantees (so called financing amounts) for the next three-year period. The proposal is subsequently referred to the respective licensee for consideration and comment, after which SSM decides on the fees and guarantees. The guarantees are assessed by the Swedish National Debt Office.

Each year, SSM also examines cost estimates in accordance with the Studsvik Act. SSM subsequently notifies the Government if the fee level needs to be changed.

8.4. **Reviewing safety analysis reports**

The safety analysis reports reviewed by SSM in compliance with enactments or internal procedures for regulatory supervision and review work have the aim of ensuring fulfilment of safety and radiation protection requirements imposed on activities involving radiation, while also keeping the requirements up to date; this includes ensuring that action is taken where weaknesses or deficiencies have been identified. This approach ensures systematic and ongoing work focusing on radiation safety improvement by the licensees.

8.4.1. Reviewing safety analysis reports in steps

SSM reviews applications for permission to construct nuclear power plants, carry out plant modifications and construct and modify other nuclear facilities, and considers authorisation of non-nuclear activities involving ionising radiation. Safety analyses are a key component of these licence applications. This implies that SSM performs assessments of how safety and radiation protection requirements will be fulfilled for each phase of a facility's lifetime (construction, test operation, routine operation, planned shutdown, decommissioning as well as closure in the case of a disposal facility). SSM examines fulfilment of the conditions in steps until the facility begins routine operation, at which point this review transitions into ongoing supervision. SSM reviews and analyses documents and materials describing and illustrating the possible siting of a facility, in addition to its design, construction and subsequent operation, decommissioning or closure. In certain licensing matters, the Government takes the decision following a statement of the findings of SSM and other government authorities in Sweden.

8.4.2. Periodic safety reviews

In the periodic safety review (PSR) of a nuclear facility, which is performed every tenth year, SSM determines whether the facility may continue to be operated at the level of safety stipulated by the licence and which is to be accounted for in the safety analysis report (SAR). The basis of input for a periodic safety review is the licensee's integrated analysis and overall assessment of the level of safety of its facility, together with the Authority's own assessments. Compliance assessments on fulfilment of SSM's regulations are performed for the operational mode in question and for continued operation of the facility from a ten-year perspective. These assessments are subsequently used for a summary assessment of radiation safety. The assessments are presented as part of review reports giving an account of the licensee's assumptions for continued safe operation of the facility and any measures for achieving the latter.

8.4.3. Integrated safety assessments

SSM performs integrated safety assessments for the purpose of illustrating the overall radiation safety situation at a nuclear facility, at a licensee or in a certain kind of activity where radiation is used, such as in medical care, academia and industry. This assessment is a combined analysis of outcomes from the supervision performed over a certain period of time, from one to three years depending on the potential radiation hazards of the activity. An integrated safety assessment is communicated to a licensee and the general public, while also serving as input for the licensee's improvement work and the Authority's orientation of future supervisory activities.

8.5. **International peer reviews**

Under SSM's Instructions, the Authority is required to propose to the Government of Sweden an appropriate point in time for the self-assessments and international peer reviews that, under the Nuclear Safety Directive and Council Directive 2011/70/Euratom, are to be performed at least every 10 years. Based on the outcomes of these assessments, measures must also be proposed as necessary against the background of the results. The result of each assessment is to be reported to the Commission in accordance with Council Directive 2009/71/Euratom and 2011/70/Euratom in addition to other Member States. The result must also be made available to the general public provided there are no ongoing conflicts as far as concerns safety issues nor aspects relating to protected information.

As per a Government assignment, SSM sent a request on 25 February 2009 to the International Atomic Energy Agency (IAEA) regarding an international peer review of the Authority and its supervisory work. An extensive preparatory work, including a self-assessment of the Swedish system, was carried out by SSM in 2011. The international peer review was carried out in 2012 in the form of a full scope Integrated Regulatory Review Service (IRRS) mission. An emergency preparedness exercise was also carried out in conjunction with the IRRS review mission. The outcomes of this review[61] were several recommendations and examples of good practice.

The summary assessment from the review mission was that the Swedish system for radiation safety is stable and well-developed. As far as concerns areas for improvement, SSM has drawn up an action plan for continuing development work.[62] A follow-up of the IRRS review mission has been agreed with the IAEA, scheduled for spring 2016.

In connection with SKB's licence application for construction a final repository for spent nuclear fuel, Sweden also initiated an international peer review of long-term radiation safety demonstrated by the licence application. This review was carried out by OECD's Nuclear Energy Agency (NEA), which in the summer of 2012 presented its final report.[63] According to the international experts engaged by the NEA, SKB's

[61] IAEA, Integrated Regulatory Review Service (IRRS) Mission to Sweden, IAEA-NS-IRRS-2012/01, 2012
[62] SSM, Action plan IRRS 2012 Sweden, document no. 12-654
[63] Nuclear Energy Agency (OECD-NEA), Radioactive Waste Management Committee, The post-closure radiological safety case for a spent fuel repository in Sweden, An international peer review of the SKB license application study of March 2011 (Final report), 2012.

analysis of long-term safety following closure of the repository has a solid foundation. The experts have nevertheless proposed areas that should be developed further by SKB prior to future steps as part of the review process.

Since 2011, SKB has been a member of WANO, the World Association of Nuclear Operators. As commissioned by SKB, WANO performed a review of SKB's operating organisation with the aim of assessing the level of safety at SKB's facilities as well as the functionality of SKB's organisation. This review took place in 2013 over a three-week period. SFR at Forsmark, the Clab interim storage facility at Oskarshamn, and the main office in Stockholm were visited by the WANO review team. The result was a list of tangible advices and constructive criticism for review and analysis by SKB's organisation. In 2015, the review and SKB's measures will receive a follow-up by WANO.

In addition to reviews of the Swedish system, of the supervisory authority and of SKB as an operating organisation, personnel from SSM and SKB also participate in corresponding international peer reviews of other countries' systems. These efforts also contribute to the exchange of knowledge and operational experience, which in turn contributes to continual development of radiation safety.

Sweden's ratification of the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management also implies a procedure involving mutual evaluations. In preparation for the fifth review meeting to be held under the Joint Convention in Vienna in May 2015, SSM has with the assistance of industry representatives produced Sweden's national report on the Swedish programme's progress.[64] At the meeting, SSM's report and presentation were reviewed by other countries, and vice versa, giving opportunities for exchange of experience and learning.

8.6. **International cooperation**

Sweden is a member of the IAEA and OECD/NEA, with permanent representations to both organisations. Sweden is also party to the Conventions of relevance for the field of radiation safety.

8.6.1. Competent authority

According to SSM's Instructions, the Authority is responsible for many of Sweden's commitments in relation to international conventions and other agreements, while also contributing to development of international standards and recommendations. SSM is extensively involved in international task groups and working parties within the frameworks of the IAEA, NEA and EU, Conventions, in addition to networks such as the Western European Nuclear Regulators' Association (WENRA), Heads of European Radiation Control Authorities (HERCA) and the International Nuclear Regulators' Association (INRA). SSM takes part in the IAEA's committees for development of standards, which also serve as the basis of SSM's official regulations and advice.

[64] Ministry of the Environment, "Sweden's fifth national report under the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management", Report Ds 2014:32.

SSM is an active member of the European Nuclear Safety Regulators Group (ENSREG) and its working groups. SSM has also contributed extensively to WENRA's work on harmonised safety levels between nuclear power countries of the European Union, which includes interim storage and disposal facilities for spent nuclear fuel and radioactive waste, in addition to decommissioning of nuclear facilities.

SSM not only takes part in international research projects, mainly within the framework of the EU's research programmes, but also the IAEA and NEA. One important example is SITEX, an FP7 Euratom project, within which European regulators run technical and scientific research collaboration on geological repositories.

8.6.2. Technical cooperation

The Swedish nuclear engineering industry has a long tradition of active international technical cooperation in the form of exchanging experiences, contributing to development of international regulatory frameworks, and taking part in international work on areas such as safety assessments and safety reviews. Several international working meetings and conferences have in recent years been held in Sweden, on waste management, decommissioning and final disposal methods.

SKB has extensive technical collaboration with corresponding organisations in Japan, Canada, Finland, France, Switzerland, Spain, the United Kingdom, Germany and the United States. SKB also participates in several committees in the IAEA, EU and NEA as well as a large number of research projects in these organisations. Joint research projects in SKB's underground laboratory at Äspö are of particular importance for this cooperation. SKB's cooperation with Posiva in Finland is the most extensive, comprising projects on disposal and canister technology as well as site investigations. Between 2009 and 2012, SKB also coordinated the EU project "Implementing Geological Disposal of Radioactive Waste Technology Platform" (IGD-TP). Here, twelve implementing organisations are running joint research and development cooperation with the aim of achieving the first European geological repository to be commissioned by 2025.

9. Abbreviations

BKAB	Barsebäck Kraft AB
Clab	SKB's interim storage facility for spent nuclear fuel at Oskarshamn
Clink	SKB's encapsulation plant of spent nuclear fuel at Oskarshamn (planned)
EIA	Environmental Impact Assessment
Final repository for spent nuclear fuel	SKB's final repository for spent fuel at Forsmark (planned), SFK
FKA	Forsmarks Kraftgrupp AB
HASS	High Activity Sealed Sources
MKB	Miljökonsekvensbeskrivning
NORM	Naturally-Occurring Radioactive Materials
OKG	OKG Aktiebolag
RAB	Ringhals AB
RIC	Ranstad Industricentrum AB
RMA	Ranstad Mineral AB
SFL	SKB's final repository for long-lived low and intermediate level waste (planned)
SFR	SKB's final repository for short-lived radioactive waste
SKB	The Swedish Nuclear Fuel and Waste Management Company (in Swedish SKB for "Svensk Kärnbränslehantering AB")
SNAB	Studsvik Nuclear AB
SSM	The Swedish Radiation Safety Authority (in Swedish SSM for "Strålsäkerhetsmyndigheten")
WSE	Westinghouse Electric Sweden AB

APPENDIX 1

Waste quantities 2011-2013

SFR[65]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	0	0	0
Short-lived low level waste (LLW-SL)	m^3	14,984*	15,007*	15,007*
Short-lived intermediate level waste (ILW-SL)	m^3	19,373*	19,763*	19,946*
Long-lived low and intermediate level waste (LILW-LL)	m^3	0	0	0
High level waste (HLW)	tonnes U	0	0	0

*Waste from BTF has been determined as 50% LLW-SL and 50% ILW-SL.

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	34 356	34 770	34 953
Long-lived low and intermediate level waste (LILW-LL)	m^3	0	0	0
High level waste (HLW)	tonnes U	0	0	0

[65] Annual report of disposed volumes, levels of activity and materials for SFR, 2011, 1339325 Rev 1.0, 28 May 2012; Annual report of disposed volumes, levels of activity and materials for SFR, 2012, 1389870 Rev 1.0, 22 May 2013; Annual report of disposed volumes, levels of activity and materials for SFR, 2013, 1427919 Rev 1.0, 19 May 2014.

Ringhals[66]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	7,401	8,160	9,581
Short-lived low level waste (LLW-SL)	m^3	558	574	618
Short-lived intermediate level waste (ILW-SL)	**m^3**	955	1,013	878
Long-lived low and intermediate level waste (LILW-LL)	**kg**	13,582	14,952	12,524
High level waste (HLW)	**tonnes U**	-	-	225

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	8914	9747	11076
Long-lived low and intermediate level waste (LILW-LL)	kg	13582	14952	12524
High level waste (HLW)	tonnes U	-	-	225

Forsmark[67]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	-	6,368	6,572
Short-lived low level waste (LLW-SL)	m^3	-	38	38
Short-lived intermediate level waste (ILW-SL)	m^3	-	-	407
Long-lived low and intermediate level waste (LILW-LL)	kg	-	321,700	328,900
High level waste (HLW)	tonnes U	-	-	167

[66] 2011 annual report of active waste management, 2176853 Rev 2.0, 10 February 2012;
2012 annual report of active waste management, 2224592 Rev 2.0, 13 March 2013;
2013 annual report of active waste management, 2265342 Rev 3.0, 24 March 2014.

[67] Forsmark 1; 2; 3 – 2011 annual report, F12L-2012-0020 Rev 0, 24 Feb. 2012; F12L-2012-0021 Rev 1, 27 Feb. 2012; F3-2012-0024 Rev 0, 24 Feb. 2012;
Forsmark 1; 2; 3 – 2012 annual report, F12L-2013-0003 Rev 0, 11 Mar. 2013; F12L-2013-0004 Rev 0, 18 Mar. 2013; F3-2013-0021 Rev 0, 14 Mar. 2013;
Forsmark 1; 2; 3 - 2013 annual report, F1-2014-0008 Rev 0, 26 Mar. 2014; F2-2014-0008 Rev 0, 27 Mar. 2014; F3-2014-0016 Rev 0, 14 Mar. 2014.

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	-	6,406	7,017
Long-lived low and intermediate level waste (LILW-LL)	kg	-	321,700	328,900
High level waste (HLW)	tonnes U	-	-	167

Oskarshamn[68]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	-	3,743	4,203
Short-lived low level waste (LLW-SL)	m^3	-	249	343
Short-lived intermediate level waste (ILW-SL)	m^3	-	871	953
Long-lived low and intermediate level waste (LILW-LL)	kg	-	539,000	791,000
High level waste (HLW)	tonnes U	-	-	164

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	-	4,863	5,499
Long-lived low and intermediate level waste (LILW-LL)	kg	-	539,000	791,000
High level waste (HLW)	tonnes U	-	-	164

[68] Oskarshamn nuclear power plant: 2011 annual report of generated, handled, registered and stored radioactive waste and operating experience from waste management, 2012-00913 Rev 1, 11 Jan. 2012; Oskarshamn nuclear power plant: 2012 annual report , 2013-03894 Rev 2, 13 Mar. 2013; Oskarshamn nuclear power plant: 2013 annual report, 2014-00535 Rev 1, 8 Jan. 2014.

Barsebäck[69]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	0	0	0
Short-lived low level waste (LLW-SL)	m^3	167	193	181
Short-lived intermediate level waste (ILW-SL)	m^3	389	450	422
Long-lived low and intermediate level waste (LILW-LL)	kg	49,324	49,135	49,135
High level waste (HLW)	tonnes U	0	0	0

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	555	642	603
Long-lived low and intermediate level waste (LILW-LL)	kg	49,324	49,135	49,135
High level waste (HLW)	tonnes U	0	0	0

Clab[70]

In accordance with SKB's classification

		2011	2012	2013
Kortlivat mycket lågaktivt avfall (VLLW)	m^3	-	107	122
Kortlivat lågaktivt avfall (LLW-SL)	m^3	-	-	-
Kortlivat medelaktivt avfall (ILW-SL)	m^3	-	24	25
Långlivat låg- och medelaktivt avfall (LILW-LL) kassetter	pcs	195	212	225
Högaktivt avfall (HLW)	tonnes U	5,404	5,577	5,740

[69] 2011 annual report of stored and treated low and intermediate level waste at the Barsebäck plant, 2176047 Rev 2, 20 Jan. 2012;
2012 annual report of stored and treated nuclear waste at the Barsebäck plant, B1021956 Rev 0, 1 Feb. 2013;
2013 annual report of stored and treated nuclear waste at the Barsebäck plant, B1024063 Rev 0, 24 Jan. 2014.

[70] Clab: 2011 annual report, 1316422 Rev 1, 28 Feb. 2012;
Clab: 2012 annual report, 1374558 Rev 2, 18 Mar. 2013;
Clab: 2013 annual report, 1420749 Rev 1, 28 Mar. 2014.

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	0	0	36
Long-lived low and intermediate level waste (LILW-LL)	pcs	185,442	169,313	167,218
High level waste (HLW)	tonnes U	0	0	0

Westinghouse[71]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	0	0	0
Short-lived low level waste (LLW-SL)	tonnes	0	0	36
Short-lived intermediate level waste (ILW-SL)	tonnes	0	0	0
Long-lived low and intermediate level waste (LILW-LL)	kg	185,442	169,313	167,218
High level waste (HLW)	tonnes U	0	0	0

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	tonnes	0	0	36
Long-lived low and intermediate level waste (LILW-LL)	kg	185,442	169,313	167,218
High level waste (HLW)	tonnes U	0	0	0

[71] Annual report for radioactive waste for the 2011 calendar year, ESO-12-056 Rev 0, 30 Mar. 2012; Annual report for radioactive waste for the 2012 calendar year, BSA 13-045 Rev 0, 27 Mar. 2013; Annual report for radioactive waste for the 2013 calendar year, BSA 14-042 Rev 0, 28 Mar. 2014.

AB SVAFO[72]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	1,140	1,140*	1,140*
Short-lived low level waste (LLW-SL)	m^3	-	267*	267*
Short-lived intermediate level waste (ILW-SL)	m^3	-	267*	267*
Long-lived low and intermediate level waste (LILW-LL)	m^3	-	3,745*	3,745*
High level waste (HLW)	tonnes U	0	0	0

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	1,140	1,674*	1,674*
Long-lived low and intermediate level waste (LILW-LL)	m^3	-	3,745*	3,745*
High level waste (HLW)	tonnes U	0	0	0

*Quantities from SVAFO's waste management plan 2012.

Studsvik Nuclear AB[73]

In accordance with SKB's classification

		2011	2012	2013
Short-lived very low level waste (VLLW)	m^3	-	-	99
Short-lived low level waste (LLW-SL)	m^3	-	-	1,262
Short-lived intermediate level waste (ILW-SL)	m^3	-	-	1,262
Long-lived low and intermediate level waste (LILW-LL)	m^3	-	-	2,525
High level waste (HLW)	tonnes U	-	-	0

[72] 2011 annual report for AB SVAFO, SVAFO/S-12/01, 28 Feb. 2012;
2012 annual report for AB SVAFO, SVAFO/S-13/02;
2013 annual report for AB SVAFO, SVAFO-14-03, 28 Feb. 2014.

[73] 2011 annual report, STUDSVIK/N-12/030, 27 Feb. 2012;
2012 annual report, STUDSVIK/N-13/045, 27 Feb. 2013;
2013 annual report, STUDSVIK/N-14/147, 26 Feb. 2014.

In accordance with the EU's classification

		2011	2012	2013
Short-lived low and intermediate level waste (LILW-SL)	m^3	-	-	2,624
Long-lived low and intermediate level waste (LILW-LL)	m^3	-	-	2,525
High level waste (HLW)	tonnes U	-	-	0

APPENDIX 2

In-depth environmental objectives evaluation 2012

Report 6500. Steps along the way: In-depth evaluation of the environmental objectives 2012, Swedish Environmental Protection Agency.

http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6500-3.pdf?pid=3809

APPENDIX 3

RD&D Programme 2013

Programme for research, development and demonstration of methods for the management and disposal of nuclear waste, Swedish Nuclear Fuel and Waste Management Company (SKB).

http://www.skb.com/publication/2670359/

APPENDIX 4

Plan 2013
(Plan Cost Estimates)

Costs from and including 2015 for the radioactive residual products from nuclear power. Basis for fees and guarantees for the period 2015-2017, Swedish Nuclear Fuel and Waste Management Company (SKB).

http://www.skb.com/publication/2478337/

2015:32

The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 300 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

Strålsäkerhetsmyndigheten
Swedish Radiation Safety Authority

SE-171 16 Stockholm
Solna strandväg 96

Tel: +46 8 799 40 00
Fax: +46 8 799 40 10

E-mail: registrator@ssm.se
Web: stralsakerhetsmyndigheten.se