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April 2017

Plan 2016

Costs from and including 2018 for the radioactive residual products from nuclear power

Basis for fees and guarantees for the period 2018–2020

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Preface

According to the regulatory framework, it is the responsibility of those companies that hold licences to own nuclear power reactors to estimate the costs for all measures that are needed to manage and dispose of spent nuclear fuel, as well as other radioactive residual products from nuclear activities, and to decommission and dismantle the reactor plants. The regulatory framework comprises the Act (2006:647) and the Ordinance (2008:715) on Financial Measures for the Management of Residual Products from Nuclear Activities. The cost estimate shall be submitted to the Swedish Radiation Safety Authority, SSM, once every three years. SKB's owners have assigned SKB the task of preparing this cost estimate for the licensees of the Swedish nuclear power plants.

The present report, which is the thirtieth Plan report since the first one was published in 1982, provides an updated compilation of the requisite costs. As in the reports submitted in previous years, estimates are reported for two scenarios, according to the planning premises for SKB's activities and according to the conditions given by legislation. This report also includes a calculation based on an operating time of 50 years, since it has been suggested by SSM in their proposal to the Government on changes in the financing legislation.

Stockholm, December 2016

Svensk Kärnbränslehantering AB

Christopher Eckerberg
CEO

Summary

A company that holds a licence to own a nuclear power plant is responsible for taking whatever measures necessary to guarantee the safe management and final disposal of spent nuclear fuel and radioactive waste from its operation and, after plant shutdown, for decommissioning and dismantling. The most important measures are to plan, construct and operate the facilities and systems that are needed for this purpose, and to conduct the related research and development. The financing of these measures is based on the payment of fees by licence holders into a fund, primarily during the period in which the reactors are in operation but also later, if necessary.

How the financing is to be arranged is regulated in the Financing Act (2006:647) and the associated Financing Ordinance (2008:715). A distinction is made in this regulatory framework between the licence holder for one or more reactors, at least one of which is in operation, and a licence holder all of whose reactors have been permanently taken out of service after 31 December 1995. A licence holder in the former category is called a reactor owner and pays fees based on electricity generated (öre/kWh). There are at present three reactor owners, namely Forsmarks Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. A licence holder in the latter category, at present Barsebäck Kraft AB, can be charged a fee in the form of a certain amount on an annual basis.

SKB has been commissioned by the owners of the nuclear power plants jointly to calculate and compile the future costs of the measures that are required. According to the regulatory framework, such a cost estimate shall be submitted to the Swedish Radiation Safety Authority every three years.

The future costs are based on SKB's current planning relating to the design of the system and the time schedule for implementation. The current design is referred to as the reference design while the implementation plan in general is called the reference scenario. The present report is based on plans presented in SKB's RD&D Programme 2016. The reference scenario reflects the nuclear power companies' current planning which means that the operating time for the newest reactors is planned for 60 years, while the older reactors are shut down according to stipulated shutdown times.

The present report contains an estimate of the cost for the reference scenario and, to a certain extent, the supporting information on which it is based. The regulatory framework does not require the submission of a cost account of this type to the Swedish Radiation Safety Authority, but since it serves as the basis for the other calculations, SKB considers its inclusion in the report to be of value. This is described in Chapter 4. The cost estimate required by the Financing Act are presented in Chapter 5.

In addition, a separate set of tables is submitted to the Swedish Radiation Safety Authority containing the detailed information that the authority requires for its review and calculations. Among other things, this set of tables shows how the costs are divided between the four licence holders of the Swedish nuclear power plants.

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

- Transportation system for radioactive residual products.
- Central interim storage facility for spent nuclear fuel, Clab.
- Final repository for short-lived radioactive waste, SFR.
- Laboratories for the development of encapsulation and disposal technology.

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

- The extension of SFR for short-lived waste from decommissioning of the nuclear power plants and a smaller amount of operational waste and also space for the interim storage of long-lived radioactive waste.
- Final repository for long-lived low- and intermediate-level waste, SFL.
- Canister factory and encapsulation facility for spent nuclear fuel adjacent to Clab.
- Final repository for spent nuclear fuel, Spent Fuel Repository.

The cost estimate according to the reference scenario also include costs for research, development and demonstration, and for SKB's central functions. In this Plan report, costs for technology development, feasibility studies, design work and assessments of post-closure safety have been allocated to the respective final repository. The facilities are the Spent Fuel Repository, the extended SFR and SFL. Costs for central functions include for example general functions such as corporate management, business support, communications, environment, general safety matters, requirements management and activities related to safety analysis reports. Furthermore, costs are presented for decommissioning of the reactors, facilities at the power plant sites for interim storage and final disposal of spent nuclear fuel and radioactive waste.

The Financing Act and the Financing Ordinance stipulate a number of conditions that have an impact on the scenario that determines the scope of the calculation model used by SKB to arrive at the basis for fees, etc. This applies above all to the reactor operating times, which serve as a basis for assessing the quantity of spent nuclear fuel and radioactive waste, as well as the requirement that it must be possible to assess any uncertainties regarding future development within different areas. In order to meet the latter requirement, SKB has chosen to apply a probabilistic uncertainty analysis. To this must be added the fact that the calculation shall only cover residual products which, according to the definition used in the Financing Act, excludes the management of operational waste. This means, among other factors, that the costs of SFR in its present function as a repository for operational waste are excluded.

The quantity of spent nuclear fuel and radioactive waste to be managed and disposed of is linked with the reactor operating times. The fee-based operating time specified in the regulations is 40 years for each of the reactors that are currently in operation. There is a stipulated minimum time, entailing that the remaining operating time shall be at least six years, unless there is reason to assume that the operating period could cease before then. In the present calculation, this regulation means operation at least up to and including 2023. The fee calculation that is performed by the Swedish Radiation Safety Authority is then based on the amount of electricity that is expected to be generated over the same period. The fees are paid into the state Nuclear Waste Fund.

Apart from the payment of fees, a reactor owner shall provide two forms of guarantees. One guarantee covers fees that, although decided, have not yet been paid. The basis for this guarantee is referred to as the financing amount. The calculation is basically conducted in the same way as for the fee basis, but the costs are limited to the management and disposal of those residual products that exist when work on the calculation commences. In this report on 31 December 2017.

The second guarantee refers to the situation in which it can be assumed that the assets in the Nuclear Waste Fund will be inadequate as a consequence of unforeseen events, at the same time as the option of increasing the payment of fees and adjusting the aforementioned guarantee is not available for some reason. The basis for this guarantee is referred to as the supplementary amount.

In the case of a licence holder whose reactors are permanently shut down, in our case Barsebäck Kraft AB, only the first type of guarantee (financing amount) is applicable when it comes to the basic cost data to be submitted to the Swedish Radiation Safety Authority. The supplementary amount specified below therefore applies only to the owners of the NPPs in Forsmark, Oskarshamn and Ringhals.

The results of the calculation are presented below. The amounts are for future costs from and including 2018, and are specified at the January 2016 price level.

Remaining basic cost	SEK 101.4 billion
Basis for financing amount	SEK 98.0 billion
Supplementary amount – at 90 % confidence level	SEK 15.1 billion

SKB and the nuclear power companies have also chosen to include a calculation based on an operating time of 50 years, since it has been suggested by SSM in their proposal to the Government on changes in the regulatory framework. The corresponding amounts in this calculation are:

Remaining basic cost	SEK 106.3 billion
Basis for financing amount	SEK 98.7 billion
Supplementary amount – at 90 % confidence level	SEK 15.5 billion

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1 Introduction

This report provides a compilation of the future costs of the measures needed to manage and dispose of the nuclear waste and the spent nuclear fuel from the Swedish nuclear power plants and to decommission them. According to Swedish legislation, a cost estimate shall be submitted to the Swedish Radiation Safety Authority (SSM) every three years. On behalf of its owners, SKB prepares a joint cost calculation for the licensees of the Swedish nuclear power plants.

As in previous reports, the present report presents cost estimates for two scenarios, according to the planning premises for SKB's activities and according to the conditions provided by legislation. The former of these cost estimates are based on a scenario according to the nuclear power companies' current plans for reactor operation, the latter on operating times for the reactors as stated in regulations. This report also includes a calculation based on an operating time of 50 years, since it has been suggested by SSM in their proposal to the Government on changes in the financing legislation.

The report is structured as follows:

Chapter 1 provides background information regarding the financing system and the relevant regulatory framework. Furthermore, it presents SSM's comments on the previous Plan report and the consultation activities that have taken place since then.

Chapter 2 describes the current design of the Swedish system for management and final disposal of nuclear waste and spent nuclear fuel as well as the plans for implementation of the nuclear waste programme.

Chapter 3 describes SKB's method for 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 costs according to the Financing Act, which constitutes the main purpose of the report. The report has been supplemented with costs calculated according to SSM's pending proposal for changes in the regulatory framework.

1.1 Premises

1.1.1 Obligations under the Nuclear Activities Act

Under the Nuclear Activities Act (1984:3), the holder of a licence for nuclear activities is responsible for ensuring the safe management and final disposal of radioactive waste arising from the activities as well as nuclear material that will not be reused. The responsibility includes planning, construction and operation of the facilities and systems needed as well as conducting the research, development and demonstration that is required.

The holder of a licence for nuclear activities is also obliged under the Nuclear Activities Act to pay the costs of the measures needed to manage and dispose of radioactive waste and spent nuclear fuel and to decommission the facilities. The licensees for the nuclear power plants in Forsmark, Oskarshamn, Ringhals and Barsebäck are Forsmarks Kraftgrupp AB, OKG Aktiebolag, Ringhals AB and Barsebäck Kraft AB.

Svensk Kärnbränslehantering AB (SKB), which is owned by Vattenfall AB, OKG Aktiebolag, Forsmarks Kraftgrupp AB and Sydkraft Nuclear Power AB (previously E.ON Kärnkraft Sverige AB), is on behalf of its owners 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 regulatory framework

According to the Act (SFS 2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities (the Financing Act) and the associated Financing Ordinance (2008:715) on Financial Measures for the Management of Residual Products from Nuclear Activities (the Financing Ordinance), the nuclear power companies are obliged to pay a fee for future waste management and decommissioning.

The regulatory framework makes 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 "*nuclear material that is not intended to be reused and nuclear waste which is not operational waste*". The nuclear waste fee shall cover costs for the management and final disposal of residual products, but not costs for the management and final disposal of operational waste. The latter costs shall be borne directly by the licence holder.

The regulatory framework also distinguishes between, on the one hand, holders of licences for one or more nuclear power reactors of which at least one is in operation and, on the other, holders of licences for nuclear power reactors, all of which have been permanently taken out of service. A licence holder in the first category is called a reactor owner and pays fees based on the electricity generated (öre/kWh). A licence holder in the second category, at present Barsebäck Kraft AB, can be charged a fee in the form of a certain amount on an annual basis. There are at present three reactor owners, namely Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. In this document the term "licence holder" is used as a collective designation for the four aforementioned nuclear power companies.

Apart from the payment of fees, a reactor owner shall provide two kinds of guarantees: one to cover the fees that have not yet been paid in and one for additional costs associated with unforeseen events. The guarantees are intended to be redeemed if the licence holder does not fulfil his obligation to pay fees and if the assets in the Nuclear Waste Fund are deemed to be inadequate. In the case of a holder of licences for reactors, all of which have been permanently shut down, i.e. at present Barsebäck Kraft AB, only the first type of guarantee is applicable.

According to the Financing Ordinance § 3, a licence holder shall, in consultation with other licence holders, prepare a cost estimate for the management and disposal of nuclear residual products and deliver it to SSM no later than January 7, every three years. SKB's owners have assigned SKB the task of preparing cost calculations for the licence holders of the Swedish nuclear power plants.

The Swedish Radiation Safety Authority (SSM) will then draw up proposals for nuclear waste fees and guarantees based on these estimates. With the exception of the guarantee that is to be provided by Barsebäck Kraft AB, which is determined by SSM, the Government determines the fees and guarantees for the following three years. If necessary, fees will be charged and guarantees provided both during the periods in which the reactors are operating as well as after permanent shutdown up until the time that the NPPs have been decommissioned and all residual products have been disposed of.

The fees are paid into the state Nuclear Waste Fund. The assets in the fund are placed in an interest-bearing account at the Swedish National Debt Office or in debt instruments issued by the state or issued in accordance with the Covered Bonds Issuance Act (2003:1223). Licence holders are entitled to receive, from the fund, reimbursement for their expenses for fulfilment of the majority of their obligations, as specified in the Nuclear Activities Act.

At the end of November 2016 there were SEK 61 billion in the nuclear power companies' shares of the Nuclear Waste Fund (market value). During the period 2015 to 2017, the average fee is 4.1 öre (100 öre = 1 SEK) per kilowatt-hour of electricity produced for the nuclear power plants that are in operation. Barsebäck Kraft AB pays an annual fee of SEK 1 042 million during the same period. In total, the nuclear power companies' parent companies pledge guarantees for SEK 29 billion.

On behalf of the Government, SSM has drawn up a proposal for changes in the Financing Act and the associated Financing Ordinance (SSM 2013). Among other things, SSM proposes a change of the operating time in the calculations from 40 years to 50 years, with a minimum remaining time of six years. The case is at present being processed by the Government Offices. SKB and the nuclear power companies therefore also present estimates that are based on this calculation assumption.

1.1.3 Amounts to report under the Financing Act

The quantity of spent nuclear fuel and radioactive waste to be disposed of depends on the reactor operating times. In the cost calculation, each reactor that has not been permanently shut down is prescribed to have a total operating time of 40 years, and a remaining operating time of at least six years, unless there is reason to assume that operation may cease before then.

According to § 2 of the Financing Ordinance, four cost amounts will serve as a basis for the calculation of fees and guarantees:

Basic cost: The sum of the anticipated costs for measures and activities referred to in § 4, Clauses 1–3 of the Financing Act, i.e. the licence holders' costs for the safe management and final disposal of residual products, safe decommissioning and dismantling of nuclear facilities, as well as the required research and development work.

Added cost: The sum of the anticipated costs for activities referred to in § 4, Clauses 4–9 of the Financing Act, for example the state's costs for R&D, management of funds, licensing, inspection, monitoring and control, as well as costs for information to the general public and support to non-governmental organisations.

Financing amount: An amount consisting of the difference between the sum of the remaining basic costs plus the added costs for those residual products that have been produced at the time the calculation was made, and the funds that have been allocated for covering these costs.

Supplementary amount: An amount that constitutes a reasonable estimate of costs that are referred to in § 4, Clauses 1–3 of the Financing Act and which may arise as a consequence of unforeseen events.

SKB shall report to SSM the remaining basic cost, the basis for the financing amount that stems from this basic cost and the supplementary amount. The added cost is calculated by SSM and is primarily attributable to certain government costs linked with the inspection of SKB and nuclear power company activities concerning the final disposal of spent nuclear fuel as well as decommissioning and dismantling of the nuclear power plants and SKB's facilities.

1.2 SSM's review of the preceding Plan report

In its review of Plan 2013 (SKB 2014), SSM noted that the factors that are particularly critical for the cost trend are the calculation of real price changes and the method for uncertainty analysis. The costs for decommissioning of reactors were in focus in SSM's review, but were not judged to be critical for the cost trend.

Consultations have been held with the Swedish Radiation Safety Authority prior to Plan 2016, to seek consensus through dialogue on the principles, methods and premises for cost calculations. The consultations for Plan 2016 included SKB's treatment of SSM's comments from the review of Plan 2013, calculations to predict the real price and cost trend as well as SSM's expectations on SKB's supporting material.

SKB takes a positive view of the fact that there has been a broad dialogue concerning Plan 2016, which has increased the mutual understanding in several issues. SSM's expectations on Plan 2016 have been presented clearly and in September guidelines were obtained for calculation and review of real price changes (SSM 2016), which will constitute the basis for the Authority's future review. SKB has clarified how the cost calculations in Plan 2016 are made. Furthermore, the licence holders' and SKB's work with decommissioning planning, uncertainties and their effects on Plan 2016 has been presented.

SKB has, in addition to the consultations, held a dialogue with SSM on expert level concerning data and models for prediction of real price and cost trends. Predictive models have been presented as well as SKB's approach to historical outcome data provided by the National Institute of Economic Research (NIER). More in-depth analyses of outcome data have been performed prior to Plan 2016 and the modelling has been further developed.

2 The nuclear waste programme

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. In addition, SKB receives some radioactive waste from other companies. This is controlled by commercial agreements between SKB and the respective companies.

The waste system and the plan for its implementation is described in the RD&D Programme 2016 (SKB 2016). Parts of this information is provided below as a background to the cost estimates presented in subsequent chapters.

The reactors' planned operating times are an important factor in the planning of the nuclear waste programme. Based on operating times, estimates are made of the quantities of radioactive waste and spent nuclear fuel that will be managed and when the need for interim storage and final disposal will arise.

An important change in prerequisites compared to Plan 2013 (SKB 2014), is the decision made in 2015 on premature shutdown in the near future of four reactors, Oskarshamn 1, Oskarshamn 2, Ringhals 1 and Ringhals 2. The reason for the premature shutdown is that the nuclear power companies no longer deem it economically viable to operate these reactors. For the other six reactors, the planned operating time is 60 years. This applies to the reactors Forsmark 1, Forsmark 2 and Forsmark 3, Oskarshamn 3 as well as Ringhals 3 and Ringhals 4.

2.1 Description of the waste system

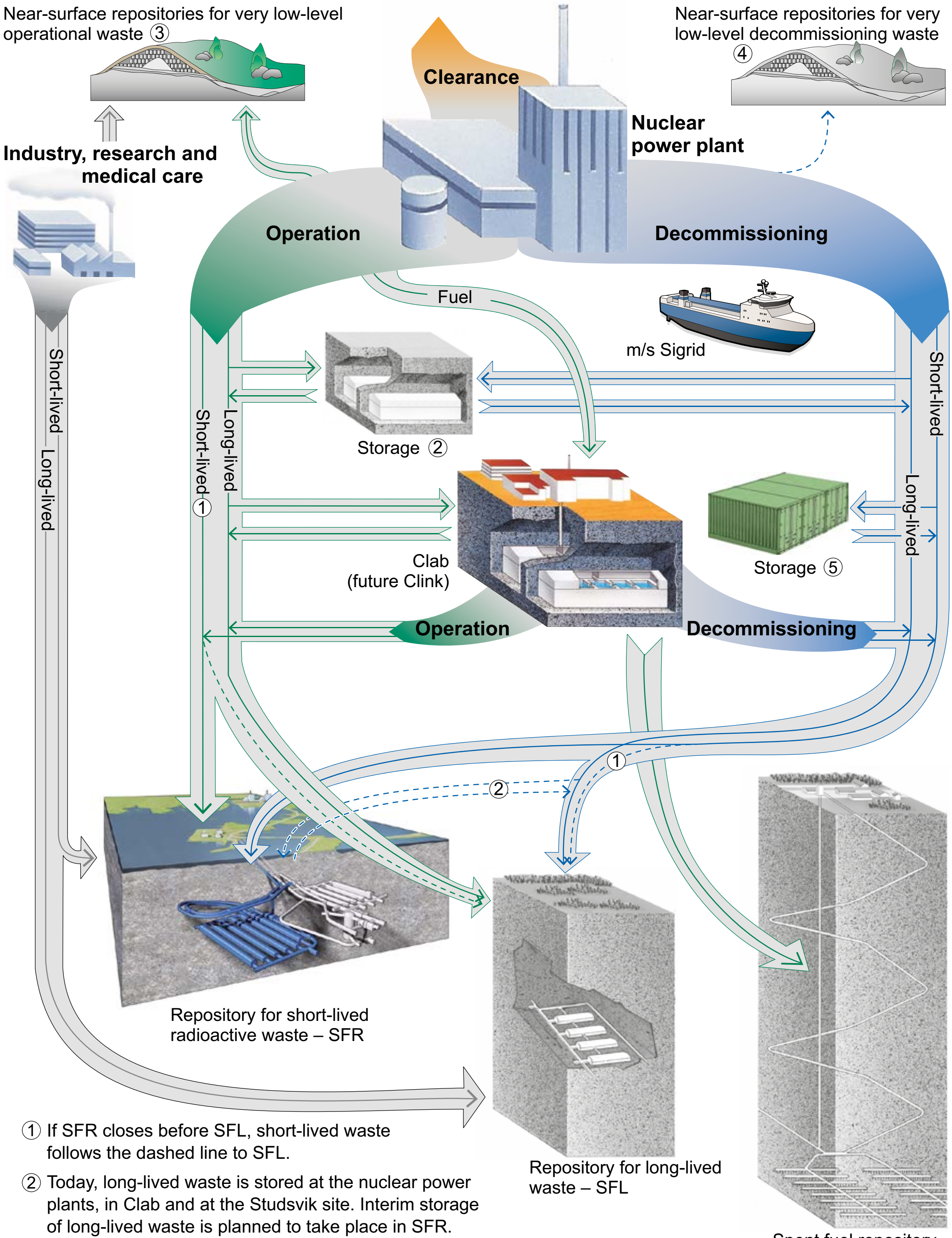
The Swedish system for management and disposal of radioactive waste consists of two main parts: one part for low- and intermediate-level waste and one part for spent nuclear fuel (the KBS-3 system).

The facilities that are in operation today are the interim storage facility for spent nuclear fuel (Clab), the final repository for short-lived radioactive waste (SFR), facilities and near-surface repositories at the nuclear power plants, plus the ship m/s Sigrid.

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

For disposal of the low- and intermediate-level waste, SFR needs to be extended, an additional repository – the final repository for long-lived waste (SFL) – needs to be established and containers for transport of long-lived waste need to be procured.

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



① If SFR closes before SFL, short-lived waste follows the dashed line to SFL.

② Today, long-lived waste is stored at the nuclear power plants, in Clab and at the Studsvik site. Interim storage of long-lived waste is planned to take place in SFR.

③ Near-surface repositories are located at the nuclear power plants sites in Forsmark, Oskarshamn and Ringhals. At the Studsvik site, similar near-surface repositories for waste from industry, research and medical care are located.

④ A possible alternative for very low-level decommissioning waste. Decision has not yet been taken.

⑤ Interim storage at nuclear power plants or other site.

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

2.2 Facilities for low- and intermediate-level waste

2.2.1 Facilities for short-lived waste

Treatment of waste

There are treatment plants for short-lived low- and intermediate-level waste at the nuclear power plants and at the Studsvik site. At the treatment plants, the waste is treated and packaged so that it meets the requirements for disposal in SFR or near-surface repositories. The purpose of the treatment may be to release the material from regulatory control, reduce its volume, concentrate its activity, solidify or condition the material.

Interim storage facilities

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

Dismantling and demolition of the first seven reactors[1] is planned to start before the extended SFR can receive decommissioning waste. This means that the existing interim storage capacity for short-lived waste will need to be extended.

Near-surface repositories

Near-surface repositories are used for very low-level waste. After roughly 50 years, the radioactivity in this waste has decreased to such low levels that it could have been cleared from a radiation protection perspective. There are near-surface repositories today on the industrial sites at the nuclear power plants in Forsmark, Oskarshamn and Ringhals as well as at the Studsvik site.

The existing near-surface repositories at the power plant sites are only licensed for operational waste. As the repositories have limited storage capacity, OKG Aktiebolag and Ringhals AB are investigating the possibility of extending their near-surface repositories. The extension is primarily for operational waste, but the use of the near-surface repositories for parts of the low-level waste from the decommissioning of the nuclear power plants may be possible.

Final repository for short-lived radioactive waste

SFR is located near the Forsmark nuclear power plant, see Figure 2-2. The repository is situated beneath the Baltic Sea, covered by about 60 metres of rock. Two one-kilometre-long access tunnels lead from the harbour in Forsmark to the repository area. The facility consists today of four 160-metre-long rock vaults, plus a 70-metre-high rock cavern in which a concrete silo has been built. The facility's total storage capacity is 63 000 cubic metres.

The design of each waste vault is adapted based on the activity level of the waste that is deposited. Low-level waste is disposed in one of the four rock vaults. Intermediate-level waste with lower activity levels is disposed in two of the rock vaults. The intermediate-level waste with the highest activity levels is disposed in the fourth rock vault. The silo will contain most of the radioactive elements in SFR.

The waste in SFR comes mainly from the nuclear power plants, Clab, Studsvik and Ågesta, whereas a minor part comes from industry, research and medical care. At the end of 2015, 38 000 cubic metres of waste had been deposited.

When SFR was built, the intention was that the facility would receive waste up to 2010. Due to the prolonged operation time of the nuclear power plants, SFR's operating phase will be prolonged, which imposes new demands on the maintenance of the facility. Today only operational waste is disposed of in SFR. SFR's storage capacity will be extended to provide room for additional short-lived waste from both operation and decommissioning. SKB has therefore submitted an application for a licence to extend the facility to hold in total about 170 000 cubic metres of waste plus nine reactor pressure vessels (RPVs) from BWRs. The RPVs from PWRs will be disposed of in SFL. Figure 2-3 illustrates SFR according to current plans when it is fully extended.

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

Figure 2-2. The final repository for short-lived radioactive waste, SFR consists of two rock vaults for concrete tanks (1-2BTF), one waste vault for low-level waste (1BLA), one waste 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 the silo top.

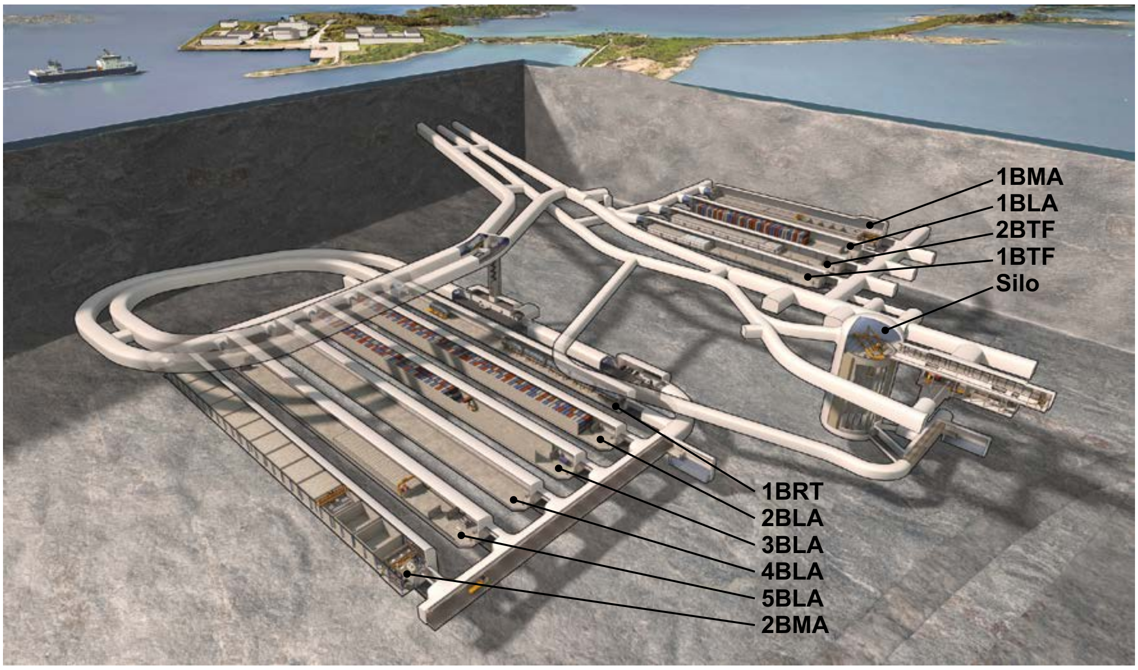


Figure 2-3. When SFR is extended, it will consist of four additional waste vaults for low-level waste (2–5BLA), one additional waste vault for intermediate-level waste (2BMA) and one waste vault for reactor pressure vessels (1BRT).

2.2.2 Facilities for long-lived waste

Treatment of waste

Currently, the possibility exists of segmenting certain used core components in order to be able to place these in steel tanks for storage at the nuclear sites.

Interim storage facilities

The final repository for long-lived waste, SFL, is planned to be commissioned around 2045. Until then, the long-lived waste needs to be interim-stored. Today most of the long-lived waste is interim-stored at the nuclear power plants, Clab and at the Studsvik site. Clab is mainly intended for interim storage of spent nuclear fuel, but in the pools storage canisters with long-lived operational waste (control rods from BWRs and other core components) are also interim-stored.

The long-lived waste produced when decommissioning the first reactors might be accommodated in the existing interim storage facilities. To increase the capacity for interim storage of long-lived waste in the future, SKB has submitted an application to use a part of the extended SFR for interim storage.

Final repository for long-lived waste

SKB plans to dispose of the long-lived waste at a relatively large depth. SFL will be the last final repository in the nuclear waste system to be commissioned. The design of the repository is in an early stage. A proposed repository concept is being evaluated at present with respect to post-closure safety. Siting of the repository is yet undecided.

The storage capacity of SFL will be relatively small compared with SKB's other final repositories. The total storage capacity is estimated to be about 16000 cubic metres. The proposed repository concept includes two repository parts, one for core components from the NPPs and one for legacy waste from AB SVAFO and Studsvik Nuclear AB. The core components, which are metallic waste, comprise about one-third of the volume, but contain (initially) the main part of the radioactivity. The repository concept is illustrated in Figure 2-4.

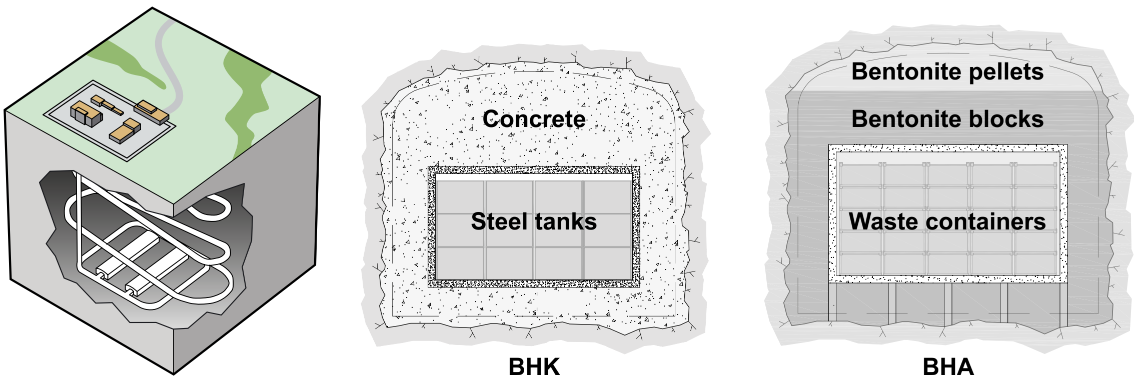


Figure 2-4. *Preliminary facility layout and the proposed repository concept for SFL, one rock vault for core components (BHK) and one rock vault for legacy waste (BHA).*

2.3 Facilities for spent nuclear fuel

Central interim storage facility for spent nuclear fuel

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

The actual storage chamber consists of two rock caverns spaced at a distance of about 40 metres and connected by a water-filled transport channel. Each rock cavern is approximately 120 metres long and contains four storage pools and one reserve pool. The top edge of the fuel is eight metres below the water surface. Clab has been in operation for more than 30 years and system upgrades and component replacements will be necessary in the future. At the end of 2015 there were 6 352 tonnes of fuel (weight of the uranium originally in the fuel) in the facility. SKB has a licence to store 8 000 tonnes of fuel in Clab. The pools can accommodate a total of about 11 000 tonnes of fuel under the assumption that the core components that are stored in Clab today are unloaded. During 2015 SKB applied for licences to extend the allowed amount to 11 000 tonnes of fuel. The facility is operated by SKB's own personnel. The permanent workforce with the facility in full operation is approximately 100.

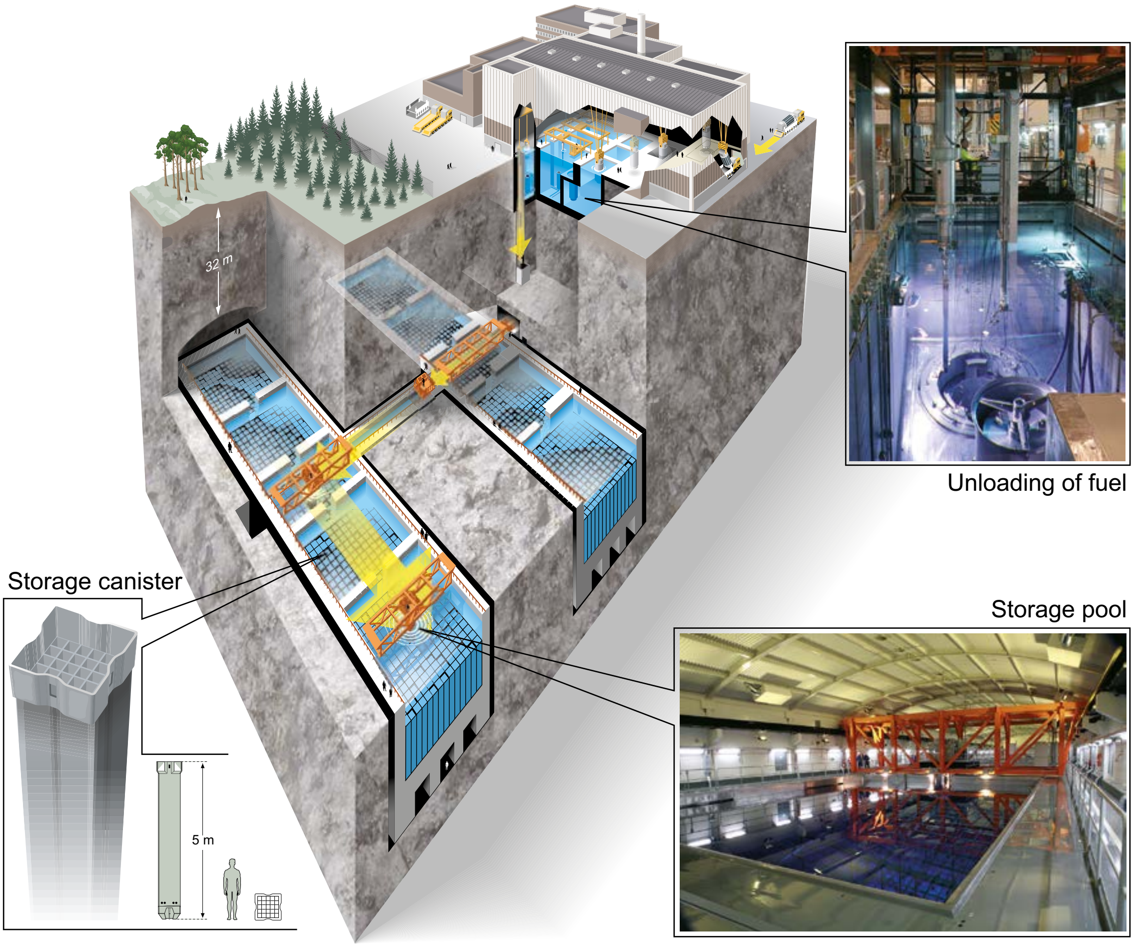


Figure 2-5. *The central interim storage facility for spent nuclear fuel, Clab.*

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 plans to do this in a new facility part adjacent to Clab, see Figure 2-6. When this encapsulation part has been connected with Clab, the two parts will be operated as an integrated facility, Central interim storage and encapsulation plant for spent fuel, Clink.

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

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

In the encapsulation plant, there will be a number of stations for different operations where all handling of fuel occurs remotely and with radiation shielding. The encapsulation process begins with the fuel being placed in a transport canister and taken up in the fuel elevator from the underground storage pools.

The fuel assemblies to be placed together in a canister are selected in such a way that 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 over to the canister. The air in the canister is replaced with argon before the canister is sealed. The copper canister is sealed by means of friction stir welding (FSW). The quality of the weld is inspected, and if it is approved the canister is taken to the machining station, where excess material is removed. Finally, a new quality inspection of the weld is performed. If necessary, the canister is cleaned before being placed in a special transport cask for transport to the Spent Fuel Repository. Clink is designed for encapsulation of 200 canisters per year.

Once all the spent fuel and other types of waste have been removed from the facility, the surface section will be decommissioned and dismantled as well as those parts of the storage pools that have become radioactive. The radioactive decommissioning waste will be transported to SFR.

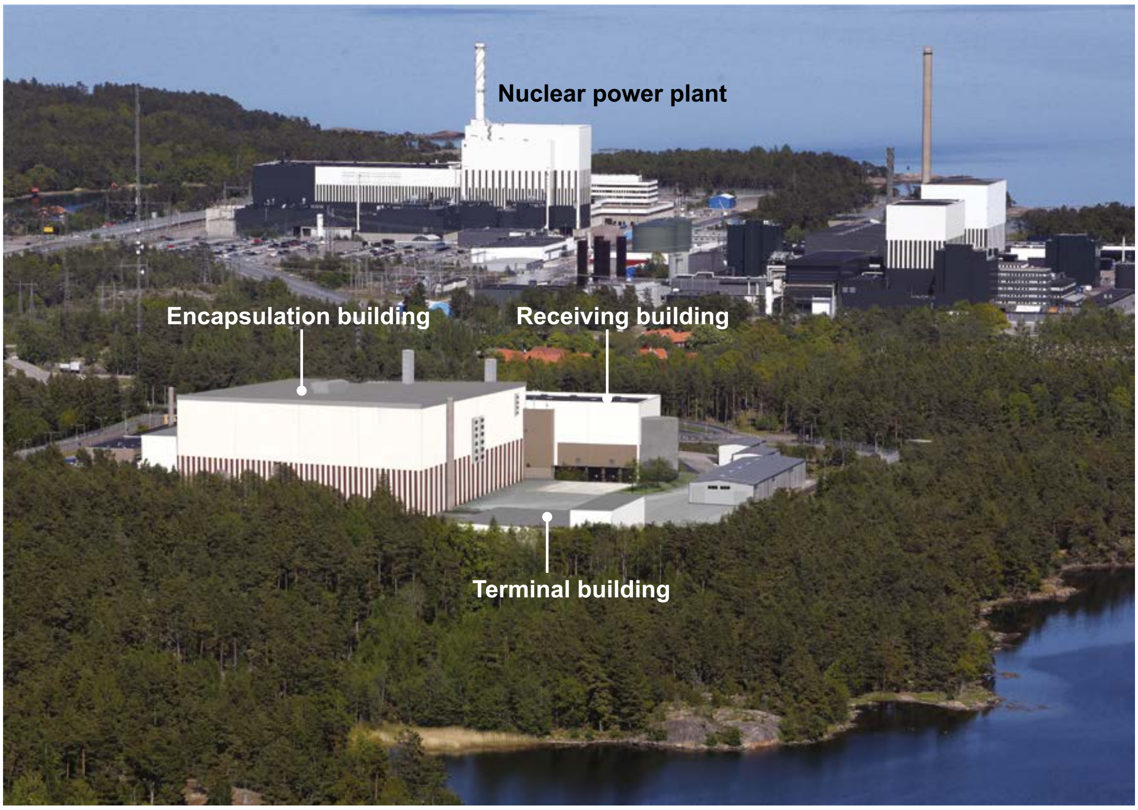


Figure 2-6. *Photo-montage that demonstrates the integrated facility for interim storage and encapsulation of spent nuclear fuel, Clink.*

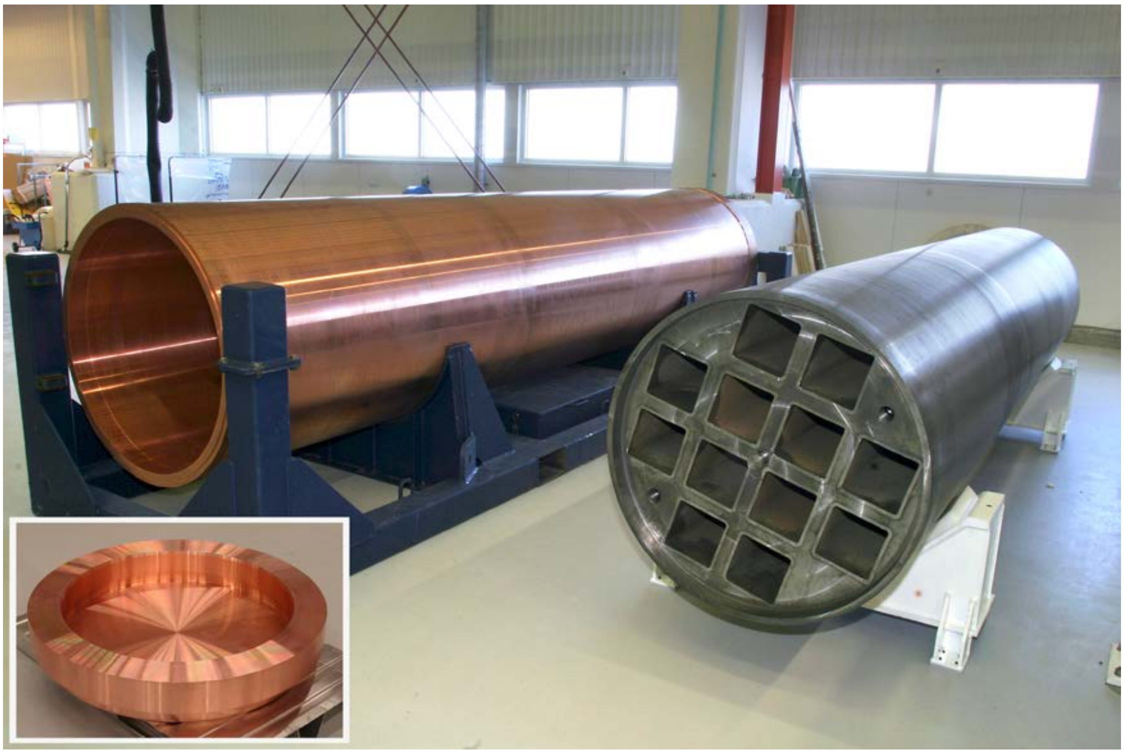


Figure 2-7. Copper shell and nodular iron insert (the inset photo shows the copper lid).

The final repository for spent nuclear fuel

Finding 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 Forsmark in Östhammar municipality and Laxemar in Oskarshamn municipality. After evaluations of the site investigations, SKB selected Forsmark as the site for the Spent Fuel Repository. A decisive factor in the selection of Forsmark was that the prospects of achieving long-term safe disposal were judged to be better there.

The final repository will consist of a surface facility and an underground facility, see Figure 2-8. The underground facility consists of a central area and a number of deposition areas plus connections to the surface facility in the form of a ramp for vehicle transport and shafts for elevators and ventilation. The deposition areas, which together comprise the repository area, will be located about 470 metres below ground and consist of a large number of deposition tunnels with bored deposition holes at the floor of the tunnels. The positioning of the deposition tunnels, as well as the spacing between the deposition holes and the design of infrastructure at the repository level, is determined on the basis of the properties of the rock, for example the location of large deformation zones, the occurrence of large or highly water-conducting fractures, and the thermal conductivity of the rock. The surface facility consists of an operations area, rock heap, ventilation stations and storeroom. The facility is designed for a maximum deposition capacity of 200 canisters per year.

The canisters are transported to the deposition level via a ramp with a specially built transport vehicle. There the canisters are transloaded to the deposition machine to be carried out to the deposition area and finally deposited. After the canisters have been emplaced in the deposition holes, surrounded by bentonite clay, the tunnel is backfilled with clay that will swell in contact with water and sealed with a concrete plug. When all fuel has been deposited, other openings are also backfilled and the surface facilities are decommissioned.

2.4 The transportation system

SKB's transportation system was built up during the 1980s. It consists of the ship m/s Sigrid, special vehicles for overland shipments and different types of transport containers for fuel and radioactive waste. The ship and the vehicles are used both for shipments of low- and intermediate-level waste and spent nuclear fuel. The different transport containers are developed for the waste they are intended for.

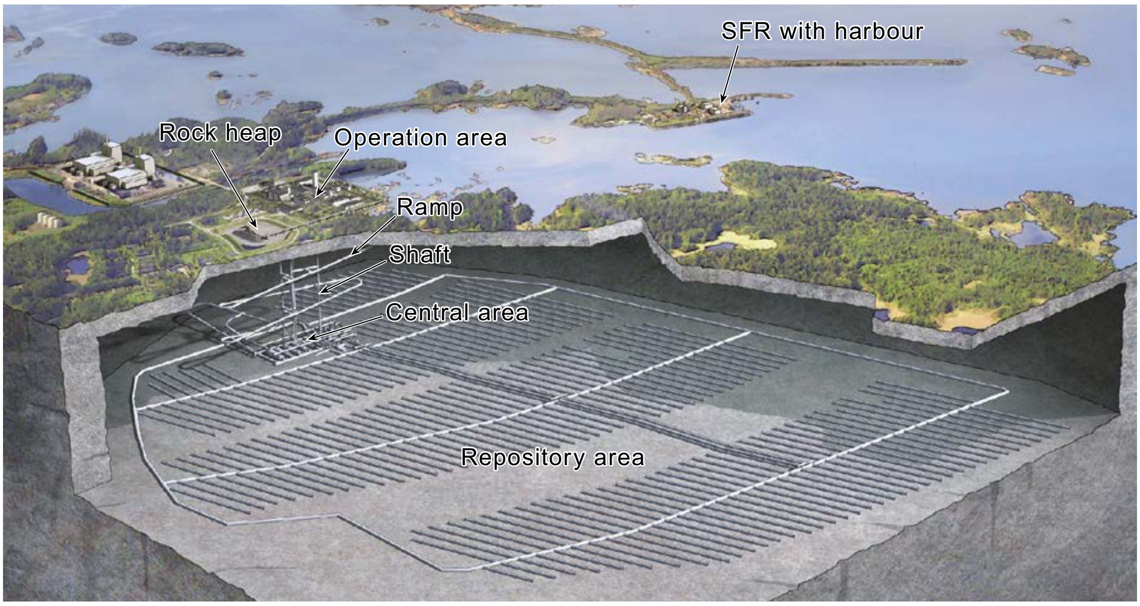


Figure 2-8. *Illustration of possible layout of the Spent Fuel Repository in Forsmark.*

M/s Sigrid was commissioned in 2014. She replaced m/s Sigyn, which was used for transportation for about 30 years. Like the old ship, the new ship has a double bottom and a double hull. This design protects the cargo in the event of grounding or collision. Sigrid has been constructed to have low fuel consumption and provide low releases to air and water and generally has a lower environmental impact than her predecessor. She can carry twelve fuel- or waste- containers. Normally, the ship, which is operated by a contractor, makes between 30 and 40 trips per year between the nuclear power plants, Studsvik, SFR and Clab.

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

Figure 2-9. *M/s Sigrid and transport container for short-lived radioactive waste (ATB) and transport cask for core components (TK).*

Today part of the long-lived waste, control rods from BWRs, is transported from the nuclear power plants to Clab. The waste is shipped in a transport cask with approximately 30 cm thick walls of steel. The spent nuclear fuel is shipped from the nuclear power plants to Clab in casks with roughly 30-centimetre-thick steel walls. These casks have cooling fins to remove the decay heat generated by the fuel. In view of the amended set of requirements for fuel transport casks, SKB started a project in 2013 to develop new casks. A contract has been signed with an American supplier and completion of a licensing basis for regulatory review is under way. The new casks are designed with double lids to protect the fuel from water penetration after an accident. The casks are constructed with an increased capacity, which means that fewer casks are needed to meet the transport demands in the Swedish system.

A new type of waste transport containers is being developed for shipping long-lived intermediate-level waste. The transport containers are intended for waste that is placed in steel tanks for dry interim storage.

An increased transport volume is envisaged in the future in conjunction with shipments of decommissioning waste and canisters with spent nuclear fuel. There is over capacity in today's transportation system so no major investments are envisaged in order to meet the increased volume.

A new type of transport casks will be developed for shipping encapsulated spent nuclear fuel from Clink to the Spent Fuel Repository.

2.5 Plan of action

Safe operation of existing facilities is a prerequisite for the work with the system for management and final disposal of spent nuclear fuel and radioactive waste. In addition, work is being pursued to construct and commission new parts and facilities as well as preparations for decommissioning of the nuclear reactors.

SKB's plans for construction and commissioning of new and extended facilities in the system for management of spent nuclear fuel and radioactive waste as well as the nuclear power companies' and SKB's plans for decommissioning of nuclear facilities are presented in the RD&D Programme 2016 (SKB 2016). It also presents the research and technology development needed to carry out these plans.

When establishing new facilities, planning follows a stepwise decision process based on requirements in the Nuclear Activities Act and the Swedish Radiation Safety Authority's Regulations. The procedure implies that SKB needs to submit increasingly detailed safety analysis reports to SSM.

- First, *applications under the Nuclear Activities Act and the Environmental Code* to construct, own and operate the facility must be submitted to SSM and the Land and Environment Court. The Government decides on permissibility and licensing, where after conditions are determined by SSM and the court.
- *Before a nuclear facility may be constructed*, a preliminary safety analysis report (PSAR) should be approved by SSM.
- When systems and processes in the facility have been tested and work as intended, the safety analysis report (SAR) should be renewed. When SSM has approved the SAR, *trial operation* can commence. Before a facility can be put into *regular operation*, the SAR must be supplemented with experience from trial operation and approved by SSM.

Each of the above milestones is actually two milestones: Firstly SKB's compilation of applications and/or SARs and secondly SSM's and/or other regulatory authorities' approval of these after completed examination. The time points for SARs determine when SKB needs to be finished with their basis for assessment and times for approval when SKB can begin their activities.

Figure 2-10 shows the general timetable, including times for coming applications, for the entire nuclear waste programme. During dismantling and demolition of a nuclear power plant, both conventional and radioactive waste that need to be managed and disposed of, is produced. In order to visualise the relation to the plans for decommissioning of the nuclear power reactors, the figure shows preparatory measures as well as dismantling of reactors.

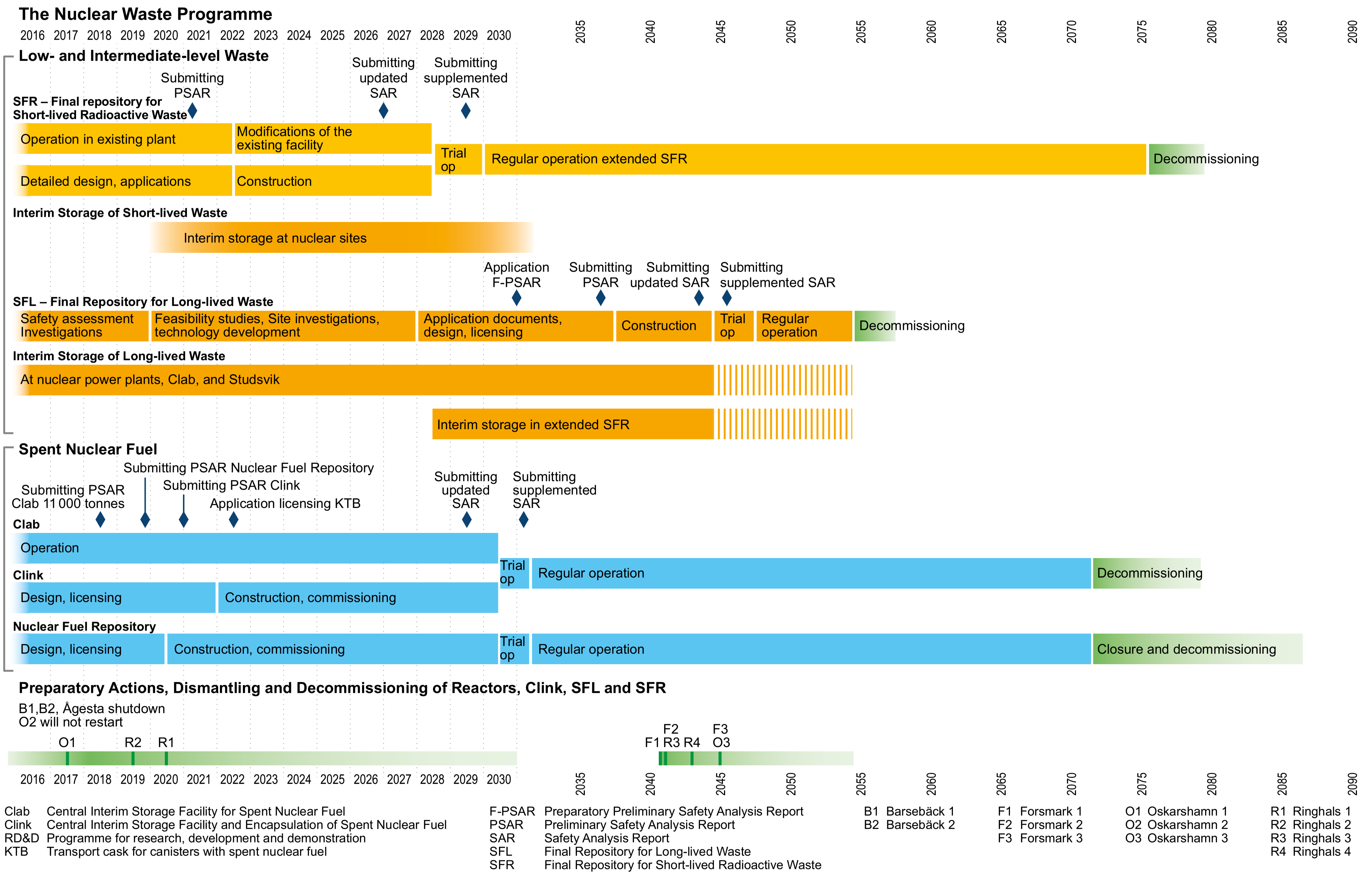


Figure 2-10. *General timetable for SKB's nuclear waste programme and decommissioning of the nuclear power plants.*

The planning for the additional facilities is largely divided into technology development and siting (SFL), design and licensing, construction, trial operation and regular operation and, finally, decommissioning. There are large uncertainties in the presented timetable, particularly during licensing phases when SKB does not control the course of events.

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

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

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. The licensing process is currently under way and, in parallel, SKB pursues technology development for barriers as well as detailed design and activities related to future safety analysis reports. According to SKB's current plans, which have been adapted to the fact that licensing will take longer than previously estimated, the construction of the extension is expected to start in 2022, with planned trial operation in 2028. The facility will be in operation until around 2075 when decommissioning can begin.

Decisions on the premature closure of four reactors affect the plan of action for low- and intermediate-level waste by increasing the need for interim storage, since the extended SFR has not yet been commissioned at the time of their decommissioning. Therefore, some of the nuclear power companies have the intention of arranging temporary interim storage facilities for short- and long-lived decommissioning waste until the extension of SFR is commissioned. There will also be a need for interim storage of operational waste during the period when construction of the extended SFR is in progress.

According to the current plans, additional reactors will be decommissioned before SFL, which will be commissioned around 2045, is completed, which means that the long-lived decommissioning waste from these reactors will be interim-stored at the power plants and in the SFR extension.

SKB plans to submit applications under the Nuclear Activities Act and the Environmental Code to construct, own and operate SFL around 2030. Up to commissioning, there are several important milestones that must be passed, such as safety evaluation of the repository concept, site selection, assessment of post-closure safety, preparation of licence applications and construction of the repository. To provide for the needs of the nuclear power companies, it is judged to be necessary to keep SFL in operation for about 10 years.

The transportation system will need to be supplemented with a new type of transport container (ATB 1T) for shipping long-lived waste in steel tanks. According to the plans, the contracted supplier will deliver the container in 2020.

2.5.2 Plan of action for spent nuclear fuel

Over the next few years, SKB will gradually prepare for construction of the Spent Fuel Repository and the encapsulation part of Clink. Most of the milestones shown in Figure 2-10 refer to times for delivery of results from research and technology development, i.e. points in time when technology components and solutions should be ready to use or have reached a certain development phase and safety analysis reports should be presented.

The establishment of the Spent Fuel Repository and Clink is divided into the following main phases: licensing and design, construction and commissioning. The application for final disposal of spent nuclear fuel under the Nuclear Activities Act and under the Environmental Code for the KBS-3 system were submitted in March 2011. Licensing of the KBS-3 system's facility parts for encapsulation and final disposal of spent nuclear fuel is under way. An announcement of the applications under the Environmental Code and the Nuclear Activities Act was made in January 2016.

According to the plans, construction of the Spent Fuel Repository's accesses will begin in 2020. The construction of Clink will commence around 2022 so that the facilities can be commissioned simultaneously in 2030. The Spent Fuel Repository and Clink are planned to be in operation until 2072. Thereafter, the Spent Fuel Repository is closed and the facilities are decommissioned and dismantled.

SKB has a licence for interim-storage of 8 000 tonnes of fuel in Clab. According to current predictions, this amount will be reached in 2023, i.e. before Clink and the Spent Fuel Repository have been commissioned. The pools in Clab can accommodate a total of about 11 000 tonnes of fuel under the assumption that the core components that are stored in Clab today are unloaded. During 2015 SKB applied for licences to extend the allowed amount to 11 000 tonnes of fuel. If no other measures than a licensed increase in storage capacity are taken, Clab's storage positions will be filled around 2027. In order to increase the physical storage capacity for fuel, SKB plans transloading of the fuel still stored in normal storage canisters to compact storage canisters, where the fuel is stored more densely. With this action, the storage capacity in Clab is calculated to suffice until 2032. A second measure, which may be taken if the need arises, is segmenting the control rods from BWRs that currently require a lot of space. After segmentation, the BWR control rods could be packed closer in storage canisters and taken back to Clab's storage pools, or interim-stored at another site. The control rods from PWRs are integrated in the fuel and require no extra space.

The transportation system will be upgraded with new fuel transport casks that comply with modern requirements. Five casks will be delivered during the period 2019–2021 and in 2019 it will be decided if a sixth transport cask should be ordered. The transportation system will also be supplemented with a new type of transport cask (KTB) for shipping encapsulated spent nuclear fuel from Clink to the Spent Fuel Repository. The first transport cask will be delivered in 2025 and the remaining casks during the period 2027–2030.

2.5.3 Plan of action for decommissioning of nuclear facilities

Decommissioning of a reactor facility includes a number of activities to release the facility from regulatory control, see Figure 2-11. Prior to decommissioning, necessary licences must exist. When a facility is decommissioned, defueling operation follows, where all fuel is transported from the reactor to Clab for interim storage. In cases where dismantling and demolition cannot commence immediately after defueling, a period of service operation follows, during which the facility is maintained awaiting the start of dismantling and demolition. The nuclear power companies' plan is to start dismantling and demolition of the facility as soon as possible after shutdown. During dismantling and demolition, activities are under way for disposing of the radioactively contaminated facility parts in the form of process systems, buildings and any contaminated soil. The dismantling and demolition phase is concluded when the site has reached a state that makes it possible to release. When the facility/facility parts have been released from regulatory control, conventional demolition and restoration of land will be carried out.

The general timetable for decommissioning of all nuclear power plants and SKB's facilities is shown in Figure 2-12.

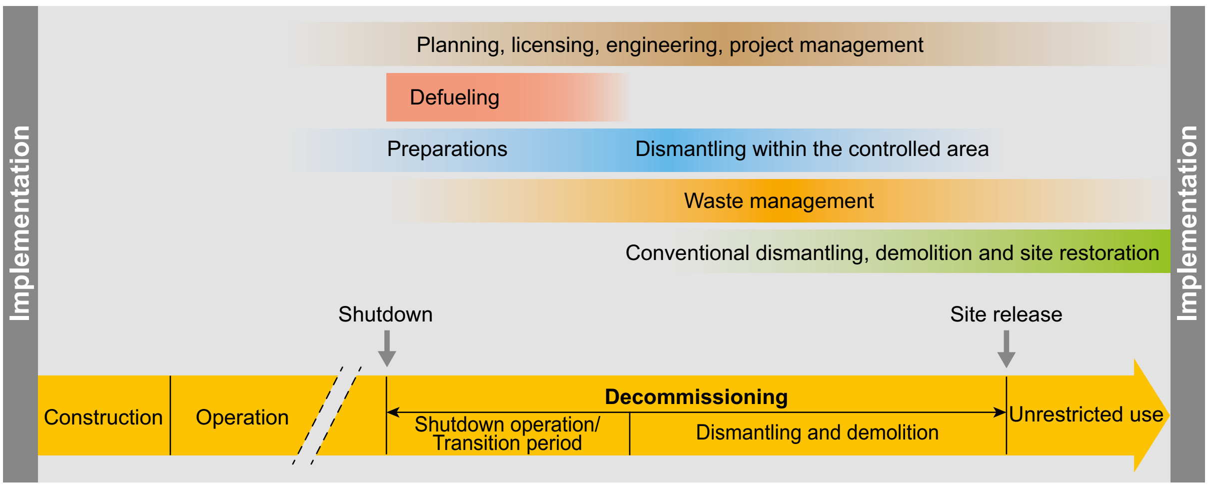


***Figure 2-11.** Overview of the different phases for decommissioning of a reactor.*

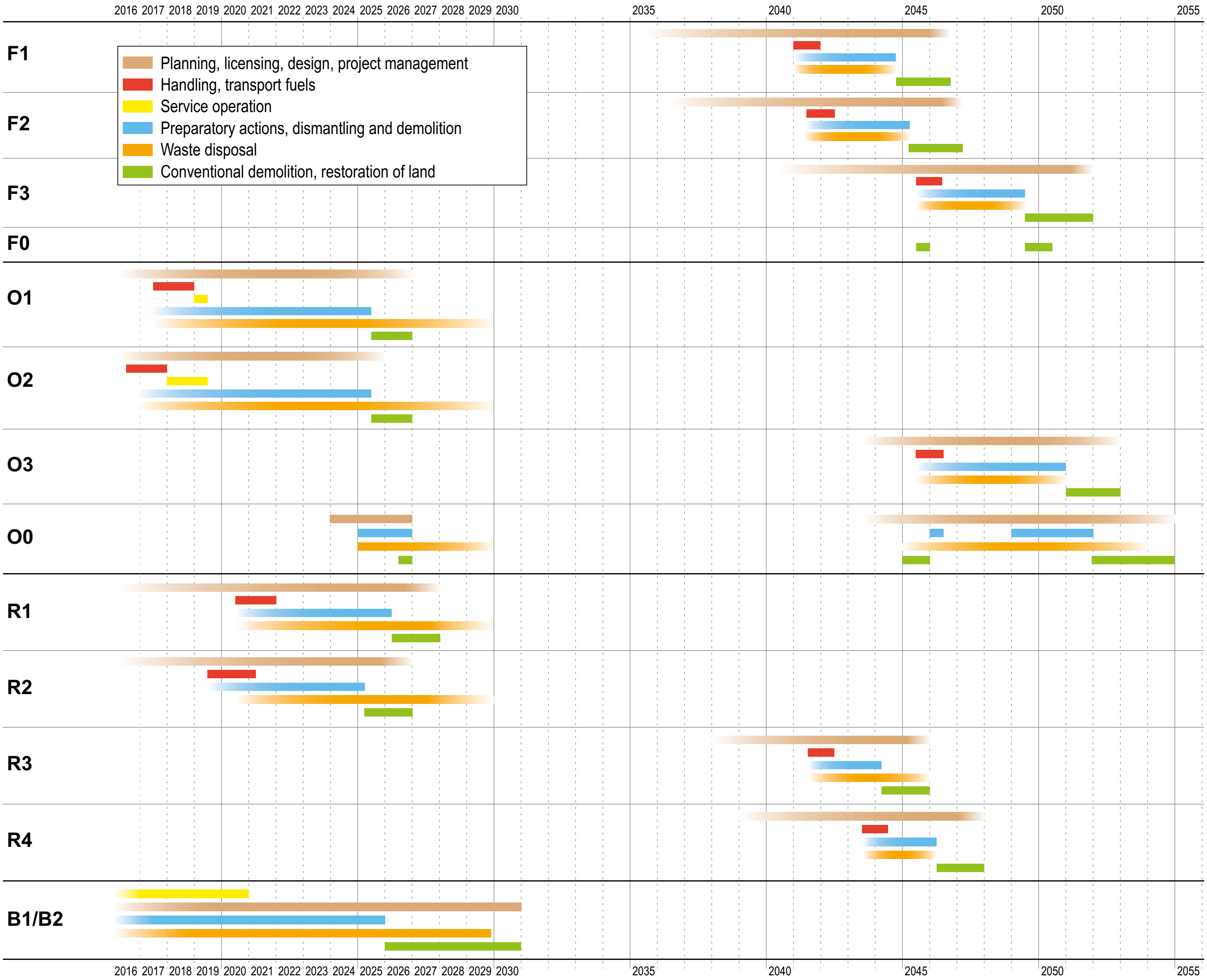


Figure 2-12. *Schematic overview of the nuclear power companies' and SKB's timetables for decommissioning (F0 and O0 are common facilities on the sites).*

Shutdown operation of Barsebäck Kraft AB's two reactors, Barsebäck 1 and Barsebäck 2, has been under way since 2006. A decision has been made to segment the reactor pressure vessel internals and store them in steel tanks in a new storage building at the plant. Dismantling and demolition of the nuclear power plant is planned to start in 2021 and clearance is planned at the end of the 2020s.

OKG Aktiebolag has initiated the preparations required to commence defueling of Oskarshamn 1 and Oskarshamn 2, followed by shutdown operation and thereafter dismantling and demolition. Oskarshamn 1 is planned to be finally shutdown in the summer of 2017 and Oskarshamn 2 will not be restarted. Decommissioning of the two reactors will be completed in 2025. Oskarshamn 3 will be in operation up until 2045.

In conjunction with the shutdown decision for Ringhals 1 and Ringhals 2, Ringhals AB started preparations for decommissioning of the two reactors while operation of Ringhals 3 and Ringhals 4 proceeds according to plan. Ringhals 1 and Ringhals 2 are planned to be finally shutdown in the summer of 2020 and 2019 and will be decommissioned in 2026 and 2025 respectively. Ringhals 3 and Ringhals 4 will be in operation until 2041 and 2043 respectively.

Forsmarks Kraftgrupp AB's reactors will be in operation for a total of 60 years, which means that Forsmark 1 will be shut down in 2040, Forsmark 2 in 2041 and Forsmark 3 in 2045. The nuclear power plant will be fully decommissioned by 2051.

Decommissioning of Clink and the Spent Fuel Repository can begin at the earliest when all spent nuclear fuel has been deposited while decommissioning of SFR can begin at the earliest when the waste from decommissioning of Clink has been deposited. SFL can, however, be decommissioned when the long-lived waste from the last reactor has been managed and disposed of.

2.5.4 Future research and development

SKB's and the nuclear power plant licensees' planning of future research and technology development for the final repositories is based on the stepwise decision process. The milestones relating to decisions steps in the form of applications and safety analysis reports, dictate when knowledge and development of the technology needs to have reached a certain level, while SSM's approval dictates when SKB can commence construction and operation of the facilities.

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

- The need for an increased process understanding, i.e. the scientific understanding of the processes that affect the final repository system and thereby 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 to be used in the system.
- The need for knowledge and competence of inspection and testing to verify that barriers and components are produced and installed according to approved specifications and thereby satisfy the requirements.

Much of the research and technology development needs to be done in a realistic setting and on a full scale. SKB has three laboratories for this purpose: the Äspö HRL, the Canister Laboratory and the Bentonite Laboratory. At Äspö, there is also an accredited water chemistry laboratory for analysis of groundwater.

3 Methods and specific assumptions for calculation of costs

A number of calculations of varying scope and based on partly different assumptions are produced during the work on estimating the costs. Some of them are intended to result in the amounts required according to the Financing Act, whereas others are intended to serve as a basis for SKB's development and planning work.

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

3.1 Calculation of the reference cost

The calculation of future costs is based on the reactor owners' current planning premises in terms of operating times and expected volumes of radioactive waste and spent nuclear fuel. This information is also the basis for planning of SKB's activities and the design and implementation of the nuclear waste programme, see Chapter 2. The current design is referred to as the reference design and the implementation plan – which includes timetables, waste quantities and other planning – is called the reference scenario and is based on the proposed focus of the activities presented in the RD&D Programme 2016 (SKB 2016). In addition to costs relating to the management of radioactive waste and spent nuclear fuel, the calculation for the reference scenario also includes costs for decommissioning and dismantling of nuclear power plants.

The reference cost is calculated in the traditional way based on a so-called deterministic method, i.e. a method in which conditions are stipulated and locked. The calculation is based on a functional description for each facility, including layout drawings, equipment lists and staffing forecasts. For facilities and systems in operation, this information is detailed and well known, while the level of detail is lower for future facilities.

For planned facilities, the cost calculations are based on the existing information at the time of calculation. Experience from previous construction of nuclear facilities as well as experience from manufacture and utilisation of prototype equipment is considered. In principle, construction and installation costs in connection with the construction of future facilities are based on quantity-related costs, non-quantity-related costs and secondary costs.

Quantity-related costs can be calculated directly with the aid of design specifications and with knowledge of unit prices, for instance for concrete casting, rock excavation and operating personnel. Experience gained from previous planning and construction of nuclear facilities, such as Clab and SFR, has been drawn on in estimating both quantities and unit prices.

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

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

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

In a number of cases, SKB's planning incorporates alternative solutions, for example in cases where development work is in progress. However – to obtain a clear and concrete basis for the cost calculations in the reference scenario, – it is necessary to assume that a certain solution will be implemented. This basic starting point for the calculations should not be regarded as a final commitment by SKB to implement a certain solution. For Plan 2016, the following assumptions have been made in the cost calculations:

- **Siting of SFL**. SKB has not yet made any decision regarding the siting of SFL. The assumption used in the reference and financing scenario is that the repository will be located adjacent to SFR in Forsmark. With the existing construction and transport tunnels in SFR as a starting point, it is assumed that the facility will be sited at a depth of approximately 300 m.
- **Deposition rate**. According to the plans, the Spent Fuel Repository and Clink will be commissioned in 2030. During the first years, the deposition rate is assumed to gradually increase to 180 canisters per year. Towards the end of the operating period, the deposition rate will decrease to 100 canisters per year. This is an adaptation to the fact that the annual inflow of spent nuclear fuel decreases as the reactors are decommissioned.

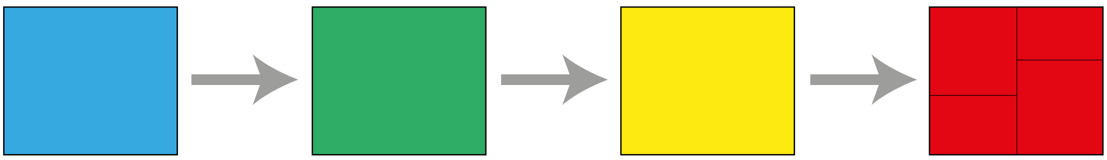
3.2 Preparation of cost calculations in accordance with the Financing Act

SKB shall, according to the Financing Act, report three amounts: the remaining basic cost, the basis for the financing amount that stems from this basic cost and the supplementary amount, see Section 1.1.2. These amounts are the end-point of the calculation that is conducted through a stepwise process and illustrated in Figure 3-1.

The cost estimates that shall be reported to the authority are derived from the cost calculations for the reference scenario, but have been adapted to the calculation assumptions that apply under the Financing Act, i.e. that the cost calculations shall be made with the assumption that each of the reactors in operation today will be operated for 40 years. There is a stipulated minimum time, entailing that the remaining operating time shall be at least six years, unless there is reason to assume that the operating period could cease before then. This means, among other things, that the operating times for the reactors are adjusted in relation to the reference scenario and that the amount of spent nuclear fuel and radioactive waste is underestimated. Furthermore, the cost calculation according to the Financing Act does not include the type of radioactive waste that constitutes operational waste, see Section 3.2.1.

SKB takes future real price changes into account in the cost estimates made in accordance with the Financing Act, see Section 3.2.2. The term real price changes refers to the price and productivity trends affecting the project that deviate from the developments in society in general, i.e. the Consumer Price Index, CPI.

Legislation states that the cost estimate should include both anticipated costs and supplementary costs to cover any impact resulting from unexpected events. This means that some form of uncertainty analysis based on probability theory should be carried out, see Section 3.2.3.



Reference scenario with 6,000 canisters of spent fuel, based on early shutdown of the oldest reactors and 60 years of operation of the other reactors.

Scenario in accordance with the Financing Act (based on peration of the reactors for 40 years or at least up to and including 2023).

Probability-based uncertainty analyses with Monte Carlo simulations (one for each relevant real discount rate).

Allocation of the costs among the four licensees.

Figure 3-1. *Stepwise process.*

Furthermore, the Financing Ordinance requires that each licence holder's share of the basic cost is specified, which means that a basis for distributing the costs among licence holders need to be developed, see Section 3.2.4.

3.2.1 Costs excluded in the financing scenario

The Financing Act makes a distinction between residual products and operational waste from nuclear activities. The nuclear waste fee and pledged guarantees shall cover costs for the management and final disposal of residual products, but not costs for the management and disposal of operational waste. This means that the cost of today's final repository for short-lived radioactive waste is not included in the financing scenario. Costs for operational waste are financed directly by the licence holders.

Apart from a licence to operate a nuclear power plant, each nuclear power company already holds a special licence, or plans to acquire one in the future, for small facilities that are located on each respective power plant site. These facilities could be interim storage facilities or disposal facilities for very short-lived radioactive operational waste and are only used by the respective licence holder. The costs of constructing and operating these small facilities are included in day-to-day operation of the nuclear power plant and are therefore not included in the cost estimates according to the Financing Act. However, the costs for future decommissioning and dismantling of these facilities should be included in the cost estimates according to the Financing Act, since these costs are temporally and materially associated with the decommissioning and dismantling of the NPPs.

New capacity will be or has been created at the power plant sites for interim storage of both short- and long-lived decommissioning waste, before the extended SFR is ready to receive this waste for final disposal or interim storage respectively. These costs are included in the decommissioning costs for Barsebäck, Oskarshamn and Ringhals.

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 license holders (operational waste) or by other stakeholders purchasing space in SKB's facilities.	Financing through the licence holders' shares of the Nuclear Waste Fund
Short-lived very low-level waste	Operational waste, compacted or in containers of concrete or steel. Interim storage at the site where the waste is produced (local interim storage). Final disposal in either on-site near-surface repositories or in SFR.	Operational and decommissioning waste from the interim storage and treatment facilities that come under the Financing Act (Clab, encapsulation plant) and decommissioning waste from NPPs. Interim storage at the nuclear sites. Final disposal in SFR.
Short-lived low- and intermediate-level waste	Operational waste from NPPs and other stakeholders, in containers of concrete or steel. Interim storage locally. Final disposal in SFR.	Same as above.
Long-lived low- and intermediate-level waste	Operational and decommissioning waste from other stakeholders. Interim storage locally. Final disposal in SFL.	Operational and decommissioning waste from NPPs. Including replaced reactor internals. Interim storage in Clab, in SFR or locally (local interim storage is 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 that is encapsulated in copper canisters. Final disposal in the Spent Fuel Repository.

3.2.2 Adjustment with respect to real price changes

In the calculations, consideration is given to real price changes through a number of conversion factors that are referred to as external economic factors, EEF. These include trends in payroll costs (including productivity trend) and costs for various input and machinery. The EEFs that have been selected for inclusion in the calculations consist of a limited number of observable macro-economic variables. The large number of variables in a project of this type are reduced in the calculation to a few selected factors, which entails a relatively significant aggregation. The following EEFs are used in the calculation:

- EEF 1 real payroll costs in the services sector,
- EEF 2 real payroll costs in the construction industry,
- EEF 3 real price for machinery,
- EEF 4 real price for construction material,
- EEF 5 real copper price,
- EEF 6 real price of bentonite,
- EEF 7 real energy price,
- EEF 8 real exchange rate SEK/USD.

Each cost item in the plan calculation relates to one of the seven first EEFs. EEF 8 is used for conversion of copper and bentonite prices given in USD.

For each EEF, a forecast is made for the future real price trend. The forecast is based on established predictive models, statistical analysis and expert judgement. Based on these forecasts, the costs are adjusted for the real cost trend from the time of calculation until the cost outcome.

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 to plan and calculate costs for projects and has been developed specifically to identify, analyse and evaluate uncertainties. The successive calculation involves a scheme implying that variations, deviations or other uncertainties that are of a general or overall nature are dealt with separately. The cost impacts of these uncertainties with different outcomes are then added together on the basis of the chosen statistical method in order to produce the total effect expressed as a probability distribution over different cost levels.

The identification and selection of uncertainties to be considered in SKB's uncertainty analysis is done in a systematic manner, with the purpose of facilitating the work and reducing the risk of overlooking essential uncertainties. This means, for example, that the uncertainties are divided into six areas:

- **Society**. This area includes legislation and regulatory matters as well as political issues in general.
- **Economics**. This area has an emphasis on economic conditions such as the real price trend for labour and the prices of input materials, business cycle factors and currency exchange rate risks.
- **Implementation**. This includes time schedule strategies, siting questions, the strategy for decommissioning of NPPs, etc.
- **Organisation**. This mainly concerns how future construction or decommissioning projects will be implemented and managed in terms of organisation.
- **Technology**. All purely technical matters are referred to this area. The greatest uncertainties are linked to the future facilities for management and disposal of both spent nuclear fuel and radioactive waste.
- **Calculation**. This area takes into account the risks of incorrect assessments in the actual calculation work. They may consist of both overestimations of difficulties (pessimistic assessment) as well as underestimations (optimistic).

Identification of uncertainties to be considered is made by a group formed for this purpose, the analysis group. The uncertainties considered by the analysis group are limited according to the principles of successive calculation, the so-called fixed preconditions. They are determined by

SKB and may entail relatively obvious limitations, such as the fact that the necessary steps must be taken within Sweden's national borders, but also the kind that constitute important policy-related standpoints, for example that only KBS-3 should be regarded as a method for the final management and disposal of spent nuclear fuel.

The identified uncertainties are then analysed and evaluated by the analysis group, whereby calculations begin. Since both calculation objects and uncertainties have been defined based in part on the probable cost, and in part on the 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 through Monte Carlo simulation. Each variable is assigned a unique random number and when all input variables 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 given by the combination of all calculation cycles.

3.2.4 Distribution of costs

The fees paid into the Nuclear Waste Fund by each licence holder are intended to cover the future costs incurred by that specific licence holder for management and disposal of radioactive waste and spent nuclear fuel. Certain costs are directly attributable to the undertakings of the individual licence holders (special costs), whereas other costs refer to activities that are conducted jointly with the other licence holders (in practice SKB's area of responsibility). These joint costs are divided between the licence holders, which is done on the basis of various agreements between the licence holders.

4 The nuclear power companies' current plans

4.1 The nuclear power companies' current plans for the reactors and the quantity of residual products

The reference scenario is based on the reactor owners' current plans for reactor operation. It is likely that the production data for the individual reactors will change during the remainder of the total operating time. However, no consideration is given to this in the reference scenario and the input is based on historical data and an extrapolation of the current situation over the entire calculation period. Any future changes will be incorporated in the basic data for the calculations once the decisions have been made.

Table 4-1 is a compilation of the reactors' historical operational data and assumptions on future electricity production and the quantity of spent nuclear fuel. The fuel quantity is given in tonnes of uranium[3]. The table presents data based on premature shutdown of the reactors O1 and O2, R1 and R2, while the remaining reactors will be in operation for 60 years. The nuclear power companies currently predict a fuel quantity corresponding to approximately 5 700 canisters. SKB will, however, design the facilities in the KBS-3 system to handle and deposit 6 000 canisters. The reference calculation thus includes 6 000 canisters of spent nuclear fuel.

The number of canisters containing spent nuclear fuel is shown in Table 4-2. The table also shows the volumes of other radioactive waste that must be accommodated in the different final repositories. The volumes refer to those containers with radioactive waste that are intended for final disposal. The table does not contain information about the quantities of very short-lived radioactive waste that is deposited in near-surface repositories on the NPP sites.

The block diagram in Figure 4-1 is a compilation of the quantities and volumes of spent nuclear fuel and radioactive waste that pass through storage and treatment facilities for deposition in the respective repositories. The quantities refer to the nuclear power companies' current planning.

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

	Thermal capacity/net capacity	Electricity production up to and including 2016	Fuel up to and including 2016	Total for planned operation: Planned operating time	Total for planned operation: Operation up to and including	Electricity production	Spent nuclear fuel
Start of commercial operation	MW	TWh	Tonnes of uranium	Years		TWh	Tonnes of uranium
F1 (BWR) 10/12/1980	2928/984	251	883	60.0	08/12/2040	434	1348
F2 (BWR) 07/07/1981	3253/1120	245	864	60.0	05/07/2041	462	1418
F3 (BWR) 22/08/1985	3300/1167	270	897	60.0	20/08/2045	536	1509
O1 (BWR) 06/02/1972	1375/473	81	367	45.4	30/06/2017	82	367
O2 (BWR) 15/12/1974	1800/638	154	537	41.1	31/12/2015	154	537
O3 (BWR) 15/08/1985	3900/1400	256	841	60.0	14/08/2045	568	1577
R1 (BWR) 01/01/1976	2540/881	197	720	44.5	14/06/2020	219	773
R2 (PWR) 01/05/1975	2500/807	210	630	44.2	13/07/2019	224	671
R3 (PWR) 09/09/1981	3135/1063	225	607	60.0	07/09/2041	421	1126
R4 (PWR) 21/11/1983	3300/1118	217	672	60.0	20/11/2043	444	1235
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	1657	5951			2656	8372
PWR total	8935/2988	651	1909			1089	3032
All total	31631/10851	2308	7860			3746	11404

[3] The fuel's actual weight in the form of complete fuel assemblies is considerably larger. A BWR fuel assembly weighs about 300 kg whereof about 180 kilograms consist of uranium. After burn-up, the uranium weight decreases slightly. For a PWR fuel assembly, the corresponding weights are about 560 kg and about 460 kg respectively.

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

	Quantity for disposal	Final repository
Spent BWR fuel		
Spent PWR fuel	5 700 canisters	Spent Fuel Repository
Other spent nuclear fuel (MOX, Ågesta, Studsvik Nuclear AB)		
Operational waste from NPPs	52 300 m³	SFR
Decommissioning waste from NPPs	73 300 m³	SFR
Operational and decommissioning waste from NPPs (reactor components)	5 600 m³	SFL
Operational waste from Clab and the encapsulation plant	2 700 m³	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m³	SFR
Operational waste from AB SVAFO and Studsvik Nuclear AB	11 500 m³	SFR
Decommissioning waste from AB SVAFO and Studsvik Nuclear AB	13 000 m³	SFR
Waste from AB SVAFO and Studsvik Nuclear AB	10 800 m³	SFL
Total short-lived radioactive waste	153 200 m³	SFR
Total long-lived radioactive waste	16 400 m³	SFL

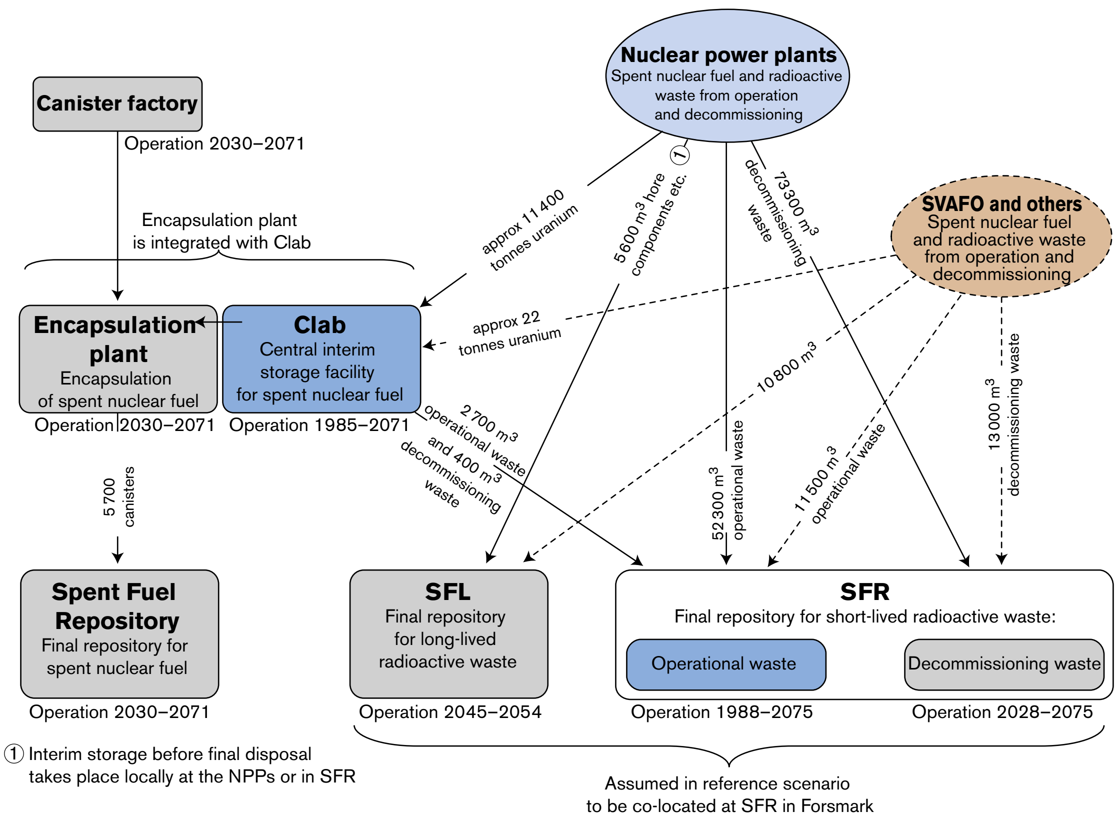


Figure 4-1. *Block diagram showing transport flows with regard to the management of residual products from nuclear power and other radioactive waste.*

4.2 Costs

4.2.1 Future costs

The licence holders' future costs for facilities and activities in the reference scenario are shown in Table 4-3. For each facility and activity, it is stated if the costs refer to *"feasibility studies, technology development and safety assessment"*, *"investment"*, *"operation and maintenance"*, *"backfilling"* or *"decommissioning and closure"*. Normally, the only costs attributable to investments are those costs that are incurred before a facility or part of a facility becomes operational or prior to major reinvestments when a facility has reached a significant age (for example today in the case of Clab). However, in the case of the Spent Fuel Repository, where extension of the repository will proceed continuously throughout the deposition phase (operating phase), the costs for this work are also included in *investment*. The cost estimates in Table 4-3 are based on current data for the reference scenario and cover neither an allowance for uncertainty and risk nor an adjustment for real price changes (adjustment for EEF).

The reference cost amounts to a total of SEK 98.0 billion. Of this, about SEK 74 billion is within SKB's sphere of operations and is therefore shared by the licence holders (joint costs). The remainder are costs for activities in which each licence holder has an individual cost responsibility (separable costs).

Figure 4-2 shows the reference cost distributed over time. A simplified time schedule is shown for the different facilities in order to give an impression of their impact on the cost flow. The two cost peaks in the chart originate on the one hand from investments in the Spent Fuel Repository and the encapsulation part of Clink, and on the other from the decommissioning of NPPs.

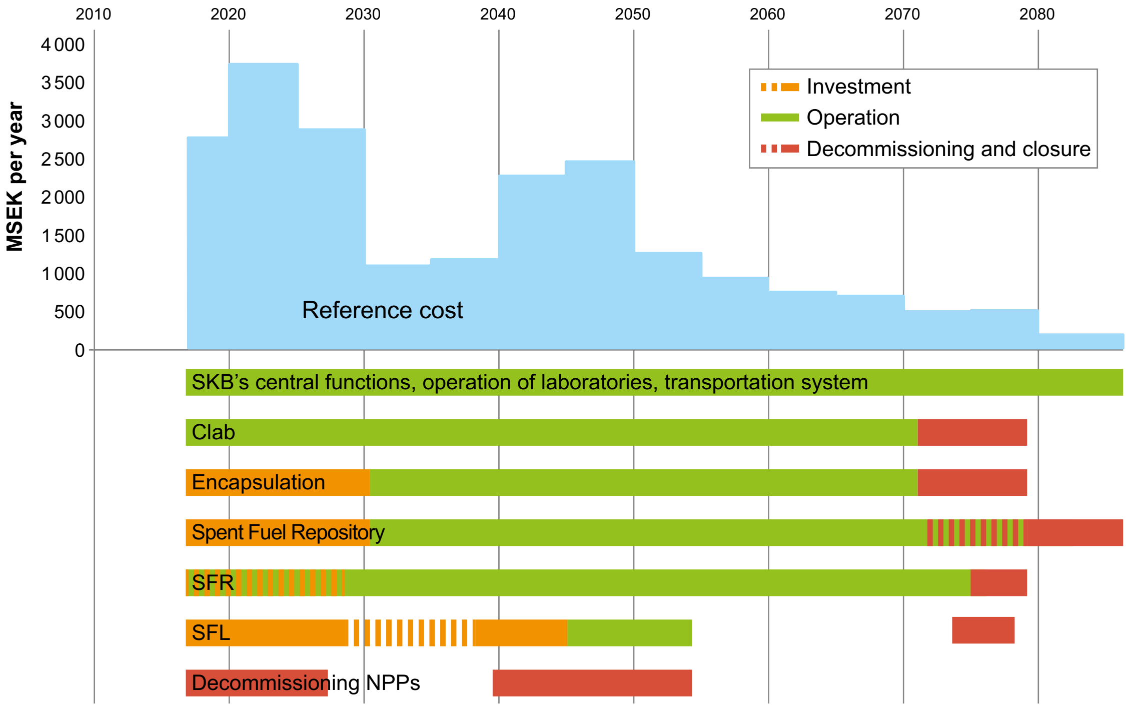


Figure 4-2. Distribution over time of the future costs for the reference scenario and general timetables for the facilities, 2016 price level.

Table 4-3. Compilation of the licence holders' future costs for the reference scenario from and including 2018, at the January 2016 price level. Rounding deviations occur.

		Cost per cost category, SEK million	Cost per facility, SEK million
SKB's central functions and operation of laboratories		5 260	**5 260**
Transportation system	investment	1 270	**2 830**
	operation and maintenance	1 570	
Clab	reinvestments	2 130	**11 210**
	operation and maintenance	8 320	
	decommissioning	750	
Encapsulation	investment	4 910	**15 310**
	operation, maintenance and reinvestments	10 150	
	decommissioning	250	
Spent Fuel Repository			
– above ground	feasibility studies, technology development and safety assessment	2 420	**31 560**
	investment and decommissioning	6 680	
	operation and maintenance (entire facility)	5 070	
	reinvestments (entire facility)	2 330	
– other rock openings	investment	2 960	
	decommissioning and closure	1 470	
– main and deposition tunnels	investment	6 380	
	decommissioning, backfilling and closure	4 260	
SFL	feasibility studies, technology development and safety assessment	800	**2 030**
	investment	720	
	operation, maintenance and reinvestments	240	
	decommissioning and closure	280	
Interim storage facilities and near-surface repositories at NPPs	investment, operation and decommissioning	110	**110**
SFR (operational waste)	operation, maintenance and reinvestments	1 090	**1 090**
SFR (decommissioning waste)	feasibility studies, technology development and safety assessment	840	**4 860**
	investment	2 080	
	operation, maintenance and reinvestments	1 610	
	decommissioning and closure	330	
Decommissioning of NPPs		23 700	**23 700**
Total reference cost (excluding adjustment for EEF and allowance for unforeseen factors and risk)			**97 970**

4.2.2 Incurred and budgeted costs

Table 4-4 shows, at the current price level, incurred costs up to and including 2015 and a forecast for the cost outcome in 2016 as well as budgeted costs for the year 2017. The costs for reprocessing of spent nuclear fuel that occurred in an earlier phase of planning are not included in the table. Figure 4-3 shows how the total cost, incurred and future, has been allocated to the various facilities. The distribution is based on the January 2016 price level, whereby previously incurred costs have been adjusted with the Consumer Price Index, CPI.

Table 4-4. Costs incurred up to and including 2015 and a forecast for the outcome in 2016 and budgeted costs for 2017, current price level.

	Incurred up to and including 2015, SEK million	Outcome 2016 (forecast), SEK million	Budget for 2017, SEK million	Total up to and including 2017, SEK million
SKB central functions	4 156	339	310	4 805
RD&D/operation of laboratorium	7 610	235	165	8 009
Transportation				
– investment/reinvestment	658	34	61	752
– operation	1 004	39	46	1 089
Clab				
– investment/reinvestment	4 211	147	172	4 530
– operation	3 051	258	299	3 608
Encapsulation				
– investment	511	15	130	656
Spent Fuel Repository (siting, site investigations and design)	4 632	178	305	5 115
SFR and SFL				
– investment/reinvestment	1 205	44	52	1 300
– operation	1 624	188	178	1 989
Decommissioning of NPPs	461	135	561	1 157
Total	**29 123**	**1 612**	**2 279**	**33 010**

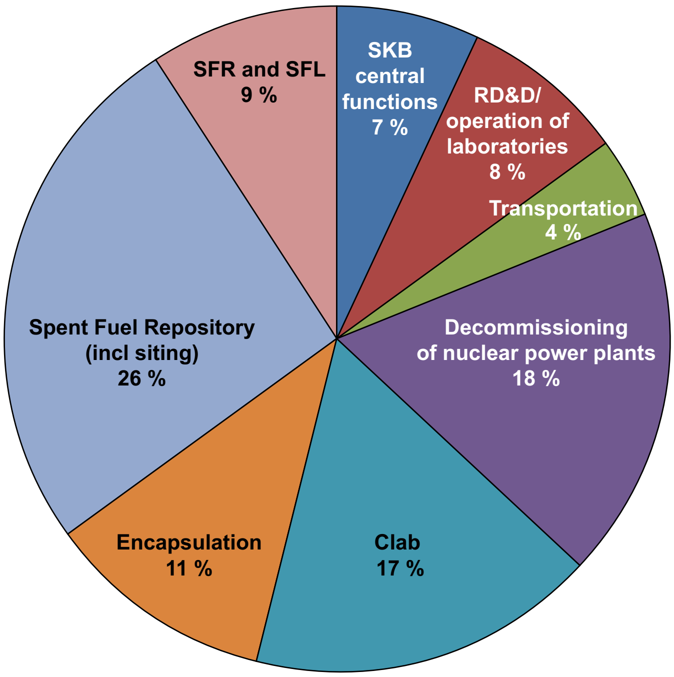


Figure 4-3. Distribution of the total cost (incurred and future) for the reference scenario. January 2016 price level.

5 Costs according to the financing scenario

This chapter presents the calculation that will serve as a basis for fees and guarantees for the period 2018–2020. The regulatory framework states that the calculation shall be based on an operating time of 40 years for the reactors that are currently in operation. There is a prescribed minimum time, entailing that the remaining operating time shall be at least six years (the six-year rule), unless there is reason to assume that the operating period could cease before then. In this calculation, this entails operation up to at least 2023.

The chapter also presents a calculation that shows the effect of changing the operating time in the calculations from 40 years to 50 years, with a minimum remaining time of six years, according to SSM's proposal for an amendment to the Ordinance.

5.1 Operating scenarios for the nuclear power plants and quantities of residual products

According to the six-year rule, it is assumed in this cost calculation that the reactors Forsmark 1, Forsmark 2, Ringhals 3 and Ringhals 4 are in operation until 2023. The reactors Forsmark 3 and Oskarshamn 3 are assumed to be operated until August 2025, when they reach an operating time of 40 years. The oldest reactors Oskarshamn 1, Oskarshamn 2, Ringhals 1 and Ringhals 2 will be shut down before schedule according to the plan presented in Chapter 2.5.3, see also Figure 5-1. Figure 5-1 shows prescribed operating times according to the Financing Act and the nuclear power companies' current planning. The figure also shows an assumed operating time of 50 years.

Table 5-1 presents operating data and fuel quantities for the scenario according to the Financing Act (40+6 years) and according to SSM's proposal for changes in the legislation (50+6 years). Table 5-2 shows the corresponding information but also a comparison with the quantities of encapsulated nuclear fuel and radioactive waste in the reference scenario.

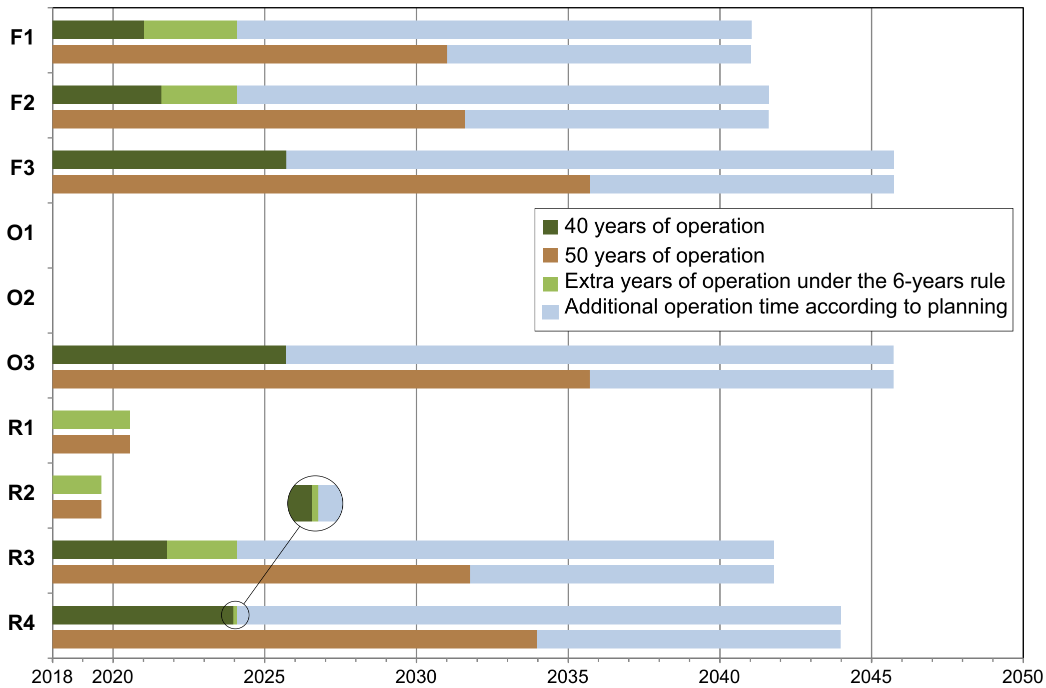


Figure 5-1. *Operating times according to the Financing Act and SSM´s proposal for change together with the planned operating times for the reactors.*

The cost calculation is relatively detailed for the scenario according to the Financing Act (40 + 6 years) and according to SSM's proposal for a changed operating time (50 + 6 years), see Section 5.3.1. In the case of the basis for the financing amount, i.e. the reconciliation on 31 December 2017, only the total amount is given for the two scenarios (Section 5.3.2). The same applies for the supplementary amount, see Section 5.3.3.

Table 5-1. Operating data plus electricity production and fuel quantities based on the financing scenario (40 + 6 years) and according to the proposal for changes in legislation (50 + 6 years).

	Operating time according to the Financing Act	Total (40 + 6 years)			Operating time according to the proposal	Total (50 + 6 years)		
		Operation up to and including	Energy production	Spent nuclear fuel		Operation up to and including	Energy production	Spent nuclear fuel
Start of commercial operation	Years		TWh	Tonnes of uranium	Years		TWh	Tonnes of uranium
F1 (BWR) 10/12/1980	43.1	31/12/2023	305	1 025	50.0	08/12/2030	358	1 165
F2 (BWR) 07/07/1981	42.5	31/12/2023	308	1 026	50.0	05/07/2031	375	1 194
F3 (BWR) 22/08/1985	40.0	21/08/2025	350	1 070	50.0	21/08/2035	443	1 290
O1 (BWR) 06/02/1972	45.4	30/06/2017	82	367	45.4	30/06/2017	82	367
O2 (BWR) 15/12/1974	41.1	31/12/2015	154	537	41.1	31/12/2015	154	537
O3 (BWR) 15/08/1985	40.0	14/08/2025	350	1 071	50.0	14/08/2035	459	1 332
R1 (BWR) 01/01/1976	44.5	14/06/2020	219	773	44.5	14/06/2020	219	773
R2 (PWR) 01/05/1975	44.2	13/07/2019	224	671	44.2	13/07/2019	224	671
R3 (PWR) 09/09/1981	42.3	31/12/2023	281	748	50.0	07/09/2031	342	918
R4 (PWR) 21/11/1983	40.1	31/12/2023	276	825	50.0	20/11/2033	359	1 030
B1 (BWR) 01/07/1975		30/11/1999	93	419		30/11/1999	93	419
B2 (BWR) 01/07/1977		31/05/2005	108	424		31/05/2005	108	424
BWR total			1 969	6 712			2 291	7 501
PWR total			781	2 244			925	2 618
All NPPs total			2 751	8 956			3 216	10 119

Table 5-2. Encapsulated nuclear fuel and radioactive waste for disposal according to the financing scenario (40 + 6 years) and according to the proposal for changes in legislation (50 + 6 years) as well as according to the reference scenario.

	Quantity for disposal			
Scenario	40 + 6 years	50 + 6 years	Reference	Final repository
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX)	4 460 canisters	5 032	6 000	Spent Fuel Repository
Operational waste from NPPs	47 900 m^3	50 100	52 300	SFR
Decommissioning waste from NPPs	73 300 m^3	73 300	73 300	SFR
Operational and decommissioning waste from NPPs (core components)	5 600 m^3	5 600	5 600	SFL
Operational waste from Clab and the encapsulation plant	2 200 m^3	2 300	2 700	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m^3	400	400	SFR
Operational waste from AB SVAFO and Studsvik Nuclear AB	11 500 m^3	11 500	11 500	SFR
Decommissioning waste from AB SVAFO and Studsvik Nuclear AB	13 000 m^3	13 000	13 000	SFR
Waste from AB SVAFO and Studsvik Nuclear AB	10 800 m^3	10 800	10 800	SFL
Total short-lived radioactive waste	148 300 m^3	150 600	153 200	SFR
Total long-lived radioactive waste	16 400 m^3	16 400	16 400	SFL

5.2 Differences compared with the reference scenario

This section concerns differences between the financial scenario and the reference scenario in Chapter 4.

Different assumptions on the reactor operating times are the most important factor affecting the quantities 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 it easier to keep the temperature around the canister after deposition within the specified limit.

To summarise, the most important differences in the operating scenarios compared with the reference scenario are:

- The number of canisters with spent nuclear fuel is reduced from the 6 000 specified in the reference scenario. Calculation of the remaining basic cost (40 + 6 years) is instead based on 4 460 canisters. The corresponding number for the scenario with 50 + 6 years is 5 032 canisters. The basic starting point for calculating the financing amount is that a total of 4 001 canisters will be deposited. It also applies for the scenario with 50 + 6 years.
- The total operating time for the Spent Fuel Repository and Clink is shorter. This means that the starting point for calculation of the remaining basic cost is a 16-year shorter operating time than in the reference scenario, and in the calculation of the basis for the financing amount a 19-year shorter operating time. The shorter operating time also have an impact on the cost calculations for other facilities, primarily SFR. The scenario (50 + 6 years) entails 13 and 16 years shorter operating time, respectively, than in the reference scenario.
- Costs for operational waste that is managed and disposed of during ongoing operation of the reactors are not included in the calculation (they do not come under the concept of "residual products"). This means, above all, that the costs for the disposal of operational waste in SFR are not included. It also means that the costs for transportation to SFR are not included, as well as a proportional share of the costs for SKB's central functions.
- Costs for space in SKB's facilities that is used for radioactive waste from others than the licence holders (SVAFO, etc.) are not included in the calculation. These costs are financed in another way.
- Once a reactor has been permanently shut down, decommissioning commences. The decommissioning and dismantling work then continues until the remaining parts of the facility can be released from nuclear regulatory control. The remaining activities are then no longer regulated according to the Nuclear Activities Act, and the continued conventional demolition work can be conducted under the same conditions as those for other industrial activities. Exactly how far the demolition work is to be conducted for the remaining parts of the facility varies from plant to plant, depending on what the plans are for the continued use of the NPP site. In Plan 2016, as in previous Plan reports, a standard deduction of 10 % of the costs for conventional demolition, included in the reference scenario, has been made. The exception is Barsebäck, where the entire cost is included. The standard deduction may be reviewed in future reports.

5.3 Costs according to current legislation and according to SSM's proposal for changes in legislation

5.3.1 Remaining basic cost and basic cost according to SSM's proposal for changes in legislation

Table 5-3 shows a compilation of the licence holders' calculated future costs that are attributable to the remaining basic cost and serve as the basis for calculating fees. The table also shows the effect of changing the prescribed operating time in the calculations to 50 + 6 years. The costs for the different objects reported in the table contain no allowance for unforeseen factors and risk. This allowance and the impact of EEF are reported as lump sums at the bottom of the table.

The calculated costs for different facilities are presented under the items *"feasibility studies, technology development and safety assessment"*, *"investment"*, *"operation and maintenance"*, *"backfilling"* and *"decommissioning and closure"* (backfilling refers only to the backfilling of deposition tunnels). Normally, the only costs allocated to investment are those incurred before a facility or part of a facility is commissioned, or major reinvestments when a facility has reached a significant age (e.g. Clab).

Table 5-3. Compilation of calculated remaining basic costs, according to SSM's proposal for changes in legislation from and including 2018, at the January 2016 price level. Rounding deviations occur.

		According to the Financing Act (40 + 6 years)		According to the proposal for changes in legislation (50 + 6 years)	
		Cost per cost category, SEK million	Cost per facility, SEK million	Cost per cost category, SEK million	Cost per facility, SEK million
SKB's central functions and operation of laboratories		4430	4430	4500	**4500**
Transportation system	investment	1020	2200	1020	**2280**
	operation and maintenance	1190		1260	
Clab	reinvestments	1750	8380	1830	**8940**
	operation and maintenance	5870		6360	
	decommissioning	750		750	
Encapsulation	investment	4730	12350	4790	**13330**
	operation, maintenance and reinvestments	7360		8290	
	decommissioning	250		250	
Spent Fuel Repository					
– above ground	feasibility studies, technology development and safety assessment	2420	24970	2440	**26940**
	investment and decommissioning	6570		6590	
	operation and maintenance (entire facility)	3300		3650	
	reinvestments (entire facility)	770		1280	
– other rock openings	investment	2860		2900	
	decommissioning and closure	1320		1380	
– main and deposition tunnels	investment	4560		5140	
	decommissioning, backfilling and closure	3170		3560	
SFL	feasibility studies, technology development and safety assessment	780	2020	770	**2010**
	investment	720		720	
	operation and maintenance plus reinvestments	240		240	
	decommissioning and closure	280		280	
Interim storage facilities and near-surface repositories at NPPs	investment, operation and decommissioning	–	–	–	**–**
SFR (operational waste)	operation and maintenance plus reinvestments	–	–	–	**–**
SFR (decommissioning waste)	feasibility studies, technology development and safety assessment	700	4430	730	**4420**
	investment	1970		1970	
	operation and maintenance	1430		1400	
	decommissioning and closure	330		330	
Decommissioning of NPPs	dismantling and decommissioning	23310	23310	23310	**23310**
Total cost "Calculation 40/Calculation 50"			**82100**		**85730**
Adjustment for EEF			**3090**		**3230**
Allowance for unforeseen factors and risks			**16190**		**17340**
Total cost "Calculation 40/Calculation 50"			**101370**		**106300**

The Spent Fuel Repository will be extended throughout the operational phase as new deposition tunnels are being excavated, the cost for this is included in *investment*.

The calculated remaining basic cost amounts to a total of SEK 101.4 billion. Of this amount, SEK 3.1 billion is an adjustment for real price and cost trends (EEF) and SEK 16.2 billion is an allowance for unforeseen factors and risk.

The corresponding amount according to SSM's proposal for changes in legislation (50+6 years) is about SEK 106.3 billion. The adjustment for EEF is SEK 3.2 billion, and the allowance for unforeseen factors and risk SEK 17.3 billion.

Figure 5-2 shows the costs according to Table 5-3 distributed over time. The figure also shows a simplified time schedule for the various facilities in order to provide an idea of their influence on the cost flow. The two cost peaks in the chart stem on the one hand from investments in the encapsulation part in Clink, the Spent Fuel Repository and the extension of SFR, and on the other hand from the decommissioning of NPPs. The scenario 50+6 years is not shown in this figure as it does not entail any major differences from the scenario according to the Financing Act. Basically, the operating time and the decommissioning of SKB's facilities are prolonged and delayed with about three years.

The graph in Figure 5-3 shows the present value of the remaining basic cost as a function of the discount rate being used for discounting to this present value. SSM's proposal (50+6 years) is also shown in the graph. The graph presents the total amounts, which means that the allowance for unforeseen factors and risk is included in both scenarios. The graph is based on separate Monte Carlo simulations for the discount rates 1, 2, 3, 4 and 5 per cent.

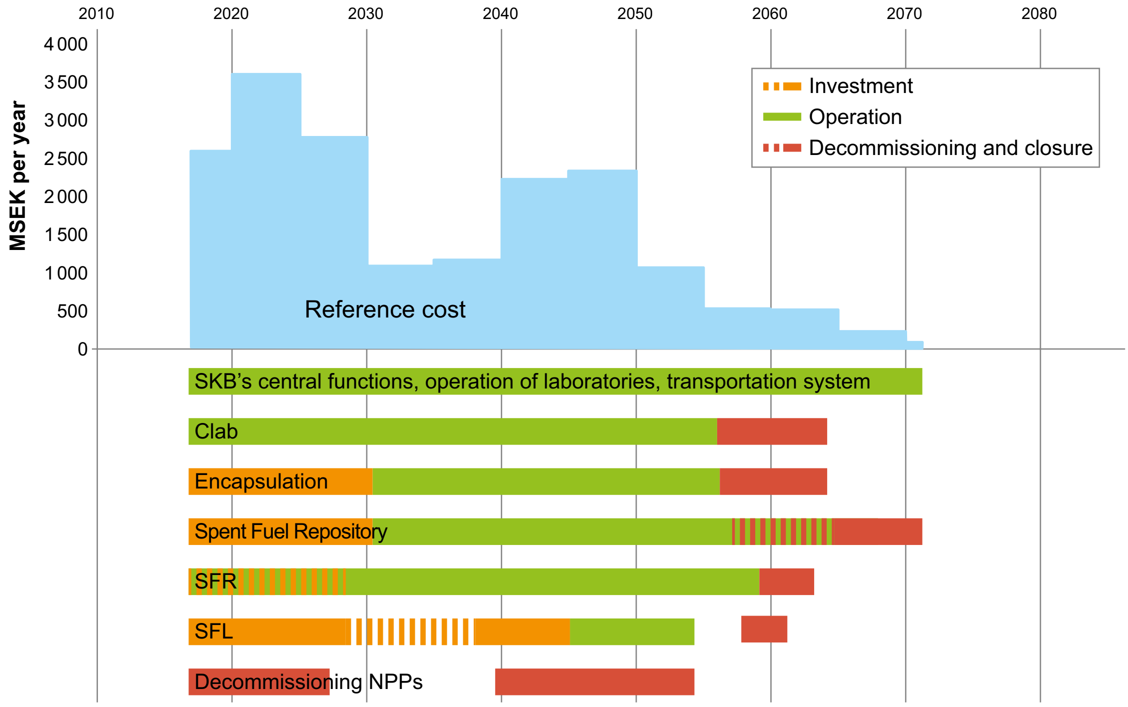


Figure 5-2. *Remaining basic cost, excluding the allowance for unforeseen factors and risk, distributed over time, and the associated time schedule for the facilities at the January 2016 price level.*

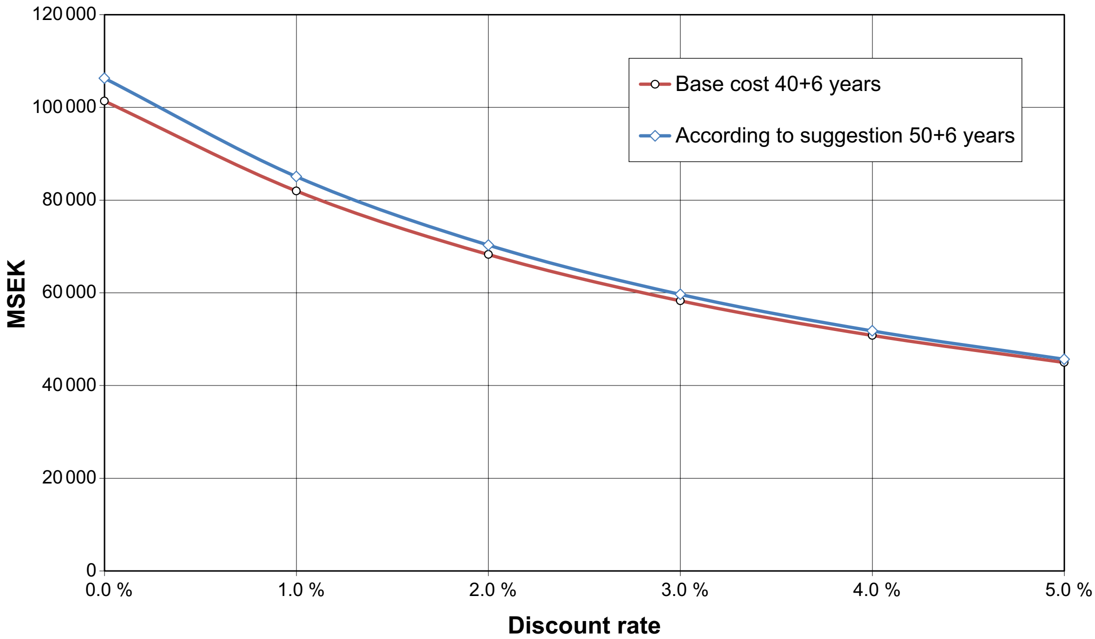


Figure 5-3. *Present value of the remaining basic cost as a function of the discount rate at the January 2016 price level.*

5.3.2 Basis for the financing amount

The financing amount serves as the basis for one of the guarantees that are to be provided by the licence holders in addition to the payment of fees. The amount is based on the input submitted by SKB (this report) and added costs calculated by the Swedish Radiation Safety Authority. SKB calculates its part of the amount in the same way as the remaining basic amount was calculated in the previous section, but when it comes to the costs of residual products the calculation only includes those quantities that exist when the calculation begins. In the case of Plan 2016, this applies only to the residual products that exist on 31 December 2017. This means, among other things, that the number of canisters decreases to 4 001 compared with the 4 460 and 5 032 that serve as the basis for calculation of the remaining basic cost and the cost according to SSM's proposal of 50 + 6 years.

The part of the financing amount based on SKB's calculations amounts to SEK 98.0 billion or SEK 98.7 billion according to SSM's proposal for changes in legislation, which is SEK 3.3 billion and SEK 7.6 billion lower than the remaining basic cost and the cost according to SSM's proposal (50 + 6 years), respectively.

5.3.3 Supplementary amount

The supplementary amount shall serve as a basis for guarantees which shall, to a reasonable level, cover costs for unforeseen events.

The supplementary amount forms the basis for a second type of guarantee that the licence holders have to provide in addition to payment of fees and the guarantee for which the financing amount forms the basis. The supplementary amount is calculated in basically the same way as the remaining basic cost.

The choice of confidence level is of crucial importance in the calculation of the supplementary amount. Here, the question is how to interpret the term "reasonable", which is found in the Ordinance[4]. SSM has chosen to base their proposals for safety on a confidence level of 90 %. SKB therefore chooses to report the supplementary amount according to this interpretation, even though

[4] According to the Ordinance (2008:715): "supplementary amount: an amount that constitutes a reasonable estimate of costs that…."

SKB and its owners consider that the concept "reasonable" should correspond to a confidence level of 80 %.

The supplementary amount only concerns those parts of the total system that belong to the three reactor owners Forsmarks Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. Barsebäck Kraft AB is not obliged to report a supplementary amount.

The supplementary amount for the three reactor owners has, with a confidence level of 90 %, been calculated to be SEK 15.1 billion (undiscounted amount).

Correspondingly, according to SSM's proposal (50 + 6 years) the supplementary amount is SEK 15.5 billion for the three reactor owners. If also Barsebäck is included, the supplementary amount can be estimated to SEK 17.8 billion.

References

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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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