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December 2022

Plan 2022

Costs from and including 2024 for the radioactive residual products from nuclear power

Basis for fees and guarantees for the period 2024–2026

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This report is the English version of SKB Plan 2022. In the event of any discrepancy between the Swedish and English versions, the Swedish original will take precedence.

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Preface

According to current regulations, the companies that hold a licence to possess nuclear power plants are responsible for preparing a cost estimate of all measures needed to manage and dispose of the nuclear fuel used in the reactors and other radioactive residual products, as well as for the decommissioning of the nuclear power plants. The regulations comprise the Act (2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities and the Ordinance (2017:1179) on the Financing of the Residual Products of Nuclear Power. The cost estimate must be submitted to the National Debt Office every three years. SKB's owners have commissioned SKB to prepare such a cost estimate jointly for the licensees for the Swedish nuclear power plants.

The present report, which is the thirty-second plan report since reporting started with Plan 82, provides an updated summary of these costs. As in previous reports, costs are reported both for the system as a whole, including management and disposal of radioactive operational waste and certain waste originating from other than the owners' facilities, and for the system subject to the limitations resulting from the regulations described above. The costs of the former are based on a scenario concerning reactor operation based on the power plant owners' current planning, while the costs of the latter are based on the operating time of the reactors set out in the regulations.

Solna, September 2022

Svensk Kärnbränslehantering AB

Johan Dasht
Managing Director

Summary

Companies that hold a licence to possess nuclear power plants are responsible for taking all the measures necessary to guarantee the safe management and final disposal of spent nuclear fuel and radioactive waste from the operation of the plants, and for decommissioning of the nuclear power plants following shutdown. The most important measures are the planning, construction and operation of the facilities and systems that are required for this purpose, and related research and development. The financing of these measures is based on the payment of fees by licence holders into a fund, primarily during the period when the reactors are in operation but also later, if necessary.

How financing is to be arranged is laid down in the Financing Act (2006:647) and associated Ordinance (2017:1179). A reactor owner is defined in that legislation as a holder of a nuclear license who own or operate one or more nuclear power reactors that have not been permanently shut down before 1 January 1975.

A reactor owner with one or more nuclear power reactors in operation pays a fee in SEK per kilowatt hour of electricity generated. This currently applies to Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. For Barsebäck Kraft AB, whose two reactors have been permanently shut down, the fee is an annual amount.

SKB has been jointly commissioned by the nuclear power companies to estimate and compile the future costs of the measures that are required. According to the regulations, such a cost report shall be submitted to the Swedish National Debt Office every three years.

The future costs are based on SKB's current planning relating to the design of the system and the timetable for implementation. The current design is referred to as the reference design, while the overall plan of action is called the reference scenario. This report is based on the proposed focus of the activities presented in SKB's RD&D Programme 2022. The reference scenario reflects the nuclear power companies' current planning, which entails that the operating time for the youngest reactors is planned to be 60 years, while the oldest reactors are permanently shut down. At present, each nuclear power company is investigating the possibilities of changing the prerequisites of its planning by extending the operating time.

The estimated costs of the reference scenario are presented in the report to a certain extent (Chapter 4). This is not required under the regulations, but since the reference scenario forms the basis for the other estimates, it is SKB's view that this makes the report more transparent. The cost report prepared in accordance with the Financing Act and the Financing Ordinance is shown in Chapter 5.

In addition, SKB submits a supplementary report to the Swedish National Debt Office, in order to enable the authority to examine the estimates on a more detailed level than is accounted for in this report. Among other things, the supplementary report shows how costs are divided across the four reactor owners.

The reference scenario includes the following facilities and systems in operation:

- Transport system for radioactive residual products.
- Central Interim Storage Facility for Spent Nuclear Fuel (Clab).
- Final Repository for Short-lived Radioactive Waste (SFR).
- Laboratories for the development of encapsulation and final disposal technology.

The reference scenario also includes the following additional facilities or parts of facilities:

- Extension of SFR to accommodate short-lived waste from the decommissioning of the nuclear power plants and a small amount of operational waste.
- Final Repository for Long-lived Waste (SFL).
- Canister manufacturing facility and encapsulation facility for spent nuclear fuel adjacent to Clab.
- Final Repository for Spent Nuclear Fuel (Spent Fuel Repository).

The reference scenario also includes the costs of support functions, feasibility studies, technology development and assessment of post-closure safety, as well as for SKB's central functions. Costs for SKB central functions include, for example, general functions such as company management, business support, communication, the environment, overall safety issues and safety assessment. Additionally, the report covers the costs of decommissioning of the reactors, the facilities at the power plant sites for interim storage and final disposal of spent nuclear fuel and radioactive waste.

The Financing Act and the ordinance contain a number of conditions that have an impact on the scenario SKB uses to prepare supporting data for fees and financing amounts. This applies above all to reactor operating times, which form the basis for assessing the amount of spent nuclear fuel and radioactive waste, as well as the requirement that it must be possible to assess any uncertainties regarding future development within different areas. In order to meet the latter requirement, SKB has chosen to apply a probabilistic uncertainty analysis. Additionally, the estimate shall only cover residual products which, according to the definition used in the Financing Act, excludes the management and disposal of operational waste. This means, among other things, that the costs of SFR in its present function as a final repository for operational waste are excluded.

The amount of spent nuclear fuel and radioactive waste to be managed and disposed of is linked to the operating times of the reactors. In the regulations, the fee-based operating time is specified as 50 years. A minimum time is laid down, meaning that a remaining operating time of at least six years shall be applied, unless there is reason to assume that operation may cease sooner. The fee is calculated by the authority and is based on the amount of electricity that is expected to be generated over the same period.

Besides payment of fees, reactor owners shall provide two forms of guarantee. One type of guarantee shall cover fees that have been decided but not yet paid. The basis for this guarantee is referred to as the financing amount. In principle, the calculation is the same as that for the fee, but the costs are limited to management and disposal of the residual products that exist when the estimate comes into effect (in respect of this report that date is 31 December 2023).

The second guarantee must supplement the financing amount in the event that it proves to be insufficient. The basis for this guarantee is called the supplementary amount. Under the new Financing Ordinance, the supplementary amount is no longer included in the reactor owners' cost estimates.

The results of the calculation are presented below. The amounts pertain to future costs with effect from 2024 and are given at the price level in January 2022.

Remaining basic cost	SEK 124.1 billion
Basis for financing amount	SEK 118.5 billion

Contents

1 Introduction

This report contains estimates of the future costs needed to manage and dispose of the nuclear waste and the spent nuclear fuel from the Swedish nuclear power plants, and for the decommissioning of the plants. According to Swedish legislation, the cost estimate must be submitted to the Swedish National Debt Office every three years. The cost estimates have been prepared by Svensk Kärnbränslehantering AB (SKB) on behalf of its owners.

This report presents the costs for two scenarios based on the following:

- The assumptions on which SKB's planning is based. This is based on the nuclear power companies' current planning for an operating time of 60 years for the reactors, referred to as the reference scenario.
- Prerequisites based on current regulations. According to the Financing Ordinance, the operating time for the reactors is 50 years, known as the financing scenario.

The operating times of the reactors is an important factor in the planning of the nuclear waste programme. Based on the reactor owners' current planning assumptions, forecasts are made for the amounts of nuclear waste and spent nuclear fuel that will be managed and disposed of in the waste system and for the point in time when there will be a need for interim storage and final disposal.

The report is structured as follows:

Chapter 1 provides background information on the financing system and applicable regulations.

Chapter 2 describes the current design of the Swedish system for management and final disposal of radioactive nuclear waste and spent nuclear fuel, as well as the plan of action for the Nuclear Waste Programme and decommissioning of the nuclear facilities.

Chapter 3 describes SKB's method for estimating costs.

Chapter 4 describes the underlying reference cost calculation based on current plans for reactor operation and SKB's activities.

Chapter 5 presents the cost estimate that falls under the Financing Act and which constitutes the primary purpose of the report.

1.1 Prerequisites

1.1.1 Obligations under the Nuclear Activities Act

According to the Nuclear Activities Act (1984:3, KTL), the holder of a licence for nuclear activities is responsible for ensuring the safe management and disposal of the nuclear waste or nuclear material generated in the operation that will not be used again. The responsibilities include planning, construction and operation of the facilities and systems that are needed, and the research, development and demonstration that is required for this purpose. Decommissioning and closure of the facilities are also included as a final step.

Under the Nuclear Activities Act, the holder of a licence for nuclear activities is also obliged to bear the costs of the measures needed for the management and disposal of radioactive waste and spent nuclear fuel and for decommissioning of the facilities. The licensees for the nuclear power plants in Forsmark, Oskarshamn, Ringhals and Barsebäck are Forsmarks Kraftgrupp AB, OKG Aktiebolag, Ringhals AB and Barsebäck Kraft AB. SKB is owned by Vattenfall AB, OKG Aktiebolag, Forsmarks Kraftgrupp AB and Sydkraft Nuclear Power AB. On behalf of its owners, SKB is responsible for the management and final disposal of the nuclear waste and spent nuclear fuel from the Swedish nuclear power plants.

1.1.2 The financing system and current regulations

In accordance with the Act (SFS 2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities (the Financing Act) and associated Ordinance (2017:1179) on Financing of the Residual Products of Nuclear Power (the Financing Ordinance), licensees for nuclear facilities are required to pay a fee for, among other things, future waste management and decommissioning.

Licence holders with licences to possess or operate one or more nuclear power reactors that have not been permanently shut down before 1 January 1975 are referred to as reactor owners in the regulations. All licensees for the nuclear power plants in Forsmark, Oskarshamn, Ringhals and Barsebäck are therefore also reactor owners.

The regulations make a distinction between, on the one hand, residual products from the nuclear activities and, on the other, radioactive operational waste. Residual products are defined as *"spent nuclear fuel or other nuclear material that will not be used again and nuclear waste that arises at a nuclear facility after the facility is permanently taken out of service*". The fee shall cover costs for the management and final disposal of residual products, but not costs for the management and disposal of operational waste. The latter are financed directly by the reactor owners.

For reactor owners with one or more nuclear reactors in operation, the fee is stated in SEK per kilowatt hour of electricity supplied. This currently applies to Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. For Barsebäck Kraft AB, whose two reactors have been permanently shut down, the fee is an annual amount.

In addition to payment of fees, reactor owners must provide two types of guarantees, one to cover the fees that have not yet been paid in and one for additional costs for unplanned events. The guarantees are intended to be redeemed if reactor owners do not fulfil their obligation to pay fees and if the assets in the Nuclear Waste Fund are deemed to be insufficient.

According to Chapter 8 of the Financing Ordinance, reactor owners are required to submit a cost estimate for the management and disposal of nuclear residual products to the Swedish National Debt Office. The cost estimate must be submitted no later than September every three years. SKB's owners have given SKB the task to prepare such a cost estimate jointly for the reactor owners.

The Swedish National Debt Office shall then draw up proposals for nuclear waste fees and guarantees based on this information. The Government shall determine the fees and the amounts forming the basis for the guarantees for the following three calendar years. If necessary, fees will be charged and guarantees must be provided both during the time the reactors are in operation and after permanent shutdown up until the time that the nuclear power plants have been decommissioned and all residual products have been disposed of.

The fees are paid to the Nuclear Waste Fund, a government authority. The Fund's assets are held in interest-bearing accounts with the Swedish National Debt Office or invested in government bonds or bonds issued in accordance with the Covered Bonds (Issuance) Act (2003:1223). Since December 2017, the Nuclear Waste Fund is also allowed to invest part of its assets in Swedish and global equities, corporate bonds and derivative instruments. Reactor owners are entitled to withdraw funds from the Fund to cover the cost of fulfilling the majority of their responsibilities under the Nuclear Activities Act.

1.1.3 Amounts to be reported under the Financing Act

The amount of spent nuclear fuel and radioactive waste to be disposed of depends on the reactors' operating times. In the cost estimate, each reactor that has not been permanently shut down should be considered to have a total operating time of 50 years, or a remaining operating time of at least six years. If there are special reasons to assume that operation may cease at an earlier date, the expected operating time shall instead be determined based on that date.

Chapter 5 of the Financing Act contains definitions of four cost items:

Basic cost – the annual expected costs for measures and activities referred to in Chapter 4, paragraphs 1–3 of the Financing Act, i.e. the license holders' costs for the safe management and final disposal of residual products, safe decommissioning and demolition of nuclear facilities, and necessary research and development activities.

Additional cost – the annual expected costs for activities referred to in Chapter 4, paragraphs 4–9 of the Financing Act, e.g. the state's costs for R&D, management of funds, licensing, supervision, monitoring and control, as well as costs for information to the public.

Financing amount – an amount specific to each license holder and which corresponds to the difference between, on the one hand, the remaining basic costs and the additional costs for the residual products generated at the time the calculation was made and, on the other hand, the license holder's share in the Nuclear Waste Fund.

Supplementary amount – an amount that supplements the financing amount in view of the fact that it may prove insufficient.

SKB shall provide a report to the National Debt Office on the total remaining Basic cost and how large a proportion of this should be used to form the basis for the financing amount. The Additional cost and Supplementary amount are calculated by the Swedish National Debt Office. The Supplementary amount shall consider uncertainties in both assets and liabilities, in contrast to the previous legislation, under which only uncertainties in liabilities were included.

2 The nuclear waste programme

On behalf of its owners, SKB is responsible for the management and final disposal of the nuclear waste and spent nuclear fuel from the Swedish nuclear power plants. In addition, SKB receives certain radioactive waste from other companies. This is regulated by agreements between SKB and the respective companies.

The waste system and the plan for implementation of this are described in RD&D Programme 2022 (SKB 2022). Parts of this information are presented below as background to the costs estimates presented in subsequent chapters.

The reactors' planned operating times are an important factor in the planning of the nuclear waste programme. Based on the operating times, forecasts are made for the amounts of radioactive waste and spent nuclear fuel that will be managed, as well as to outline when the need for interim storage and final disposal will occur.

The planning for the nuclear waste system is based on the reactor owners ' current planning assumptions. The two reactors at Barsebäck nuclear power plant were shut down in 1999 and 2005, the Oskarshamn nuclear power plant shut down two of three reactors in 2015 and 2017, and two of four reactors at the Ringhals nuclear power plant were shut down in 2019 and 2020 respectively. All the reactors that have now been shut down were commissioned in the 1970s. For the six reactors in operation, the planned operating time is 60 years (commissioned in the 1980s). This applies to the reactors Forsmark 1, Forsmark 2 and Forsmark 3, Oskarshamn 3, Ringhals 3 and Ringhals 4. The youngest reactors, Forsmark 3 and Oskarshamn 3, will therefore be in operation until 2045 according to the reactor owners ' current planning.

For the six reactors in operation, each nuclear power company is investigating the possibilities of changing its planning assumptions by extending the operating time.

2.1 Description of the waste system

The Swedish system for management and disposal of radioactive waste is divided into two main parts: one for low- and intermediate-level waste and one for spent nuclear fuel (the KBS-3 system).

The facilities that are in operation today are the Central Interim Storage Facility for Spent Nuclear Fuel (Clab), the Final Repository for Short-lived Radioactive Waste (SFR), near-surface repositories and facilities adjacent to the nuclear power plants, as well as the ship, the M/S Sigrid.

For final management and disposal of the spent nuclear fuel, what remains is to construct and commission large parts of the system of facilities needed for final disposal of spent nuclear fuel. This includes a new facility part adjacent to Clab for encapsulation of the spent nuclear fuel, casks for transport of canisters containing spent nuclear fuel and a final repository for spent nuclear fuel.

SFR needs to be extended for management and disposal of the low- and intermediate-level waste. Furthermore, an additional final repository, the Final Repository for Long-lived Waste (SFL), will need to be constructed and transport casks for long-lived waste need to be procured.

Figure 2-1 provides an overview of the complete system for management and disposal of Sweden's radioactive waste and spent nuclear fuel. The illustration shows the flow from the waste producers via interim storage facilities and processing facilities to different types of final repositories. Solid lines represent transport flows to existing or planned facilities. Dotted lines represent alternative waste management routes.

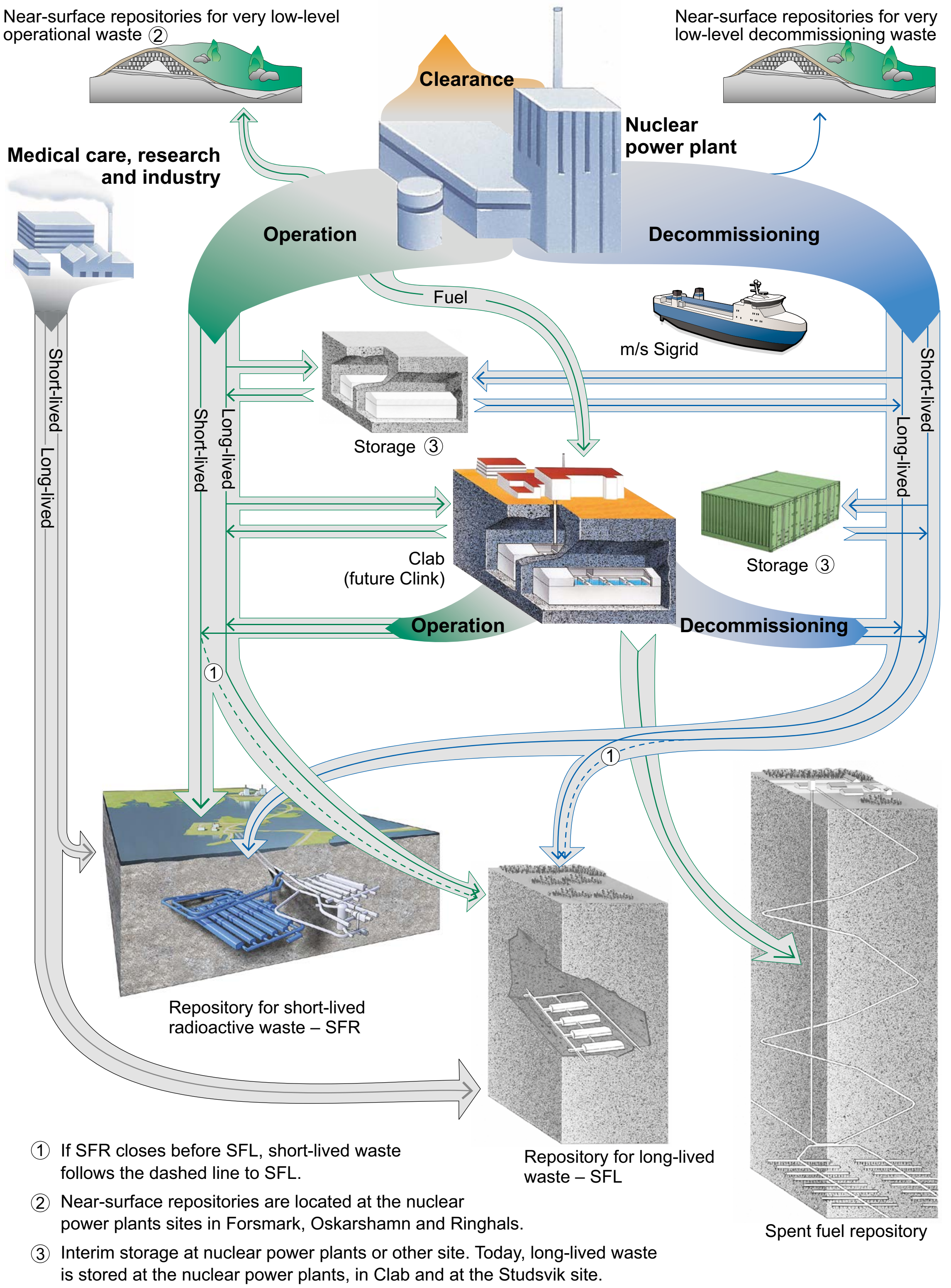

Figure 2-1. *The system for management and disposal of Sweden's radioactive waste and spent nuclear fuel. Solid lines represent transport flows to existing or planned facilities. Dotted lines represent alternative waste management routes.*

2.2 Facilities in the system for low- and intermediate-level waste

2.2.1 Facilities for short-lived waste

The system for low- and intermediate-level waste consists of facilities for handling, interim storage and final disposal. The waste is divided into three categories depending on the level of radioactivity: short-lived, very low-level waste, short-lived waste and long-lived waste. The facilities and management of the waste are adapted to the waste according to this division. The system includes facilities operated by SKB and facilities operated by each of the nuclear power companies. In addition, there are facilities at the Studsvik site, several of which are owned and operated by commercial enterprises, at which waste from the nuclear power plants and Clab is managed or kept in interim storage as necessary. The current facilities within the system will be supplemented with new facilities and extension of existing facilities to manage and dispose of all the radioactive waste that will arise during operation and decommissioning of the Swedish nuclear power reactors and SKB's nuclear facilities.

Treatment of waste

At the nuclear power plants and at the Studsvik site there are treatment plants for short-lived low- and intermediate-level waste. At these plants, the waste is treated and packaged so that it meets the requirements for disposal in SFR or in near-surface repositories. The purpose of the treatment may be to release the material from regulatory control, reduce its volume, concentrate its activity, solidify or condition the material. Furthermore, the waste is placed in waste packages that meet the requirements for each waste type and the receiving final repository. Decommissioning of nuclear power reactors generates large quantities of waste during a short time compared with the operation of the reactors. The capacity for management of waste will therefore be increased in conjunction with decommissioning as necessary.

Interim storage

At the nuclear power plants, there are facilities for interim storage of short-lived low- and intermediate-level waste. These currently serve as buffer storage facilities for operational waste prior to further handling, such as treatment and packaging into finished waste packages prior to transport to SFR for disposal.

Dismantling and demolition of the first seven reactors[1] has begun before completion of the extension of SFR. This means that the capacity for interim storage of short-lived waste will be increased to accommodate the waste from decommissioning at the nuclear power plants Barsebäck, Oskarshamn, Ringhals and Ågesta. A new interim storage facility for low-level waste has been built at Barsebäck. At the Oskarshamn nuclear power plant, the existing interim storage facility LLA (storage building for low-level waste) has been extended. Interim storage at Ringhals takes place in rebuilt existing storage facilities for intermediate-level waste and in a new storage facility for low-level waste, which will be built at the waste area.

Near-surface repositories

Some of the low-level waste contains very low levels of activity. Waste that has a surface dose rate of less than 0.5 mSv/h and that contains mainly short-lived radionuclides, with a half-life shorter than about 30 years, may be deposited in near-surface repositories. This waste is currently disposed of in the existing near-surface repositories that are licensed for operational waste. These are located on the industrial sites at the nuclear power plants in Forsmark, Oskarshamn and Ringhals. According to current practice, the area must be under institutional control for about 30 years after the last disposal of waste. The near-surface repositories that currently exist at the power plant sites are only licensed for operational waste. The existing near-surface repository adjacent to the Oskarshamn nuclear power plant will be extended to have capacity and a licence for disposal of the waste from decommissioning of Oskarshamn 1 and Oskarshamn 2, as well as for the remaining operational waste from Oskarshamn 3. The planning of the extension of the near-surface repository at Oskarshamn includes capacity for receiving waste from the decommissioning of Barsebäck. There are also plans to increase the capacity of near-surface repositories at Forsmark and Ringhals.

[1] Barsebäck 1, Barsebäck 2, Oskarshamn 1, Oskarshamn 2, Ringhals 1, Ringhals 2 and the Ågesta reactor.

Final repository for short-lived radioactive waste

SFR is located adjacent to the Forsmark nuclear power plant, see Figure 2-2. The repository is situated beneath the Baltic Sea, with rock overburden of around 60 metres. Two one-kilometre access tunnels lead from the harbour in Forsmark to the repository area. The waste vaults currently consist of four rock vaults that are 160 metres long, and a 70-metre-high waste vault in which a concrete silo has been built.

The waste in SFR primarily comes from the nuclear power plants, Clab, Studsvik and Ågesta, while a minor portion comes from industry, research and medical care. The facility has a licensed disposal capacity of 63 000 cubic metres of short-lived waste, and by the end of 2021/2022, 40 500 cubic metres of waste had been disposed of at the facility.

Post-closure safety of SFR is based on limiting the amount of long-lived radionuclides in the repository and on retardation of radionuclides in the engineered and natural barriers. The design of each waste vault is adapted on the basis of the activity level of the waste that is disposed of there. Low-level waste is disposed in one of the four waste vaults. Intermediate-level waste with lower activity levels is disposed in two of the waste vaults. Intermediate-level waste with higher levels of activity is disposed of in the fourth waste vault or concrete silo. The silo will contain most of the radioactive elements in SFR.

Currently, only operational waste is disposed of in SFR. In order to make space for additional short-lived waste from both operation and decommissioning, the storage capacity will be increased by about 117 000 cubic metres to a total storage capacity for final disposal of around 180 000 cubic metres. Figure 2-3 shows SFR as it will appear when fully extended, based on current plans.

Figure 2-2. *The final repository for short-lived radioactive waste (SFR) consists of two waste vaults for concrete tanks (1–2BTF), a waste vault for low-level waste (1BLA), a waste vault for intermediate-level waste (1BMA) and a silo for intermediate-level waste. a) View of the surface facility, b) SFR underground, c) waste vault, d) View of silo top.*

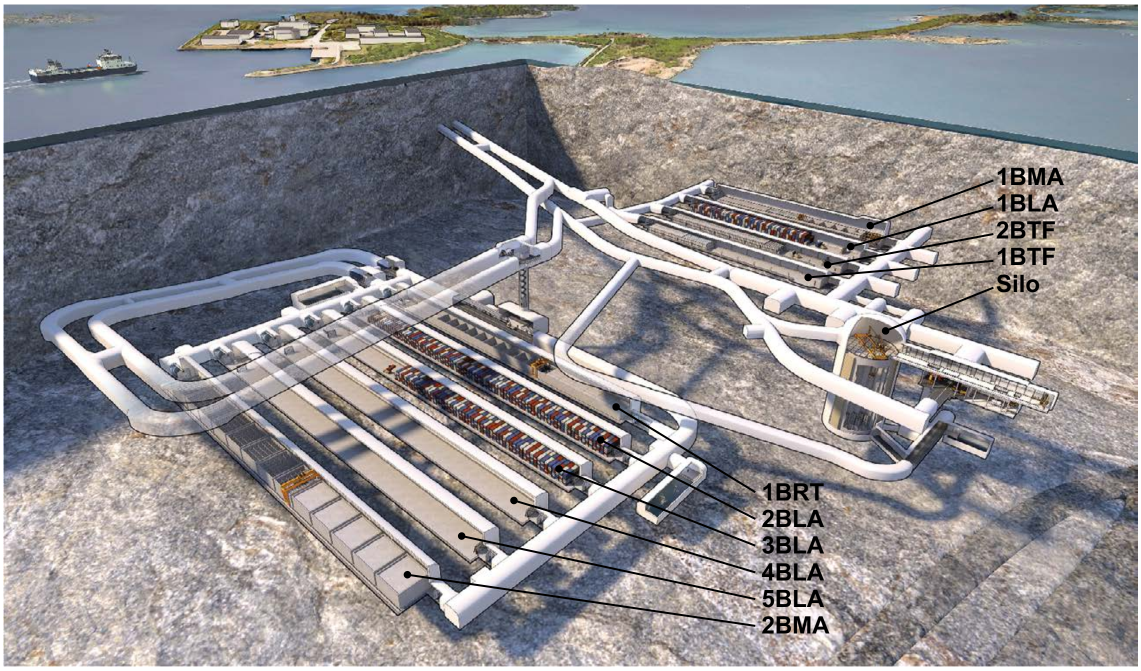

Figure 2-3. *When SFR is fully extended, it will consist of an additional six waste vaults: four waste vaults for low-level waste (2–5BLA), one waste vault for intermediate-level waste (2BMA) and one waste vault for reactor pressure vessels (1BRT).*

Following extension, there will be a total of two waste vaults for intermediate-level waste, one in the existing part (1BMA) and one in the extension part (2BMA). For low-level waste there will be a total of five waste vaults following extension, one in the existing part (1BLA) and four in the extension part (2–5 BLA). In the existing part, there are two waste vaults for concrete tanks (1–2 BTF) and a silo for the most active waste. The extension will have a waste vault for reactor pressure vessels (1BRT) from boiling water reactors (BWR).

2.2.2 Facilities for long-lived waste

Treatment of waste

Today it is possible to segment certain used core components at the nuclear power plants and after that place these in steel tanks for local interim storage. Previously, this has been done when upgrading the reactors, but now this is mainly carried out as a part of the decommissioning projects.

Interim storage

SFL is planned to be commissioned in the early 2050s. Until then, the long-lived waste needs to be kept in interim storage. Currently, the bulk of the long-lived waste is kept in interim storage at the nuclear power plants, in Clab and at the Studsvik site. Clab is primarily intended for interim storage of spent nuclear fuel, but storage canisters containing long-lived operational waste (control rods from BWRs and other core components) are also placed in interim storage in the storage pools.

Long-lived waste that arises from decommissioning of reactors is placed in interim storage at the nuclear power plants where the waste is generated or in interim storage at another site.

Forsmarks Kraftgrupp AB currently operates an interim storage facility in a building at site, where both short-lived and long-lived waste from maintenance stoppages and power uprates is stored.

OKG Aktiebolag has an interim storage facility for long-lived waste in a special rock cavern on the Simpevarp Peninsula (BFA). The operating permit is held by OKG Aktiebolag, but BFA is licensed for interim storage of core components from all Swedish nuclear power plants. At present, waste from the Oskarshamn nuclear power plant and Clab is stored in BFA. BFA is estimated to have sufficient capacity for the long-lived waste that will be generated during decommissioning of Oskarshamn 1 and Oskarshamn 2.

Ringhals AB operates an interim storage facility in a building that is deemed to have sufficient capacity for the long-lived waste that will be generated during decommissioning of Ringhals 1 and Ringhals 2.

Barsebäck Kraft AB operates an interim storage facility in a building at the site, where long-lived waste from Barsebäck 1 and Barsebäck 2 is stored. The waste consists of segmented reactor internals placed in steel tanks. In order to be able to release Barsebäck Kraft AB's site from regulatory control before SFL is commissioned, there are plans to transport the steel tanks to another interim storage facility.

Final repository for long-lived waste

The Final Repository for Long-lived Waste (SFL) will be the last final repository in the nuclear waste system to be commissioned. SKB plans to dispose of the long-lived waste at a relatively great depth in order to avoid negative effects of permafrost on the engineered barriers. According to current plans, construction will begin in the mid-2040s, with the facility being commissioned 10 years thereafter. It will have an operating time of 10 years. The siting of the repository has yet to be decided. The storage capacity of SFL will be relatively small in comparison with SKB's other final repositories. The required storage capacity is estimated to be around 16 000 cubic metres.

The design of the repository is at an early stage. SKB has developed a repository concept that includes two repository parts, one for metallic waste, mainly core components, and one for legacy waste. Post-closure safety of the proposed repository concept for SFL is based on the retardation of radionuclides in the engineered and natural barriers.

The core components, which consist of metallic waste, comprise about one-third of the volume, but contain (initially) the majority of the radioactivity. SKB plans to use an engineered barrier made of concrete for the design of the repository section for core components.

Legacy waste will be placed in interim storage and managed by AB SVAFO, Studsvik Nuclear AB and Cyclife Sweden AB in Studsvik. Additional waste comes from other Swedish research, industry and medical care. SKB is proposing that the engineered barrier for this repository part consist of a combination of bentonite and concrete. The repository concept is shown in Figure 2-4.

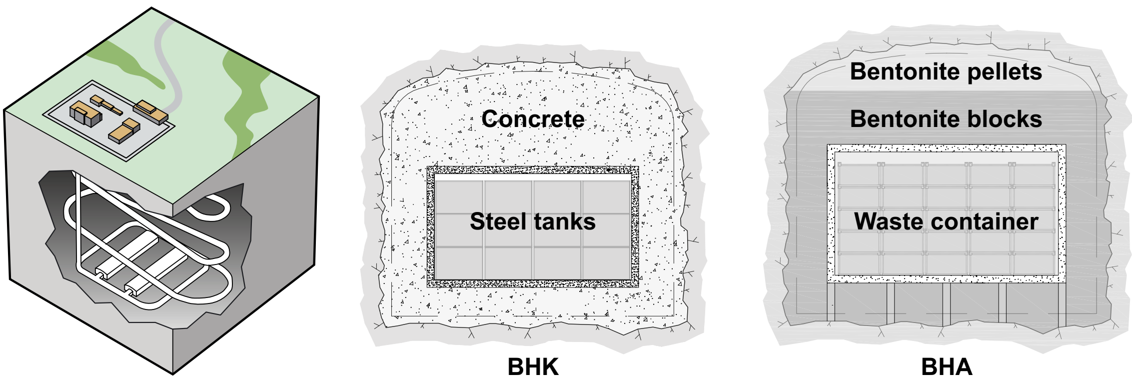

Figure 2-4. *Preliminary facility design (left) and proposed repository concept for the Final Repository for Long-lived Waste (SFL) with a waste vault for core components and segmented PWR reactor tanks (BHK) and a waste vault for legacy waste (BHA).*

2.3 Facilities in the KBS-3 system for spent nuclear fuel

The KBS-3 system consists of the facilities required for implementation of the KBS-3 method. The Central Interim Storage Facility for Spent Nuclear Fuel (Clab) is located in the municipality of Oskarshamn. The spent nuclear fuel from the Swedish nuclear power plants is placed in interim storage at this facility. A new plant will be built adjacent to Clab for encapsulation of the spent nuclear fuel. Following completion, it will be operated as a joint facility, Clink, for interim storage and encapsulation of spent nuclear fuel. The Spent Fuel Repository for final disposal of the encapsulated spent nuclear fuel will be built adjacent to the Forsmark nuclear power plant in Östhammar Municipality. Here, all spent nuclear fuel from Swedish nuclear power will be disposed of in copper canisters surrounded by bentonite at a depth of about 500 metres in the rock. Canister transport casks will be developed for sea transport of the encapsulated fuel from Clink to the Spent Fuel Repository.

Central interim storage facility for spent nuclear fuel – Clab

The interim storage facility for spent nuclear fuel, Clab, which was commissioned in 1985, is situated at the nuclear power plant in Oskarshamn. The facility consists of a receiving section at ground level and a storage section more than 30 metres below the surface. In the receiving section, the transport casks with spent nuclear fuel are received and unloaded under water. The fuel is then placed in storage canisters. The canisters are taken down in a fuel elevator to the storage section, where the spent nuclear fuel is placed in interim storage in storage pools filled with water, see Figure 2-5.

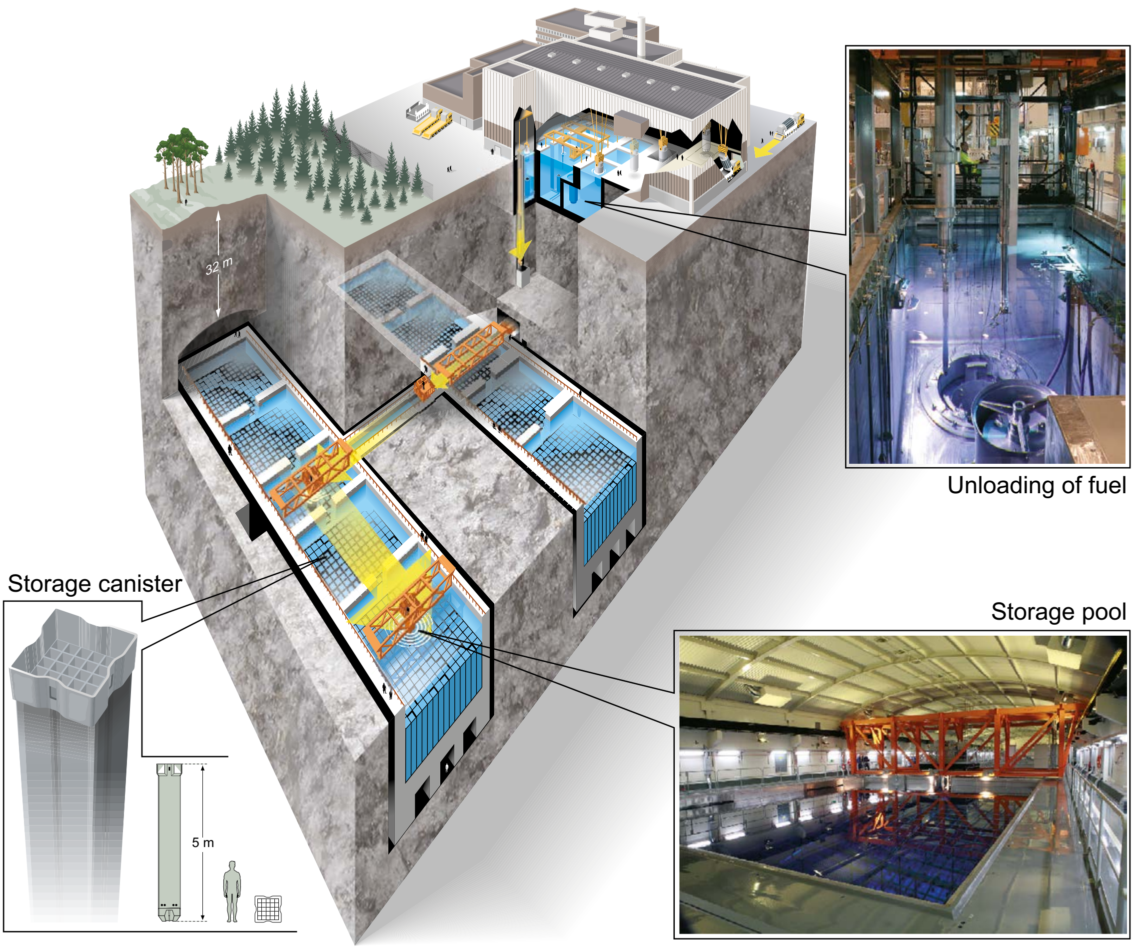

Figure 2-5. *The central interim storage facility for spent nuclear fuel (Clab).*

There are two types of storage canisters for spent nuclear fuel: normal storage canisters and compact storage canisters. The two canister types have the same outer dimensions, but a compact storage canister holds more fuel assemblies.

The actual storage chamber consists of two rock caverns spaced around 40 metres apart and connected by a water-filled transport canal. Each rock cavern is approximately 120 metres long and contains four storage pools and one reserve pool. The top edge of the fuel is eight metres below the surface of the water. The radiation level at the edge of the pool is so low that staff do not need radiation protection.

Clab has been in operation for more than 30 years and system upgrades and replacement of components will be necessary in the future. A number of projects are in progress or have recently been completed, including an upgrade of the cooling chain in order to increase the cooling capacity, replacement of the fire alarm system and modifications in the facility to be able to receive a new type of transport cask.

The Government has granted SKB a licence under the Nuclear Activities Act (KTL) and permissibility under the Swedish Environmental Code (MB) to increase the maximum permissible quantity of nuclear fuel for interim storage in Clab from 8 000 tonnes to 11 000 tonnes, calculated as the original quantity of uranium. There is room to receive the increased quantity of fuel in the existing facility. At the turn of the year 2021/2022, approximately 7 500 tonnes of spent nuclear fuel were kept in interim storage in Clab. According to the current forecast, the amount will exceed 8 000 tonnes in 2024.

Central facility for interim storage and encapsulation of spent nuclear fuel – Clink

Before the spent nuclear fuel is disposed of, it will be encapsulated in copper canisters. This will be carried out in a new plant adjacent to Clab, see Figure 2-6. The two facility parts will be operated as a joint facility, the Central facility for interim storage and encapsulation of spent nuclear fuel, Clink.

The canister that will be used consists of a copper shell and an insert, see Figure 2-7. There are two types of inserts, one that holds twelve fuel assemblies from BWRs and one that holds four fuel assemblies from PWRs. There are also other fuel types that have to be disposed of. These can be placed in one of the two types of insert.

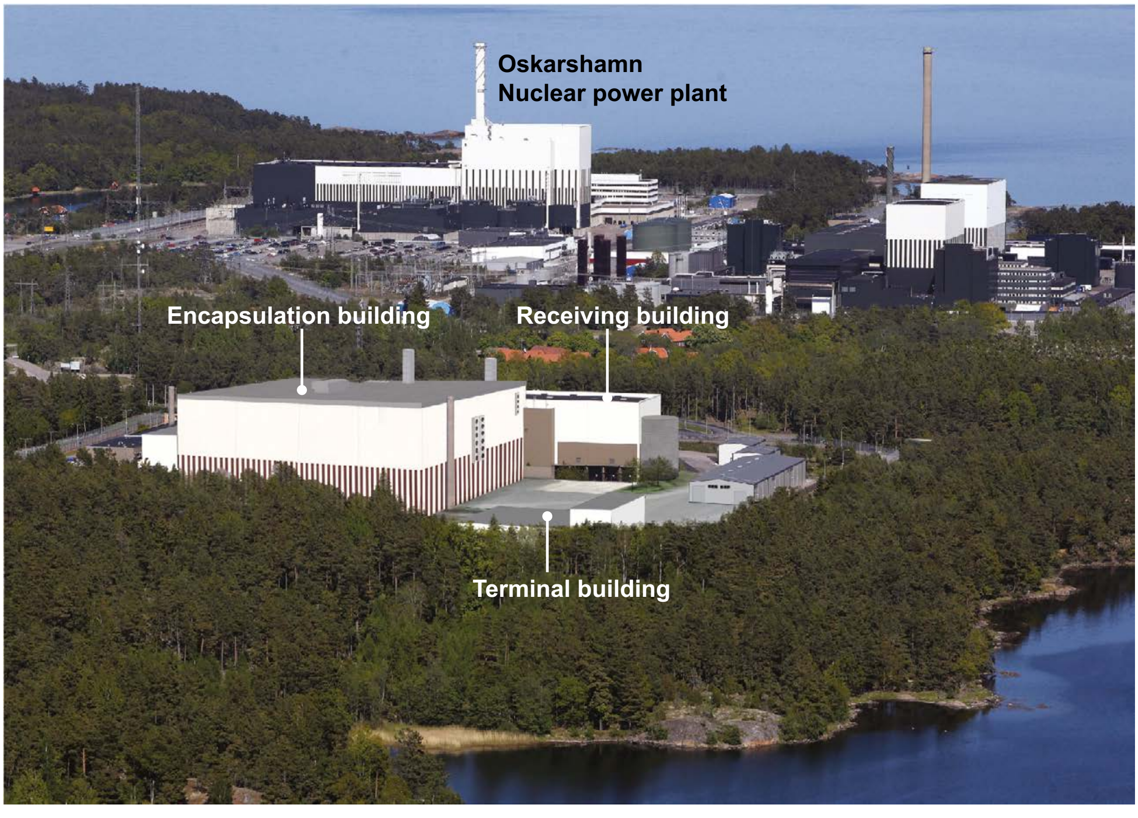

Figure 2-6. *Photomontage showing the facility for interim storage and encapsulation of spent nuclear fuel, Clink.*

__Figure 2-7.__ Copper canister. Length about 5 metres, diameter about 1 metre, copper thickness about 5 centimetres.

The different components of the canister and insert will be produced by different subcontractors. Following delivery to SKB, they will be inspected, assembled and processed before they are used for encapsulation of fuel. Clink is designed for filling and sealing of 200 canisters per year.

Once all the spent fuel and other types of waste that have been kept in interim storage have been removed and transported from the facility, the above-ground parts will be demolished, as will those parts of the storage pools that have become radioactive. The radioactive decommissioning waste will be transported to SFR.

Spent Fuel Repository

The Spent Fuel Repository will be built adjacent to the Forsmark nuclear power plant in Östhammar Municipality. All spent nuclear fuel from the Swedish nuclear power programme will be disposed of there. The final repository will consist of a surface facility and an underground facility, see Figure 2-8. The underground facility consists of a central area and a number of deposition areas. Furthermore, there are connections to the surface facility in the form of a ramp for vehicle transport and shafts for hoist and ventilation.

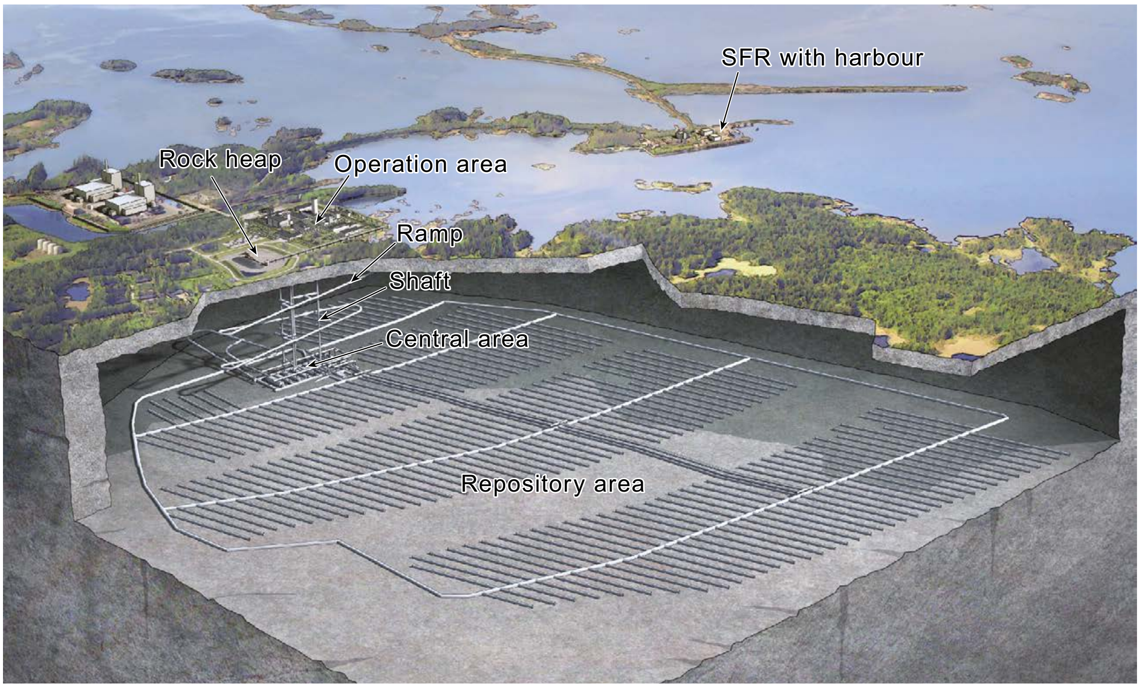

__Figure 2-8.__ Illustration of potential design of the Spent Fuel Repository in Forsmark.

The deposition areas together constitute the repository area. Each deposition area consists of a number of deposition tunnels with deposition holes bored into the tunnel floors. The location of the deposition tunnels, as well as the spacing between the deposition holes, is determined on the basis of the properties of the rock. Important properties include the location of large deformation zones, the presence of large or highly water-conducting fractures and the thermal conductivity of the rock. The repository depth will be 450–500 metres below ground level. The above-ground facility consists of an operations area, rock heaps and storage buildings.

A purpose-built transport vehicle is used to transport the canisters via the ramp down to the deposition level. There, the canisters are transloaded to a deposition machine and transported out to the deposition area for final disposal. Once the canisters have been placed in the deposition holes, where they are surrounded by bentonite clay, the tunnel is backfilled with clay that will swell in contact with water and sealed with a concrete plug. When all fuel has been disposed of, the other openings are also backfilled and the above-ground facilities are decommissioned.

The facility is designed for a total quantity of spent nuclear fuel corresponding to approximately 6 000 canisters with a deposition capacity of 200 canisters per year. However, the reactor owners' current forecasts are for a smaller quantity of spent nuclear fuel corresponding to 5 600 canisters.

2.4 The transport system

SKB's transport system was constructed in the 1980s and is continuously being developed. It consists of the ship, the M/S Sigrid, special vehicles for overland transport and various types of transport containers for fuel and radioactive waste. The ship and the vehicles are used for transportation of low- waste, intermediate-level waste and spent nuclear fuel. The various transport containers have been specifically designed for the waste they are intended for.

The M/S Sigrid was commissioned in 2014. The ship replaced the M/S Sigyn, which was used for transport for around 30 years. Like the old ship, the new ship has a double hull. This design protects the cargo in the event of grounding or collision. In total, the ship holds twelve transport casks intended for spent nuclear fuel or nuclear waste. Normally, the ship, which is operated by a contractor, makes between 30 and 40 trips per year between the nuclear power plants, Studsvik, SFR and Clab.

Short-lived low- and intermediate-level waste is transported from the nuclear power plants, Clab and the Studsvik site to SFR. Low-level waste does not need any radiation shielding and can therefore be transported in ISO-containers. Intermediate-level waste, on the other hand, requires radiation shielding, and the majority is embedded in concrete or bitumen at the nuclear power plants. The waste is transported in transport containers with steel walls that are 7–20 cm thick, depending on how radioactive the waste is, see Figure 2-9.

Currently, part of the long-lived waste, control rods from BWRs, is transported from the nuclear power plants to Clab. They are transported in transport casks with steel walls that are approximately 30 cm thick. The spent nuclear fuel is also transported from the nuclear power plants to Clab in casks with around 30 cm thick steel walls. These casks are also equipped with cooling fins to remove the decay heat generated by the fuel.

Work is under way to renovate and upgrade waste transport containers to enable the transportation of more types of radioactive waste. Transport casks are also being developed for larger core components in steel tanks.

A new transport container for the transportation of spent nuclear fuel is in development. This is being done to meet tighter safety requirements. The design of the new transport cask differs from the current transport casks, which is why modifications for this are being carried out at the nuclear power plants and at Clab.

The transport system will be supplemented with transport casks for encapsulated nuclear fuel prior to operation of Clink and the Spent Fuel Repository.

Figure 2-9. *M/S Sigrid and transport casks for short-lived radioactive waste (ATB), for core components (TK) and spent fuel assemblies (TB).*

2.5 Plan of action

SKB's planning for the construction and commissioning of new and extended facilities in the system for management and disposal of spent nuclear fuel and radioactive waste, as well as the research and technology development needed to perform this task, is presented in the RD&D Programme 2022 (SKB 2022). The Programme also presents the reactor owners' and SKB's plans for decommissioning of nuclear facilities.

In the past year, several important government decisions have been taken that will allow the work to move forward.

- In August 2021, the Government decided to permit an increase in interim storage of spent nuclear fuel while awaiting the construction and commissioning of a final repository. In the spring of 2022, the licensing process for extended storage in Clab continued and negotiations on conditions have been held at the Land and Environment Court. An application for approval of the PSAR has been submitted to the Swedish Radiation Safety Authority (SSM). The storage capacity in Clab can only be increased following the judgment from the Land and Environment Court (MMD) and approval of the PSAR and SAR.
- In December 2021, the Government decided on permissibility under MB and a licence under KTL for continued and expanded operations at SFR in Forsmark in Östhammar Municipality. The decision meant that the process for the extension of SFR will proceed to negotiations on conditions at the Land and Environment Court at the end of 2022 and that the application for construction will be submitted to SSM. Construction on the extension of SFR can only begin after the judgment of MMD and approval of the PSAR.
- In January 2022, the Government decided to grant permission for the final repository for spent nuclear fuel in Forsmark in Östhammar Municipality. The Government has also decided to permit the encapsulation plant needed to handle the spent nuclear fuel in Oskarshamn Municipality. The continued licensing process, with negotiations on conditions and submission of an application prior to construction (including PSAR), is expected to continue in 2023–2024. Construction of the facilities for the Spent Fuel Repository and Clink can only begin after a judgment from MMD and approval of the PSAR.

These decisions mean that individual milestones have been reached, but the review of licensing cases under MB and KTL continues and will continue for several years. How long each case will take before an enforcement decision is made or a judgment is announced cannot be specified in advance, and requires flexibility in SKB's planning. Against this background, increased storage capacity in Clab and the extension of SFR will have high priority, primarily to ensure continued operation of reactors and to enable management of waste from the reactors that are undergoing decommissioning. As regards the KBS-3 system, measures linked to ongoing licensing and optimisation of facilities and barriers will be carried out.

For SFL, the focus in the short term will be on work on development of the inventory, packaging and acceptance criteria.

2.5.1 Plan of action for the nuclear waste programme

SKB's planning for changes in existing facilities and construction of new facilities is based on a stepwise decision process based on SSM's regulations. Planning for new facilities is based on the different licences and consents that are required according to this stepwise process and the steps constitute milestones.

Once the Government has decided on a licence in accordance with KTL and permissibility under MB, MMD shall issue an environmental permit and set out conditions under MB, and SMM will continue the stepwise licensing process, see Figure 2-10. In the stepwise licensing process, approval from SSM of several iterations of the safety analysis reports are needed. This stepwise process, common to all nuclear facilities, includes:

- Approval of safety analysis report prior to construction – based on the presentation of a preliminary safety analysis report (PSAR), which describes the planned design of the facility, how the activities are organised and how the requirements are fulfilled.
- Approval of safety analysis report prior to trial operation and prior to regular operation – based on successive presentations of an updated and a supplemented safety analysis report (SAR). The SAR must comprehensively demonstrate how the safety of the facility will be achieved, describe the facility as built, analysed and verified, and demonstrate how the requirements for its structure, function, organisation and operation are fulfilled.

The operating period of a final repository begins with trial operation, during which spent nuclear fuel or radioactive waste is disposed of. On completion of trial operation, the activities shift into a management phase during regular operation. Decommissioning and closure of the facilities will then take place during the decommissioning phase. The holder of a licence to possess or operate a nuclear facility must submit a systematic, overall assessment of safety and radiation protection at least every ten years. In conjunction with these assessments, a review and compilation of the level of knowledge in the areas that are essential for radiation safety are also carried out.

Figure 2-11 shows the overall timetable, including the dates of future applications, for the entire nuclear waste programme.

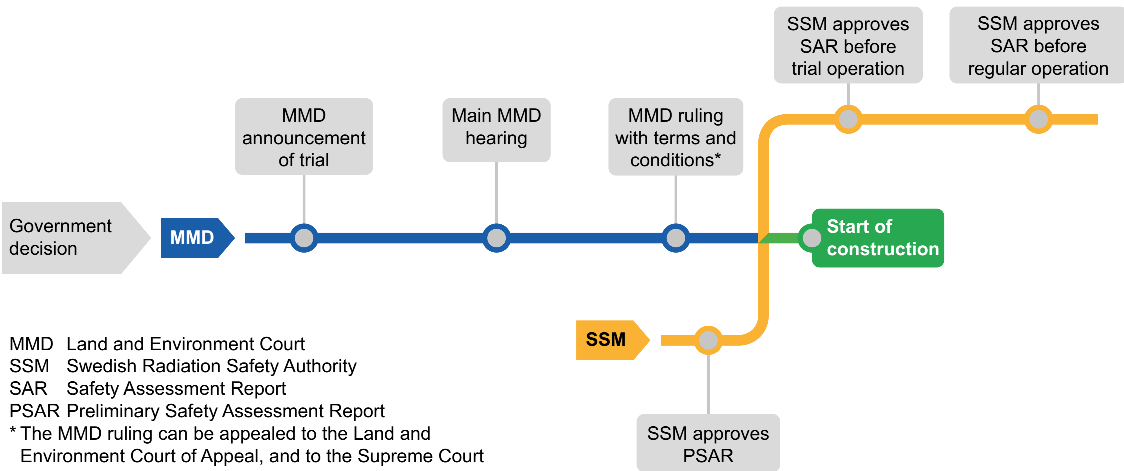

Figure 2-10. *A Government decision on a licence pursuant to KTL and permissibility under MB is followed by a process on conditions and a judgment by MMD, as well as a stepwise licensing process by SSM.*

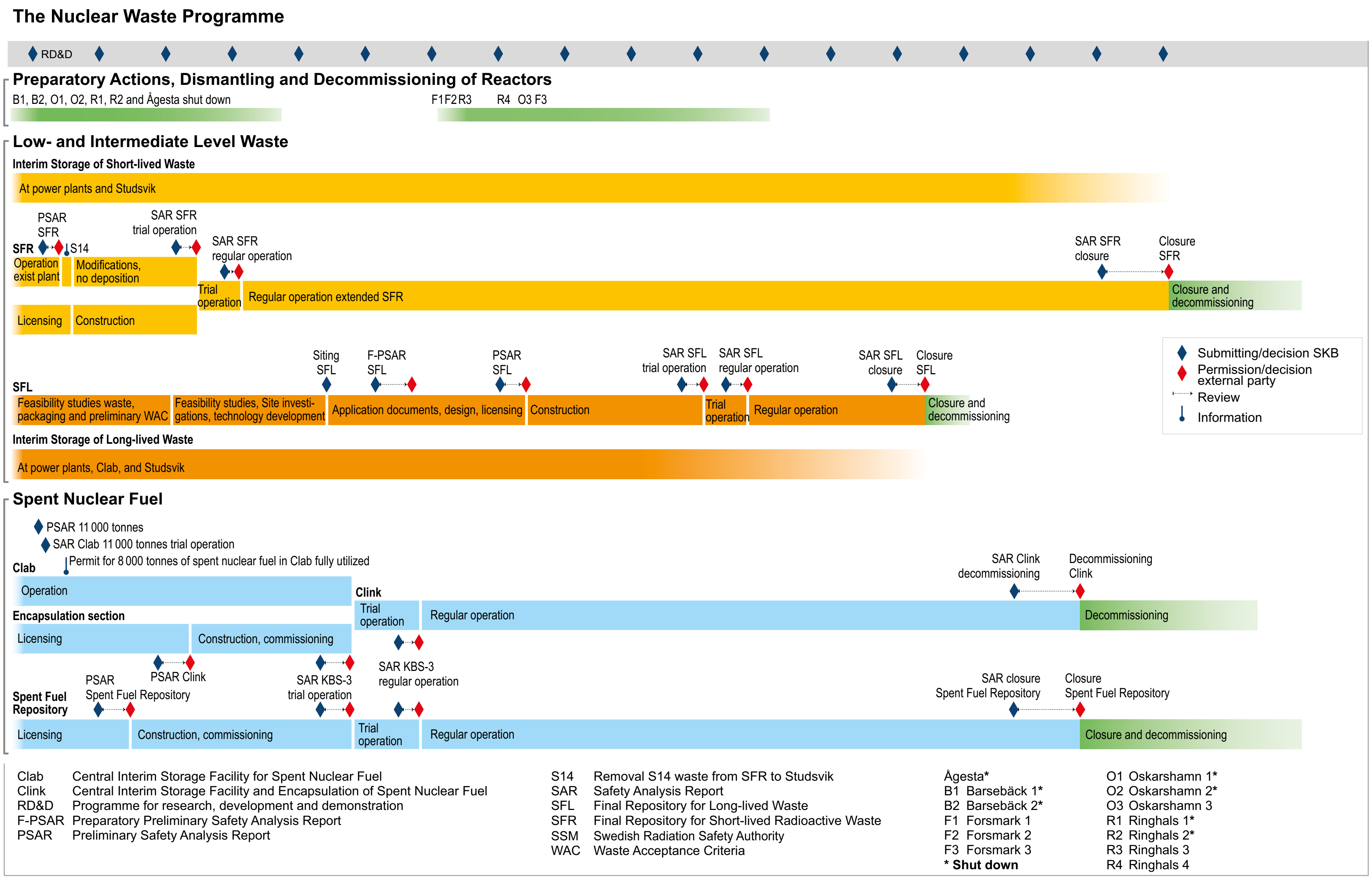

Figure 2-11. *Overall plan of action for SKB's nuclear waste programme and plans for decommissioning of reactors.*

2.5.2 Plan of action for low- and intermediate-level waste

The final repositories that SKB plans to establish for low- and intermediate-level waste include an extension of SFR and construction of SFL. The owners of reactors that are decommissioned before the extended SFR facility is commissioned intend to arrange temporary interim storage facilities for the short-lived decommissioning waste. The reactor owners are planning for interim storage of the long-lived decommissioning waste either at the nuclear power plants or at another site.

Short-lived waste

The licensing process for the extension of SFR with regard to the detailed conditions of the applications under MB is planned to be carried out in the first half of the 2020s, as is the submission of the PSAR, which is the next step in the licensing process in accordance with KTL. At the same time, SKB is continuing work on the detailed design of underground openings and installations of systems in the facility. Preparatory work for construction and preparatory investigations will be carried out prior to the start of construction. According to SKB's current planning, construction of the extension is expected to start in the mid-2020s and trial operation will begin in the early 2030s, see Figure 2-11. The facility is planned to be in operation until the early 2070s, when decommissioning can begin.

The work on dismantling and demolishing the first seven reactors will begin before the extended SFR is commissioned. Barsebäck Kraft AB, OKG Aktiebolag and Ringhals AB therefore plan to place short-lived decommissioning waste in interim storage, primarily at the power plant sites, but other sites may also be considered. Interim storage of operational waste will also be necessary during the period when construction of the extended SFR facility is in progress, since no disposal will take place in the facility.

The strategy for disposal of the reactor pressure vessels from BWRs is segmentation and placement in moulds. Segmented reactor pressure vessels will be placed in interim storage with other intermediate-level short-lived decommissioning waste.

Long-lived waste

SFL is the last repository that SKB is planning to commission and commissioning is planned to take place during the 2050s. Before commissioning, several important milestones must be reached, such as site investigations and site selection, assessment of post-closure safety, preparation of licence applications and construction.

During the 2030s, SKB plans to submit applications in accordance with KTL and MB to construct, possess and operate SFL. Following submission, work will continue on, for example, planning of the system and detailed design. Construction of SFL is expected to begin in the 2040s. In order to meet the needs of the reactor owners, SFL is expected to need to be in operation for around ten years.

The schedule is based on a scenario where SFL is located at one of the sites of which SKB has previous knowledge. If more extensive site investigations are required, SKB believes that commissioning of SFL will be postponed.

Closure of SFL will take place when all long-lived waste held in interim storage and the long-lived waste from decommissioning of the last nuclear power plant have been disposed of. Before closure, SKB needs to ensure that the waste from decommissioning of Clink is suitable for SFR and does not need to be disposed of in SFL.

Since several reactors will be decommissioned before the final repository is commissioned, long-lived waste from decommissioning will need to be placed in interim storage. The reactor owners currently estimate that it is possible to create sufficient interim storage capacity at the nuclear power plants.

Existing and planned interim storage facilities for long-lived waste will be used until it is possible to transport the waste to SFL. In addition to a commissioned SFL, this will also require a new type of licensed waste transport cask.

2.5.3 Plan of action for spent nuclear fuel

The facilities in the KBS-3 system are Clab, an encapsulation plant and the Spent Fuel Repository where the spent nuclear fuel will be disposed of.

Overall planning

The establishment of the facilities in the KBS-3 system is divided into the following main phases: licensing (and design), construction, commissioning, operation and decommissioning and closure. Once the Government decisions on permissibility under MB and a licence according to KTL for interim storage capacity in Clab of 11 000 tonnes and the KBS-3 system have been obtained, the next milestones are the main hearings on permits and conditions in MMD and submission to SSM of applications prior to construction of the Spent Fuel Repository and Clink.

Interim storage

In order to continue to receive the spent fuel during the 2030s, measures are needed to free up storage space. If no measures are taken, the storage positions will be filled by the end of the 2020s. Storage capacity is increased by reloading the spent nuclear fuel stored in normal storage canisters into compact storage canisters. The compact canisters have the same dimensions as the normal canisters, but hold more fuel assemblies. SKB plans to begin transloading of spent nuclear fuel in the mid-2020s. In addition to transloading of the fuel, space is freed up by unloading control rods from the BWR reactors and core components that currently require large storage volume in Clab's pools. These will temporarily be kept in interim storage at another site.

Encapsulation

Over the next few years, SKB will gradually prepare for construction of the encapsulation part of Clink. Construction of the encapsulation plant adjacent to Clab will also include facility modifications at Clab. Operation of Clab will continue throughout the construction of the encapsulation plant, but receiving of spent nuclear fuel may need to be limited during certain times. The construction phase will be concluded when the two facility parts are connected both physically and in terms of processes.

Commissioning of Clink will take place in two steps, with approval from SSM required for each step. First, trial operation is carried out after an application to SSM which contains an updated SAR. Prior to trial operation, safety-related technical specifications and other documents relating to instructions and control of operation will be prepared. Integrated testing that tests the facility as a whole will also be carried out as part of commissioning.

According to the plans, construction of Clink will begin during the second half of the 2020s, and commissioning will take place during the second half of the 2030s. Decommissioning of the facility will take place during the 2070s.

Production system for canisters

Renewed analyses and planning of the production system for copper canisters will be carried out during the RD&D period in order to determine the scope and timetable for the establishment of the production system.

Besides optimisation and design of canister components, current and planned technology development mainly concerns the processes for management and quality control of the production of canister components, welding of canister bottoms and sealing of the canister lid and development of inspection and testing of components and welds.

Final disposal

In line with the progress of the licensing processes, preparations required to begin construction of the access facilities to the Spent Fuel Repository will be started as soon as possible after all licences have been obtained. The design of the facility will continue in parallel with the licensing process, and will include technical construction preparations, geological investigations and surface investigations.

Detailed design will be carried out gradually as the facility is extended, and will consider results from technology development. The results of the detailed design are needed as a basis for, among other things, in-depth planning, procurement and construction works. During the ongoing licensing process, detailed design is therefore carried out primarily for facility parts that will be built early on.

Initially, during the construction phase, parts of the operations area will be filled in and handling areas and temporary construction arrangements will be established. This will be followed by construction of the above-ground and underground facilities, which will be built in parallel.

Construction of the underground facilities will be divided into three parts: (1) access facilities (shafts and ramp) will be driven down to repository level, (2) the central area's underground openings will be built and technical systems installed, and (3) the first deposition area will be established and the facility will be commissioned and tested. When the repository level is reached, construction of the central area will begin. The excavation works for access facilities and the central area will be accompanied by installation works for the equipment that is needed to operate the facility.

Excavation of the access facilities and construction of the central area will yield in-depth knowledge of rock conditions, which will be used, for example, for measures regarding rock support and sealing in tunnels or modifications of the repository design. The information will also be used to support an updated SAR prior to trial operation.

The purpose of preparing a deposition area early is firstly to use a part of the area for production line testing and integrated testing, and secondly to gather the necessary geoscientific data required to substantiate an updated SAR prior to trial operation.

Operation of the final repository includes gradual construction and completion of site-adapted deposition tunnels with deposition holes, as well as installation of buffers, transport and storage of canisters, backfilling and plugging of the deposition tunnels. Commissioning of the subsystems of the final repository will take place gradually, as the systems are built and installed. As in the case of Clink, the systems will be tested prior to commissioning.

According to the plans, construction of the Spent Fuel Repository will begin during the second half of the 2020s, with commissioning expected to take place during the second half of the 2030s. Decommissioning of the facility will take place during the 2070s.

2.5.4 Plan of action for very low-level waste

Management of very low-level operational waste is currently carried out at the nuclear power plants. During decommissioning of nuclear power reactors, the volumes of low-level waste that will need to be handled will increase substantially. In order to handle the large volumes of very low-level waste that are generated during dismantling and demolition of the nuclear power reactors, the reactor owners have identified a need for near-surface repositories for disposal of large portions of this waste.

A review of the waste forecasts for very low-level decommissioning waste is under way, both with regard to estimated total quantities and distribution between different waste categories. In addition to the above, work is continuously carried out on improving management and disposal of the very low-level waste in order to reduce waste volumes.

2.5.5 Plan of action for decommissioning of nuclear facilities

Decommissioning to release a nuclear facility from regulatory control includes a number of activities. Prior to decommissioning, the necessary licences must be in place. When a facility is decommissioned, shutdown operation begins, when all fuel is transported from the reactor to Clab for interim storage. If necessary, this is followed by service operation, until dismantling and demolition begin. The reactor owners plan to start dismantling and demolition as soon as possible after final shutdown. When the facility/parts of the facility have been released from regulatory control, conventional demolition and restoration of land can commence.

Figure 2-12 shows the overall activity and milestone plan for decommissioning of all nuclear power plants and SKB's facilities.

Barsebäck 1 and Barsebäck 2 have obtained the necessary licences and dismantling and demolition at the nuclear power plant is under way. Clearance of the entire site is planned to begin at the end of the 2020s and will be completed during the 2030s.

Dismantling and demolition is in progress at Oskarshamn 1 and Oskarshamn 2. Shared facilities that are not required for operation or decommissioning of Oskarshamn 3 will be demolished in parallel with the demolition of Oskarshamn 1 and Oskarshamn 2. Other shared facilities will be dismantled

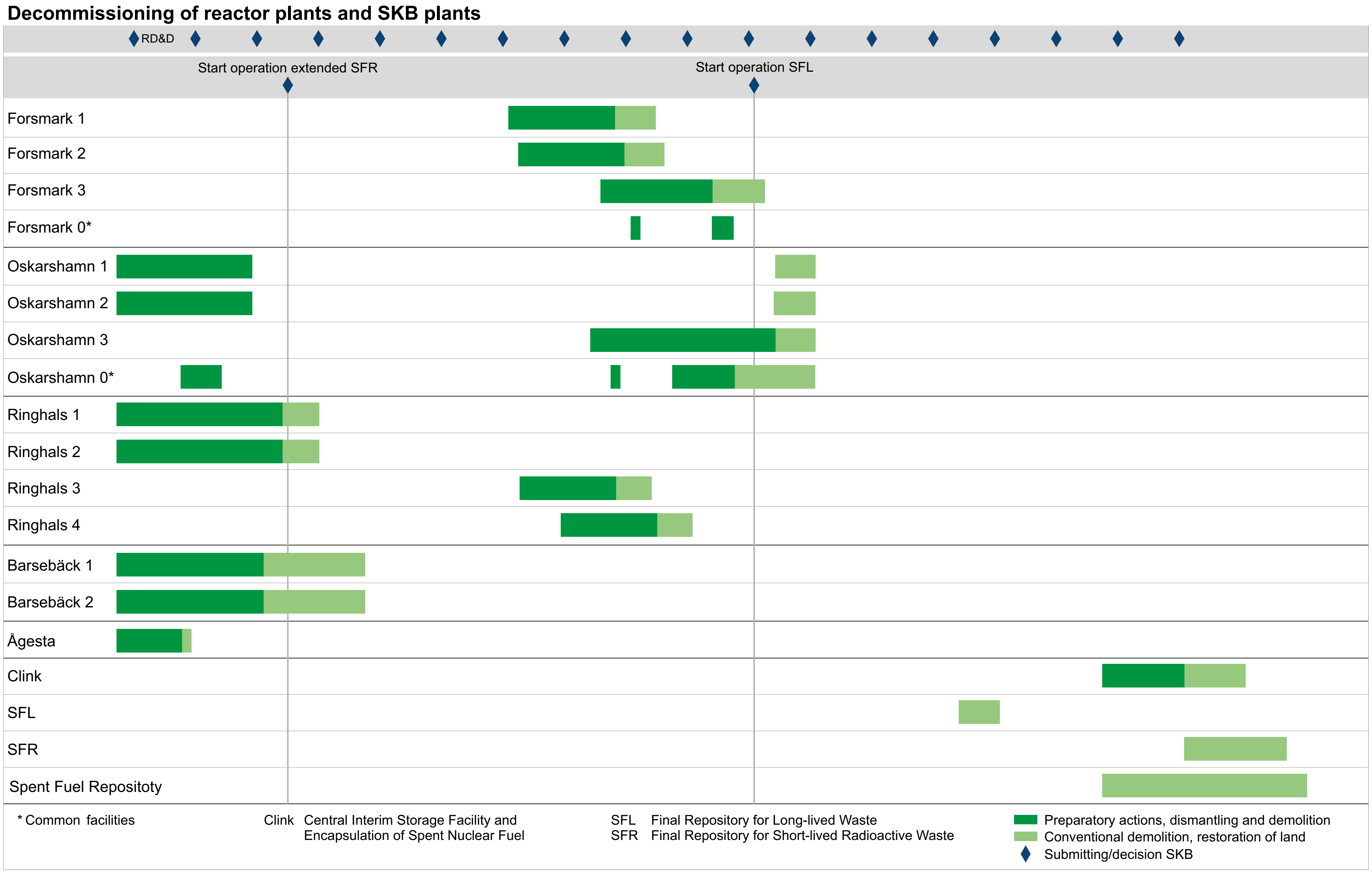

Figure 2-12. *Overview of the nuclear power companies' activity plans for decommissioning of reactor facilities (Forsmark O and Oskarshamn 0 refer to shared service facilities at the power plant sites).*

and demolished after the completed decommissioning of Oskarshamn 3, or left to other actors. Oskarshamn 3 is planned to be in operation until the mid-2040s.

Ringhals 1 and 2 are fuel-free, and planning and preparations to commence dismantling and demolition are under way. Dismantling and demolition of the two reactors is expected to be completed in the early 2030s. Ringhals 3 and Ringhals 4 are planned to remain in operation until the first half of the 2040s.

The reactors in Forsmark are planned to be in operation for 60 years, i.e., until the mid-2040s.

SKB's facilities

Decommissioning of Clink and the Spent Fuel Repository can begin at the earliest when all spent nuclear fuel has been disposed of, while decommissioning of SFR can begin at the earliest when the waste from decommissioning of Clink has been disposed of. However, SFL can be decommissioned once the long-lived waste from the last reactor has been disposed of. The closure of SFL assumes that the decommissioning waste from Clink does not contain any long-lived waste and that all long-lived waste managed by AB SVAFO has been disposed of.

2.5.6 Plan of action for transportation

Overall planning

The need to transport spent nuclear fuel and radioactive waste is expected to gradually increase during the 2030s as several of SKB's new facilities are commissioned. The additional volumes, compared with the current situation, will mainly consist of encapsulated spent nuclear fuel, which will be regularly transported from Clink to the Spent Fuel Repository, and decommissioning waste from decommissioned nuclear power plants, which will be transported to SFR and, starting in the 2050s, also to SFL. There will also be an increased need to transport operational waste to SFR due to the suspension of final disposal that will be in place during the period of construction of the extended facility.

The ship's capacity, including other components in the transport system, is not estimated to present a barrier for the implementation of the nuclear waste programme. There is currently overcapacity in the transport system, and the system is expected to be able to manage the increased transport volume.

2.5.7 Continued research and development

SKB 's and the reactor owners' planning for future research and development activities for the final repositories and Clink is based on the plan of action, in which the stepwise decision process provides the basis for important milestones. Applications and safety analysis reports dictate when knowledge and development of technology need to have reached a certain level. The process demonstrates SKB's knowledge and ability to design facilities that meet regulatory requirements.

The need for continued research and development activities can be divided into three main areas:

- Increased process understanding, i.e., the scientific understanding of the processes that affect the final repository system and thus the basis for assessing their importance for post-closure safety.
- Knowledge and competence concerning design, structure, manufacture, and installation of the barriers and components to be used in the facilities.
- Knowledge and competence concerning inspection and testing to verify that barriers and components are produced and installed according to approved specifications and thereby fulfil the requirements.

One part of the development work is to demonstrate how the developed solutions work in practice. On completion of the experiments at the Äspö HRL, demonstration tests will be carried out in connection with the construction of the planned final repositories. This forms part of the testing and verification of proposed solutions. For the Spent Fuel Repository, monitored long-term experiments during the repository's operating time are being considered to provide in-depth information for the final safety assessment prior to closure. As an integral part of the research and development work, studies are being conducted of how the technical solutions may be optimised and made more efficient, without having a negative impact on safety. The opportunities for such technology optimisation are deemed to be particularly good when it comes to the interaction between different technical systems and production lines. The development work so far has primarily focused on finding suitable solutions for individual systems and production lines.

3 Method for estimating costs

A number of calculations are prepared as part of the work of estimating costs. Several of the estimates serve as a basis for the amounts requested under the Financing Ordinance, while others are used as a basis for SKB's development and planning work.

The facilities that SKB operates, or is planning for, are intended for the management and disposal of spent nuclear fuel and radioactive waste from the Swedish nuclear power plants. At the same time, SKB will, in return for payment, also receive minor quantities of radioactive waste from industrial plants, research facilities and other institutions (for example within medical care) at these facilities. The costs of management and disposal of this waste are not included in SKB's cost estimates.

3.1 Preparing the reference cost estimate

SKB bases its estimations of future costs on the reactor owners' current planning assumptions regarding operating times and expected volumes of radioactive waste and spent nuclear fuel. This information also forms the basis for the planning of SKB's activities and the design and implementation of the nuclear waste system, see Chapter 2. The current design, called the reference scenario, is based on the proposed focus of the activities presented in the RD&D Programme 2022 (SKB 2022). In addition to the costs of management and disposal of radioactive waste and spent nuclear fuel, the estimate for the reference scenario also includes costs for decommissioning and demolition of nuclear power plants.

The reference cost is calculated in a traditional way, using a deterministic method, i.e., a method in which assumptions are stated and fixed. The basis for the calculation includes, among other things, a functional description for each facility, including layout drawings, lists of equipment and staffing forecasts.

The cost estimates for future facilities are based on the data available at the time of calculation. Experience from previous construction of nuclear facilities and the manufacture and use of prototype equipment is also considered. In principle, construction and installation costs for the construction of future facilities are based on quantity-related costs, non-quantity-related costs and so-called secondary costs.

Quantity-related costs can be estimated directly based on supporting data and with knowledge of unit rates, for instance, for concrete casting, rock blasting and operating personnel. Experience gained from previous extension of nuclear facilities, such as Clab and SFR, has been utilised to estimate both quantities and unit rates.

In the early stages of planning, not all details are included on drawings or otherwise specified. However, the extent of these details can be estimated based on experience from other similar projects. The costs for these, i.e., the non-quantity-related costs, are normally obtained by means of an experience-based percentage allowance referred to as an "allowance for unspecified items".[2]

Costs for administration, design, procurement and inspection, as well as costs for temporary buildings, machinery, accommodation, offices and similar are defined as secondary costs. These costs are also relatively well known on a percentage basis.

In a number of cases, SKB's planning includes alternative proposals for solutions, for example, in cases where development work is in progress. However, in order to obtain an unambiguous and concrete basis for the cost estimates, in the reference scenario it is assumed that a specific solution will be implemented. Using this assumption in the calculations should not be regarded as a final decision by SKB. For Plan 2022, the following assumptions have been made in the cost estimates:

[2] This should not be confused with allowance for unforeseen factors, an allowance that is not included in the reference cost estimate. Unforeseen factors are assumed to be part of the total uncertainty covered by the uncertainty analysis.

- **Siting of SFL.** SKB has not yet decided where SFL should be sited. The assumption made in the reference and financing scenario is that the repository will be located adjacent to SFR in Forsmark. Taking the existing construction and transport tunnels in SFR as the starting point, it is assumed that the facility will be sited a couple of hundred metres further down in the rock. As a consequence of the assumption concerning the shared location, SFL will be decommissioned at the same time as SFR.
- According to the current plans, the BWR reactor pressure vessels will be segmented. There is also a policy decision to segment the PWR reactor pressure vessel from Ringhals 2. A decision regarding the reactor pressure vessels from Ringhals 3 and 4 will be taken closer to the time of decommissioning of these reactors. The assumption that applies in the reference and financing scenario is that all PWR reactor pressure vessels will be segmented.
- **Rate of deposition.** According to the plans, the Spent Fuel Repository and Clink will be commissioned in the late 2030s. In the first few years, the rate of deposition is assumed to increase gradually to 180 canisters per year.

3.2 Preparation of cost estimates in accordance with the Financing Act

In accordance with the Financing Act, SKB shall report two amounts: the remaining basic cost and how large a part of this should form the basis for the financing amount, see Section 1.1.2. The amounts are specified in accordance with the requirements of the Financing Ordinance. These amounts are the result of calculations performed in a stepwise process, as illustrated in Figure 3-1.

The costs to be reported to the authority are derived from the cost estimates for the reference scenario, but they have been adjusted for the assumptions that apply according to the Financing Ordinance. This means that the cost estimates must be based on the assumption that the reactors that are currently in operation will be operated for 50 years or a remaining operating time of at least six years. If there are special reasons to assume that operation may cease earlier, the operating time must be determined on the basis of that date. This means that the operating times for the reactors are adjusted compared with the reference scenario and that the amount of spent nuclear fuel and radioactive waste is reduced. Furthermore, in accordance with the Financing Act, the cost estimate shall not include the type of radioactive waste that constitutes operational waste, see Section 3.2.1.

SKB takes into account future real price changes in the cost estimates that are prepared in accordance with the Financing Act, see Section 3.2.2. Real price changes refer to price and productivity trends affecting the project that deviate from the general development in society, i.e., the consumer price index (KPI).

In accordance with legislation, the cost report must refer to expected costs. This means that some form of uncertainty analysis based on probability theory should be applied, see Section 3.2.3.

Furthermore, the Financing Ordinance requires that each reactor owner's share of the basic cost must be specified, which means that a basis for allocating costs between the licensees needs to be prepared, see Section 3.2.4.

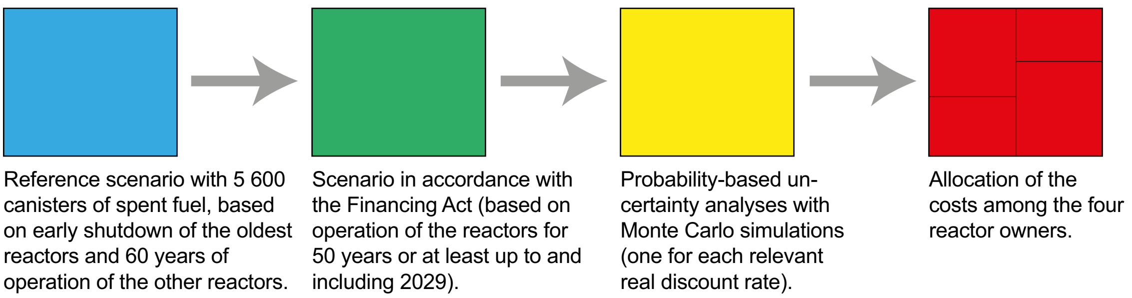

***Figure 3-1.** Stepwise process for calculations.*

3.2.1 Costs excluded in the financing scenario

The Financing Act makes a distinction between residual products and operational waste from nuclear activities. The nuclear waste fee and pledged guarantees shall cover the costs of management and disposal of residual products, but not the costs of management and disposal of operational waste. This means, among other things, that the cost of the current final repository for short-lived radioactive waste is excluded in the financing scenario. Costs for operational waste are financed directly by the reactor owners.

Apart from a licence to operate nuclear power plants, each nuclear power company holds separate licences, or plans to acquire these in the future, for small facilities located on the respective power plant sites. These relate to interim storage facilities and near-surface repositories for very low-level operational waste. The costs of constructing and operating these small facilities are considered to be part of the costs of day-to-day operation of the nuclear power plants and are therefore not included in the cost estimates, in accordance with the Financing Act. However, the costs of decommissioning these facilities in the future shall be included in the cost estimates, since these costs are temporally and materially associated with the decommissioning and demolition of the nuclear power plants.

3.2.2 Adjustment for changes in real costs

The calculations take into account changes in real costs by means of a number of conversion factors that are referred to as external economic factors, EEF. These include cost trends (including productivity) for labour costs, as well as costs for various input materials and machinery. The external economic factors that have been selected for inclusion in the estimates consist of a limited number of observable macro-economic variables. The large number of variables that exist in a project of this nature are reduced in the calculation to a few selected factors, which results in relatively strong aggregation. The following EEFs are used in the plan estimates:

- EEF 1 real labour costs, service sector
- EEF 2 real labour costs, construction industry
- EEF 3 real cost of machinery
- EEF 4 real cost of building materials
- EEF 5 real price of copper
- EEF 6 real price of bentonite
- EEF 7 real price of energy
- EEF 8 real exchange rate SEK/USD

Each cost item in the plan estimate is assigned to one of the first seven EEFs. EEF 8 is used to convert copper and bentonite prices in USD.

For each of the EEFs, a forecast is prepared for future real development. The forecast is based on established forecast models, statistical analyses and expert judgements. Based on the forecasts, the costs are adjusted for the real cost trend from the time the estimate was made until the cost becomes due.

3.2.3 Probabilistic uncertainty analysis

In order to address the regulatory requirements on taking uncertainty into account, SKB uses a probabilistic cost estimation method, the successive principle (Lichtenberg 2000). The method is used for planning and costing of projects and has been specially developed to identify, analyse and evaluate uncertainties. The successive calculation involves a systematic approach that means that variations, deviating events or other uncertainties of a general or overall nature are dealt with separately. The cost impacts of these uncertainties for different outcomes are then added together according to the chosen statistical method in order to produce the total impact expressed as a probability distribution across different cost levels.

The identification and selection of uncertainties that are taken into consideration in SKB's uncertainty analysis is done using a systematic approach, the purpose of which is to facilitate the work and reduce the risk of significant uncertainties being overlooked. This involves, among other things, placing the uncertainties into six areas:

- **Society.** This area includes legislation and regulatory matters, and political issues in general.
- **Economy**. Area with the emphasis on economic conditions such as the real trend in labour costs and the prices of input materials, business cycle factors and currency risks.
- **Implementation**. This includes timetable strategies, siting issues, strategy for decommissioning of nuclear power plants, etc.
- **Organisation**. This mainly concerns how future construction or decommissioning projects will be implemented and managed in terms of organisation.
- **Technology**. The area includes all purely technical issues. The greatest uncertainties concern the future facilities for management and disposal of both spent nuclear fuel and radioactive waste.
- **Cost estimation**. This area considers the uncertainties for incorrect assessments in the actual calculation process. These may consist of both overestimation of difficulties (pessimistic assessment) and underestimation (optimistic).

Identification of the uncertainties that should be considered is managed within a group appointed for this purpose, the analysis group. The uncertainties considered by the analysis group are limited according to the principles that apply for successive calculation, known as fixed preconditions. These limitations are determined by SKB and include that management and disposal shall take place within Sweden's borders and that only KBS-3 shall be considered as the method for management and disposal of the spent nuclear fuel.

The identified uncertainties are analysed and evaluated by the analysis group, whereupon the estimation process begins. By defining both calculation objects and uncertainties based on probable cost and low and high values, the different items can be described as stochastic variables and added together according to statistical rules. In the plan report, this is done by means of a Monte Carlo simulation. Each variable is assigned a unique random number and after all the input variables have been handled in this way the calculation is added together. This process is repeated 5 000 times (cycles), each time with a new set of random numbers. All outcomes are saved and based on this, a result can be obtained in the form of a probability distribution, produced by combining all the calculation cycles.

3.2.4 Allocation of costs

The fees that are paid into the Nuclear Waste Fund by each reactor owner are intended to cover individual reactor owners' future need for funds for management and disposal of radioactive waste and spent fuel. Some costs are directly attributable to the individual reactor owners' obligations, while other costs concern activities that are conducted jointly with the other licence holders (in practice, SKB's area of responsibility). These shared costs are divided between the licensees, based on various agreements between the licensees.

4 Costs according to the reference scenario

4.1 Operating scenarios for the reactors and the amount of residual products

The reference scenario is based on the nuclear power plant owners' current plans for operation of the reactors. It is likely that the production data for individual reactors will change during the remaining total estimated operating time. The reference scenario does not take this into consideration, however, and the supporting data is based on historical data as well as extrapolation of the current situation, which will apply for the entire period covered by the estimate. Any future changes will be incorporated when such decisions are taken and any associated licences have been obtained.

Table 4-1 comprises a summary of the reactors' historical operational data and assumptions regarding future electricity production and the amount of spent nuclear fuel. The amount of fuel is given in tonnes of uranium.[3] The nuclear power companies' current forecasts are for around 5 600 canisters, which also serves as a basis for the reference calculation. At present, each nuclear power company is investigating the possibilities of changing the prerequisites of its planning by extending the operating time.

The number of canisters containing spent nuclear fuel is shown in Table 4-2. The table also contains information on the volumes of other radioactive waste for which space is needed in the various final repositories. The volumes refer to casks containing radioactive waste that are ready for final disposal. The table does not include the amounts of waste that are disposed of in near-surface repositories at the power plant sites.

The block diagram in Figure 4-1 is a summary of the amounts and volumes of spent nuclear fuel and radioactive waste that passes through storage and treatment facilities before final disposal in the respective final repositories. The amounts refer to the reference scenario.

Table 4-1. Operational data and electricity generation and fuel quantities based on planned operation.

				Until the end of 2022		Total for reference scenario			
Start of commercial operation			Thermal power/ net power MW	Electricity generation TWh	Spent nuclear fuel Tonnes of uranium	Planned operating time Year	Operation until	Electricity generation TWh	Spent nuclear fuel Tonnes of uranium
F1	(BWR)	10 Dec 1980	3 200/1 098[1]	296	999	60.0	08 Dec 2040	450	1 369
F2	(BWR)	07 Jul 1981	3 253/1 120	298	994	60.0	06 Jul 2041	462	1 366
F3	(BWR)	22 Aug 1985	3 300/1 167	325	1 004	60.0	21 Aug 2045	537	1 484
O1	(BWR)	06 Feb 1972	1 375/473	109	370		30 Jun 2017	109	370
O2	(BWR)	15 Dec 1974	1 800/638	154	537		31 Dec 2015	154	537
O3	(BWR)	15 Aug 1985	3 900/1 400	316	988	60.0	14 Aug 2045	557	1 542
R1	(BWR)	01 Jan 1976	2 540/881	220	768		31 Dec 2020	220	768
R2	(PWR)	01 May 1975	2 500/807	221	649		30 Dec 2019	221	649
R3	(PWR)	09 Sep 1981	3 135/1 063	272	810	60.0	08 Sep 2041	427	1 158
R4	(PWR)	21 Nov 1983	3 300/1 118	267	796	60.0	20 Nov 2043	445	1 180
B1	(BWR)	01 Jul 1975	1 800/600	93	419		30 Nov 1999	93	419
B2	(BWR)	01 Jul 1977	1 800/600	108	424		31 May 2005	108	424
BWR total			22 968/7 977	1 921	6 503			2 691	8 280
PWR total			8 935/2 988	760	2 254			1 094	2 987
Total			**31 903/10 965**	**2 681**	**8 757**			**3 784**	**11 267**

[1] For the years 2023 and 2024, the values are 3 075/1 040 and 3 200/1 098 respectively.

[3] The actual weight of the fuel in the form of complete fuel assemblies is much greater. One BWR assembly weighs approximately 300 kg, of which around 180 kg consists of uranium. Burnup causes the uranium weight to decrease slightly. For a PWR assembly, the corresponding weights are approximately 560 kg and 460 kg, respectively.

Table 4-2. Encapsulated nuclear fuel and radioactive waste to be disposed of.

	Quantity for final disposal	Final repository
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX, Ågesta, Studsvik)	5 600 canisters	Spent Fuel Repository
Operational waste from the nuclear power plants	53 500 m^3	SFR
Decommissioning waste from the nuclear power plants	76 400 m^3	SFR
Operational and decommissioning waste from the nuclear power plants (core-related components)	5 600 m^3	SFL
Operational waste from Clab and the encapsulation plant	3 200 m^3	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m^3	SFR
Operational waste from SVAFO and Studsvik	14 200 m^3	SFR
Demolition waste from SVAFO and Studsvik	5 600 m^3	SFR
Waste from SVAFO and Studsvik	10 800 m^3	SFL
Total short-lived radioactive waste	**153 300 m^3**	**SFR**
Total long-lived radioactive waste	**16 400 m^3**	**SFL**

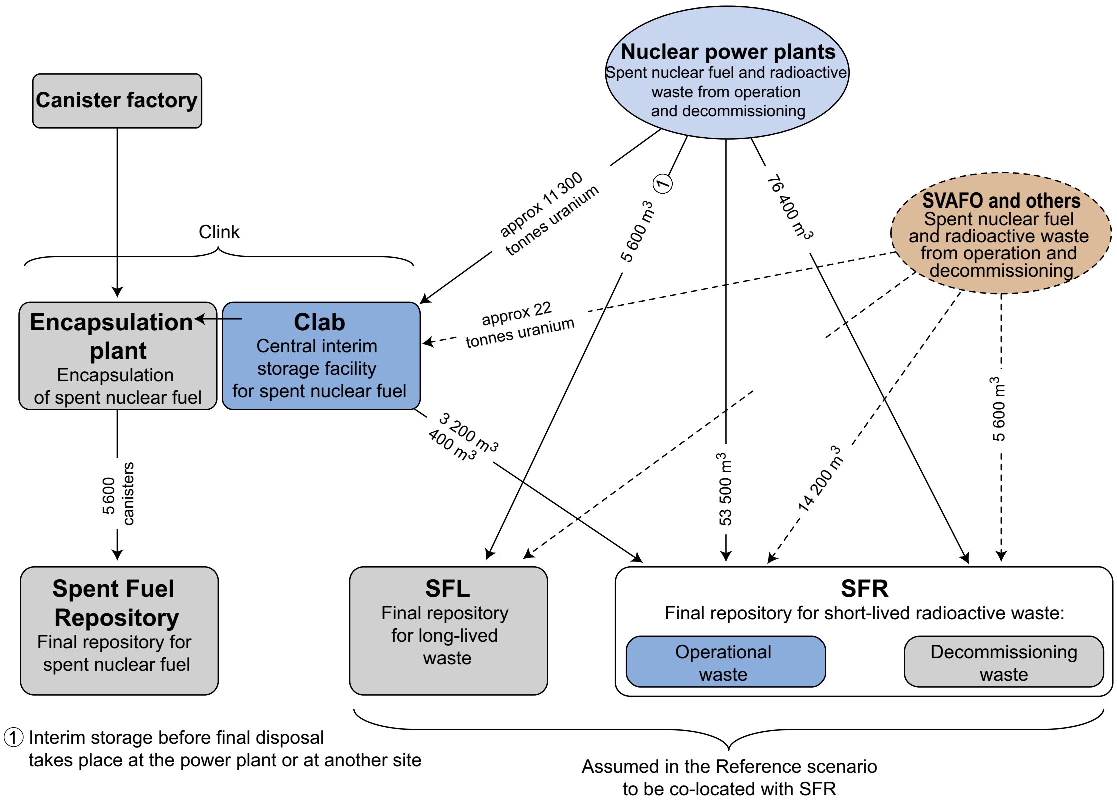

Figure 4-1. *Block diagram showing transport flows for the management of residual products from nuclear power and other radioactive waste.*

4.2 Cost report

4.2.1 Future costs

The reactor owners' future costs for the various facilities and activities in the reference scenario are presented in Table 4-3. For each facility and activity, the table shows whether the costs relate to *"feasibility studies, technical development and safety assessment", "investment", "operation and maintenance", "backfill"* and "*decommissioning and closure*".

The reference scenario also includes costs for support functions and central support. Support functions include costs for portfolio management, requirements management, project and design support and administrative support. These costs are included and allocated to each facility. Centralised costs for SKB include central functions such as company management, business support, communication, environment, overall safety issues and safety analysis report. Central support functions are accounted for separately in Table 4-3.

Normally, only costs incurred before commissioning of a facility or part of a facility are allocated to investment. However, in the case of the Spent Fuel Repository, where extension of the number of deposition tunnels will take place on a continuous basis throughout the operational phase, the costs for this work are also included in *the investment*. The cost estimates in Table 4-3 are based on current supporting data for the reference scenario and include neither allowances for unforeseen factors and risk nor adjustments for future real price changes (adjustment for EEF).

The reference cost amounts to a total of SEK 107.0 billion. Of this, SEK 82.6 billion falls within SKB's sphere of operations and is therefore shared between the licence holders (joint costs). The remainder comprise costs for activities for which each licence holder has an individual cost responsibility (separate costs).

Figure 4-2 shows the reference cost distributed over time. A simplified timetable is shown for the different facilities in order to provide an understanding of their impact on cost flow. The two cost peaks in the diagram originate on the one hand from the investment in the Spent Fuel Repository and the encapsulation part of Clink, and on the other, from the decommissioning of the nuclear power plants.

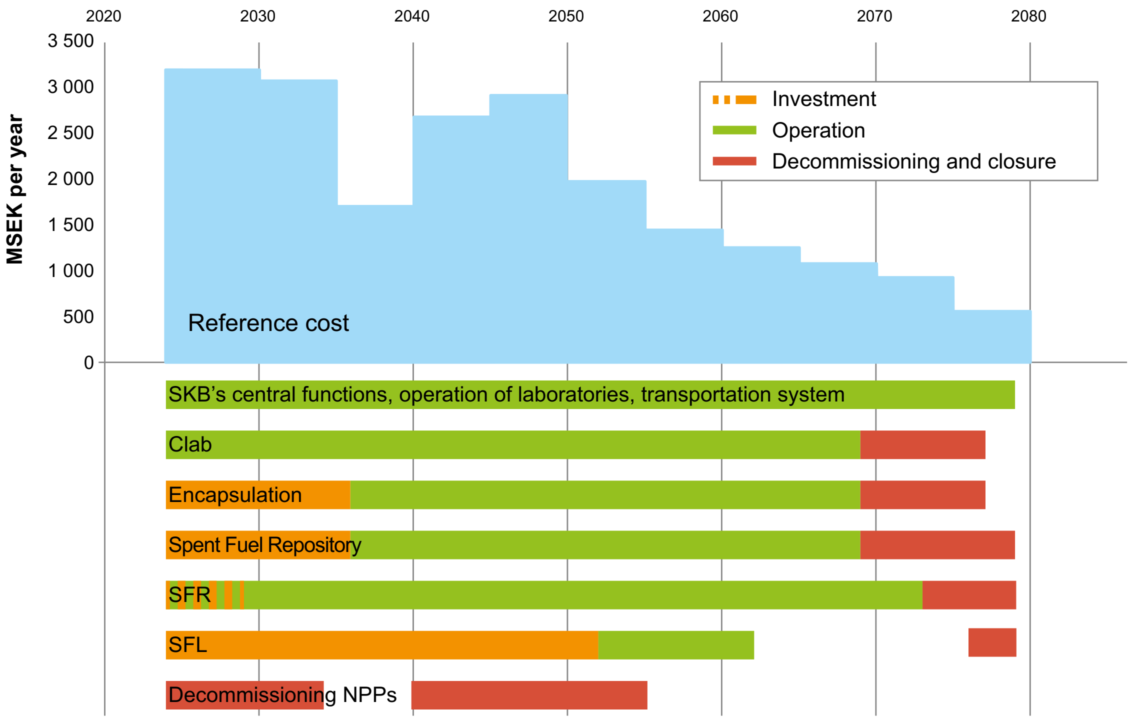

***Figure 4-2.** Distribution over time of the future costs for the reference scenario and general timetables for the facilities, price level January 2022.*

Table 4-3. Summary of the licensees' future costs for the reference scenario with effect from 2024, price level January 2022.

		Cost per cost category SEK m	Cost per facility SEK m
SKB central functions		7 740	**7 740**
Transport	Investment	1 520	**4 100**
	Operation and maintenance	2 580	
Clab	Operation and maintenance	7 290	**10 440**
	Reinvestment	2 170	
	Demolition	990	
Encapsulation	Investment	4 590	**17 210**
	Operation and maintenance & reinvestment	12 340	
	Demolition	280	
Spent Fuel Repository			
Above ground	Feasibility studies, technology development and safety assessment	1 330	**34 760**
	Investment and demolition	10 330	
	Operation and maintenance (entire facility)	7 130	
	Reinvestment (entire facility)	2 550	
Other underground openings	Investment	2 460	
	Demolition and closure	1 560	
Main tunnels and deposition tunnels	Investment	5 250	
	Demolition, backfill and closure	4 150	
SFL	Feasibility studies, technology development and safety analysis	560	**2 140**
	Investment	800	
	Operation and maintenance & reinvestment	420	
	Demolition and closure	360	
Interim storage facilities and near-surface repositories at the nuclear power plants	Investment, operation and demolition	110	**110**
SFR (operational waste)	Operation and maintenance & reinvestment	770	**770**
SFR (demolition waste)	Feasibility studies, technology development and safety analysis	440	**5 480**
	Investment	2 900	
	Operation and maintenance & reinvestment	1 740	
	Demolition and closure	410	
Decommissioning of nuclear power plants		24 230	**24 230**
Total reference cost (without adjustment for EEF and allowances for unforeseen factors and risk)		**106 990**	**106 990**

Rounding differences may occur.

4.2.2 Costs incurred and budgeted costs

Table 4-4 shows costs incurred (at current price level) up to the end of 2021 and the forecast for cost outcome for the years 2022 and 2023. Costs of reprocessing incurred in an earlier phase are not included in the table. Allocation of the total cost, both incurred costs and future costs, among the various facilities is shown in Figure 4-3. The distribution is based on the January 2022 price level, where previously incurred costs have been adjusted upwards using the Consumer Price Index (KPI).

Table 4-4. Previously incurred costs at current price level.

	Costs incurred until the end of 2021 SEK m	Outcome 2022 (forecast) SEK m	Forecast for 2023 SEK m	Total until the end of 2023 SEK m
SKB central functions	6 070	300	210	6 580
RD&D	8 770	0	0	8 770
Transport	2 450	150	310	2 910
Clab	9 440	310	280	10 030
Encapsulation	1 140	100	120	1 360
Spent Fuel Repository	6 380	330	320	7 040
SFR and SFL	4 000	200	250	4 460
Decommissioning of nuclear power plants	4 760	1 450	1 450	7 660
Total	**43 010**	**2 840**	**2 940**	**48 790**

Rounding differences may occur.

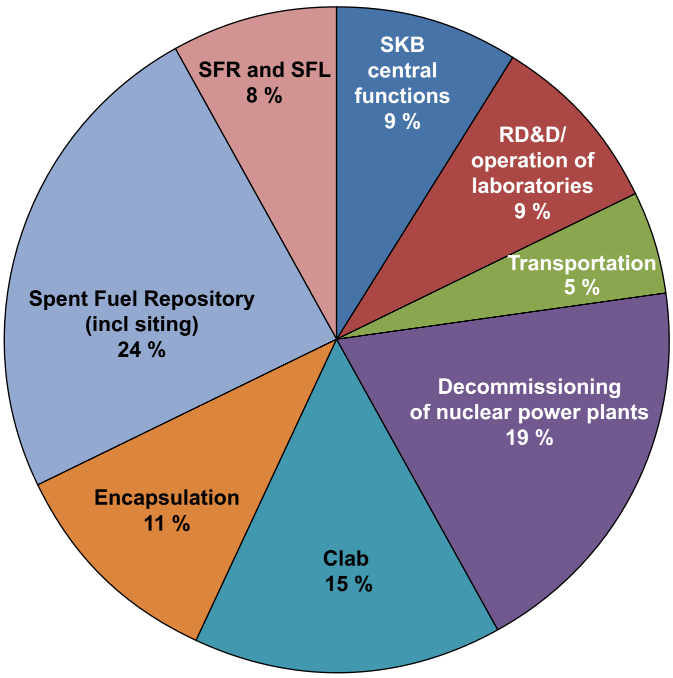

Figure 4-3. *Distribution of the total cost (incurred and future costs) for the reference scenario. Price level January 2022.*

5 Costs according to the financing scenario

In this section, the cost estimation that will form the basis for fees and financing amounts for the years 2024–2026 is presented. According to the regulations, for the reactors that are in operation, the calculation shall be based on an operating time of 50 years or a remaining operating time of at least six years. If there are special reasons to assume that operation may cease at an earlier date, the expected operating time shall instead be determined based on that date.

5.1 Operating scenarios for the reactors and the amount of residual products

The future assumed operating time according to the Financing Act and the nuclear power companies' current planning is shown in Figure 5-1.

Table 5-1 shows operating data and fuel quantities for the scenario according to the Financing Act (50+6 years). Table 5-2 shows this in more detail, but also with a comparison with the quantities in the reference scenario.

The cost report contains quite detailed information for the scenario according to the Financing Act (50+6 years), see Section 5.3.1. For the basis used for the financing amount, i.e., the reconciliation on 31 December 2023, only the total amount is given.

Table 5-1. Operating data and electricity generation and fuel quantities based on the financing scenario (50+6 years).

Start of commercial operation			Total for basic cost			
			Operating time according to the Financing Act Number of years	Operation until the end of	Energy generation TWh	Spent nuclear fuel Tonnes of uranium
F1	(BWR)	10 Dec 1980	50.0	10 Dec 2030	365	1 170
F2	(BWR)	07 Jul 1981	50.0	07 Jul 2031	373	1 171
F3	(BWR)	22 Aug 1985	50.0	22 Aug2035	443	1 285
O1	(BWR)	06 Feb 1972		30 Jun 2017	109	370
O2	(BWR)	15 Dec 1974		31 Dec 2015	154	537
O3	(BWR)	15 Aug 1985	50.0	15 Aug 2035	451	1 305
R1	(BWR)	01 Jan 1976		30 Dec 2020	220	768
R2	(PWR)	01 May 1975		30 Dec 2019	221	649
R3	(PWR)	09 Sep 1981	50.0	09 Sep 2031	344	980
R4	(PWR)	21 Nov 1983	50.0	20 Nov 2033	361	1 005
B1	(BWR)	01 Jul 1975		30 Nov 1999	93	419
B2	(BWR)	01 Jul 1977		31 May 2005	108	424
BWR total					**2 317**	**7 450**
PWR total					**926**	**2 633**
Total					**3 243**	**10 083**

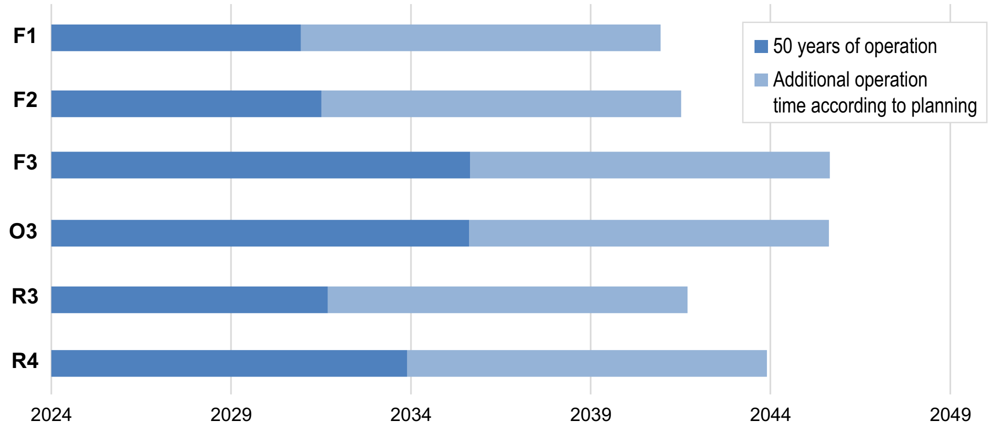

Figure 5-1. Assumptions of future operating time according to the Financing Act and the planned operating time for the reactors.

Table 5-1. Encapsulated nuclear fuel and radioactive waste to be disposed of according to 50 years of operation.

	Quantity for final disposal		Final repository
	50 years	**Reference**	
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX, Ågesta, Studsvik)	4 963 capsules	(5 600)	Spent Fuel Repository
Operational waste from the nuclear power plants	48 900 m^3	(53 500)	SFR
Decommissioning waste from the nuclear power plants	76 400 m^3	(76 400)	SFR
Operational and decommissioning waste from the nuclear power plants (core-related components)	5 600 m^3	(5 600)	SFL
Operational waste from Clab and the encapsulation plant	3 000 m^3	(3 200)	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m^3	(400)	SFR
Operational waste from SVAFO and Studsvik	14 200 m^3	(14 200)	SFR
Demolition waste from SVAFO and Studsvik	5 600 m^3	(5 600)	SFR
Waste from SVAFO and Studsvik	10 800 m^3	(10 800)	SFL
Total short-lived radioactive waste	**148 500 m^3**	**(153 300)**	**SFR**
Total long-lived radioactive waste	**16 400 m^3**	**(16 400)**	**SFL**

5.2 Change compared with reference scenario

This section covers changes compared with the reference scenario described in Chapter 4.

This primarily involves various assumptions of reactor operating times which have an impact on the amounts of spent nuclear fuel and radioactive waste.

The following is a summary of the most important changes in operating scenarios compared with the reference scenario:

- The number of canisters containing spent nuclear fuel is lower than the 5 600 included in the reference scenario. Estimate of the remaining basic cost of 4 963 canisters. The starting point for estimating the basis for the financing amount is that a total of 4 378 canisters will be disposed of.
- The total operating time for the Spent Fuel Repository and Clink is reduced. This means that the estimation of the remaining basic cost will be based on an operating time that is three and half years shorter than in the reference scenario, while the estimation of the basis for the financing amount is based on an operating time that is seven years shorter. The shorter operating times also have an impact on the cost estimates for other facilities, primarily SFR (decommissioning waste).

- Costs for operational waste that is managed and disposed of during ongoing operation of the reactors are not included in the estimate (does not fall under the concept "residual products"). Primarily, this means that the costs of final disposal of operational waste in SFR are not included. It also means that the costs of transport to SFR are excluded, as are a proportional share of the costs for SKB's central functions.
- Costs for space in SKB's facilities that is used for radioactive waste from sources other than the licensees (SVAFO, etc.) are not included in the estimate. These costs are financed by other means.
- Once a reactor has been permanently shut down, decommissioning commences. The decommissioning work then continues until the remaining components of the facility receive clearance, in other words, are released from the demand for nuclear regulatory control. The remaining activities are then no longer subject to the provisions of the Nuclear Activities Act (KTL), and the continued conventional demolition work can be conducted under the same conditions as those for other industrial activities. The extent to which demolition will take place for the remaining parts of the facilities varies from plant to plant depending on what the plans are for the continued use of the nuclear power plant sites. In Plan 2022, as in previous plan reports, a standard deduction of 10 % has been made of the costs for conventional demolition included in the reference scenario. An exception is made for Barsebäck, where the entire cost is included. The standard deduction may be reviewed in future reports.

5.3 Cost report

5.3.1 Remaining basic cost

Table 5-3 contains a summary of the licensees' estimated future costs attributable to the remaining basic cost and which form the basis for calculating fees. The costs of the various objects reported in the table do not include allowances for unforeseen factors and risk. Such allowances, as well as the effect of future real price and cost trends (EEF), are presented at the bottom of the table.

The estimated costs of the various facilities are presented under the items *"feasibility studies", "technical development and safety assessment", "investment", "operation and maintenance"*, *"backfill"* and *"decommissioning and closure"* (backfill refers only to the backfilling of deposition tunnels). Normally, only costs incurred before commissioning of a facility or part of a facility are allocated to investment. However, in the case of the Spent Fuel Repository, where extension of the number of deposition tunnels will take place continuously throughout the operational phase the costs of this work are also included in investment.

The scenario according to the Financing Act also includes costs for support functions and central support functions. Support functions include costs for portfolio management, requirements management, project and design support and administrative support. These costs are included and allocated to each facility.

Centralised costs for SKB include central functions such as company management, business support, communication, environment, overall safety issues and safety analysis report. Central support functions are accounted for separately in Table 5-3.

The total remaining basic cost amounts to SEK 123.9 billion. Of this, SEK 5.7 billion comprises an adjustment for real price and cost trends (EEF), while SEK 18.0 billion comprises allowances for unforeseen factors and risk.

Figure 5-2 shows the costs according to Table 5-3 distributed over time. The figure also shows a simplified timetable for the different facilities to give an idea of their influence on the cost flow. The two cost peaks in the diagram stem from the investment in the encapsulation part in Clink, the Spent Fuel Repository and the extension of SFR, as well as from decommissioning of the nuclear power plants.

The diagram in Figure 5-3 shows the present value of the remaining basic cost for discount rates of between 0 and 4 %. The diagram refers to the total amounts, which includes the allowance for unforeseen factors and risk and adjustment for EEF. The supporting data for the diagram was obtained by means of a number of separate Monte Carlo simulations using different discount rates that are constant over time. This illustrates the dependence of the remaining basic cost on the discount rate. In order to obtain a correct allowance for unforeseen factors and risk, for both the remaining basic cost and the financing amount, a Monte Carlo simulation should be performed with the same discount rate curve that is used in the calculation of fees and financing amounts.

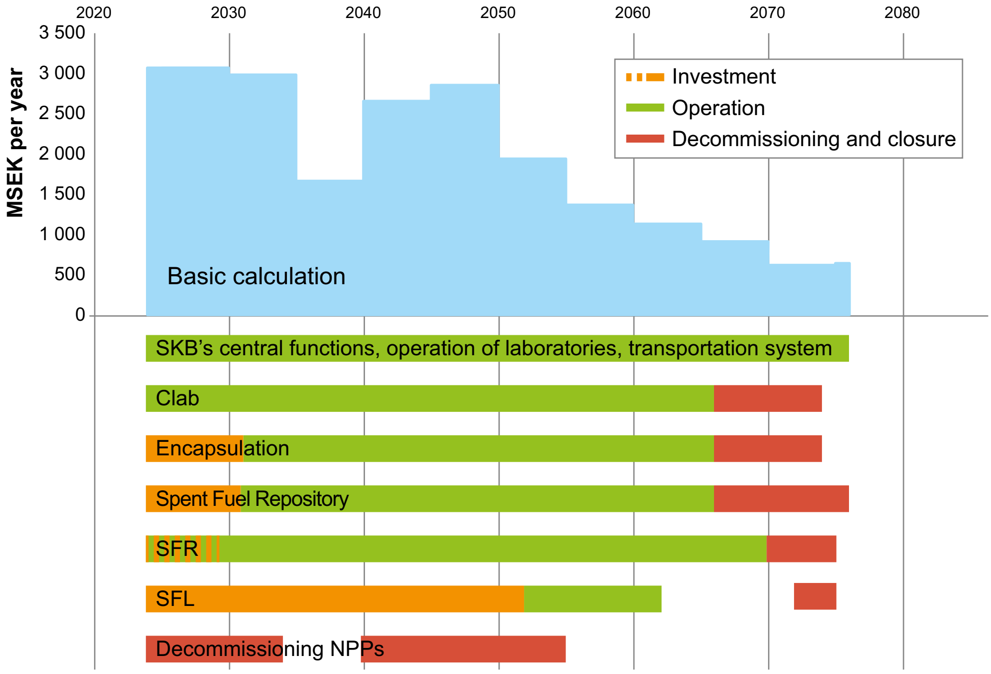

***Figure 5-2.** Remaining basic cost, excluding allowance for unforeseen factors and risk, distributed over time and associated timetable for the facilities, price level January 2022.*

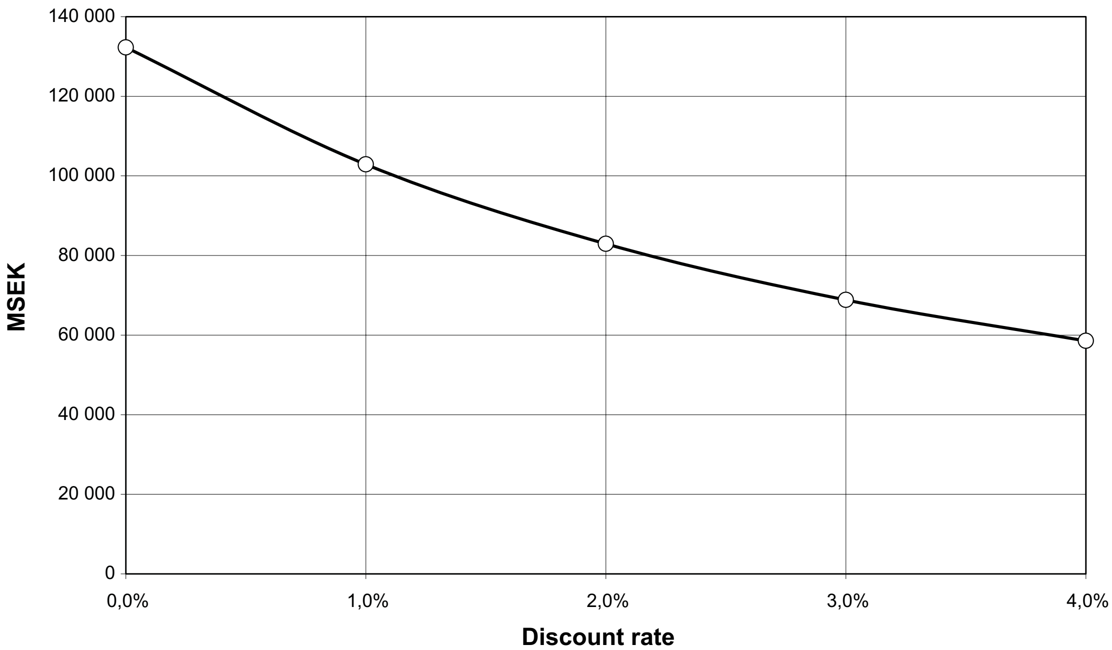

***Figure 5-3.** Present value of the remaining basic cost as a function of the discount rate, price level January 2022.*

Table 5-2. Remaining basic costs with effect from 2024, price level January 2022.

		Cost per cost category SEK m	Cost per facility SEK m
SKB central functions		7 060	**7 060**
Transport	Investment	1 480	**3 740**
	Operation and maintenance	2 260	
Clab	Operation and maintenance	6 820	**9 880**
	Reinvestments	2 070	
	Demolition	990	
Encapsulation	Investment	4 590	**15 850**
	Operation and maintenance & reinvestment	10 980	
	Demolition	280	
Spent Fuel Repository			
Above ground	Feasibility studies, technology development and safety assessment	1 310	**32 170**
	Investment and demolition	10 270	
	Operation and maintenance (entire facility)	6 470	
	Reinvestment (entire facility)	1 900	
Other underground openings	Investment	2 390	
	Demolition and closure	1 460	
Main tunnels and deposition tunnels	Investment	4 680	
	Demolition, backfill and closure	3 690	
SFL	Feasibility studies, technology development and safety analysis	560	**2 140**
	Investment	790	
	Operation and maintenance & reinvestment	420	
	Demolition and closure	360	
Interim storage facilities and near-surface repositories at the nuclear power plants	Investment, operation and demolition	-	-
SFR (operational waste)	Operation and maintenance & reinvestment	-	-
SFR (demolition waste)	Feasibility studies, technology development and safety analysis	420	**5 450**
	Investment	2 870	
	Operation and maintenance & reinvestment	1 750	
	Demolition and closure	410	
Decommissioning of nuclear power plants		23 830	**23 830**
Total basic estimate		100 120	**100 120**
Adjustment for EEF		5 740	
Allowance for unforeseen factors and risk		18 270	
Total remaining basic cost		**124 130**	

Rounding differences may occur.

5.3.2 Basis for financing amount

The financing amount forms the basis for one of the guarantees that licence holders must provide, in addition to the payment of fees. The cost basis for the financing amount is compiled using the supporting material provided by SKB (this report) and additional costs calculated by the Swedish National Debt Office. SKB calculates its part of the amount in the same way as the remaining basic cost, but the calculation only includes the quantities of residual products that exist when the calculation begins. For Plan 2022, this refers to the residual products that exist on 31 December 2023. This means, among other things, that the number of canisters will decrease to 4 378 compared with the 4 963 that forms the basis for estimation of the remaining basic cost.

The part of the financing amount that is based on SKB's calculations amounts to SEK 118.5 billion, which is SEK 5.6 billion lower than the remaining basic cost.

6 References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.

Lichtenberg S, 2000. Proactive management of uncertainty using the successive principle: a practical way to manage opportunities and risks. Copenhagen: Polyteknisk Press.

SKB, 2022. RD&D Programme 2022. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste. Svensk Kärnbränslehantering AB.

Arkitektkopia AB, Bromma, 2023

SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

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