Technical Report

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December 2019

Plan 2019

Costs from and including 2021 for the radioactive residual products from nuclear power

Basis for fees and guarantees for the period 2021–2023

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Svensk Kärnbränslehantering AB

This report is the English version of SKB Plan 2019. 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 the current regulations, it is the responsibility of the licence holders for the reactors to prepare a calculation of the costs for all measures that are needed to manage and dispose of spent nuclear fuel from the reactors and other radioactive residual products as well as for dismantling and demolishing the nuclear power plants. The regulations comprise the Act (2006:647) and Ordinance (2017:1179) on Financial Measures for the Management of Residual Products from Nuclear Activities. The cost calculation has to be submitted to the Swedish National Debt Office once every three years. SKB's owners have given SKB the task of preparing the aforementioned cost calculation jointly for the permit holders for the Swedish nuclear power plants.

This report, which is the thirty-first Plan report since the start with Plan 82, provides an updated summary of these costs. As in the earlier reports, the costs are reported both for the system in its entirety including management and disposal of radioactive operational waste and some waste that originates from others than the shareholders' power plants, as well as for the system with the limitations that follow from the regulations as above. The former costs have been based on a scenario for reactor operation based on the reactor owners' current plans, the latter on the reactors' operating time as stipulated in the regulations.

Solna, September 2019

Svensk Kärnbränslehantering AB

Eva Halldén

Eva Halldén
CEO

Summary

A company that is licenced to own a nuclear power plant is responsible for taking all the necessary steps to safely and securely manage and finalize spent nuclear fuel and radioactive waste and decommissioning nuclear power plants after completion of operations. The most important measures are planning, constructing and operating the facilities and systems that are needed for this purpose, as well as conducting the related research and development. The financing of these measures is based on the licence holders paying the fees into a fund, primarily during the time the reactors are in operation but also later, if this should be necessary.

How the financing is to be arranged is regulated in the Financing Act (2006:647) with associated Ordinance (2017:1179). A reactor owner is defined in the legislation as a holder of a nuclear licence who own or operate one or more nuclear power reactors that have not been permanently taken out of service prior to 1 January 1975.

A reactor owner with one or more nuclear power reactors in operation pays the fee in SEK per kilowatt-hour electricity generated. Today, this applies to Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. For Barsebäck Kraft AB, whose reactors have been permanently taken out of service, the fee is specified as an annual amount.

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

The future costs are based on SKB's current plans for the system's design and timeplan for its implementation. The current design is called the reference design and the plan of action in general is called the reference scenario. This report is based on the proposed focus of the operations as presented in SKB's R&D Programme 2019 (SKB 2019). The reference scenario reflects the nuclear power companies' current plans, which means that the operating time for the youngest reactors is planned to be 60 years, while the oldest are shutdown according to the adopted shutdown dates.

This report presents the cost calculation of the reference scenario and the basis for this to some extent. There are no requirements in the regulations for this type of report to be submitted to the Swedish National Debt Office, but since it serves as the basis for the other calculations, SKB considers its inclusion to be of value. This is done in Chapter 4. The cost report according to requirements in the Financing Act is found in Chapter 5.

In addition, a separate report is submitted to the Swedish National Debt Office containing the detailed information that the authority requires for its review and calculations. Among other things, the report provides information on how the costs are distributed across the four reactor owners.

The reference scenario covers 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 development of encapsulation and final disposal technology.

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

- Extension of SFR to also dispose of 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 factory and encapsulation facility for spent nuclear fuel adjoining Clab.
- Final repository for spent nuclear fuel, Spent Fuel Repository.

The costs according to the reference scenario not only cover costs for supporting functions, feasibility studies, technical development and analysis of post-closure safety, but also for SKB's central functions. Costs for feasibility studies, technical development, and analysis of post-closure safety are reported

under each final repository, i.e. the Spent Fuel Repository, the extended SFR and SFL. The cost for supporting functions comprise of costs for the functions portfolio management, requirement management, project and design support as well as administrative support. These costs are allocated to the relevant facility respectively. Costs for central support from SKB may include general functions such as corporate management, business support, communications, environmental protection, overall safety and security issues. Moreover, costs for decommissioning of the reactors, facilities at the nuclear power sites for interim storage and final disposal of spent nuclear fuel and radioactive waste are presented.

The Financing Act together with the ordinance stipulate a number of conditions that have an effect on the scenario that determines the scope of the calculation model used by SKB in the calculation of fee basis etc. Above all, this applies to the reactors' operating times, which form the basis for the assessment of the amount of spent nuclear fuel and radioactive waste as well as the requirement that any uncertainties regarding future development in different areas must be assessed. In order to meet the latter requirement, SKB has chosen to apply a probabilistic uncertainty analysis. Added to that, the calculation shall only cover residual products which, according to the Financing Act's definitions, exclude handling and disposal of operational waste. Among other things, this excludes the costs for SFR in its present function as a final repository for operational waste.

The amount of spent nuclear fuel and radioactive waste that will be managed and disposed of is linked to the operating time of the reactors. The fee-based operating time is specified in the regulations to 50 years. A minimum time is stipulated, meaning that a remaining operating time of at least six years shall be applied unless there are reasons to assume that operation could cease before then. The calculation of the fee, which is done by the authority, is then based on the electricity expected to be generated during the same period.

Apart from paying fees, a reactor owner has to pledge two types of guarantee. The first guarantee is to cover the fees adopted that have not yet been paid. The basis for this guarantee is called the financing amount. The calculation is carried out, in principle, in the same way as that for the fee basis, but the costs are limited to the management and disposal of the residual products that exist when the calculation commences, in this report 31 December 2020.

The second guarantee shall supplement the Financing amount should the means turn out to be insufficient. The basis for this guarantee is called the Supplementary amount. According to the new Financing Ordinance, the Supplementary amount is no longer included in the reactor owners' cost reporting.

The results of the calculation are presented below. The amounts are for future costs from and including 2021 and are given at the January 2019 price level.

The remaining Basic cost	SEK 110.0 billion
Basis for the financing amount	SEK 103.1 billion

Contents

1 Introduction

This report presents a calculation of the future costs for all measures that are needed to manage and dispose of the nuclear waste and the spent nuclear fuel from the Swedish nuclear power plants and to decommissioning them. According to Swedish legislation, the cost calculation has to be submitted to the Swedish National Debt Office every three years. On behalf of its owners, SKB prepares a joint cost calculation for the licence holders for the Swedish nuclear power plants.

In this report, the costs are presented for two scenarios, firstly according to the premises on which SKB plans its activities and, secondly, according to the conditions stipulated in the legislation. The former costs are based on a scenario concerning the nuclear power companies' current plans, the latter on the reactors' operating time as given in the regulations.

The report is structured as follows:

Chapter 1 provides background information concerning the financing system and current regulations.

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

Chapter 3 presents SKB's method for performing the cost calculations.

Chapter 4 presents the underlying reference calculation that is based on current plans for reactor operation and SKB's activities.

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

1.1 Premises

1.1.1 Obligations under the Nuclear Activities Act

According to the Act (1984:3) on Nuclear Activities (the Nuclear Activities Act, KTL), the licence holder for nuclear activities is responsible for ensuring the safe management of the nuclear waste and spent nuclear fuel arising from the activities. The responsibility includes planning, constructing and operating the facilities and systems that are needed as well as conducting research, development and demonstration that is required.

The licence holder for nuclear activities is also obliged, under the Nuclear Activities Act, to cover the costs for the measures that are needed for managing and disposing of radioactive waste and spent nuclear fuel as well as for decommissioning of the facilities. Licence holders for the nuclear activities in Forsmark, Oskarshamn, Ringhals and Barsebäck are Forsmarks Kraftgrupp AB, OKG Aktiebolag, Ringhals AB and Barsebäck Kraft AB.

Svensk Kärnbränslehantering AB is owned by Vattenfall AB, OKG Aktiebolag, Forsmarks Kraftgrupp AB and Sydkraft Nuclear Power AB. On behalf of its owners, SKB is responsible for management and final disposal of the nuclear waste and the spent nuclear fuel from the Swedish nuclear power plants.

1.1.2 The financing system and current regulations

According to the Act (SFS 2006:647) on Financing of Nuclear Residual Products (the Financing Act) and associated Ordinance (2017:1179) on Financing of Nuclear Residual Products (the Financing Ordinance), the licence holders for nuclear activities are obliged to pay a fee for the future waste management and decommissioning.

Licence holders with licences to own or operate one or more nuclear power reactors that have not been permanently taken out of service prior to 1 January 1975, are called reactor owners in the regulations. Thus, all licence holders for the nuclear power plants in Forsmark, Oskarshamn, Ringhals and Barsebäck are 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 reused and nuclear waste that arises at a nuclear facility after the nuclear facility is permanently taken out of service"*. The fee shall cover costs for the management and final disposal of residual products but, in contrast, not costs for management and final disposal of operational waste. The latter are financed directly by the reactor owner.

A reactor owner with one or more nuclear power reactors in operation pays the fee in SEK per kilowatt-hour electricity generated. Today, this applies to Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. For Barsebäck Kraft AB, whose reactors have been permanently taken out of service, the fee is specified as an annual amount.

Besides paying fees, a reactor owner has to provide for two types of guarantee, 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 the reactor owner does not fulfil his obligation to pay fees and the funds in the Nuclear Waste Fund are deemed to be insufficient.

A reactor owner, according to Section 8 of the Financing Ordinance, shall submit a cost calculation for the management and disposal of nuclear residual products to the Swedish National Debt Office. The calculation has to be submitted no later than September every three years. SKB's owners have given SKB the task of preparing this cost calculation for the reactor owners jointly.

The Swedish National Debt Office will then prepare proposals for nuclear waste fees and guarantees based on this information. The Government determines the fees and amounts forming the basis for the guarantee for the next three calendar years. If necessary, fees will be charged and guarantees provided both during the time the reactors are in operation as well as after permanent shutdown until the nuclear power plants are decommissioned and all residual products disposed of.

The fees are paid into the Government administered Nuclear Waste Fund. The assets in the fund are placed in an interest bearing account with the Swedish National Debt Office, bonds issued by the Government or issued according to the Covered Bond Issuance Act (2003:1223). Since December 2017, the Nuclear Waste Fund is also permitted to place funds in Swedish and global shares, corporate bonds as well as derivative instruments with the purpose of limiting risks and streamlining the administration of the funds. The reactor owners are entitled to withdraw money from the fund for their costs for fulfilling the majority of their obligations under the Nuclear Activities Acts.

1.1.3 Amounts to report under the Financing Act

The amount of spent nuclear fuel and radioactive waste that has to be disposed of is dependent on the reactors' operating times. In the cost calculation, each reactor, which has not been permanently shutdown, is considered to have a total operating time of 50 years, or a remaining operating time of at least six years. If there is specific reason to assume that the operation could cease at an earlier date, the expected operating time shall instead be determined based on that time.

In Section 5 of the Financing Act, four cost amounts are defined:

Basic cost – the annual anticipated costs for measures and activities as intended in Section 4, 1–3, of the Financing Act, i.e. the permit holders' costs for the safe management and final disposal of residual products, safe dismantling and demolition of nuclear facilities, as well as the required research and development activities.

Added cost – the annual anticipated costs for the activities as intended in Section 4, 4–9, of the Financing Act, e.g. the state's cost for R&D, management of funds, licensing, supervision, monitoring and control, as well as costs for information to the general public and support to non-governmental organisations.

Financing amount – an amount that for each permit holder is equivalent to the difference between, on the one hand, the remaining Basic costs and added costs for the residual products generated at the time the calculation was made and, on the other side, the permit holder's share in the nuclear waste fund.

Supplementary amount – an amount that supplements the Financing amount taking into consideration that it could turn out to be insufficient.

SKB shall report to the Swedish National Debt Office the total and remaining Basic cost and how large a part of this should be added to the basis for the financing amount.

The Added cost and Supplementary amount are calculated by the Swedish National Debt Office. The Added cost is primarily attributable to certain government costs connected with the supervision of SKB's and the nuclear power companies' activities concerning the final disposal of spent fuel as well as dismantling and demolition of the nuclear power plants and SKB's facilities. The Supplementary amount, according to the proposal for the new legislation, has to take into consideration to the uncertainties on both the asset and the liability side in contrast to the previous, where only uncertainties on the liability side 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 the spent nuclear fuel from the Swedish nuclear power plants. In addition, SKB accepts some radioactive waste from other companies. This is regulated by agreement between SKB and the companies concerned.

The waste system and the plan for implementing this are described in the R&D programme 2019 (SKB 2019). Parts of this information are reproduced below as background to the cost estimates that are presented in subsequent chapters.

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

The planning for the nuclear waste system is based on the reactor owners' current planning assumptions. During 2015, decisions were made about the premature shutdown of four reactors, Oskarshamn 1, Oskarshamn 2, Ringhals 1 and Ringhals 2, which were put into operation during the 1970s. Oskarshamn 1 and Oskarshamn 2 have been taken out of service, while Ringhals 1 and Ringhals 2 are planned to be taken out of service at the end of 2020 and 2019 respectively. For the other six reactors, the planned operating time is 60 years. This applies for the reactors Forsmark 1, Forsmark 2 and Forsmark 3, Oskarshamn 3 as well as Ringhals 3 and Ringhals 4. The youngest reactors, Forsmark 3 and Oskarshamn 3, will thereby be in operation until 2045 according to the plans the reactor owners have to day.

2.1 Description of the waste system

The Swedish system for managing and disposal of radioactive waste is divided into two main parts, one for the low- and intermediate-level waste and one for the 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), local facilities and near-surface repositories at the nuclear power plants as well as the ship, M/S Sigrid.

What still remains to be done for the final disposal of the spent nuclear fuel, is to construct and commission large parts of the system of facilities needed for the final disposal of spent nuclear fuel. This includes a new facility part for encapsulation of the spent nuclear fuel adjoining Clab (the integrated facility is called Clink), casks for transport of canisters containing spent nuclear fuel and a final repository for spent nuclear fuel.

For disposal of the low- and intermediate-level waste, SFR needs extending. Furthermore, an additional repository, the Final repository for long-lived waste (SFL), needs to be constructed and casks for transporting long-lived waste procured.

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

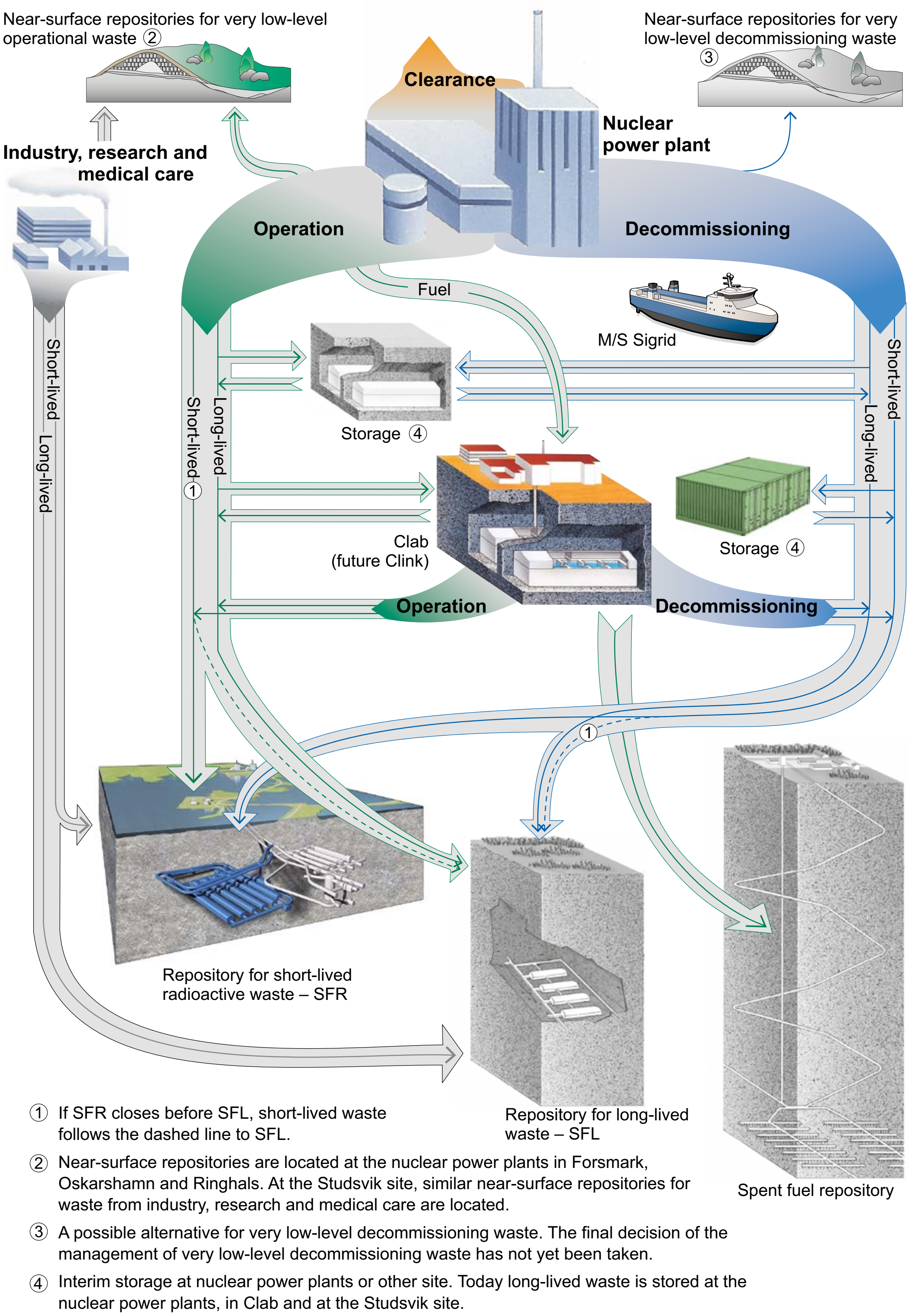

Figure 2-1. *The system for managing Sweden's radioactive waste and spent nuclear fuel. Solid lines represent the flows to existing or planned facilities. Dashed lines represent alternative handling routes.*

2.2 Facilities for low- and intermediate-level waste

2.2.1 Facilities for short-lived waste

Treatment of waste

At the nuclear power plants and at the Studsvik site, there are treatment facilities for short-lived low- and intermediate-level waste. Here, the waste is treated and packaged to comply with the requirements for disposal in SFR or in near-surface repositories. The purpose of the treatment may be releasing the material from regulatory control, reducing the volume, concentrating the activity, solidifying or conditioning the material.

Interim storage facilities

At the nuclear power plants there are facilities for interim storage of short-lived low- and intermediate-level waste. Today, these function as buffer storage for operational waste prior to further handling, such as processing and packaging prior to transport to SFR for disposal.

Dismantling and demolition of the first seven reactors[1] are planned to start before the extended SFR can receive decommissioning waste. This means that the existing interim storage capacity for short-lived waste, must be increased. A new interim storage facility for low-level waste could consist of a paved surface or a building for storage of ISO containers. Intermediate-level waste requires, a building with radiation shielding.

Near-surface repositories

Parts of the low-level waste inventory have very low activity. Today, this waste is disposed of in the near-surface repositories at the industrial sites at the nuclear power plants in Forsmark, Oskarshamn and Ringhals. According to current practise, it is a requirement that the area remains under institutional control for approximately 30 years after the last disposal of waste.

The existing near-surface repositories on the nuclear power sites are only licensed for operational waste. Currently, Ringhals has an application underway for a permit to extend its near-surface repository for operational waste. When it comes to decommissioning waste, feasibility studies are underway to analyse the possibility to extending the near-surface repository at Oskarshamn's nuclear power plant. The extension would then be licensed for both operational and decommissioning waste. Furthermore, the possibility of establishing a new near-surface repository for decommissioning waste at Ringhals is under investigation.

Final repository for short-lived radioactive waste

The SFR is located near Forsmark's nuclear power plant, see Figure 2-2. The repository is situated below the Baltic Sea, with approximately 60 metres of rock cover. From the port at Forsmark, two one-kilometre-long access tunnels lead to the repository area. The facility consists of four 160-metre-long rock vaults and a 70-metre-high rock cavern in which a concrete silo has been built. The facility has a licensed storage capacity of 63 000 cubic metres.

The post-closure safety of the SFR is based on *limiting* the quantity of long-lived nuclides in the repository and *retardation* of radionuclides in the engineered and natural barriers. The design of each waste vault is adapted based on the level of activity of the waste that is disposed of in it. Low-level waste is disposed of in one of the four rock vaults. Intermediate-level waste with low levels of activity is diposed of in two of the rock vaults. Intermediate-level waste with higher activity is disposed of in the fourth rock vault or in the concrete silo. The silo will contain most of the activity in SFR.

The waste in SFR derives primarily from the nuclear power plants, Clab, the Studsvik site, and Ågesta, while a smaller proportion originates from industry, medical care and research. At the end of 2018, 40 000 cubic metres of waste had been disposed of.

When SFR was built, the intention was the facility would receive waste until 2010. As the nuclear power reactors have been operated longer, SFR's operational phase will run for a longer time than was originally intended, which entails new demands on the maintenance of the facility.

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

At present, only operational waste is disposed of in SFR. SFR's storage capacity will be extended to provide space for additional short-lived waste from both operation and decommissioning. Therefore SKB has applied for extending the facility by approximately 117 000 cubic metres' storage capacity to hold a total of approximately 180 000 cubic metres of waste. Figure 2-3 shows SFR as it will appear, according to current plans, when it is fully extended.

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

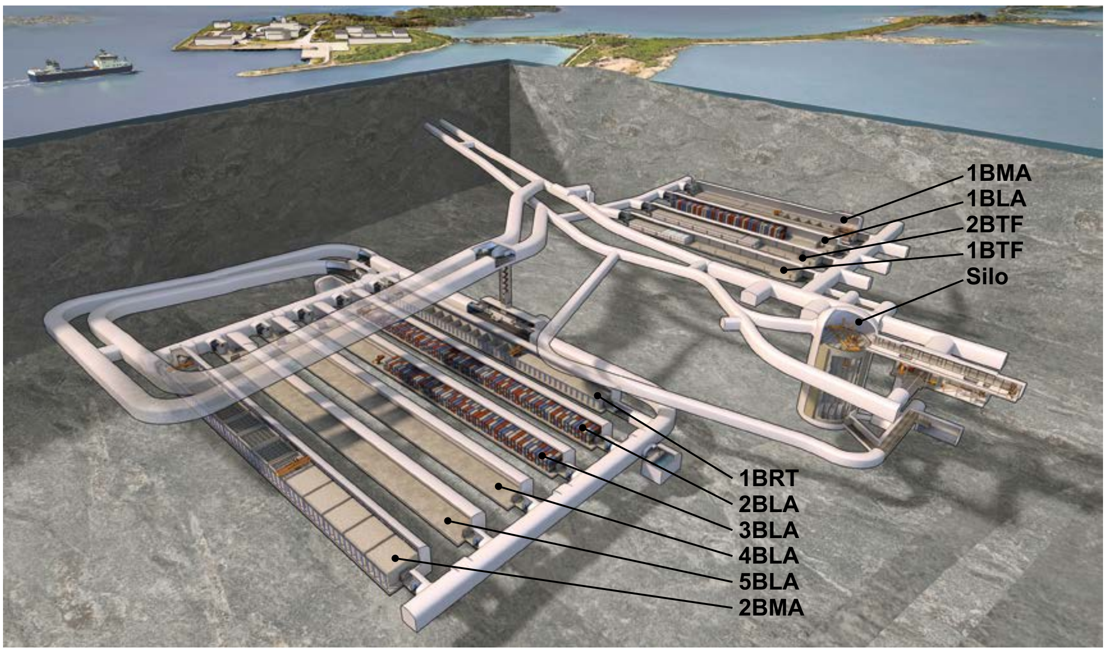


Figure 2-3. When SFR is fully extended, it will consist of a further six rock vaults; four rock vaults for low-level waste (2–5BLA), a rock vault for intermediate-level waste (2BMA) and a rock vault for reactor pressure vessels (1BRT).

2.2.2 Facilities for long-lived waste

Treatment of waste

It is currently possible at the nuclear power plants to segment used core components in order to then place them in steel tanks for local interim storage. That was previously done when upgrading the reactors, but is now primarily performed as a part of the decommissioning projects. The reactor pressure vessels internals from Barsebäck 1 and Barsebäck 2 are segmented. Corresponding work has also been performed on Oskarshamn 2, while segmentation is underway at Oskarshamn 1. This is planned to be completed by the spring of 2020.

Interim storage facilities

The final repository for long-lived waste, SFL, is planned for commissioning sometime around 2045. Until then, the long-lived waste needs to be in interim storage. Currently, the greatest part of the long-lived waste is 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 with long-lived operational waste (control rods from BWRs and other core components) are also in interim storage in the pools. In order to increase the capacity for interim storage of spent nuclear fuel in Clab, SKB is planning to segment the BWR control rods that are in interim storage in Clab to reduce the volume taken up by the control rods. Afterwards, these will be stored once again in Clab until they can go for final disposal.

Long-lived waste produced during decommissioning of the first reactors is deemed to be possible to accommodate in existing interim storage facilities at the power plants or at another site.

Final repository for long-lived waste

SKB is planning to dispose of the long-lived waste at a relatively large depth. This final repository (SFL) will be the last final repository in the nuclear waste system to be commissioned. Siting of the repository has yet to be decided. The storage capacity of SFL will be relatively small compared to SKB's other final repositories. The storage capacity required is estimated to be approximately 16 000 cubic metres.

The development of the repository is yet at an early stage. SKB has developed a repository concept consisting of two waste vaults; one for core components and segmented PWR reactor pressure vessels from the nuclear power plants and one for legacy waste. The post-closure safety for the proposed repository concept for SFL is based on 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 main part of the radioactivity. For core components SKB is planning to design the waste vault with an engineered barrier of concrete.

The legacy waste is stored and managed by AB SVAFO and Studsvik Nuclear AB in Studsvik. Further waste comes from Cyclife Sweden AB, Swedish research, industry and medical care. For this waste vault, SKB proposes that the engineered barrier will consist of bentonite. The repository concept is illustrated in Figure 2-4.

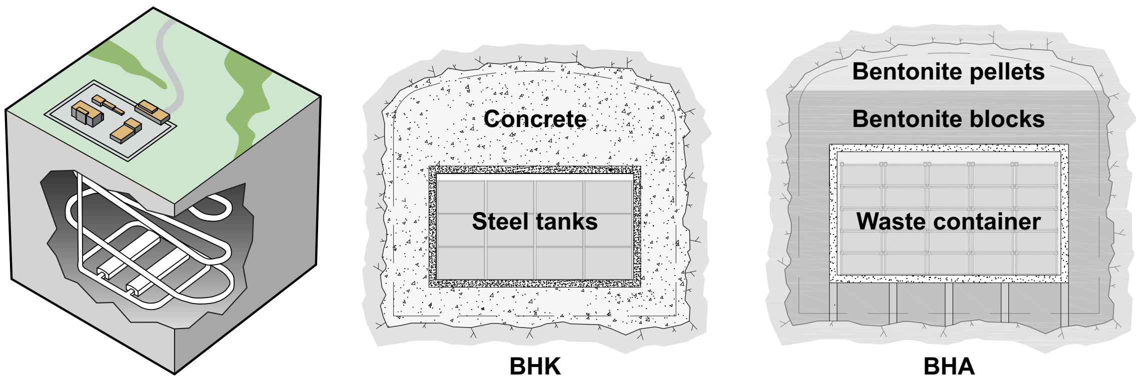


Figure 2-4. Preliminary design (on the left) and proposed repository concept for SFL with a rock vault for core components and segmented PWR reactor pressure vessels (BHK) and a rock vault for legacy waste (BHA).

2.3 Facilities in the KBS-3 system

Central interim storage facility for spent nuclear fuel

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

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

The actual storage chamber consists of two rock caverns with a separation of approximately 40 metres, which are connected by a water-filled transport canal. Each rock cavern is roughly 120 meters long and contains four storage pools and a reserve pool. The top edge of the fuel is eight metres below the surface of the water. At the pool edge, the radiation level is so low that the personnel do not need to use radiation protection.

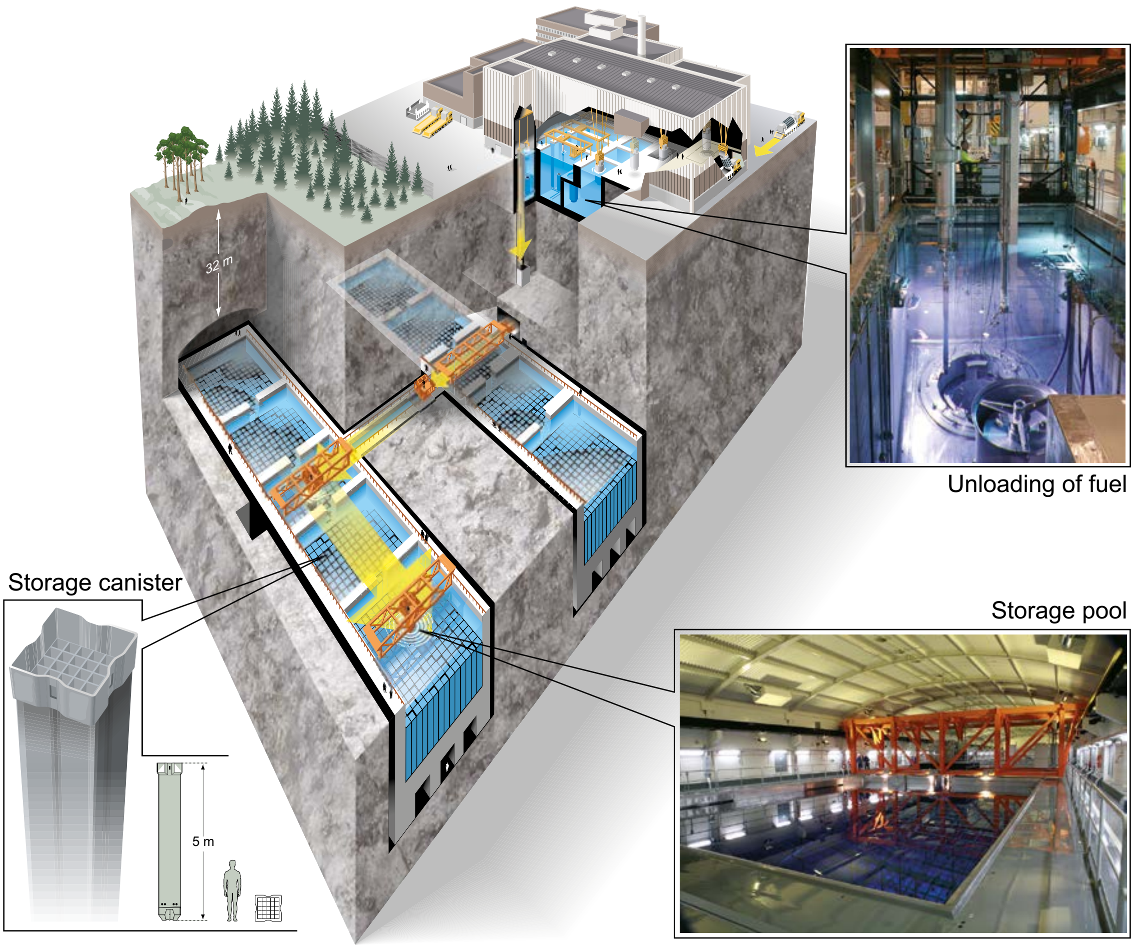


***Figure 2-5.** The central interim storage facility for spent nuclear fuel, Clab.*

Clab has now been in operation for more than 30 years, and system upgrades and the replacement of components will be necessary in the future. A number of projects are underway, or have recently been completed, including upgrading the cooling chain to increase the cooling capacity, replacement of fire alarm systems and adjustments in the facility to enable the reception of a new type of transport cask.

At the end of 2018, there were 7002 tonnes of fuel (counted as the original quantity of uranium) in the facility. SKB has a licence for storing 8000 tonnes of fuel in Clab. According to current forecasts it is estimated that the allowed amount will be reached around 2023/2024. The pools can accommodate a total of approximately 11000 tonnes of fuel on the condition that the core components that are currently stored in Clab are removed from the facility and stored at another location. During 2015, SKB applied, according to the Nuclear Activities Act and the Environmental Code, to increase the licenced storage to 11000 tonnes of fuel. This is being handled as a part of the application for the entire KBS-3 system. The application in its entirety is now with the Government for a decision on permissibility and licences.

Central facility for interim storage and encapsulation of spent nuclear fuel

Before the spent nuclear fuel is disposed of, it will be encapsulated in copper canisters. SKB is planning to do this in a new part of the facility adjoining Clab, see Figure 2-6. When this encapsulation section has been connected to Clab, both sections of the facility will be operated as an integrated facility, Central facility for interim storage and encapsulation of spent nuclear fuel, Clink.

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

The canister's components, such as insert, copper shell and lid, will be produced by various subcontractors. A facility will be needed for final machining, assembly and inspection of the canister components. This will not be a nuclear facility.

The encapsulation section will contain a number of stations for different operations, where all handling of the fuel is done remotely and with radiation shielding. The encapsulation process starts by placing the fuel in a transport canister and taking it up in the fuel elevator from the underground storage pools.

The fuel assemblies that will be placed together in a canister are selected so the total decay heat in the canister will not be too high. The selected fuel assemblies are dried in a radiation-shielded handling cell and lifted into the canister. The air in the canister is replaced by argon before it is sealed. The copper canister is sealed using friction stir welding (FSW). Inspection is conducted on the weld's surface and whether the weld parameters have been kept within the applicable limits. If the weld is approved, the canister is moved on to the machining station, where the canister is machined to its final dimensions. The canister is then taken to the next station where the sealing weld is checked using non-destructive testing. If necessary, the canister is cleaned before it is placed in a special transport cask for transport to the Spent Fuel Repository. Clink is designed to fill and seal 200 canisters a year.

Once all fuel and other waste in interim storage in the facility has been removed, the parts above ground will be decommissioned as will the parts of the storage pools that have become radioactive. The radioactive decommissioning waste will be transported to SFR.

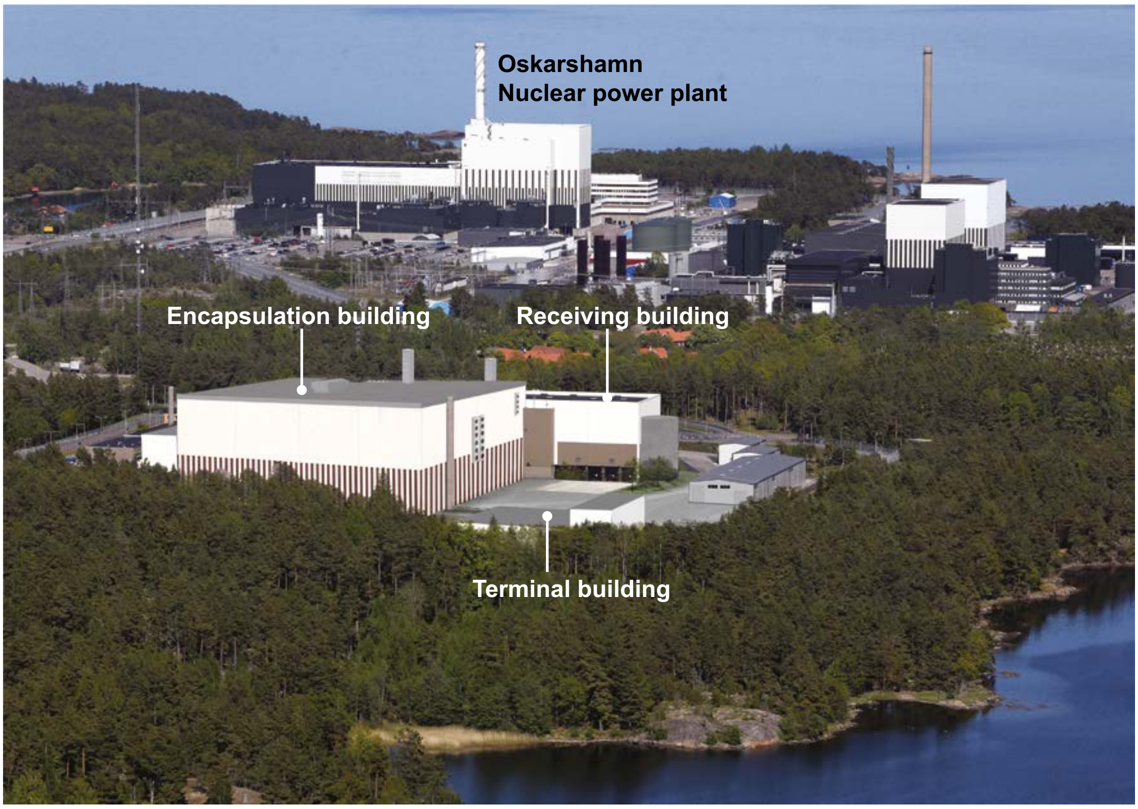


Figure 2-6. *Photomontage showing the integrated facility for interim storage and encapsulation of spent nuclear fuel, Clink.*

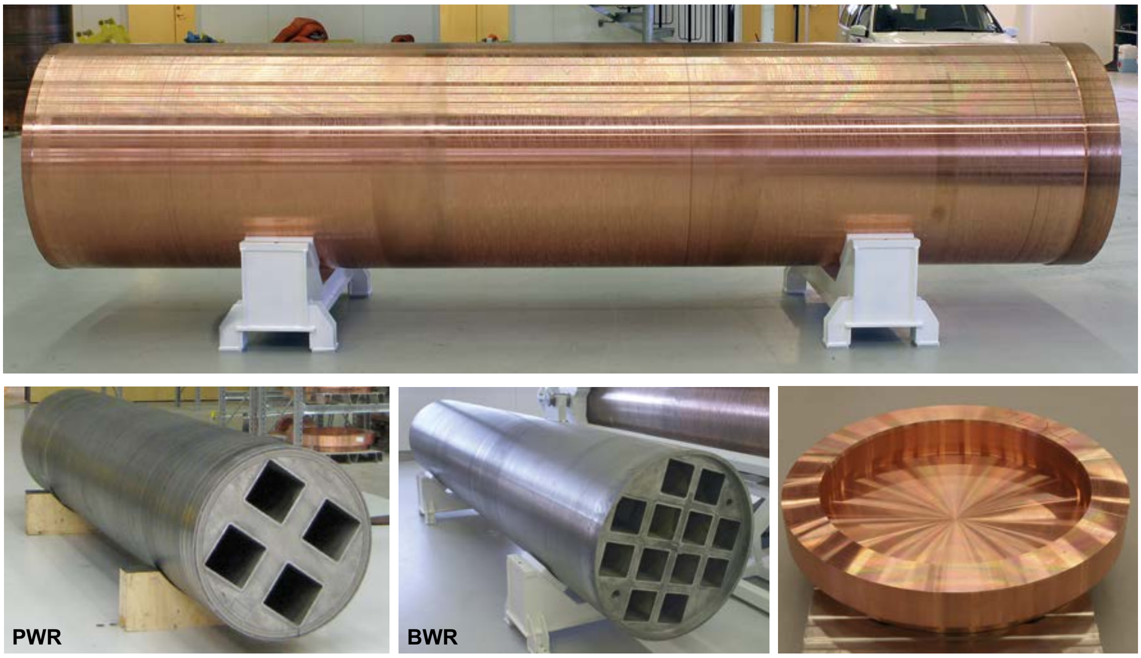


Figure 2-7. *Copper canister with nodular cast iron inserts for PWR and BWR and copper lid. The canister's length, diameter and copper thickness are 4 835 mm, 1 050 mm and 50 mm respectively. A canister with a BWR insert weighs a total of approximately 24.6 tonnes, of which the copper weighs 7.4 tonnes, the insert 13.6 tonnes and fuel assemblies 3.6 tonnes.*

The Spent Fuel Repository

The work to find a suitable site for a final repository for spent nuclear fuel took several decades. At the end of the site selection process, the choice stood between the Forsmark site in Östhammar Municipality and the Laxemar site in Oskarshamn Municipality. After evaluation of the site investigations, SKB selected the Forsmark site for the Spent Fuel Repository. The rock at the Forsmark site was considered to provide better conditions for post-closure safety. Post-closure safety of the Spent Fuel Repository is based primarily on complete containment of the spent nuclear fuel in copper canisters and secondarily on retardation of radionuclides in the surrounding clay and rock barriers, in case of canister failure.

The final repository will consist of a facility above ground and an underground facility, see Figure 2-8. The underground facility consists of a central area and a number of deposition areas as well as connection to the surface facility in the form of a ramp for vehicle transports and shafts for elevators and ventilation. The deposition areas, which together comprise the repository area, will be approximately 470 metres below ground level and consist of a large number of deposition tunnels with drilled deposition holes at the floor of the deposition tunnels. The placement of the deposition tunnels, as well as the separation between the deposition holes and the design of the infrastructure at the repository level, is determined based on the rock's properties, for example, the location of large deformation zones, presence of long or highly water-conducting fracture zones and the rock's thermal conductivity. The surface facility consists of operational areas, rock heap, possible ventilation stations and storages.

The facility is designed for a total quantity of spent nuclear fuel equivalent to approximately 6 000 canisters, with a deposition capacity of 200 canisters a year. However, the forecasts of the reactor owners are for a lower quantity of spent nuclear fuel, equivalent to 5 600 canisters. The canisters are transported to the deposition level via the ramp using a specially constructed transport vehicle. They are then transloaded to a deposition machine for transport to the deposition area where they are finally deposited. Once the canisters are placed in the deposition holes, surrounded by bentonite clay, the tunnels are backfilled with clay that will swell upon contact with water and sealed with a concrete plug. When all of the fuel has been deposited, the other spaces are backfilled and the surface facilities decommissioned.

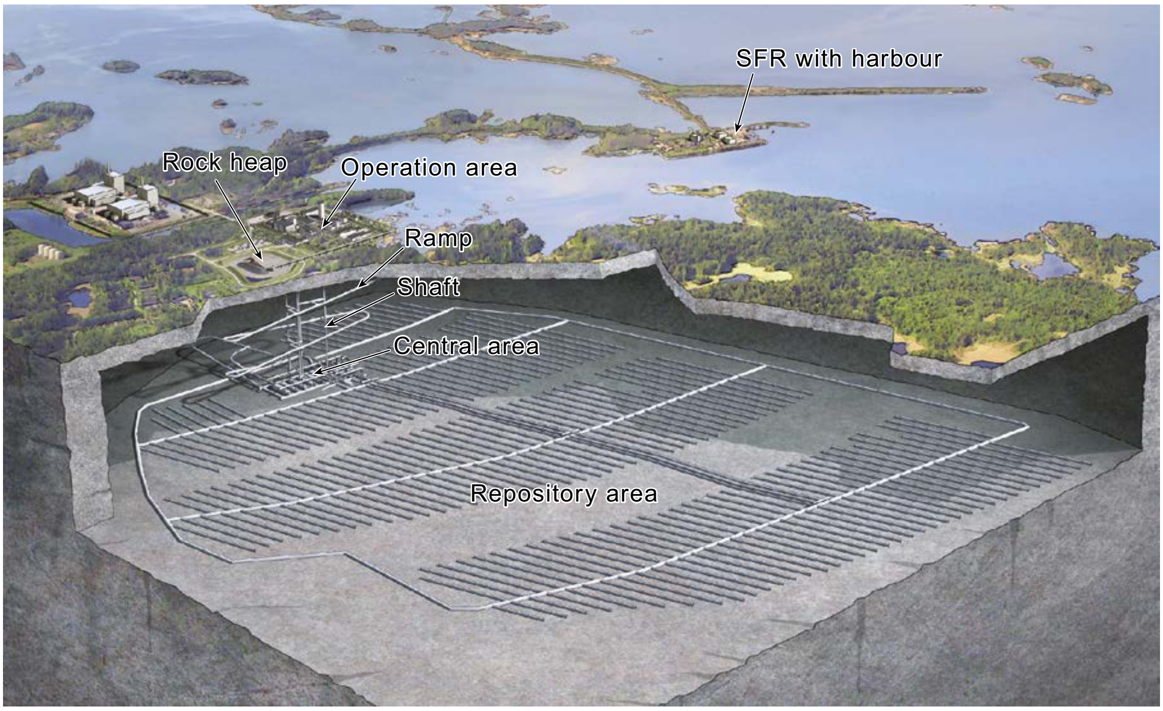


***Figure 2-8.** Illustration of the possible design for the Spent Fuel Repository in Forsmark.*

2.4 The transport system

SKB's transport system was constructed during the 1980s and has been developed continuously. It consists of the ship M/S Sigrid, special vehicles for overland transports and various types of transport casks and containers for fuel and radioactive waste. The ship and the vehicles are used for transporting both low- and intermediate-level waste as well as spent nuclear fuel. The different transport casks and containers have been specifically developed for the type of waste for which they are intended.

M/S Sigrid was taken into operation in 2014. She replaced M/S Sigyn, which was used for transports for approximately 30 years. The new ship, like the old one, has a double bottom and a double hull. This design protects the load in the event of grounding or collision. She holds twelve fuel- or waste casks. Normally, the ship, which is operated on contract, makes around 20 trips a year between the nuclear power plants, the Studsvik site, SFR and Clab.

The 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, for this reason, can be transported in ISO containers. Intermediate-level waste, in contrast, requires radiation shielding and most of it is embedded in concrete or bitumen at the nuclear power plants. The waste is transported in transport casks with steel walls 7–20 centimetre thick, depending on how radioactive the waste is, see Figure 2-9.

Today, some of the long-lived waste, control rods from BWRs, is transported from the nuclear power plants to Clab. They are transported in a transport cask with steel walls approximately 30 centimetres thick. The spent nuclear fuel is also transported from the nuclear power plants to Clab in casks with steel walls approximately 30 centimetres thick. Moreover, these casks are provided with cooling fins to radiate away the decay heat generated by the fuel.

2.5 Plan of action

Safe operation of existing facilities is a fundamental condition for the work with the system for management and final disposal of spent nuclear fuel and radioactive waste. In addition, work is underway to erect and commission new parts and facilities together with preparations for decommissioning the nuclear power plants.

SKB's plans for constructing and commissioning new and extended facilities in the system for managing spent nuclear fuel and radioactive waste as well as the research and technical development that is needed to perform this is presented in the R&D program 2019 (SKB 2019). The nuclear power companies' and SKB's plans for decommissioning nuclear facilities are also presented therein.

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

SKB's planning for new facilities involves a stepwise decision process that is based on SSM's regulations. The regulations state, that development and licensing of nuclear facilities shall take place through a process in which the requirements on the facility, its design and technical solutions are gradually established. 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. The most important milestones, which are in common for all the planned facilities, are:

- A licence under **the Nuclear Activities Act and permissibility under the Swedish Environmental Code to construct, own and operate a new nuclear facility** – on the basis of a Preparatory Preliminary Safety Analysis Report (F-PSAR) and an Environmental Impact Statement (EIS). During licensing, the applications are reviewed by SSM and the Land and Environment Court. The concerned municipality must approve the activities. The Government grants approval under the Environmental Code and issues licences under the Nuclear Activities Act (KTL). After this, the Land and Environmental Court issues licences and conditions according to the Environmental Code.
- **Approval to begin construction** – when a licence has been obtained under the Nuclear Activities Act, an application for construction, including a number of documents, PSAR included, must be submitted to SSM to obtain approval allowing the start of construction.
- **Approval of the safety analysis report (SAR) prior to trial operation and regular operation respectively** – based on continuous presentations of an updated and supplemented safety analysis report (SAR). The SAR must be approved by SSM.
- **Approval of the SAR prior to closure of the repository** – based on a revised safety analysis report (SAR) and a plan for closure and decommissioning. This report must also be approved by SSM.

The operating period for a final repository begins with trial operation, which means that radioactive waste is disposed of. After trial operation, the operations shift to a management phase during regular operation. The holder of a licence to own or operate a nuclear facility must at least every ten years submit a new, systematic, overall evaluation of safety and radiation protection. In conjunction with these evaluations, a review and compilation of the level of knowledge in the areas that are essential for the radiation safety are also carried out.

Figure 2-10 shows the general timeplan, including the times for coming applications, for the nuclear waste programme.

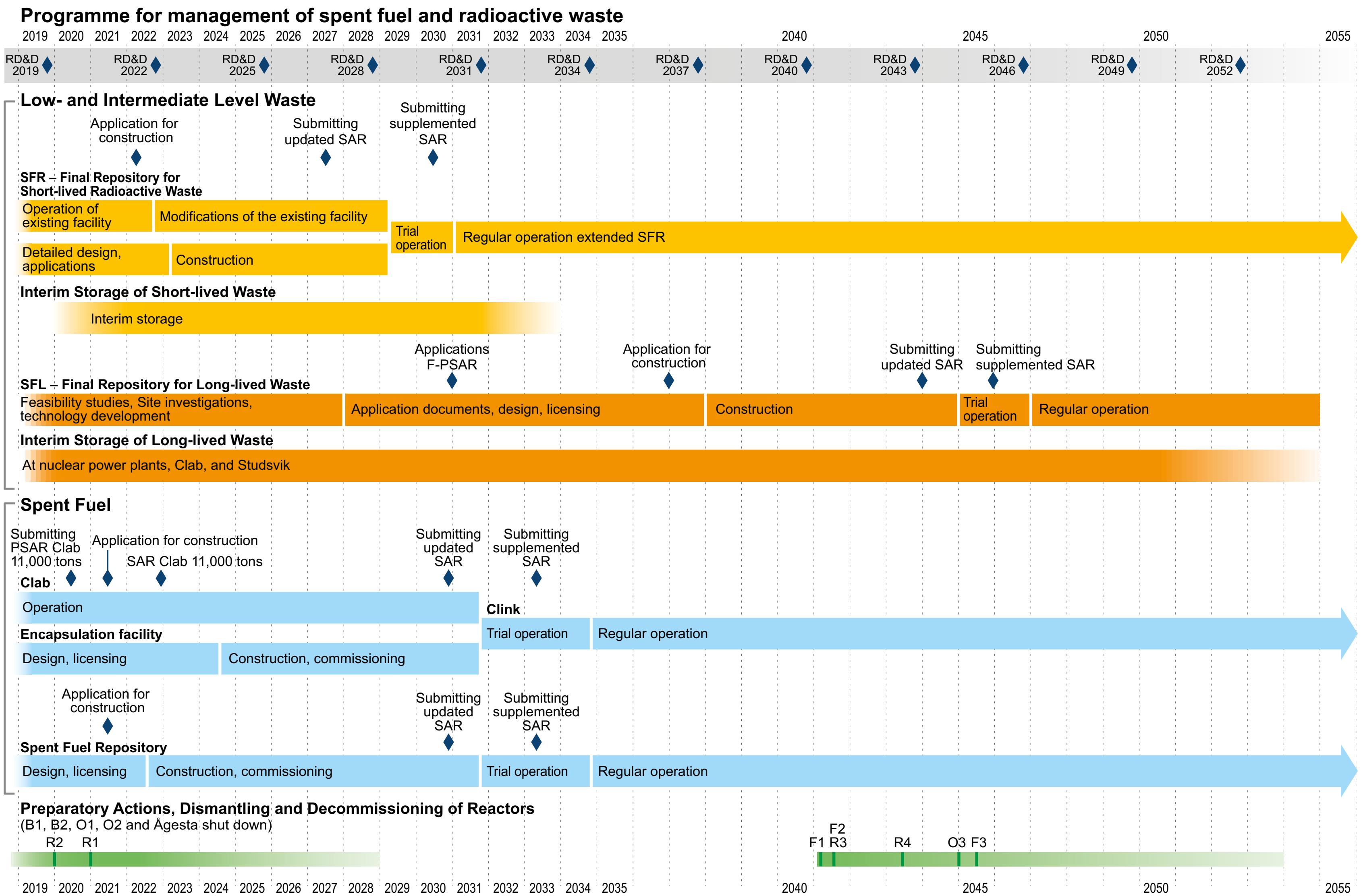
2.5.1 Plan of action for very low-level waste

Today, most very low-level operational waste is processed and kept in interim storage locally at the power plants or at another site. The waste from Forsmark, Ringhals and Oskarshamn is deposited batchwise in the local near-surface repositories. There is no near-surface repository at Barsebäck. For this reason, the very low-level waste is deposited in SFR (in the rock vault for low-level waste, BLA).

Today's near-surface repositories are only licensed for operational waste. Ringhals AB has applied for a permit to extend its near-surface repository for operational waste. The application is currently being considered by SSM.

Since large volumes of very low-level decommissioning waste will be generated, the reactor owners also see a need to deposit this waste in near-surface repositories. Today, feasibility studies are underway to analyse the possibility for expanding the near-surface repository at Oskarshamn. The extension would then be licensed for both operational and decommissioning waste. An investigation is also underway to examine the possibility of depositing waste from Barsebäck in the near-surface repository at Oskarshamn. The possibility of establishing a new near-surface repository for both operational and decommissioning waste at Ringhals is also under investigation.

One alternative to near-surface repositories is deposition of the very low-level decommissioning waste in SFR. Another alternative under investigation is whether parts of the waste could be incinerated in conventional waste incineration facilities. A prerequisite for the procedure is that the residual products that are generated can be released from regulatory control.



Clab	Central Interim Storage Facility for Spent Nuclear Fuel
Clink	Central Interim Storage Facility and Encapsulation of Spent Nuclear Fuel
RD&D	Programme for research, development and demonstration
F-PSAR	Preparatory Preliminary Safety Analysis Report
PSAR	Preliminary Safety Analysis Report
SAR	Updated safety report for approval to start regular operation Supplemented safety report submitted for approval to start regular operation
SFL	Final Repository for Long-lived Waste
SFR	Final Repository for Short-lived Radioactive Waste

B1 Barsebäck 1*	O1 Oskarshamn 1*
B2 Barsebäck 2*	O2 Oskarshamn 2*
Ågesta*	O3 Oskarshamn 3
F1 Forsmark 1	R1 Ringhals 1
F2 Forsmark 2	R2 Ringhals 2
F3 Forsmark 3	R3 Ringhals 3
* Shut down	R4 Ringhals 4

Figure 2-10. *Overall timeplan for SKB's nuclear waste programme and plans for decommissioning the reactors.*

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

The final repositories that SKB is planning to establish for low- and intermediate-level waste include an extension of SFR and construction of SFL.

At the end of 2014, SKB submitted an application under the Nuclear Activities Act and the Environmental Code to extend SFR for operational and decommissioning waste. Currently, the licencing processes are in progress. Supplementary information for the applications was submitted during 2015–2017. In December 2017, SSM and the Land and Environmental Court at Nacka District Court announced the licence application to construct an extension of SFR. In the new facility, mainly decommissioning waste will be disposed of. In January 2019, SSM informed the Land and Environmental Court that the application to extend SFR complies with the Environmental Court's requirements for permissibility. Main hearing in the Land and Environmental Court takes place in the autumn 2019.

According to SKB's current planning, which has been adapted to the fact that the licensing of the applications is estimated to take longer that previously assumed, the extension of SFR is expected to start in 2023, with a planned trial operation 2029, see Figure 2-10. The facility is planned to be in operation until 2069, when the decommissioning can be started.

The decisions on the premature closure of four reactors affect the plan of action for low- and intermediate-level waste through an increased need for interim storage, since the extended SFR has not been commissioned at the time these reactors will be decommissioned. Some of the reactor owners therefore intend to arrange temporary interim storage facilities for short-lived decommissioning waste until the extended SFR has been commissioned. There will also be a need for interim storage of operational waste during the period when the extension of SFR is underway.

SFL is planned to be commissioned in 2045. Since most of the reactors according to current planning will be decommissioned before this, the long-lived decommissioning waste will need to be interim stored locally at the power plants or at another location.

SKB is planning to submit licence applications, according to the Nuclear Activities Act and the Environmental Code, for permission to construct, own and operate SFL sometime around 2030. In order to meet the needs of the nuclear power companies, SFL is estimated to be in operation for approximately ten years.

2.5.3 Plan of action for spent nuclear fuel

In the coming years, SKB will successively prepare the construction of the Spent Nuclear Fuel Repository and the encapsulation part of Clink. The majority of the milestones shown in Figure 2-10 refer to deliveries of results from research and technical development, i.e. the times when technical components and solutions should be ready for commissioning or reached a given phase of development and when the safety analysis reports should be submitted.

The applications under the Nuclear Activities Act for construction, ownership and operation for a nuclear facility for final disposal of spent nuclear fuel and under the Environmental Code for the KBS 3 system were submitted in 2011. The activities that will lead to the construction, operation and deposition are presented there. The applications also include results from analyses of the safety during operation and after closure. SKB has submitted six supplements to the Land and Environmental Court based on the opinions received from the consultation round. SKB has also replied continuously to SSM's questions and requests for supplementary information and clarification.

An application under the Nuclear Activities Act for the encapsulation facility was submitted in 2006. The application was supplemented in 2009 regarding a merger of the encapsulation facility with Clab to give an integrated facility, Clink. In 2011, a further supplement was made with those parts concerning the KBS-3 system. During its review of the application, SSM requested supplementary information in 2012. SKB responded by submitting an update of the preparatory preliminary safety analysis report at the end of 2014 and supplements to the applications to both SSM and the Land and Environmental Court in March 2015. The last named supplement, also included an additional application to increase the interim storage in Clab to 11 000 tonnes spent nuclear fuel.

Announcement of the applications under the Environmental Code and the Nuclear Activities Act was made in January 2016. The main hearing in the Land and Environmental Court was held in autumn 2017 and January 2018, both SSM and MMD submitted their statement to the former Ministry of Environment and Energy (from 1 April 2019, the Ministry of Environment). In letters from the department, 1 June 2018, SKB was given the opportunity to supplement the case according to the issues identified by the Land and Environmental Court regarding the canister's properties and the post-closure safety (forms of corrosion and other processes). In June 2018, Oskarshamn Municipality made a positive decision regarding their veto right and approved the construction of Clink. SKB replied in April 2019 to the request for supplementary information to the Ministry of Environment.

The establishment of the Spent Fuel Repository and Clink is divided into the following main phases: licencing (and design), construction and commissioning.

According to the plans, the construction of the Spent Fuel Repository's accesses can start 2022. The construction of Clink starts approximately 2024, allowing the facilities to be commissioned simultaneously in 2031. The Spent Fuel Repository and Clink are planned to be in operation until the end of 2065. Thereafter, the Spent Fuel Repository is closed and the facilities dismantled and demolished.

SKB has a licence for the interim storage of 8 000 tonnes of fuel in Clab. According to today's forecasts, this stored quantity is estimated to be reached approximately 2023/2024, i.e. before Clink and the Spent Fuel Repository have been commissioned. The pools in Clab can accommodate a total of 11 000 tonnes of fuel on the condition that the core components that are currently stored in Clab are removed. During 2015, SKB supplemented the KBS-3 application for Clab and Clink. The supplement was part of an additional application to extend the licenced storage capacity in Clab to 11 000 tonnes of spent nuclear fuel. This is being handled as a part of the application for the entire KBS-3 system. The application in its entirety is now with the Government for a decision on permissibility and licences.

According to current plans, the trial operation of the Spent Fuel Repository and Clink will start approximately 2031. In connection with this, the unloading of the fuel from Clab can also commence. In order to be able to receive the spent fuel generated up to this time requires, apart from increasing the permit specified storage capacity, measures to free up storage room for fuel. If no other measures are implemented, the storage positions will be filled by around 2028. To increase the physical storage capacity for the fuel, SKB is planning to segment the control rods from the BWR reactors, which currently requires large storage capacity. After segmentation, the control rods can be packed more tightly in new storage canisters and then be returned to Clab's storage pools.

SKB is planning to start segmenting the control rods from the BWR reactors in the mid-2020s. For the control rods that are currently stored in Clab, this work will take approximately five years. For new control rods, the segmentation is carried out successively when they arrive for interim storage. By means of this measure, the storage space is estimated to suffice until approximately 2034.

2.5.4 Plan of action for decommissioning reactor facilities

Decommissioning of a reactor facility includes many activities to release the facility from regulatory control (clearance). Prior to decommissioning, the necessary licences must be available. When a facility is finally shutdown, the defueling operation starts where all fuel is transported from the reactor to Clab for interim storage. If necessary, a shutdown operation follows, while awaiting start of dismantling and decommissioning. During defueling operation/service operation, a number of preparatory measures are permitted to commence. The measures are controlled by the developed licence conditions and their purpose is to prepare the facility for dismantling and demolition. The nuclear power companies are planning to start dismantling and demolishing the facility as soon as possible after permanent shutdown. When the facility and/or facility parts have been released from regulatory control, conventional demolition and restoration of the ground will be carried out.

Because the dismantling and demolition of Barsebäck 1, Barsebäck 2, Oskarshamn 1, Oskarshamn 2, Ringhals 1, Ringhals 2 and Ågesta will commence before the extended SFR and SFL are ready to receive short and long-lived decommissioning waste, the licence holders need to keep the waste in interim storage locally at power plants or at another site.

Figure 2-11 below shows the overall planning for decommissioning of all nuclear power plants.

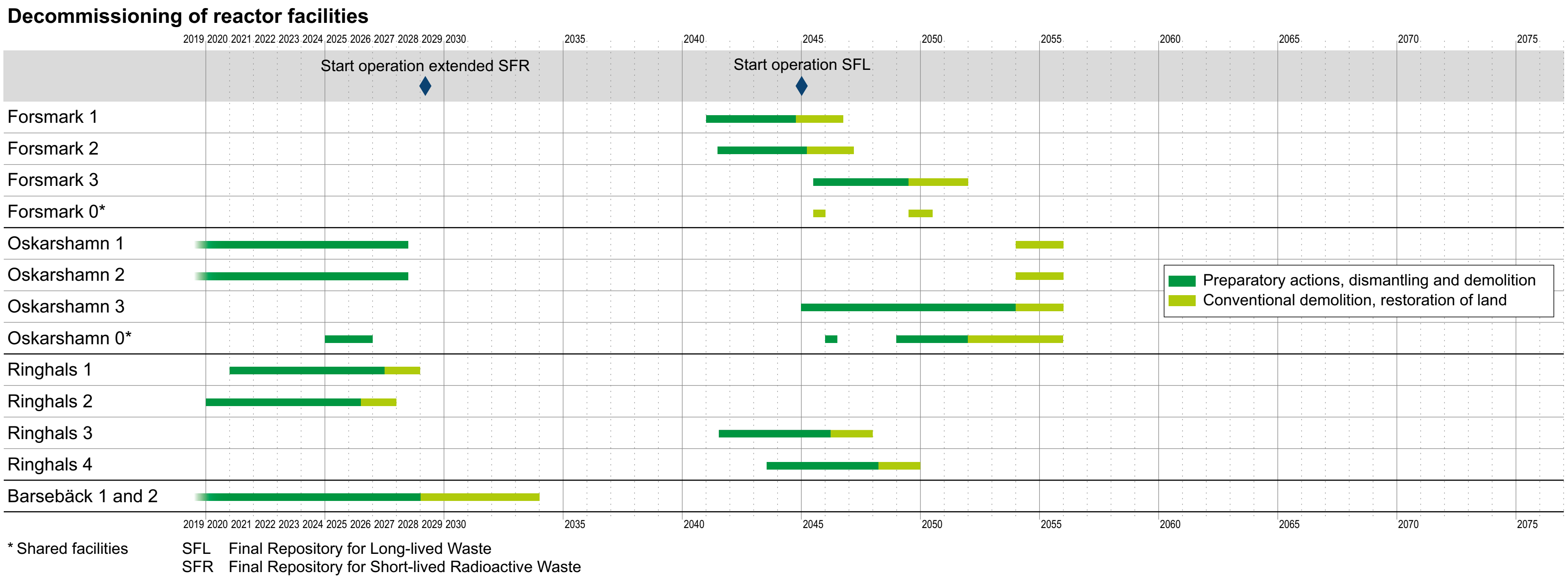


Figure 2-11. *Overview of the nuclear power companies' timeplans for decommissioning reactor facilities (Forsmark O and Oskarshamn 0 respectively refer to shared service facilities on the nuclear power sites).*

Barsebäck Kraft AB has segmented the internals of the reactor pressure vessels from the reactors Barsebäck 1 and Barsebäck 2. Necessary licences have been obtained for dismantling and demolition. Preparatory measures required for dismantling and demolition have been completed. Dismantling and demolition of the nuclear power plant starts in 2020 and clearance is planned to start at the end of the 2020s and to be completed in the 2030s.

OKG Aktiebolag has started dismantling and demolishing the reactors Oskarshamn 1 and Oskarshamn 2, where a number of preparatory measures have been taken. Segmentation of the reactor internals has been completed at Oskarshamn 2 and is now underway at Oskarshamn 1. This is estimated to be completed during the spring of 2020. Dismantling and demolition will start during 2020. Final clearance of the buildings is planned to around 2028. Oskarshamn 3 is planned to remain in operation until 2045, when the decommissioning will commence. The clearance of Oskarshamn 3 is planned to be completed around 2053.

Ringhals 1 and Ringhals 2 are planned to be shutdown permanently at the end of 2020 and 2019 respectively. Ringhals 3 and Ringhals 4 are planned to remain in operation until 2041 and 2043 respectively. According to current plans, the BWR reactor pressure vessel from Ringhals 1 will be segmented. There is also a strategic decision to segment the PWR reactor pressure vessel from Ringhals 2. For Ringhals 3 and Ringhals 4, this is still an open question. In the reference calculation, it is assumed that all PWR reactor pressure vessels are segmented.

All of Forsmark Kraftgrupp AB's reactors are planned to operate for 60 years in total, which means that Forsmark 1 will be shut down in 2040, Forsmark 2 in 2041 and Forsmark 3 in 2045. The nuclear power plant is planned to be decommissioned in its entirety around 2051.

The decommissioning of Clink and the Spent Fuel Repository can commence at the earliest once all of the spent nuclear fuel has been disposed of, while the decommissioning of SFR can commence no earlier than when the waste from the decommissioning of Clink has been disposed of. SFL can be decommissioned when the long-lived waste from the last reactor has been disposed of. The closure of SFL presumes that the decommissioning waste from Clink does not contain any long-lived waste.

2.5.5 Plan of action for transports

The transport system's tasks are to provide transportation of spent nuclear fuel from the Swedish nuclear power plants to Clab in Oskarshamn, and transportation of radioactive waste from the nuclear power plants and the Studsvik site to SFR in Forsmark. The majority of the transports are carried out using the ship M/S Sigrid and the remainder with terminal vehicles by land. Currently, M/S Sigrid makes approximately 20 trips per year.

The transport system will be supplemented with a new type of transport cask (ATB 1T) for the transport of long-lived waste in steel tanks. According to the plans, this will be delivered during summer 2020.

The transport system will also be upgraded with new fuel transport casks that comply with modern requirements. The contract covers five casks and the first of these will be delivered during spring 2021. The transport system will also be supplemented with a new type of transport cask (KTB) for the transport of encapsulated spent nuclear fuel from Clink to the Spent Fuel Repository. The first transport cask will be delivered in 2029 and the rest during the period 2030–2034.

After 2030, the need to transport spent nuclear fuel and radioactive waste is expected to increase successively as several of SKB's new facilities have been commissioned. The additional volumes, compared with the current situation, are primarily encapsulated spent nuclear fuel, which will be regularly transported from Clink to the Spent Fuel Repository, and decommissioning waste from the nuclear power plants destined for SFR and SFL, when these repositories are commissioned.

During these transports, canister transport casks and waste transport casks respectively as well as ISO containers will be used. Transports of operational waste to SFR and spent nuclear fuel to Clab for interim storage of spent nuclear fuel will continue for as long as there are nuclear power reactors in operation.

When SFL is commissioned in 2045, the load on the transport system will be at its greatest. Transports will take place with copper canisters to the Spent Fuel Repository at the same time as transports of short and long-lived decommissioning waste from the decommissioning of the last reactors to the final repositories SFR and SFL respectively. There is overcapacity in the current transport system and the system is anticipated to cope with the increased transport volume.

2.5.6 Continued research and development

SKB's and the licence holders' planning for future research and technical development for the final repository is based on the stepwise decision process. The milestones relating to the decision steps in the form of applications and safety analysis reports dictate when knowledge and development of technology need to have reached a given level, while SSM's approval dictates when SKB can start constructing and operating facilities.

When SKB submits applications to construct, own and operate a facility, the purpose is to demonstrate that SKB has the knowledge and capability to design it to comply with the authorities' requirements. Even when SKB has reached the required degree of maturity in research and development to obtain licences under KTL, continued research and technical development is required in the succeeding stepwise licensing process. This involves; further development of the technology and systems required in order to be able to construct and then commission the facility, conduct research to reduce any remaining uncertainties in the assessments of post-closure safety of final repositories and support for the development and optimisation of the facility.

The need for continuing research and development can be divided into three main categories:

- The need for increased understanding of processes, i.e. the scientific understanding of processes that affect the final repository system and thus the basis for assessing their importance for post-closure safety.
- The need for knowledge and competence in design, construction, manufacture and installation of the components included in the system.
- The need for knowledge and competency in inspection and testing to verify that barriers and components are produced and installed in compliance with approved specifications and thereby meet the requirements.

One part in the development work is to demonstrate that the solutions work in practice. Demonstration experiments will continue, primarily at the Äspö laboratory. During construction of the planned final repositories, some demonstration experiments may be performed at each repository.

As an integrated part of the research and development work, studies are conducted on how the technical solutions can be optimised and made more efficient, without any negative effect on safety. The conditions for the aforementioned technical optimisation are judged to be particularly good regarding the interaction between different technical systems and production lines, because the development work to date has focused on finding suitable solutions for single systems and production lines.

Planning and preparations are underway prior to the decommissioning of the Swedish nuclear power reactors. The need for research and development to perform the decommissioning is relatively limited. Development and research for waste from the decommissioning is included in the presentation for the appropriate repository.

3 Method for calculating costs

During the work with the cost calculations, a number of estimates are produced with varying scope and based on partially different assumptions. Some of the estimates are intended to result in the amounts required according to the Financing Ordinance, whereas others are produced as support for SKB's development and planning process.

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 also accept, in return for payment, small amounts of radioactive waste from industry, research and medical care. Costs for managing and disposing of this waste are not included in SKB's cost calculations.

3.1 Reference cost calculation

SKB's calculation of the future costs is based on the reactor owners' current planning assumptions regarding operating times and expected volumes of radioactive waste and spent nuclear fuel. This information is also the basis for planning SKB's activities as well as the design and implementation of the nuclear waste system, see Chapter 2. The current design is called the reference design and the implementation – which includes timeplans, quantities of waste and planning in general – is called the reference scenario. The scenario is based on the activities presented in the R&D program 2019 (SKB 2019). Apart from the costs for the management and disposal of radioactive waste and spent nuclear fuel, the calculation for the reference scenario also includes costs for dismantling and demolishing nuclear power plants.

The reference cost is calculated in a traditional way using a deterministic method, where the conditions are stipulated and locked. The calculation is, among other things, based on a functional description for each facility, including layout drawings, lists of equipment, staffing forecasts.

For the future facilities, the cost calculations are based on the data available at the time of the calculation. Moreover, consideration is taken both to experience from the previous constructions of nuclear facilities as well as the manufacturing and use of prototype equipment developed. In principal, 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 with the help of supporting data and with knowledge of unit prices, for example, for pouring concrete, blasting rock and operating personnel. During the assessment of both quantities and unit prices, experience has been collected, including from previous extensions of nuclear facilities, for example Clab and SFR.

At the early stages, not all details are presented on supporting drawings or otherwise specified. However, the scope of these details can be estimated with good accuracy based on experience from similar works. The costs for these, the **non-quantity-related costs**, are usually obtained from an experience-based percentage allowance, called "allowance for unspecified items"[2].

The costs for administration, planning and design, procurement and control as well as costs for temporary buildings, machines, accommodations, offices and suchlike are defined as **secondary costs**. These costs are also relatively well known on a percentage basis.

[2] This should not be confused with the allowance for unforeseen factors, an allowance that is not included in the reference calculation. Unforeseen factors are assumed to constitute a part of the total uncertainty, which is managed in the uncertainty analysis.

In a number of cases, SKB's planning includes alternative proposals for solutions, for example, in cases where development work is underway. However, in the reference scenario – to obtain an unambiguous and concrete basis for the cost calculations – it is assumed that a given solution will be implemented. This starting point for the calculations should not be considered to be a final decision on SKB's part. For Plan 2019, the following has been assumed in the cost calculations:

- **Siting of SFL**. SKB has still not decided where SFL should be sited. The assumption that applies in the reference and financing scenarios is that the repository is located adjoining SFR in Forsmark. Starting from the construction and transport tunnels in SFR, the facility is placed a couple of hundred metres deeper down in the rock.
- According to the current plans, the BWR reactor vessels will be segmented. There is also a strategic decision to segment the PWR reactor vessel from Ringhals 2. Decisions on the reactor vessels for 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 scenarios is that all PWR reactor vessels are segmented.
- **Rate of deposition**. According to the plans, the Spent Fuel Repository and Clink will be taken into operation 2031. During the first years, the rate of deposition is assumed to increase gradually to 180 canisters a year. Towards the end of the operating period, the deposition rate will decrease to 100 canisters a year. This reduction is an adjustment to the fact that annual inflow of spent nuclear fuel decreases in step with the permanent shutdown of the reactors.

3.2 Cost calculation preparation according to the Financing Act

According to 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 according to the requirements in the Financing Ordinance. These amounts are the result of a calculation that is performed by a stepwise process as illustrated in Figure 3-1.

The costs that have to be reported to the Swedish National Debt Office are derived from the cost calculations for the reference scenario, but have been adjusted to the assumptions that apply according to the Financing Ordinance. This means that the cost calculations shall be performed assuming that the reactors that are currently in operation will run for 50 years or a remaining operating time of at least six years. If there are special reasons to assume that the operation could cease earlier, then the expected operating time shall be determined based on that time. This implies that the operating times for the reactors are adjusted compared to the reference scenario and the amount of spent nuclear fuel and radioactive waste is reduced. Furthermore, according to the Financing Act the cost calculation has not to include operational waste, see Section 3.2.1.

SKB takes into consideration future real price changes in the cost calculations prepared according to the Financing Act, see Section 3.2.2. Real price changes refer to the price and productivity trends affecting the project that deviate from the developments in society as a whole, i.e. the Consumer Price Index (CPI).

The legislation stipulates that the cost calculations shall concern the anticipated costs. As a result, some form of uncertainty analysis based on probability theory should be applied, see 3.2.3.

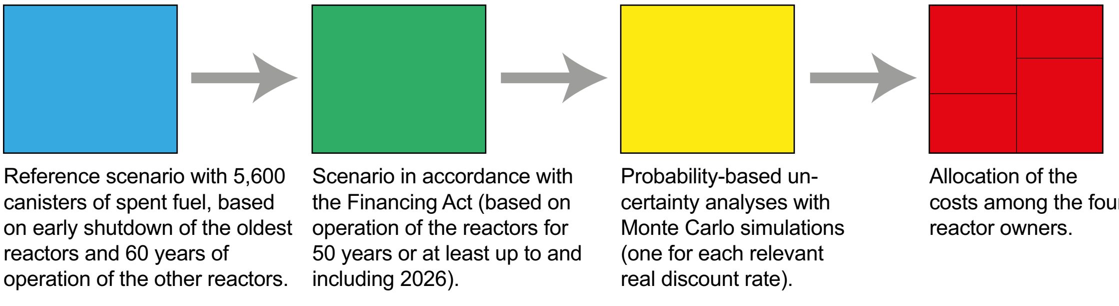


Figure 3-1. *A stepwise process.*

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

3.2.1 Costs that are excluded in the financing scenario

The Financing Act makes a distinction between operational waste and residual products from nuclear activities. The nuclear waste fee and pledged guarantee shall cover costs for the management and final disposal of residual products but, in contrast, not costs for the management and final disposal of operational waste. Among other things, this means that the cost for today's 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 permits to operate the nuclear power plants, each of the nuclear power companies holds separate licences, or are planning for such in the future, for small facilities that are located on the relevant power plant site. They concern interim storage and near-surface repository of very low-level operational waste. The facilities are only used by the respective licence holder. The costs for constructing and operating these small facilities are considered part of the costs for the day-to-day operation of the nuclear power plant and for this reason, are not included in the cost calculations according to the Financing Act. But the costs for decommissioning these facilities in the future have to be included in the calculations, because they are temporally and materially associated with the dismantling and demolition of the nuclear power plants.

Table 3-1 presents the items that are excluded from the financing scenario.

Table 3-1. Financing of different types of residual products and operational waste.

	Direct financing by the licence holders (operational waste) or by another stakeholder who buys space in SKB's facilities	Financing of the licence holders' shares of the Nuclear Waste Fund
Short lived very low-level waste	Operational waste compacted or in concrete or steel containers. Interim storage at the site where the waste is produced (local interim storage). Final disposal either in near-surface repository on the power plant´s sites or in SFR.	Operational and decommissioning waste from the interim storage facilities and processing facilities that fall under the Financing Act (Clab, encapsulation facility) and decommissioning waste from the nuclear power plants. Interim storage at the power plants or at another site. Final disposal in SFR or in local near-surface repositories.
Short-lived low- and intermediate-level waste	Operational waste from the power plants and other stakeholders, in concrete or steel containers. Interim storage at the power plants or at another site. Final disposal in SFR.	As above.
Long-lived low- and intermediate-level waste	Operational and decommissioning waste from other stakeholders. Interim storage at the power plants or at another site. Final disposal in SFL.	Operational and demolition waste from the nuclear power plants. Including replaced core components. Interim storage in Clab, at the power plants or at another site (directly financed). Final disposal in SFL.
Spent nuclear fuel	Spent nuclear fuel from SVAFO (Ågesta) and Studsvik. Encapsulated in the same copper canisters as other spent nuclear fuel. Final disposal in the Spent Fuel Repository.	Spent nuclear fuel encapsulated in copper canisters. Final disposal in the Spent Fuel Repository.

3.2.2 Adjustment with respect to real cost changes

In the calculations, consideration is given to the real cost change by means of a number of conversion factors called External Economic Factors, EEF. These include the cost trends (including the productivity development) for payroll costs and costs for various input materials and machines. The external economic factors that are selected for inclusion in the calculation consist of a limited number of observable macroeconomic variables. The large number of variables that exist in a project of this magnitude are reduced during the calculation to a few selected factors, which involve a relatively large aggregation. The following EEFs are used in the Plan calculation:

- EEF 1 real payroll cost in the service sector
- EEF 2 real payroll cost in the building industry
- EEF 3 real price for machinery
- EEF 4 real price for building materials
- EEF 5 real copper price
- EEF 6 real price for bentonite
- EEF 7 real energy price
- EEF 8 real exchange rate SEK/USD

Each cost item in the Plan calculation refers to one of the first seven EEFs. EEF 8 is used for conversion of the copper and bentonite prices, which are specified in USD.

For each one of the EEFs, a forecast is produced for the future real trend. The forecast is based on established forecasting models, statistical analyses and expert judgements. Based on the forecasts, the costs are adjusted for the real cost trend from the time of the calculation until the cost becomes due.

3.2.3 Probabilistic uncertainty analysis

To meet the statutory requirements on consideration of uncertainty, SKB uses a probabilistic calculation method, the successive principle (Lichtenberg 2000). The method is used for planning and calculating the costs of projects and has been developed specifically to identify, analyse and evaluate uncertainties. The successive calculation contains a systematism that means variations, deviating events or other uncertainties that are of a general or overall character, are handled separately. The cost effects of these uncertainties with different outcomes are then summarised according to the selected statistical method to give the total effect expressed as a probability distribution over different cost levels.

The identification and selection of uncertainties that are considered in SKB's uncertainty analysis is conducted according to a given systematism, the purpose of which is to facilitate the work and reduce the risk for missing significant uncertainties. This involves placing the uncertainties into six areas:

- **Society**. The area includes, for example, legislation and regulatory matters or political issues in general.
- **Economy**. Area with its emphasis on economic conditions such as the real trend in payroll costs and prices for input goods, business cycle factors and currency exchange rate risks.
- **Implementation**. Here belong timeplan strategies, siting issues, strategy for decommissioning the nuclear power plants etc.
- **Organisation**. Primarily this concerns how the future construction or decommissioning projects will be performed and managed in terms of organisation.
- **Technology**. This area includes all pure technical issues. The greatest uncertainties are linked to the future facilities for managing and disposing of both spent nuclear fuel and radioactive waste.
- **Cost estimation**. The areas considers the uncertainties for incorrect assessment in the calculation process. This could consist of overestimation of difficulties (pessimistic assessment) as well as underestimation (optimism).

Identification of the uncertainties that should be considered is managed in a group assembled for the purpose, the analysis group. The uncertainties that are considered by the analysis group are limited in accordance with the principles that apply for successive calculation, the so-called fixed preconditions. These are determined by SKB and may entail relatively obvious limitations, such as management and disposal shall be within Sweden's borders, but also such that constitute important policy positions, for example, that only KBS-3 shall be considered as the method for the final management and disposal of spent nuclear fuel.

The identified uncertainties are analysed and then evaluated by the analysis group, whereby the calculations commence. Since both the calculation objects and the uncertainties have been defined partly on probable cost and partly low and high value, the different items can be described as stochastic variables and summarised according to statistical rules. In the Plan report, this is done by a Monte Carlo simulation. Each variable is assigned a unique random number and, after all variables included have been handled in this way, the calculation is summarised. This process is repeated a number of times (cycles), each time with a new set of random numbers. All outcomes are saved and, form the basis for the result in the form of a probability distribution, which is given 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 the individual reactor owner's future needs for funds for the management and disposal of radioactive waste and spent fuel. Some costs are directly attributable to the individual reactor owner's obligations while others concern activities that are performed jointly with the other licence holders (in practice, SKB's area of responsibility). These joint costs are divided between the licence holders, based on the various agreements between the licence holders.

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 reactor owners' current plans for the operation of the reactors. It is probable that production data for the individual reactors will change during the remaining total estimated operating time. However, in the Reference scenario no consideration is given to this, instead, the supporting data is based on, apart from historical data, the current situation which is applied for the entire calculation period. Any future changes will be incorporated when decisions on them have been made and any associated permits have been obtained.

Table 4-1 constitutes a summary of the reactors' historical operating data and assumptions for future electricity production and amount of spent nuclear fuel. The amount of fuel is given as tonne uranium[3]. The table reproduces data based on the premature shutdown of the reactors Oskarshamn 1, Oskarshamn 2, Ringhals 1 and Ringhals 2, while the remaining reactors are operated for 60 years. The nuclear power companies' current forecasts are for approximately 5 600 canisters, which also forms the basis for the Reference calculation.

The number of canisters with spent nuclear fuel is given in Table 4-2. The volumes of other radioactive waste, for which space must be prepared in the different final repositories, are also given in the table. The volumes refer to the containers of radioactive waste that are ready for final disposal. The table does not include the waste placed in near-surface repositories for very low-level nuclear waste that are on the power plant sites.

The block diagram in Figure 4-1 is a summary of the quantities and volumes of spent nuclear fuel and radioactive waste that passes through storage and processing facilities before finally being deposited in the appropriate final repository. The quantities refer to the Reference scenario.

Table 4-1. Operating data and electricity production and fuel quantities based on planned operation.

			To the end of 2019		Total for the reference scenario			
Start of commercial operation		Thermal power/nett power MW	Electricity production TWh	Spent nuclear fuel tonne uranium	Planned operating time years	Operation to	Electricity production TWh	Spent nuclear fuel tonne uranium
F1 (BWR)	10/12/1980	2928/984	274	947	60.0	09/12/2040	433	1367
F2 (BWR)	07/07/1981	3253/1120	272	923	60.0	06/07/2041	460	1373
F3 (BWR)	22/08/1985	3300/1167	298	940	60.0	21/08/2045	535	1486
O1 (BWR)	06/02/1972	1375/473	109	370		30/06/2017	109	370
O2 (BWR)	15/12/1974	1800/638	154	537		31/12/2015	154	537
O3 (BWR)	15/08/1985	3900/1400	286	927	60.0	14/08/2045	563	1521
R1 (BWR)	01/01/1976	2540/881	217	751	45.0	30/12/2020	221	768
R2 (BWR)	01/05/1975	2500/807	221	645	44.7	30/12/2019	221	645
R3 (BWR)	09/09/1981	3135/1063	249	758	60.0	08/09/2041	422	1185
R4 (BWR)	21/11/1983	3300/1118	242	739	60.0	20/11/2043	443	1198
B1 (BWR)	01/07/1975	1800/600	93	419		30/11/1999	93	419
B2 (BWR)	01/07/1977	1800/600	108	424		31/05/2005	108	424
BWR total		22696/7863	1812	6238			2676	8264
PWR total		8935/2988	712	2142			1085	3028
Total all		31631/10851	2524	8380			3762	11293

[3] The fuel's real weight in the form of complete fuel assemblies is considerably greater. A BWR assembly weighs approximately 300 kg, of which approximately 180 kg is uranium. After burn up, the weight of uranium has reduced slightly. For a PWR assembly, the corresponding weights are approximately 560 kg and approximately 460 kg respectively.

Table 4-2. Encapsulated nuclear fuel and radioactive waste for deposition.

	Quantity for final disposal	Final repository
Spent BWR fuel		
Spent PWR fuel	5600 canisters	The Spent Fuel Repository
Other spent nuclear fuel (MOX, Ågesta, Studsvik site)		
Operational waste from the nuclear power plants	53500 m^3	SFR
Decommissioning waste from the nuclear power plants	76400 m^3	SFR
Operational and decommissioning waste from the nuclear power plants (reactor components)	5600 m^3	SFL
Operational waste from Clab and the encapsulation facility	3200 m^3	SFR
Decommissioning waste from Clab and the encapsulation facility	400 m^3	SFR
Operational waste from SVAFO and Studsvik	14200 m^3	SFR
Decommissioning waste from SVAFO and Studsvik	5600 m^3	SFR
Waste from SVAFO and Studsvik site	10800 m^3	SFL
Total short-lived radioactive waste	153300 m^3	SFR
Total long-lived radioactive waste	16400 m^3	SFL

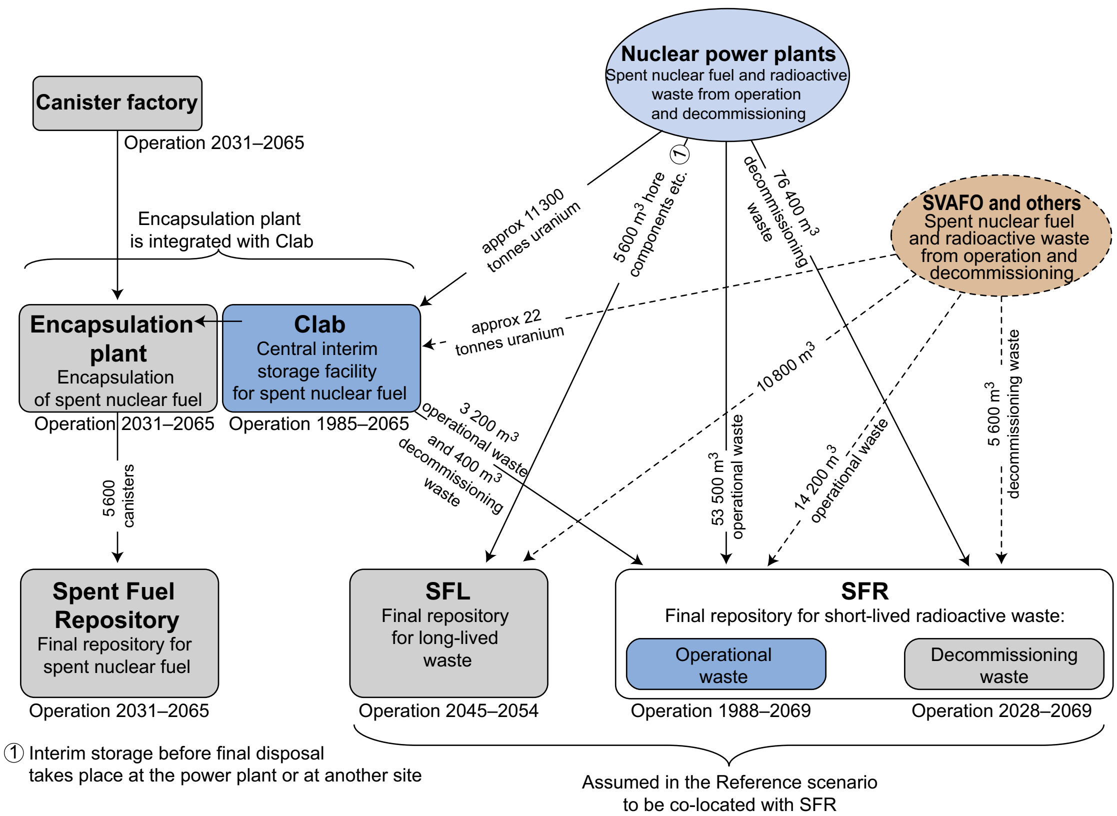


Figure 4-1. *Block diagram showing the transport flows for the management of nuclear power's residual products and other radioactive waste.*

4.2 Cost report

4.2.1 Future costs

The reactor owners' future costs for various facilities and activities in the Reference scenario are presented in Table 4-3. For each facility and activity respectively, it is specified if the costs refer to *"feasibility studies, technical development and safety analysis", "investment", "operation and maintenance", "backfilling"* and *"decommissioning and closure"*.

The Reference scenario also covers costs for supporting functions as well as central support. Supporting functions include costs for portfolio management, requirement management, project and design support as well as administrative support. These costs are included and allocated to the relevant facility. Costs for SKB central functions include such as corporate management, business support, communication, environmental protection and overall safety and security issues. The central functions are presented separately in Table 4-3.

Normally, only the costs that have incurred before a facility or a facility part is commissioned are assigned to investment. However, the costs of the Spent Fuel Repository, where the extension of the deposition tunnel system will be done continuously during the operating phase, are also included in the *investment*. The cost estimate in Table 4-3 is based on current supporting information for the Reference scenario and covers neither allowance for uncertainty and risk nor adjustment for real price changes (adjustment for EEF).

The reference cost amounts to a total of SEK 94.1 billion. Of this, SEK 70.4 billion falls within SKB's sphere of operations and is, thus, shared by the licence holders (joint costs). The remainder are costs for activities where each reactor owner has an individual cost responsibility (separate costs).

Figure 4-2 shows the Reference cost distributed over time. A simplified timeplan is presented for the various facilities to give an understanding of their effect on the cost flow. The two cost peaks in the diagram originate partially from the investment in the Spent Fuel Repository and the encapsulation part of Clink and partially from the decommissioning of the nuclear power plants.

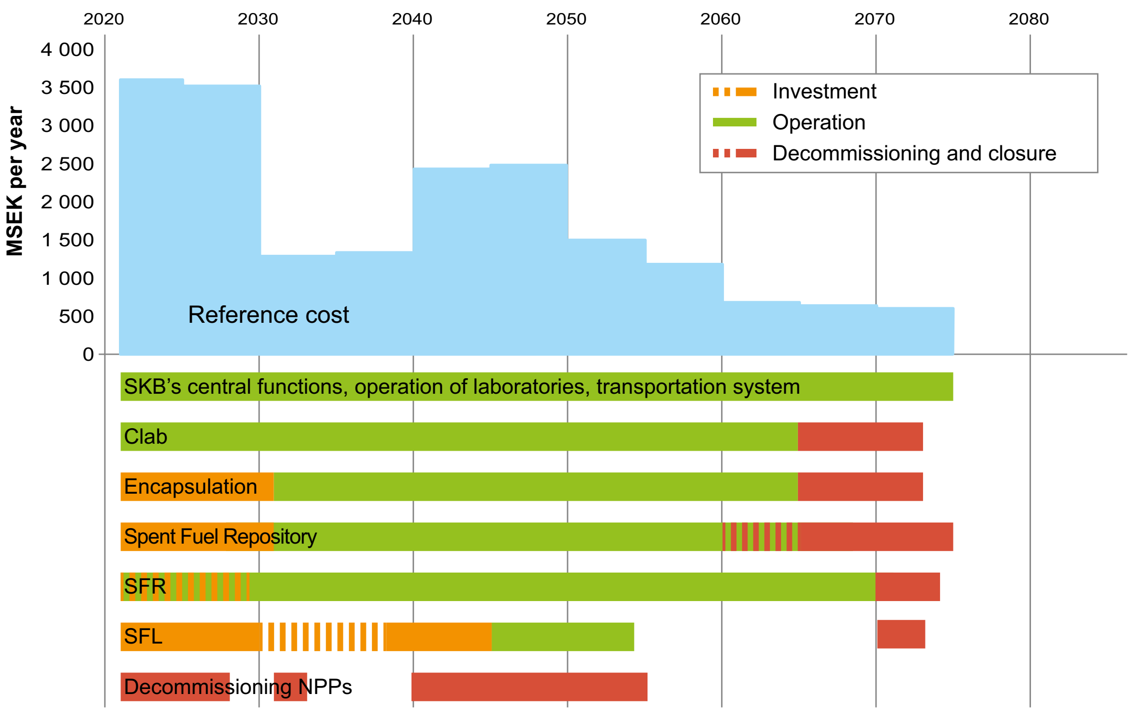


Figure 4-2. The distribution over time of the future costs for the reference scenario as well as outline timeplans for the facilities, price level January 2019.

Table 4-3. Summary of the licence holders' future costs for the reference scenario with effect from 2021, price level January 2019.

		Cost per cost category SEK million	Cost per facility SEK million
SKB central functions		5700	**5700**
Transports	investment	1100	**2660**
	operation and maintenance	1560	
Clab	operation and maintenance	6560	**9420**
	reinvestments	1950	
	decommissioning	910	
Encapsulation	investment	4850	**15110**
	operation and maintenance as well as reinvestments	9990	
	decommissioning	260	
The Spent Fuel Repository			
– above ground	feasibility studies, technical development and safety analysis	1060	**30020**
	investment and decommissioning	6280	
	operation and maintenance (entire facility)	5470	
	reinvestments (entire facility)	2100	
– other rock caverns	investment	3100	
	decommissioning and closure	1520	
– main and deposition tunnels	investment	6290	
	decommissioning, backfilling and closure	4190	
SFL	feasibility studies, technical development and safety analysis	590	**1800**
	investment	570	
	operation and maintenance as well as reinvestments	300	
	decommissioning and closure	340	
Interim storage facilities and near-surface repository at the nuclear power plants	investment, operation and decommissioning	110	**110**
SFR (operational waste)	operation and maintenance as well as reinvestments	1020	**1020**
SFR (decommissioning waste)	feasibility studies, technical development and safety analysis	510	**4530**
	investment	2230	
	operation and maintenance as well as reinvestments	1450	
	decommissioning and closure	340	
Decommissioning of the nuclear power plants		23700	**23700**
Total reference cost (without adjustment for EEF and allowance for unforeseen factors and risk)		94080	**94080**

There may be rounding off differences.

4.2.2 Expended and budgeted costs

Table 4-4 presents expended costs (current price level) up to the end of 2018 and forecast for the cost outcome 2019 and budgeted costs for 2020 (forecast) respectively. The costs for reprocessing, incurred in an earlier phase, are not included in the table. Figure 4-3 shows how the total cost, expended and future, is allocated to the various facilities. The distribution is based on January 2019 price level, where previously expended costs have been adjusted upwards by the Consumer Price Index, CPI.

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

	Expended to the end of 2018 SEK million	Outcome 2019 (forecast) SEK million	Forecast 2020 SEK million	Total to the end of 2020 SEK million
SKB central functions	5146	331	303	5780
R&D	8270	234	262	8766
Transport	1939	214	193	2347
Clab	8463	311	325	9099
Encapsulation	733	152	146	1032
The Spent Fuel Repository	5285	256	404	5945
SFR and SFL	3510	32	175	3717
Decommissioning of nuclear power plants	1767	810	1082	3660
Total	**35114**	**2339**	**2891**	**40345**

There may be rounding off differences.

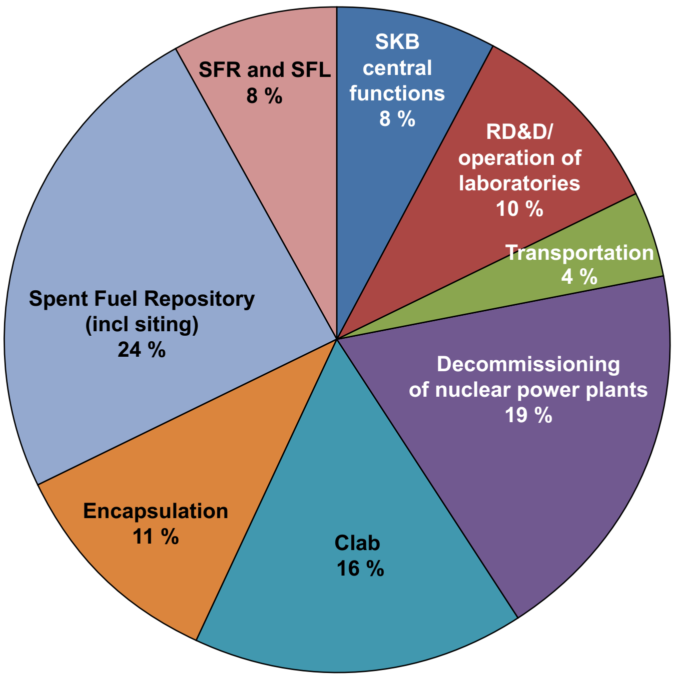


Figure 4-3 . Distribution of the total cost (expended and future) for the reference scenario. Price level January 2019.

5 Costs according to the financing scenario

In this section, the calculation that will form the basis for fees and guarantees for the years 2021–2023 is presented. The regulations stipulate that, among other things, 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 is specific reason to assume that the operation could cease at an earlier date, the expected operating time shall instead be determined based on that time.

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

In Figure 5-1, the future assumed operating time according to the Financing Act and according to the nuclear power companies' current plans are presented.

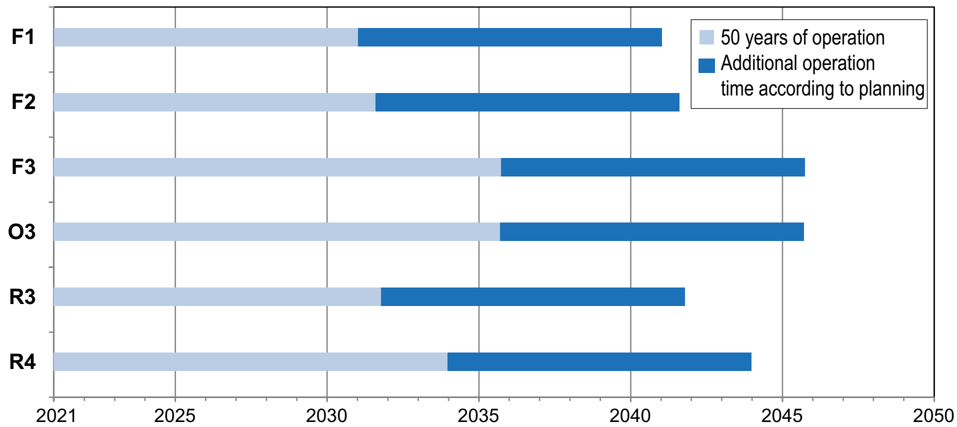


Figure 5-1. *The assumptions for the future operating times according to the Financing Act and the planned operating times for the reactors.*

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

The cost report is relatively detailed for the scenario according to the Financing Act (50 + 6 years), see Section 5.3.1. For the basis for the financing amount, i.e. the settlement on 31 December 2020, only the total amount is given (Section 5.3.2).

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

Start of commercial operation			Operating time according to the Financing Act, number of years	Total for basic cost Operation to the end of	Energy production TWh	Spent fuel, tonne uranium
F1	(BWR)	10/12/1980	50.0	10/12/2030	357	1 169
F2	(BWR)	07/07/1981	50.0	07/07/2031	372	1 178
F3	(BWR)	22/08/1985	50.0	22/08/2035	442	1 286
O1	(BWR)	06/02/1972		30/06/2017	109	370
O2	(BWR)	15/12/1974		31/12/2015	154	537
O3	(BWR)	15/08/1985	50.0	15/08/2035	454	1 296
R1	(BWR)	01/01/1976	45.0	30/12/2020	221	768
R2	(BWR)	01/05/1975	44.7	30/12/2019	221	645
R3	(BWR)	09/09/1981	50.0	09/09/2031	342	991
R4	(BWR)	21/11/1983	50.0	20/11/2033	258	1 021
B1	(BWR)	01/07/1975		30/11/1999	93	419
B2	(BWR)	01/07/1977		31/05/2005	108	424
BWR total					2 311	7 447
PWR total					922	2 657
Total all					3 233	10 105

Table 5-2. Encapsulated nuclear fuel and radioactive waste for deposition according to the financing scenario (50 + 6 years).

	Quantity for final disposal 50 + 6 years	Reference	Final repository
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX, Ågesta, Studsvik site)	4 977 canisters	(5 600)	The 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 (components close to core)	5 600 m^3	(5 600)	SFL
Operational waste from Clab and the encapsulation facility	3 000 m^3	(3 200)	SFR
Decommissioning waste from Clab and the encapsulation facility	400 m^3	(400)	SFR
Operational waste from SVAFO and Studsvik site	14 200 m^3	(14 200)	SFR
Demolition waste from SVAFO and Studsvik site	5 600 m^3	(5 600)	SFR
Waste from SVAFO and Studsvik site	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 Changes compared to the reference scenario

This section concerns changes in relation to the description of the reference scenario in Chapter 4.

These are first and foremost different assumptions on the operating time for the reactors that have consequences for the amount of spent nuclear fuel and radioactive waste. The assumed operating time also affects the deposition rate for the canisters of spent nuclear fuel. Shorter operating times entail prolonged interim storage, which makes compliance with the temperature requirement around the canister after deposition, easier.

To summarize, the most important changes in the operating scenarios compared to the reference scenario are:

- The number of canisters with spent nuclear fuel reduces from the 5 600 that are included in the reference scenario. Calculation of the remaining Basic cost is based on 4 977 canisters. The starting point for the calculation of the basis for the Financing amount is that 4 193 canisters will be deposited.
- The total operating time for the Spent Fuel Repository and Clink is shorter. This means that the operating time is five years shorter than in the reference scenario for the calculation of the remaining Basic cost and, for the calculation of the basis for the financing amount, an operating time that is ten years shorter. The shorter operating time also affects the cost calculations 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 calculation (do not fall under the term residual products). Above all, this means that the costs for final disposal of operating waste in SFR are not included. This also means that the costs for the transports to SFR are excluded, likewise a proportional share of the costs for SKB's central functions.
- Costs for space in SKB's facilities occupied by radioactive waste from others than the licence holders (AB SVAFO and others) are not included in the calculation. These costs are financed in another way.
- Once a reactor has been permanently shutdown, the decommissioning commences. Work with decommissioning then continues until the facility's remaining parts obtain radioactive clearance. The remaining activities are then no longer regulated by the Nuclear Activities Act and the continuing decommissioning can be carried out on the same conditions as for other industrial activities. How far the decommissioning will be taken for the remaining parts of the facility varies between the power plants, depending on the plans for the continued use of the power plant site. In Plan 2019, as in earlier Plan reports, a standardised deduction of 10 % has been made on the costs for conventional demolition, which is included in the reference scenario. The exception is Barsebäck, where the entire cost is included. The standardised deduction may be reviewed in future reports.

5.3 Cost report

5.3.1 Remaining basic cost

Table 5-3 summarises the licence holders' estimated future costs that are attributable to the remaining basic cost, which constitutes the basis for calculating fees. The costs that are presented in the table specifically for the various objects do not include allowance for unforeseen factors and risk. This allowance, as is the effects of future real price and cost developments (EEF), is presented at the bottom of the table.

The calculated costs for various facilities are presented under the items *"feasibility studies, technical development and safety analysis", "investment", "operation and maintenance", "backfilling"* and *"decommissioning and closure"* (backfilling only concerns backfilling the deposition tunnels). Normally, only the costs that are incurred before a facility or part of a facility is commissioned, are allocated to investment. However, in the Spent Fuel Repository, where the extension of the deposition tunnels will be carried out continuously during the operating phase, the costs for this are also included in the investment.

The scenario according to the Financing Act also covers costs for supporting functions as well as central support. Supporting functions include costs for portfolio management, requirement management, project and design support as well as administrative support. These costs are included and allocated to the relevant facility. Costs for SKB central functions include such as corporate management, business support, communication, environmental protection and overall safety and security issues. The central functions are presented separately in Table 5-3.

The total for the remaining basic costs amounts to a total of SEK 110.0 billion. Of this, SEK 4.8 billion is an adjustment for real price and cost trends (EEF) and an SEK 19.1 billion allowance 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 timeplan for the various facilities to give an understanding about the effect these have on the cost flow. The two cost peaks in the diagram originate partially from the investment in the encapsulation section of Clink, the Spent Fuel Repository and the extension of SFR, and partially from the decommissioning of the nuclear power plants.

The diagram in Figure 5-3 shows the present value of the remaining Basic cost for discount rates between 0 and 4 %. The diagram concerns the total amount, which means that the allowance for unforeseen factors and risk as well as an adjustment for EEF are included. The underlying data for the diagram was produced by a number of separate Monte Carlo simulations using different discount rates that are constant over time. This visualizes the remaining basic cost's dependence 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 for fees and guarantees.

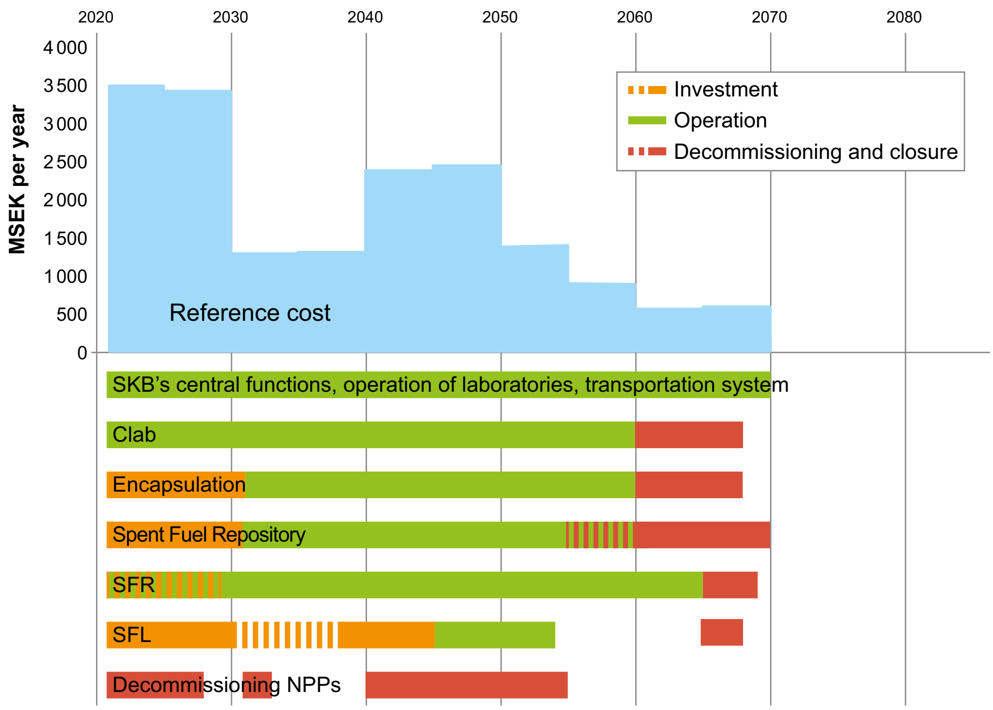


Figure 5-2. *Remaining basic cost, excluding allowance for unforeseen factors and risk, distributed over time and associated timeplan for the facilities, price level January 2019.*

Table 5-3. Remaining basic costs with effect from 2021, price level January 2019.

		Cost per cost category SEK million	Cost per facility SEK million
SKB central functions		5 090	5 090
Transports	investment	830	2 130
	operation and maintenance	1 300	
Clab	operation and maintenance	5 630	8 270
	reinvestments	1 730	
	decommissioning	910	
Encapsulation	investment	4 830	13 880
	operation and maintenance as well as reinvestments	8 780	
	decommissioning	260	
The Spent Fuel Repository			
– above ground	feasibility studies, technical development and safety analysis	1 020	27 310
	investment and decommissioning	6 260	
	operation and maintenance (entire facility)	4 710	
	reinvestments (entire facility)	1 550	
– other rock caverns	investment	3 060	
	decommissioning and closure	1 460	
– main and deposition tunnels	investment	5 530	
	decommissioning, backfilling and closure	3 730	
SFL	feasibility studies, technical development and safety analysis	590	1 800
	investment	570	
	operation and maintenance as well as reinvestments	300	
	decommissioning and closure	340	
Interim storage facilities and near-surface repository at the nuclear power plants	investment, operation and decommissioning	-	-
SFR (operational waste)	operation and maintenance as well as reinvestments	-	-
SFR (decommissioning waste)	feasibility studies, technical development and safety analysis	500	4 310
	investment	2 120	
	operation and maintenance as well as reinvestments	1 350	
	decommissioning and closure	340	
Decommissioning of the nuclear power plants		23 340	23 340
Total base calculation		86 130	
Adjustment for EEF		4 760	
Surcharge for unforeseen factors and risk		19 140	
Total remaining basic cost		110 030	

There may be rounding off differences.

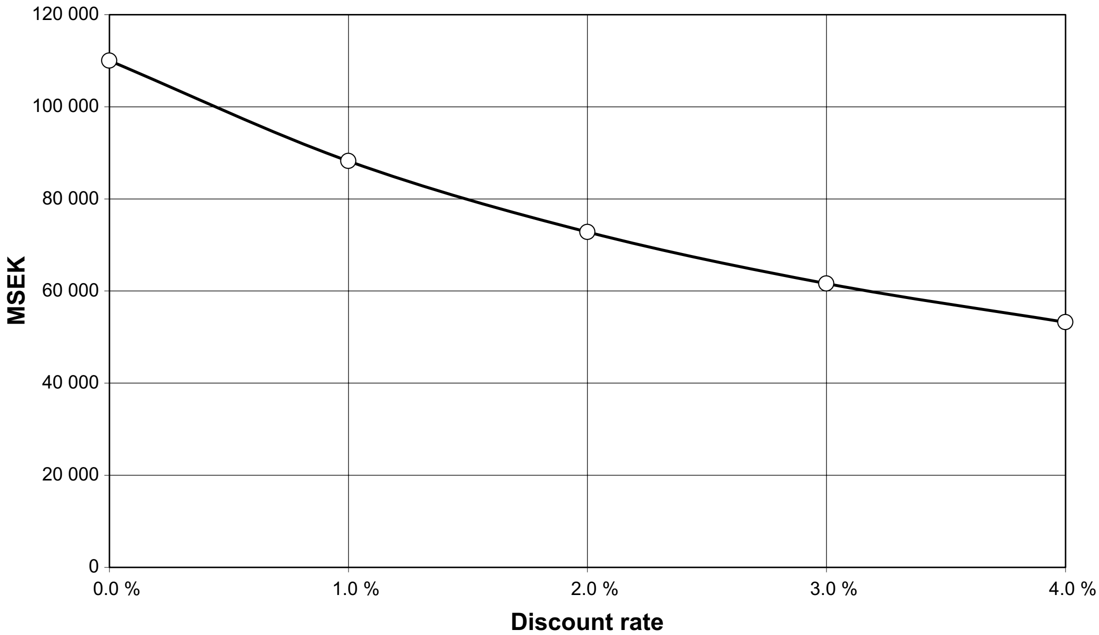


Figure 5-3. *The present value of the remaining Basic cost as a function of the discount rate, price level January 2019.*

5.3.2 Basis for the financing amount

The financing amount serves as the basis for one of the guarantees that the licence holders have to pledge for in addition to paying fees. The financing amount's cost data consists of the data provided by SKB (this report) and the added costs that are 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 covers the quantities of residual products that exist when the calculation begins. For Plan 2019, this concerns the residual products that exist on 31 December 2020. Among other things, this has the consequence that the number of canisters decreases to 4 193 compared to the 4 977 which is the basis for the calculation of the remaining basic cost.

The part of the financing amount, which is based on SKB's calculations, totals SEK 103.1 billion, which is SEK 6.9 billion less than the remaining basic cost.

6 References

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Arkitektkopia AB, Bromma, 2019

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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