Technical Report

TR-14-16

Plan 2013

Costs from and including 2015 for the radioactive residual products from nuclear power

Basis for fees and guarantees for the period 2015–2017

Svensk Kärnbränslehantering AB

May 2014

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

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Preface

According to the current regulatory framework, it is the responsibility of those companies that hold licences to own nuclear power reactors to prepare a calculation of the costs of all measures that are needed to manage and dispose of spent nuclear fuel that has been used in the reactors, as well as other 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 (which are referred to hereinafter as the Financing Act and the Financing Ordinance, respectively). The cost calculation shall be submitted to the Swedish Radiation Safety Authority once every three years. SKB's owners have assigned SKB the task of preparing such a cost calculation jointly for the licensees of the Swedish nuclear power plants.

This report, which is the twenty-ninth plan report since the first one was published in 1982, gives an updated compilation of the requisite costs. As with the reports submitted in previous years, costs are reported both for the system for managing nuclear waste as a whole, including the management and disposal of radioactive operational waste and certain waste that derives from facilities other than those belonging to SKB owners, as well as for the system with the restrictions that follow from the regulatory framework referred to above. The former costs have been based on a scenario concerning reactor operation that is founded on the current planning of the nuclear power plant owners, whereas the latter are based on the assumed reactor operating time that is stipulated in the provisions mentioned above.

The report is divided into three parts:

Chapters 1 and 2, which provide background information on the financing system and SKB's calculation model.

Chapter 3, which provides information on the underlying calculation and is based on plans for reactor operation and SKB's activities.

Chapter 4, which concerns the cost calculations required under the Financing Act and Ordinance, being the primary purpose of the report.

Stockholm, May 2014

Svensk Kärnbränslehantering AB

Christopher Eckerberg

Managing Director

Summary

A company that holds a licence to own a nuclear power plant is responsible for taking whatever measures are necessary to guarantee the safe management and final disposal of spent nuclear fuel and radioactive waste that derive from its operation and, after plant shutdown, for decommissioning and dismantling it. 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 work. 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.

Precisely 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). At present there are three reactor owners in this category: Forsmark 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 for which they are in this way responsible. According to the regulations, a cost account of this type 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 schedule in general is called the reference scenario. The present report is based on the proposed plan of the activities that are presented in SKB's RD&D Programme 2013. The reference scenario reflects the nuclear power companies´ current planning, which means that each reactor is expected to operate during 50 or 60 years.

For information purposes, the present report contains an account of the cost calculation for the reference scenario and, to a certain extent, the figures 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 done in Chapter 3. The cost accounts required by the Financing Act are presented in Chapter 4. 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 activities and calculations. Among other things, this set of tables shows how the costs are divided between the four licence holders.

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

- Transport system for spent nuclear fuel and radioactive waste.
- Central interim storage facility for spent nuclear fuel, Clab.
- 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 to hold short-lived waste from decommissioning of the nuclear power plants and a smaller amount of operational waste and in order to provide space for the interim storage of long-lived radioactive waste.
- Repository for long-lived waste, SFL.
- Canister factory and encapsulation facility for spent nuclear fuel adjacent to Clab.
- Repository for spent nuclear fuel, Spent Fuel Repository.

The costs according to the reference scenario also include costs for research, development and demonstration (RD&D), and for SKB's central functions. The latter comprise general functions such as corporate management, business support, communications, environment, general safety matters, etc. Also included are costs for decommissioning of the reactors as well as of on-site facilities in the vicinity of the NPPs used for interim storage or disposal of 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 demand that it must be possible to assess any uncertainties regarding future development within different areas. The latter requirement means that a probability-based uncertainty analysis of the type applied by SKB is considered necessary. 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. In the case of reactors that have been in operation for at least 34 years, the remaining operating time shall, however, be assumed to be at least six years unless there is no reason to assume that the operating period could cease beforehand. In the present calculation, this regulation means operation at least up to and including 2020. 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.

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. This type of guarantee gradually diminishes as the reactor operating time approaches 34 years, but will then level off at the minimum period of six more years as specified above. 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 2014.

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.

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 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 2015, and are specified at the January 2013 price level.

Remaining basic cost	SEK 100.8 billion
Basis for financing amount	SEK 95.4 billion
Supplementary amount – at 80% confidence level	SEK 11.1 billion.

Contents

Definitions

BFA	Rock cavern for waste situated at Oskarshamn NPP.
BWR	Boiling water reactor.
Clab	Central interim storage facility for spent nuclear fuel located in the Municipality of Oskarshamn.
Clink	A central facility for the management, interim storage and encapsulation of spent nuclear fuel.
RD&D	Research, Development and Demonstration.
NPP	Nuclear power plant.
Spent Fuel Repository	Repository for spent nuclear fuel.
PWR	Pressurised water reactor.
SFL	Repository for long-lived radioactive waste.
SFR	Repository for short-lived radioactive operational and decommissioning waste situated in the Municipality of Östhammar.
TWh	Terawatt-hour. A unit of energy equal to a billion kWh.
MWh	Megawatt-hour. A unit of energy equal to a thousand kWh.
MWd	Megawatt-day. A unit of electricity equal to 24,000 kWh.
Tonnes of uranium or tU	Quantity of spent nuclear fuel defined as the weight of uranium contained in the fuel assemblies when they are placed in the reactor (before irradiation).
Capacity factor	The ratio, expressed as a percentage, of the energy generated during the year to the energy that could theoretically have been generated if the nuclear power unit had been operated at full capacity for every hour of the year (normally between 75% and 90%).
Burnup	A value that here specifies the quantity of energy obtained from the fuel, normally expressed in MWd per kg of uranium (MWd/kgU).
Residual products	"Nuclear material that will not be reused and nuclear waste that does not constitute operational waste" according to the Act (2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities). Nuclear material is in this case spent nuclear fuel. Operational waste is radioactive waste that is managed and disposed of during operation or immediately after the nuclear reactor has been permanently shut down.

1 The financing system

1.1 The financing system and current regulatory framework

A company that holds a licence to own a nuclear power plant is responsible, according to § 10–14 of the Act (1984:3) on Nuclear Activities , for taking whatever measures are necessary to guarantee the safe management and disposal of spent nuclear fuel and radioactive waste that derive from the nuclear power reactors. The licence holders also have the responsibility for decommissioning and dismantling the nuclear power plants at the end of their operational life. Included in this responsibility is the planning, construction and operation of the facilities and systems that are needed for this purpose, and conducting the research and development work related to it. Licence holders are also responsible for meeting the costs incurred.

The measures are financed by the licence holders paying fees into a fund, the Nuclear Waste Fund, which is administered by the State. These payments are made primarily during the period in which the reactors are in operation but also later if necessary. In addition to these fees, licence holders shall provide certain guarantees to the State. This financing system is regulated in the so called Financing Act (2006:647) and the associated Financing Ordinance (2008:715)[1]. In this report, unless otherwise specified, the term "Financing Act" is used as a collective term for the said Act and Ordinance.

According to Government regulations, the Nuclear Waste Fund is allowed to invest its assets (fees that are paid to the fund) in interest-bearing accounts at the 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 Act on Nuclear Activities.

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 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 hand, holders of licences for nuclear power reactors, all of which have been permanently taken out of service. A licence holder in the former category is called a reactor owner and pays fees based on the electricity generated (öre/kWh). 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. 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 common designation for the four nuclear power companies mentioned above.

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 sites for very short-lived radioactive operational waste. The facilities are only used by the respective licence holder. The costs of constructing and running these small facilities are included in day-to-day operation of the nuclear power plant and are therefore not included in the cost calculations according to the Financing Act. However, the costs for future decommissioning and dismantling of these facilities should be included in the cost calculations according to the Financing Act, since these costs are temporally and materially associated with the decommissioning and dismantling of the NPPs.

[1] Act (2006:647) on Financial Measures for the Management of Residual Products from Nuclear Activities and the Ordinance (2008:715, last revised 2010:1547) on Financial Measures for the Management of Residual Products from Nuclear Activities.

A licence holder shall, in consultation with other licence holders, calculate the costs of managing and disposing of the spent nuclear fuel and radioactive waste as well as for decommissioning and dismantling the nuclear power plant. The licence holders have jointly commissioned SKB to compile and present these calculations. A cost calculation is to be submitted to the Swedish Radiation Safety Authority every three years.

The Government has decided that the Swedish Radiation Safety Authority should, on the basis of these calculations; draw up proposals for nuclear waste fees and guarantees. Decisions on the size of fees and guarantees are made by the Government with the exception of the guarantee that is to be provided by Barsebäck Kraft AB, which guarantee is to be determined by the Swedish Radiation Safety Authority. 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 quantity of spent nuclear fuel and radioactive waste to be disposed of depends on the reactor operating times. According to the regulations, the cost calculations are to be based on an assumed operating period of 40 years for each of the ten reactors that are currently in operation. In the case of reactors that have been in operation for at least 34 years, the remaining operating time shall, however, be assumed to be six years, provided there is no reason to assume that the operating period could terminate beforehand. For Plan 2013, which will serve as a basis for fees and guarantees for the period 2015–2017, this means that five reactors are assumed to remain in operation up to and including the year 2020. These will by then have been in operation for over 40 years[2].

Two types of guarantees should be provided by the licence holders. The first is a guarantee that is intended to cover the fees that have not yet been paid in. The second is a guarantee for additional costs associated with so-called 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.

1.2 Amounts to report under the Financing Act

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.
- *Added cost:* The sum of the anticipated costs of activities that are referred to in § 4, Clauses 4–9 of the Financing Act.
- *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 the Swedish Radiation Safety Authority 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 the Swedish Radiation Safety Authority and is primarily attributable to certain government costs linked with the inspection of SKB and nuclear power company activities concerning the disposal of spent nuclear fuel as well as of the decommissioning and dismantling of nuclear power plants and of SKB's facilities.

[2] Up to and including 2020, the assumed operating times for Forsmark 1 will be 40.1 years, for Oskarshamn 1 48.9 years, for Oskarshamn 2 46.0 years, for Ringhals 1 45.0 years and for Ringhals 2 45.7 years.

SKB's reporting of the remaining basic cost comprises a calculation of the licence holders' future costs for the safe management and final disposal of residual products as well as for a safe decommissioning and dismantling of nuclear facilities and for the research and development work that is needed for the measures referred to. The remaining basic cost in this year's report refers to those costs that will be incurred from and including 2015 on the assumption of a reactor operating time of 40 years or alternatively a remaining operating time of at least six years.

From the calculation of the remaining basic cost, it shall be possible to deduce, on the one hand, the total amount of the licence holders' future basic costs and, on the other, that part of the total amount that is attributable to the costs of joint facilities and activities. Furthermore, for each licence holder a specification shall be made of that part of the total future basic cost which is attributable to the licence holder's reactors and how great a share of the total quantity of generated and anticipated residual products is attributable to residual products from each licence holder.

In addition, there are regulations concerning a more detailed reporting for the coming years containing not only calculated costs but also calculated energy production. This information is submitted to the Swedish Radiation Safety Authority separate together with this Plan report.

The second of the three amounts that SKB reports to the Swedish Radiation Safety Authority is a calculation of that part of the remaining basic cost which is to serve as a basis for the financing amount. This amount is attributable to the costs that the licence holders will have as a consequence of reactor operation up to and including the calculation year, which in this year's report will be year-end 2014/2015.

Finally, the third amount that SKB has to report to the Swedish Radiation Safety Authority is the supplementary amount. According to the Financing Ordinance, this must be equivalent to "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's interpretation of the concept "reasonable" can be seen from Section 4.3.4 below. The guarantee that is to be provided based on the supplementary amount concerns only reactor owners. This means that Barsebäck Kraft AB is exempted from the requirement to report a supplementary amount.

The present report shows the costs only on a total level, or in other words in total for all licence holders.

2 SKB's calculation model

For an account of costs that SKB has to report to the Swedish Radiation Safety Authority, see Chapter 1. These costs are to be based on a fictive operating scenario for the reactors, specified as 40 years (alternatively at least six years' remaining operation). However, the costs that are to be reported to the authority are derived from cost calculations drawn up for a different operating scenario – a scenario that is attributable to the reactor owners' current plans for operating the reactors. It is also this latter scenario that serves as a basis for the planning of SKB's operations. Those costs that are calculated on the basis of this scenario are referred to as the "reference cost".

The reference cost is not included in SKB's obligation, according to the Financing Act, to submit cost calculations. But the compilation of the reference cost must nevertheless be regarded as the first step in SKB's calculation model. Owing to the importance of the reference cost as a base for other cost calculations, SKB has considered it suitable to also include it in this report, and has thus devoted a special chapter to it, Chapter 3.

2.1 The calculation model – a staged process

The cost calculations are conducted in four steps, illustrated schematically in Figure 2-1.

Step 1 (blue box)

The future costs are based on SKB's current planning regarding the design and implementation of the system for managing and disposing of spent nuclear fuel and radioactive waste. The current design is referred to as the reference design and the implementation – which incorporates time schedules, waste quantities and planning in general – is referred to as the reference scenario. The reference scenario is based on the proposed focus of the activities presented in SKB's RD&D Programme 2013.

The reference scenario is based on the current NPP planning assumptions[3], which means 50 or 60 years of operation, see Section 3.2.1. Rounded off, this gives a quantity of spent fuel that is equivalent to 6,200 copper canisters.

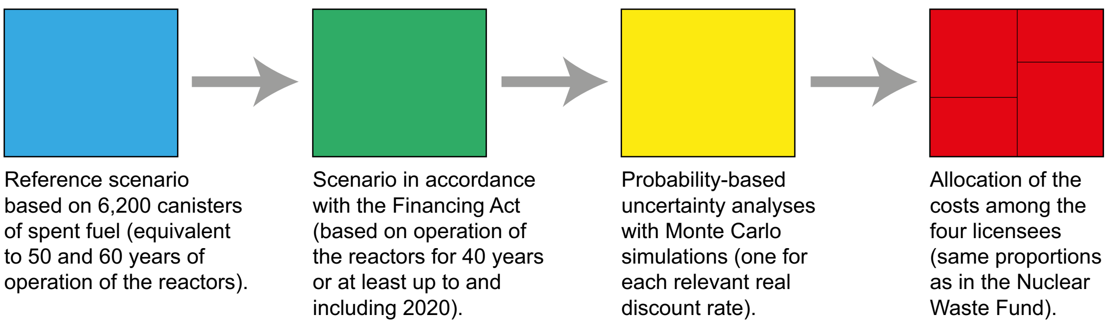

Figure 2-1. *The four steps in SKB's calculation model.*

[3] Note that the operating time for Oskarshamn 1 has been changed since RD&D Programme 2013 was published. The new planning assumption is 50 years instead of 60 years.

In a number of cases, SKB's planning incorporates alternative proposals for solutions, for example in cases where development work is in progress. On the other hand, in the reference scenario – in order to obtain a clear and concrete basis for the cost calculations – it is necessary to assume from the outset that a certain solution will be implemented. This basic starting point for the calculations should nevertheless not be regarded as a final commitment by SKB to implement a certain solution.

The calculation of the costs that follow from the reference design and the reference scenario is presented in Chapter 3.

Step 2 (green box)

The costs that are to be reported in accordance with the Financing Act are lower than those for the reference scenario. This is primarily a consequence of an assumed shorter operating time for the reactors, i.e. 40 years instead of 50 and 60 years respectively. This means, among other things, that the quantity of spent nuclear fuel and radioactive waste will be smaller than in the reference scenario. Furthermore, the cost calculation according to the Financing Act does not include the type of radioactive waste that constitutes operational waste. Consequently, among other things the cost of today's final repository for short-lived radioactive waste, SFR, is not included in the calculation.

The deviations from the reference scenario dealt with in Step 1, as well as the costs of the items to be incorporated within the framework of the Financing Act, are presented in Chapter 4.

Step 3 (yellow box)

The Financing Act prescribes that the cost accounting should relate to both anticipated costs and supplementary costs to cover any impact resulting from unexpected events. The latter means that some form of uncertainty analysis based on theoretical probability considerations should be carried out. Since the mid-1990s, SKB has used a method called "the successive principle" or simply "successive calculation". A brief presentation of the method is given in Section 2.3 below.

Step 4 (red box)

The fees paid into the Nuclear Waste Fund are intended to cover the costs incurred by each specific licence holder[4]. 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 (common costs) are divided between the licence holders, which is done on the basis of various agreements that have been entered into between the licence holders. The procedure for this, as well as the results of the subdivision, are not described in this report, but are submitted to the Swedish Radiation Safety Authority in the form of a special set of tables.

Relationships between the different calculations – a summary

A number of calculations of varying scope and based on partly different assumptions are produced during the work on the cost calculations. 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 or for the financial accounting of SKB's owners. The calculations that are of relevance for reporting in accordance with the Financing Act are presented in Figure 2-2.

As mentioned previously, the reference calculation (the blue circle in Figure 2-2) is covered in considerable detail in Chapter 3. The calculation referred to as *Calculation 40 (real)* (the green box on the left-hand side) is dealt with in Chapter 4 and the associated uncertainty analysis (the yellow box) is presented in Section 2.3 below. The other two green boxes are given no further consideration in this report apart from the fact that the outcome of *Calculation December 2014 (real)* is presented. This serves as a basis for calculation of the financing amount. The allowance for unforeseen events and risk in these two calculations originates from the uncertainty analysis conducted for *Calculation 40 (real)* (yellow box). All calculations, with the exception of the reference cost, are corrected to account for an assumed real cost trend (hence the addition of "*real*"). See also Section 2.3.1.

[4] Fees are also paid on the basis of the so-called Studsvik Act, although costs under this Act are not dealt with in this report.

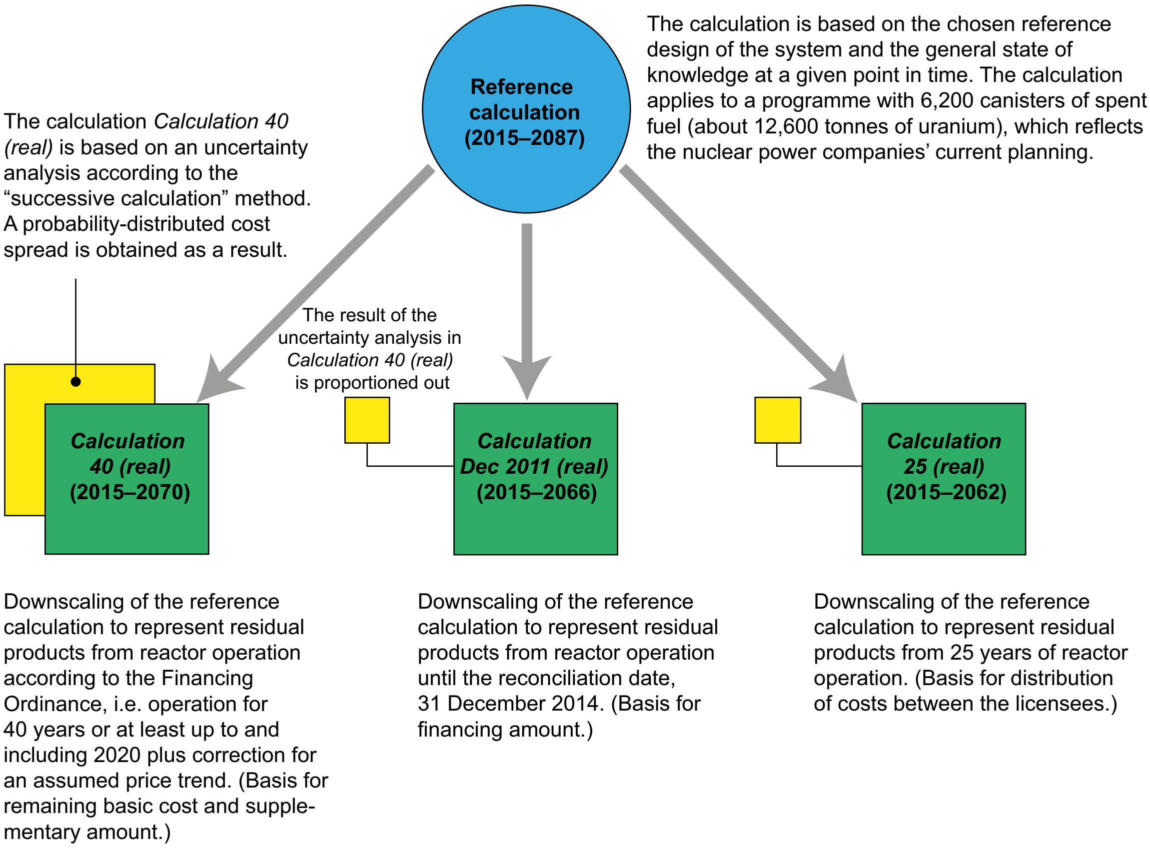

Figure 2-2. *Connection between the calculations that have been performed.*

2.2 Calculation of reference cost

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. This type of cost calculation is normally burdened with an allowance for unforeseen factors and perhaps also for risks. However, this is not the case here, since all types of uncertainties are dealt with separately in the special uncertainty analysis that is conducted and described below in Section 2.3.

The calculations of the reference cost are based on functional descriptions for each facility resulting in layout drawings, equipment lists, manpower forecasts, etc. In the case of facilities and systems that are in operation, this basic input is extremely detailed and well known, while the level of detail is lower for future facilities.

For construction and installation costs in connection with the construction of future facilities, a base cost is calculated for each cost item, including:

- Quantity-related costs.
- Non-quantity-related costs.
- Secondary costs.

Quantity-related costs can be calculated directly with the aid of design specifications and with knowledge of unit rates, for instance for concrete casting, rock blasting and operating personnel. Experience gained from the previous planning and construction of nuclear facilities, such as NPPs, 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, the magnitude of the details 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"[5].

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.

2.3 Compilation of costs to be reported in accordance with the Financing Act

2.3.1 Adjustment with respect to future real price changes

Since many years, future real price changes have been considered in the cost calculations made by SKB in accordance with the Financing Act, The term real price changes is understood in this report to mean the price and productivity trends in the project that deviate from the developments in society in general. The latter is expressed as the Consumer Price Index, CPI. Price changes are dependent on developments in society and are beyond SKB's control. In the calculations, consideration is given to the 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), costs for various input materials and machinery, as well as currency exchange rates. For each such factor, the real price and cost trend are given in the form of a so-called trend line. The trend lines are based on historical data.

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 that are to be found in a project of this type is in this way reduced in the calculation to these few selected factors, which entails a relatively significant aggregation. It is the responsibility of the calculator to determine to which of these selected variables a certain cost item is attributable.

2.3.2 The successive principle – a probability-based calculation method

For the calculation of those amounts that are to be reported pursuant to the Financing Act, use is made of a probability-based (probabilistic) calculation method that applies statistical methods to consider the variations and uncertainties that naturally appear when assessing the costs of a project. The method is based on a calculation principle called "the successive principle", which was developed by Steen Lichtenberg and is described in greater detail in his *Proactive Management of Uncertainty using the Successive Principle*, published in 2000.

A core aspect when applying the successive principle is the methodology used for structuring the calculation and for establishing probability distributions for the variations and uncertainties selected for inclusion in the analysis. This is done by means of assessments that are made by a group specifically composed for the task and known as the "analysis group". This analysis group has a broad-based membership from areas linked to nuclear activities as well as from areas that are totally detached from such activities.

Each cost item and each variation or uncertainty is regarded as a variable, which with a varying degree of probability can achieve different values (stochastic variables). For the purpose of the calculation, suitable functions are assigned that define these probability distributions. The total cost is arrived at by adding together all the cost items on the basis of the rules that apply for the addition of stochastic variables. This means that each amount that can be determined is linked to a certain probability of not exceeding that amount.

[5] This should not be confused with "allowance for unforeseen events", which is not included in the reference calculation. Unforeseen factors are assumed to be part of the total uncertainty that is dealt with in the uncertainty analysis.

The method also gives indications as to where the major uncertainties lie. They can then be broken down and analysed in greater detail, after which the calculation can be repeated, resulting in less uncertainty. This successive convergence towards an increasingly accurate forecast has given the method its name.

2.3.3 Brief description of the methodology applied

The management and final disposal of spent nuclear fuel and the decommissioning and dismantling of NPPs is in many respects a unique project. By the time that the project is expected to be completed, planning and implementation will have been in progress for some one hundred years. The project is also subject to constant detailed review by various regulating authorities and other official bodies. A continuous technology development will continue throughout the entire planning and implementation period.

The unique character of the project warrants a departure from the method of adding together stochastic variables as ordained by the classic successive principle. Instead, SKB applies the so-called Monte Carlo simulation, which is an iterative method, the outcome of which is steered by a random number generator. The method gives a high degree of flexibility, which suits the special circumstances that have to be addressed. Examples of such circumstances are:

- The calculation extends over a very long period of time. In a present value calculation, the effects of various events will differ depending on the discount rate chosen and when the event occurs.
- There are interdependencies between some of the stochastic variables that are identified by the analysis group.
- The calculation is very extensive and contains a considerable number of variations and uncertainties. The Monte Carlo simulation makes it possible to follow and register the calculation procedure in detail, which is preferable in order to be able to check and understand how different events can affect the outcome.
- Certain events are of such an extensive nature that – if they were to occur – they would change the calculation basis on a principal level. Such events have to be dealt with in a two-stage process: the probability of such an event happening and then the likely outcome if such an event were to occur.

The methodology applied is illustrated schematically in Figure 2-3. The description that follows below relates to the designations in the figure.

Initially, the scope of the calculation is determined and it is given a structure. The scope is determined, among other things, by the so-called fixed preconditions, which lock the frameworks of both the project design as well as the general conditions for the calculation. The structuring that follows means that all the costs calculated are broken down into a number of "calculation objects". In general these are equivalent to the various types of costs, or in other words investment, operation, decommissioning, backfilling and closure for different facilities. The input values in the calculation consist of the "probable" cost of each calculation object and of the total amount **(1)**. These probable costs are normally taken from the reference calculation, which will have then been scaled down in the way described previously.

The next step is to determine the variations and uncertainties that are to be included in the uncertainty analysis. They may be of a type that only affects individual calculation objects, **(2)**, for example uncertainty in workforce or canister cost. Alternatively, they could affect different calculation objects in several different parts of the system **(3)**, for example change in time schedule or change in regulatory requirements. Each variation is defined in terms of its scope (low or high alternative) and an assessment is made of which calculation objects are affected by the variation. The low and high alternatives are specified together with their respective confidence levels (the probability of the cost not being exceeded).

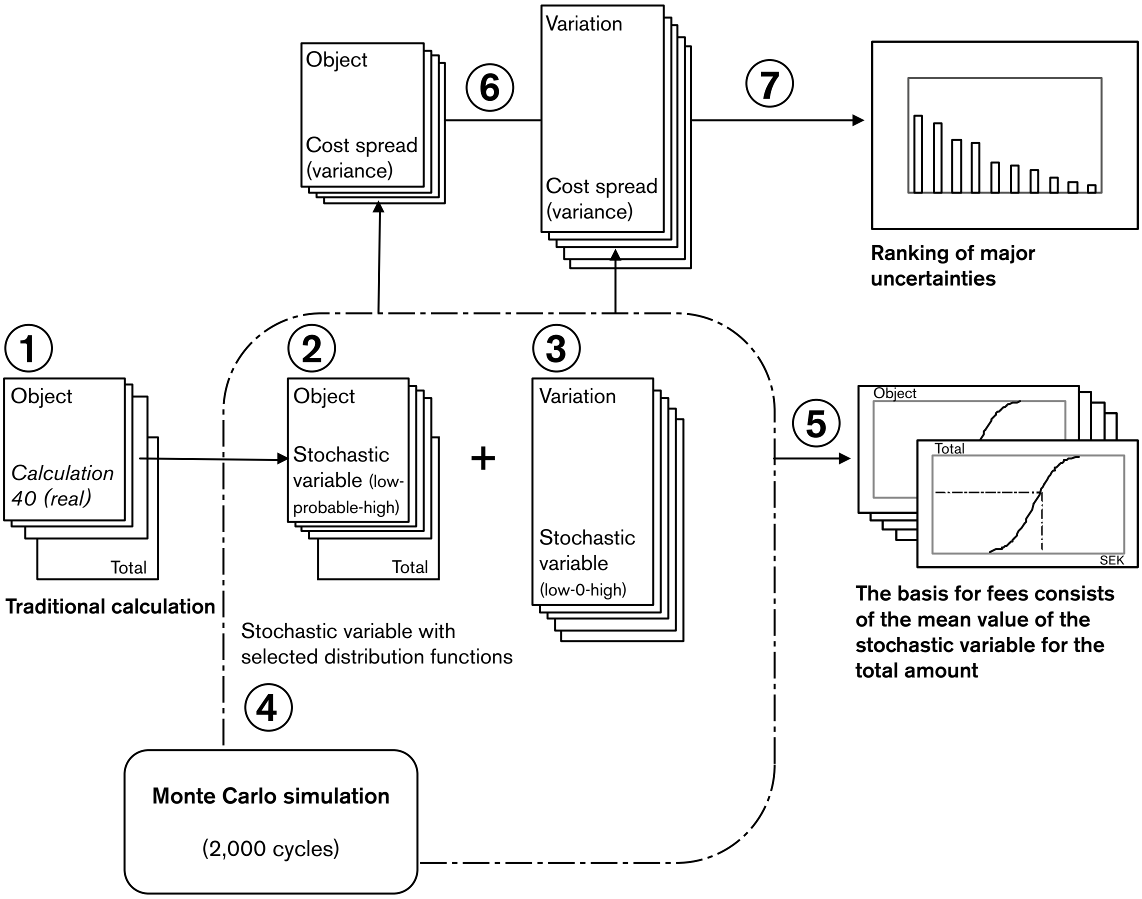

Figure 2-3. *Schematic description of the calculation steps (figures refer to the description in the text).*

Subsequently, an evaluation is made of the impact made by the selected variations and uncertainties on the different calculation objects. Since both the calculation objects and the variations and uncertainties have been defined not only with their respective probable costs but also with a range of values (lowest and highest cost related to confidence levels), the different cost items can be described as stochastic variables with associated distribution functions. The functions are chosen so that the probability distribution matches the character of the variation as closely as possible. Special properties of the variation, such as a pronounced imbalance of the outcome or an "either-or-value" (discrete distribution), will have an impact on the choice of probability function.

Finally, the outcome is calculated and summarised in the Monte Carlo simulation **(4)**. Monte Carlo simulation means that the calculation is performed a number of times – referred to as cycles or iterations. In each cycle, the outcome is determined for each variable on the basis of the selected probability distribution through a random figure, specific for the variable in question, which determines the level of confidence. The random figures are renewed for each cycle. A cycle can thus be claimed in the model to represent an "implementation" of the project. The final result consists of the probability distribution that is given by all calculation cycles together. In the calculations that serve as a basis for the calculations in Plan 2013, the simulation covers 2,000 cycles, which are judged to give a sufficient level of accuracy in the results.

For each object, as well as for the total sum, the results give a distribution function **(5)** from which the cost can be obtained from the chosen confidence level or as a mean value for the 2,000 calculations. In addition, during the course of the calculation procedure it is possible to obtain partial results **(6)** which enable the uncertainties in the analysis to be evaluated and ranked **(7)**.

Since a number of the variations influence the time schedule to a significant extent, the final outcome also depends on the cost of capital that is chosen for discounting to present value[6] (the so called discount rate). The calculations are therefore performed with a number of different discount rates (see comments in Section 4.3.2 to Figure 4-3).

2.3.4 General information on the variations and uncertainties that are taken into account in the calculation

The successive calculation houses a scheme implying that variations, deviations or other uncertainties that are of a general or overall nature are dealt with separately and individually. 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 these uncertainties also normally take place on the basis of certain systematics with the aim of facilitating the work and reducing the risk that essential uncertainties are neglected. Therefore, in the work resulting in this document, the uncertainties are arranged under six headings:

- **Society**. This group consists of uncertainties that SKB has little or no influence over, for example, legislation and regulatory matters or political issues in general.
- **Economics**. This group is of the same character as the "Society" group but with the 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 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 group. The greatest uncertainties are for obvious reasons to be found in connection with the future facilities for the management and disposal of both spent nuclear fuel and radioactive waste. One particularly large group within the area is made up of most of the object-specific variations or uncertainties (see below).
- **Calculation**. This group takes into account the risks of incorrect assessments in the actual calculation work. They may consist of both overestimations of the difficulties (pessimistic assessment) as well as underestimations (optimistic).

Variations or uncertainties that are restricted to individual calculation items are dealt with by applying a simpler procedure that does not require the same systematic approach. They are often of less importance to the cost outcome.

The identification of those uncertainties that should be weighed in and their probability-related character are issues that are handled by a group that has been specially formed for the purpose – the analysis group. However, the selections of uncertainties to be considered according to the principles of the applied calculation methodology are limited by the previously mentioned fixed preconditions. These are decided at a high level within SKB. They 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.

According to the methodology applied by SKB, certain uncertainties are considered to be of such a character that they are only allowed to influence the guarantees that are to be provided and not the size of the fees. Such events are considered to affect the system to a fundamental extent. The costs for such events have only an impact on the supplementary amount.

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[6] For example, an uncertainty allowance that is 20% without discounting at a 50% confidence level may be 15% after discounting at a certain cost of capital. This is because considerable uncertainties lying far in the future tend to decline in importance when discounted.

Some of the uncertainties are presented below in order to exemplify the choice:

In the “Society” group, for example, there is uncertainty regarding future legislation as well as future regulations made by authorities. These uncertainties apply both to nuclear activities as well as to traditional industrial activities.

In the “Economics” group, the greatest uncertainty consists of the view of the future real price and cost trend (EEF). The economic situation for different investments is also included, although it is of less importance.

Various time schedule questions are included in the “Implementation” group as well as questions relating to the siting of future facilities.

The “Organisation” group contains no uncertainties with a major impact. In this group are included issues as the organisational implementation of the future facilities during the investment phase. Also included is the decommissioning of NPPs.

With the fixed precondition that only KBS-3 is to be considered as a method for the final management and disposal of spent nuclear fuel, there are few uncertainties in the “Technology” group that are of significant importance. Most general uncertainties concern the rock works in the future investments for the repository.

In the last group, “Calculation”, there are uncertainties concerning the individual sub-calculations with respect to their realism. This is to a large extent linked with the question of optimism or pessimism on the part of those persons or organisations that make the respective calculations. The uncertainty has a relatively major impact since it covers the entire calculation.

3 Costs according to the reference scenario

3.1 General system description

A cost calculation that is based on SKB's current planning serves as a basis for the costs presented in this report. Planning primarily applies to the design of the system which currently constitutes the main alternative in SKB's development work and is referred to as the reference design. Current planning also includes assumptions concerning future events for which decisions have not yet been made. These assumptions are necessary in order to be able to compile a comprehensive basis for the cost calculation. They are presented in greater detail in the next section.

The reference design, together with these assumptions, comprises what we refer to as the reference scenario. This in turn constitutes the basic input for calculation of the reference cost.

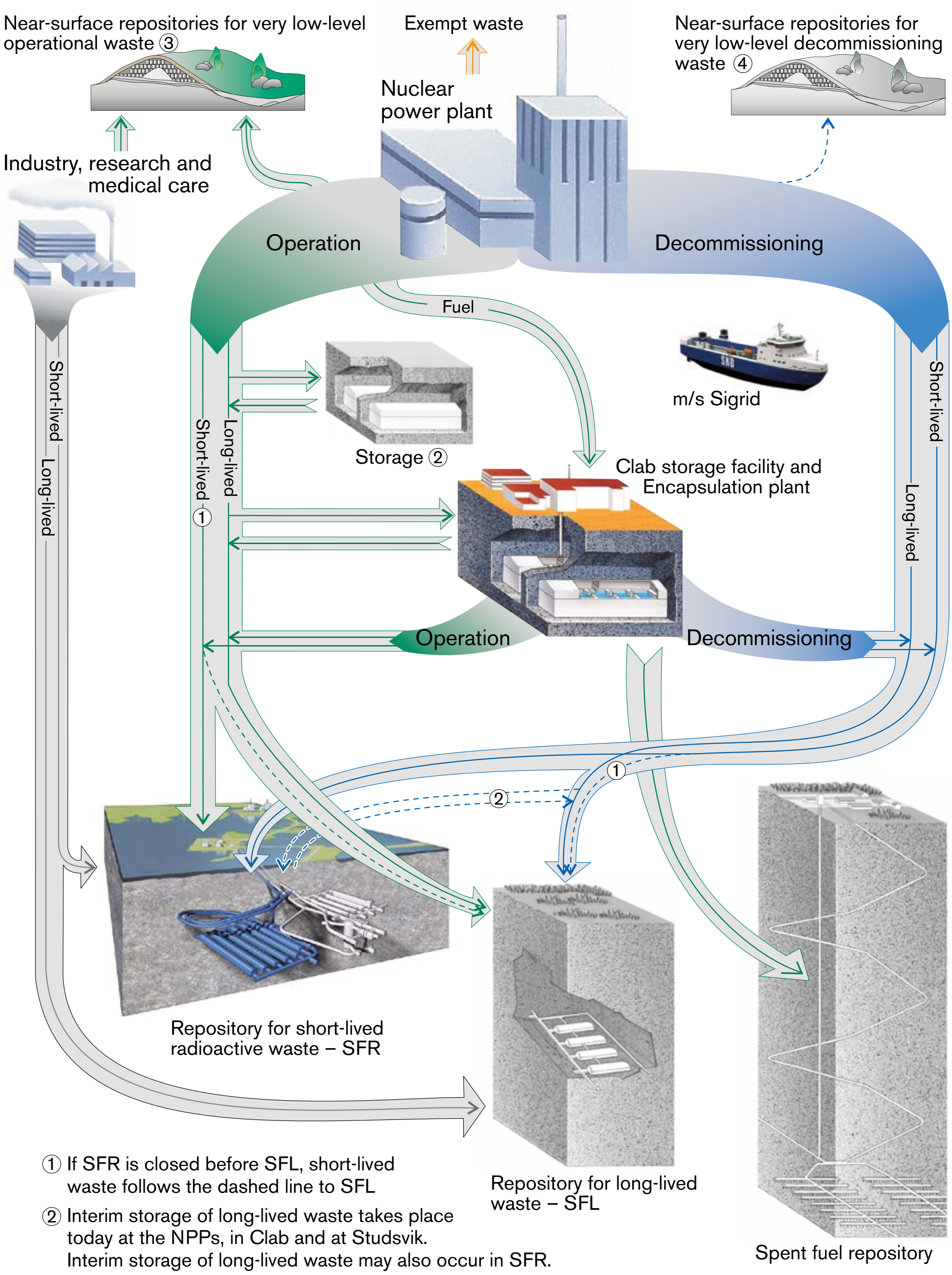
The facilities that SKB operates or is planning for in the future are intended for the management and disposal of residual products and radioactive operational waste from the Swedish NPPs. At the same time, it is assumed that SKB, in these facilities, will in return for payment also receive minor quantities of radioactive waste from industrial plants, research facilities and other institutions (for example within health care). The space required to handle these quantities, on the scale we know today, is included in the reference scenario and the costs are included in the reference calculation. But these costs are not included in the cost calculations that SKB has to report pursuant to the Financing Act (presented in Chapter 4), since they are financed by funds other than those originating from the licence holders' shares in the Nuclear Waste Fund.

As stated in Section 1.1, the term residual products is defined in the Financing Act as "Nuclear material that will not be reused and nuclear waste that does not constitute operational waste". With this definition, the products that are to be managed and disposed of can be classified as indicated in Table 3-1.

Table 3-1. Types of residual products and other radioactive waste for management and disposal.

	Direct financing by the licence holder (operational waste) or by another stakeholder who purchases space in SKB's facilities. **The costs are included in those costs reported in Chapter 3 of this report.**	**Financing within the framework of the Financing Act (only residual products as defined in the Financing Act).** **The financing is provided through the Nuclear Waste Fund. The costs are dealt with in Chapter 4 of this report.**
Short-lived very low-level waste	Operational waste, compacted or in containers of concrete or steel. Interim storage at the place where the waste is produced (local interim storage). Final disposal in either on-site or 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 locally. Disposed of 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. Disposed of in SFR.	Same as above.
Long-lived low- and intermediate-level waste	Operational and decommissioning waste from other stakeholders. Interim storage locally. Disposed of 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). Disposed of in SFL.
Long-lived high-active residual products	Spent nuclear fuel from SVAFO (Ågesta) and Studsvik. Encapsulated in the same copper canisters as other spent nuclear fuel. Disposed of in the Spent Fuel Repository.	Spent nuclear fuel that is encapsulated in copper canisters. Disposed of in the Spent Fuel Repository.

Figure 3-1 gives an integrated overview of the Swedish system for the management and disposal of nuclear power-based residual products and other radioactive waste. The figure illustrates the flow of residual products and other radioactive waste from the NPPs and other producers of such waste via interim storage and treatment facilities to different types of repositories. With the exception of the NPPs and the interim storage facilities or near-surface repositories located at the plants where the waste is generated, all facilities are planned, built, operated and decommissioned under SKB's auspices.



① If SFR is closed before SFL, short-lived waste follows the dashed line to SFL

② Interim storage of long-lived waste takes place today at the NPPs, in Clab and at Studsvik. Interim storage of long-lived waste may also occur in SFR.

③ There are near-surface repositories at the NPPs in Forsmark, Oskarshamn and Ringhals. There is also a similar near-surface repository at Studsvik, to which some waste from industry, research and medical care is sent.

④ Possible alternative for very low-level decommissioning waste. A decision has not yet been made on this.

Figure 3-1. *Overview of the Swedish system for management and disposal of the residual products from nuclear power and other radioactive waste.*

SKB is also responsible for the transportation of spent nuclear fuel and radioactive waste between the facilities. In Sweden, all the existing facilities are located on the coast, where the future facilities are also intended to be sited. The transport system is thus based on transportation by sea with a special purpose-built ship, M/S Sigrid.

Several of the facilities are in operation, which provides a sound basis for the cost calculations. The future facilities are in various stages of design and development, and the cost calculations for these facilities have been based on drawings, specifications, manpower schedules, etc, and on experience from the manufacture and use of developed prototype equipment. The facilities are described individually in Sections 3.3 and 3.4.

In addition to costs relating to the management and disposal of residual products and other radioactive waste, the total calculation also includes the costs for decommissioning and dismantling of NPPs. Conducting this work is not part of SKB's undertaking, but is instead a matter for the individual nuclear power company concerned. SKB is only responsible for managing and disposing of the radioactive waste from decommissioning and dismantling and, as things stand at present, for the investigation work on and cost estimates for decommissioning. The special preconditions that apply for decommissioning are presented in Section 3.2.4.

SKB's work in connection with the management and disposal of the residual products for nuclear power and other radioactive waste can be related to a number of systems or operational areas. With the exception of SKB's central functions for management and operational support as well as departments for communication and for environmental and safety issues, they are described in this chapter under the headings:

- Facilities within the system for low- and medium-level waste.
- Facilities within the KBS-3 system.
- The transport system.

RD&D – research, development and demonstration – is described here under "Facilities within the KBS-3 system" since it is largely focused on the management and disposal of spent nuclear fuel.

The system for the management and disposal of low- and intermediate-level waste is related to activities that incorporate both management of the currently existing waste as well as planning and work on building up the system that is needed in order to be able to deal with the future low- and intermediate-level waste in a safe way. The repository facilities that SKB plans to establish for low- and medium-level waste consist of an extension of SFR (Final repository for short-lived radioactive waste) and the construction of SFL (Final repository for long-lived waste). SKB is also investigating the question of a near-surface repository intended for waste with a very low level of radioactivity.

Within the KBS-3 System it remains to construct and commission the facilities that are required for encapsulation and disposal of the spent nuclear fuel. This includes the construction of a facility section for encapsulation of the spent nuclear fuel adjacent to Clab and the construction of a repository where the canisters can be deposited. SKB also plans to construct a factory for fabrication of the copper canisters.

3.2 Special preconditions as a basis for the cost calculation

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

The reference scenario is based on the reactor owner's current plans for reactor operation. Depending on the reactor concerned, the total planned operating time is 50 or 60 years, see Table 3-3. The planned operating time for Oskarshamn 1 has been changed from 60 years to 50 years since RD&D Programme 2013 was published.

It is highly likely that the production data for the individual reactors will change during the remaining total calculated operating time. No consideration is given to this in the reference scenario, however, and the input is based on historical data and an extrapolation of the current situation, which will apply for the entire calculation period. Any future changes will be incorporated in the basic data for the calculations once the decisions have been made and any additional licences obtained.

Table 3-2 shows historical data concerning the total energy production and the average capacity factor up to and including 2013 (the final months of 2013 are a forecast).

Table 3-3 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.[7] The table reports data based on an operating time of 50 or 60 years for the different reactors. In the basic data for the reference calculation this means approximately 6,200 canisters of spent nuclear fuel.

Table 3-2. Energy production and average capacity factors for the past ten years.

Year	Energy production, TWh	Capacity factor, %	Comment
2004	75.2	92	
2005	69.6	87	Barsebäck 2 was shut down on May 31, 2005.
2006	65.0	83	
2007	64.3	82	
2008	61.3	78	
2009	50.0	63	
2010	55.7	71	
2011	58.1	74	
2012	63.8	81	
2013	63.2	80	

Table 3-3. Operating data plus electricity production and fuel quantities based on 50 and 60 years' operation.

Start of commercial operation			Thermal capacity net output	Energy production		Fuel	Total for reference scenario			
				up to and incl. 2013	mean value from and incl. 2014	up to and incl. 2013	Planned operating time	Operation up to and incl.	Energy production	Spent nuclear fuel
			MW	TWh	TWh/y	tonnes of uranium	yr		TWh	tonnes of uranium
F1	(BWR)	1980-12-10	2,928 / 984	228	7.5	823	60	2040-12-08	431	1,425
F2[1]	(BWR)	1981-07-07	2,928 / 990	222	7.5	803	60	2041-07-05	429	1,460
F3	(BWR)	1985-08-22	3,300 / 1,170	244	8.8	817	60	2045-08-20	522	1,582
O1	(BWR)	1972-02-06	1,375 / 473	100	3.5	371	50	2022-02-05	128	452
O2	(BWR)	1974-12-15	1,800 / 638	154	6.4	533	60	2034-12-14	289	872
O3	(BWR)	1985-08-15	3,900 / 1,400	226	11.2	766	60	2045-08-14	581	1,767
R1	(BWR)	1976-01-01	2,540 / 855	181	6.4	671	50	2025-12-31	257	870
R2	(PWR)	1975-05-01	2,652 / 866	194	6.3	595	50	2025-04-30	266	804
R3	(PWR)	1981-09-09	3,135 / 1,051	205	8.2	655	60	2041-09-07	432	1,275
R4	(PWR)	1983-11-21	2,775 / 935	196	7.3	620	60	2043-11-20	414	1,193
B1	(BWR)	1975-07-01	1,800 / 600	93		423		1999-11-30	93	423
B2	(BWR)	1977-07-01	1,800 / 600	108		442		2005-05-31	108	442
BWR total			22,371 / 7,710	1,556	51	5,649			2,839	9,292
PWR total			8,562 / 2,852	595	22	1,871			1,113	3,272
All NPPs total			30,933 / 10,562	2,152	73	7,520			3,952	12,564

[1] Forsmark 2 has since autumn 2012 held a licence for trial operation to max. 3,253 MW thermal capacity, which is equivalent to 1,120 MW net electrical output. The higher capacity was put into effect in spring 2013. Plan 2013 is based on a previously conducted forecast for F2.

[7] The actual weight of the fuel in the form of complete fuel assemblies is much greater. One BWR assembly weighs abouty 300 kg, of which approximately 180 kg consists of uranium. After burnup, the weight of the uranium will have decreased somewhat. In the case of a PWR assembly, the corresponding weights are about 560 kg and 460 kg, respectively.

The number of canisters containing spent nuclear fuel is shown in Table 3-4 together with a specification of the space needed in the various repositories for other radioactive waste. The volumes refer to those containers with radioactive waste that are intended to be disposed of. The table does not contain information about the quantities of very short-lived radioactive waste that are deposited in near-surface repositories on the NPP sites.

The block diagram in Figure 3-2 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 reference scenario.

3.2.2 Overall time schedule for implementation

In RD&D Programme 2013, a presentation is given of the overall time schedule for the entire nuclear waste programme. The programme contains an outline of measures that are needed in order to implement the programme and of the times at which SKB plans to submit applications and other statutory accounts. According to the mentioned programme, Clink and the Spent Fuel Repository shall be constructed so that trial operations can be initiated in 2029. Following an introductory stage, the capacity will gradually increase to the deposition of 180 canisters per year. Towards the end of the operating period, the deposition rate will decrease to 100 canisters per year. This reduction is an adaptation to the fact that the annual inflow of spent nuclear fuel will cease when the reactors are shut down.

According to current plans, the extension of SFR will be completed so that the deposition of waste from the decommissioning and dismantling of the Barsebäck plant, Ågesta and the facilities in the Studsvik industrial area can be started in 2023. The deposition of decommissioning waste will continue until the last reactor has been decommissioned.

The planning for SFL means that it should be possible for waste to be received from the mid-2040s until all the long-lived decommissioning waste from the NPPs has been disposed of.

Section 3.6 contains a figure (Figure 3-15) illustrating the approximate points in time when different future costs are incurred, and for which facilities.

Table 3-4. Encapsulated nuclear fuel and radioactive waste to be disposed of.

	Quantity for disposal	Repository
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX, Ågesta, Studsvik)	6,200 canisters	Spent Fuel Repository
Operational waste from NPPs	53,200 m^3	SFR
Decommissioning waste from NPPs	73,300 m^3	SFR
Operational and decommissioning waste from NPPs (reactor components)	3,700 m^3	SFL
Operational waste from Clab and the encapsulation plant	3,400 m^3	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m^3	SFR
Operational waste from SVAFO and Studsvik	11,500 m^3	SFR
Decommissioning waste from SVAFO and Studsvik	13,000 m^3	SFR
Waste from SVAFO and Studsvik	11,800 m^3	SFL
Total short-lived radioactive waste	154,800 m^3	SFR
Total long-lived radioactive waste	15,500 m^3	SFL

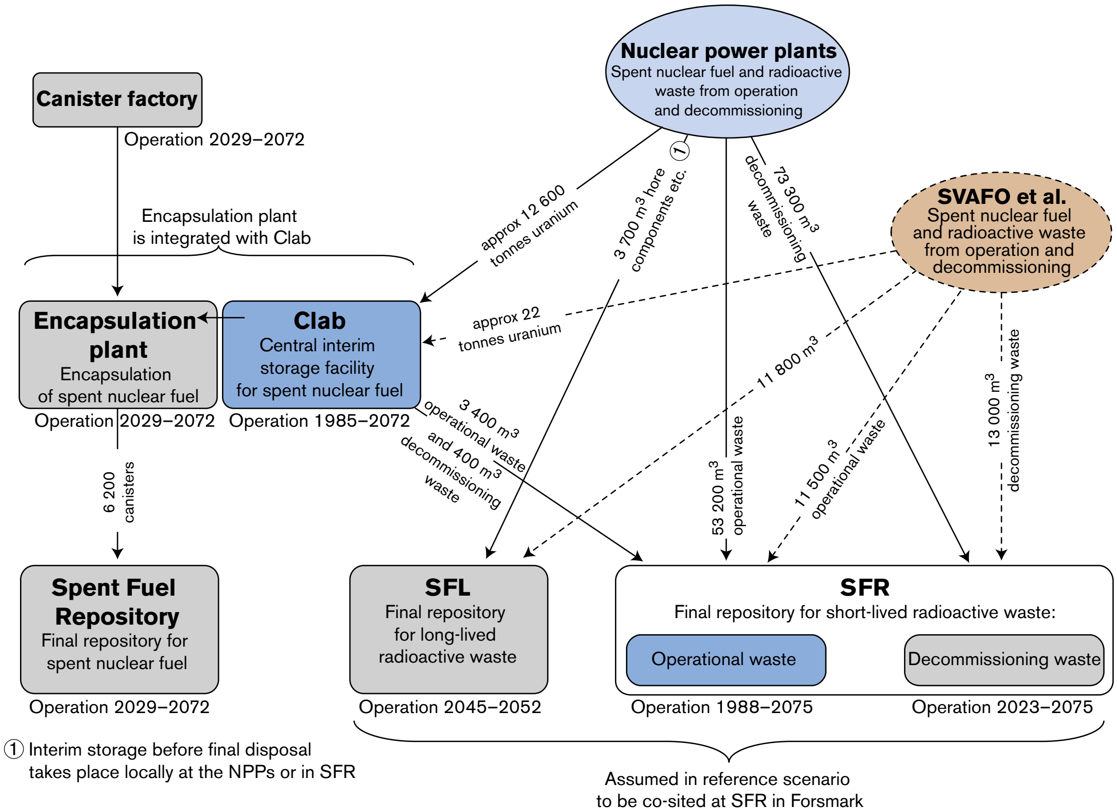


Figure 3-2. *Block diagram showing the transport flows with respect to the management and disposal of residual products from nuclear power and other radioactive waste as a basis for the reference scenario.*

3.2.3 Siting of future facilities

In March 2011, SKB applied for a licence to construct a final repository for spent nuclear fuel in Forsmark and an encapsulation plant in Oskarshamn. The application pursuant to the Act on Nuclear Activities for the encapsulation plant was submitted in 2006 and supplemented in 2009 with respect to a merger of the encapsulation plant with Clab to form an integrated facility to be referred to as Clink. In March 2011, a further supplement was made.

SKB has not yet made any final decision regarding the siting of SFL. The assumption that is used in the reference scenario is that the repository will be located in Forsmark. With the existing construction and transport tunnels in SFR as a basic starting point, it is assumed that the facility will be sited at a rock depth of approximately 300 m. As with other specific uncertainties, the uncertainty associated with this assumption is dealt with first when the uncertainty analysis is conducted.

As regards the canister factory, SKB has decided it should be located in the vicinity of Oskarshamn. As this is not a nuclear facility, its siting is considered as an ordinary industrial siting issue, in which various alternatives are assessed with respect to economy, safety and environmental impact.

3.2.4 Decommissioning of nuclear power plants

The measures for managing and disposing of the radioactive residual products from nuclear power include the planning for and decommissioning of NPPs. After all the radioactive material has been removed, the remaining activity consists of final conventional demolition. The costs associated with this activity are also included in the reference cost.

Once a reactor has been permanently shut down, decommissioning commences. The decommissioning and dismantling work then continues until the remaining components of the facility are 'cleared', or in other words released from the demand for nuclear regulatory control. The remaining activities are then no longer subject to the rulings of the Act on Nuclear Activities, 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 2013, as in previous plan reports, a standard deduction of 10% of the costs for conventional demolition has been made. The exception is Barsebäck, where the entire cost is included. The standard deduction may be reviewed in future reports.

The time schedule for when a nuclear power plant is to be decommissioned is influenced by a number of different factors. Decommissioning and dismantling can be carried out in a safe way a short time after shutdown, but there may be advantages in doing it later. However, in the reference calculation it is assumed that the decommissioning and dismantling of those reactors that are currently in operation will commence immediately after the reactors have been shut down.

Decommissioning and dismantling activities will begin with the reactors in Barsebäck. It is assumed in the calculations that these activities can be started in 2023, by which time it is anticipated that SFR will be ready to receive decommissioning waste.

Shutdown operation is the activity from that point in time when the nuclear power reactor is finally shut down until all the fuel has been removed from the facility. In those cases where decommissioning and dismantling cannot be commenced immediately after shutdown operation, a period of so-called service operation is initiated. Decommissioning and dismantling is then expected to take from five to seven years and to employ on average 200 personnel per reactor facility. Figure 3-3 is a schematic illustration of the main activities during the decommissioning procedure.

The radioactive waste from the decommissioning and dismantling activities is LLW and ILW. However, the activity level varies considerably between different components. It is the waste from the internal parts of the reactor vessel that has the highest activity level.

The short-lived waste will be transported directly to SFR and be deposited there. The long-lived waste, which includes the internal parts of the reactor vessel, will be interim-stored either locally at the NPPs or temporarily in SFR. This waste will be subsequently deposited in SFL, which in the reference scenario is assumed to be completed by the mid-2040s.

It will be possible for a large quantity of the decommissioning waste to be released for unrestricted use after treatment, and be thereby dealt with in line with the regulations that apply for demolition waste in general.

3.3 Description of facilities within the system for low- and intermediate-level waste

3.3.1 SFR – repository for short-lived radioactive waste

A repository for operational waste from all the Swedish nuclear power plants is situated at the Forsmark NPP site and has been in operation since 1988. The facility is located beneath the Baltic Sea with a rock cover of approximately 60 m. Two approximately 1 km-long access tunnels lead from the harbour in Forsmark down to the repository area. SFR is also used for the final storage of radioactive operational waste from Clab and radioactive waste from non-electricity-generating activities, including Studsvik. By the end of 2013/beginning of 2014, some 35,000 m^3 of waste will have been deposited in SFR. The repository is planned to be extended in the near future to provide space for radioactive decommissioning waste. Such material will initially come from Barsebäck, where dismantling works are expected to commence in 2023.

SFR consists today of four 160 m-long rock vaults and a 70 m-high cylindrical rock cavern containing a concrete silo. This silo is used for disposal of the category of waste that contains most of the radioactive substances. Figure 3-4 shows an outline drawing of SFR and pictures from various disposal chambers. Figure 3-5 shows the future extension that is planned to be completed by 2023.

The concrete silo stands on a bed of sand and bentonite. Internally it is subdivided into vertical shafts into which the waste is lowered and embedded in porous concrete. The space between the silo and the rock wall is filled with bentonite. Once the silo has been filled, the space above will be filled with a mixture of sand and bentonite, and with sand and crushed rock.

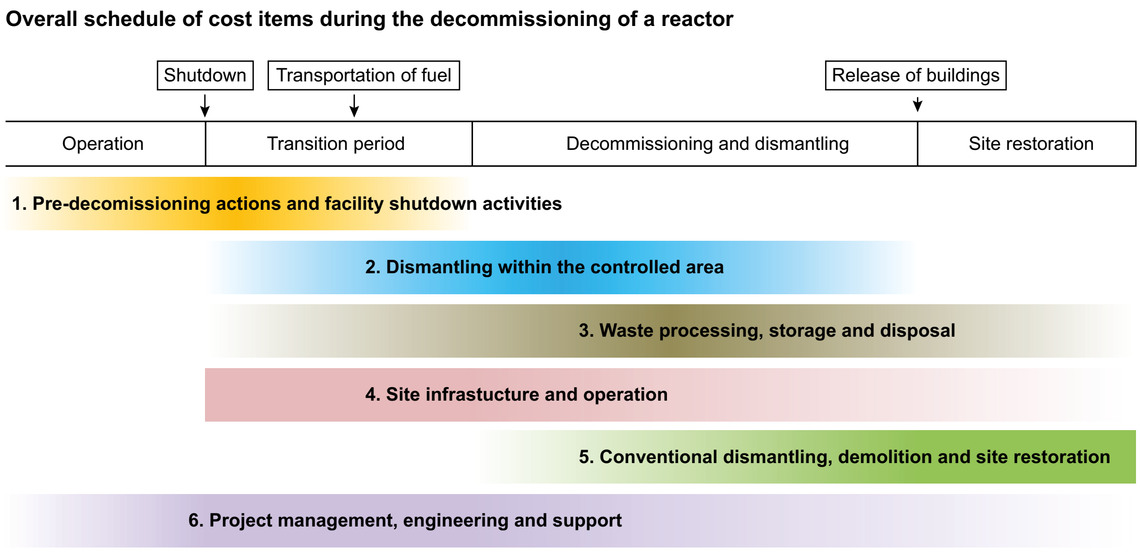


Figure 3-3. *Outline drawing of the main activities included in decommissioning.*

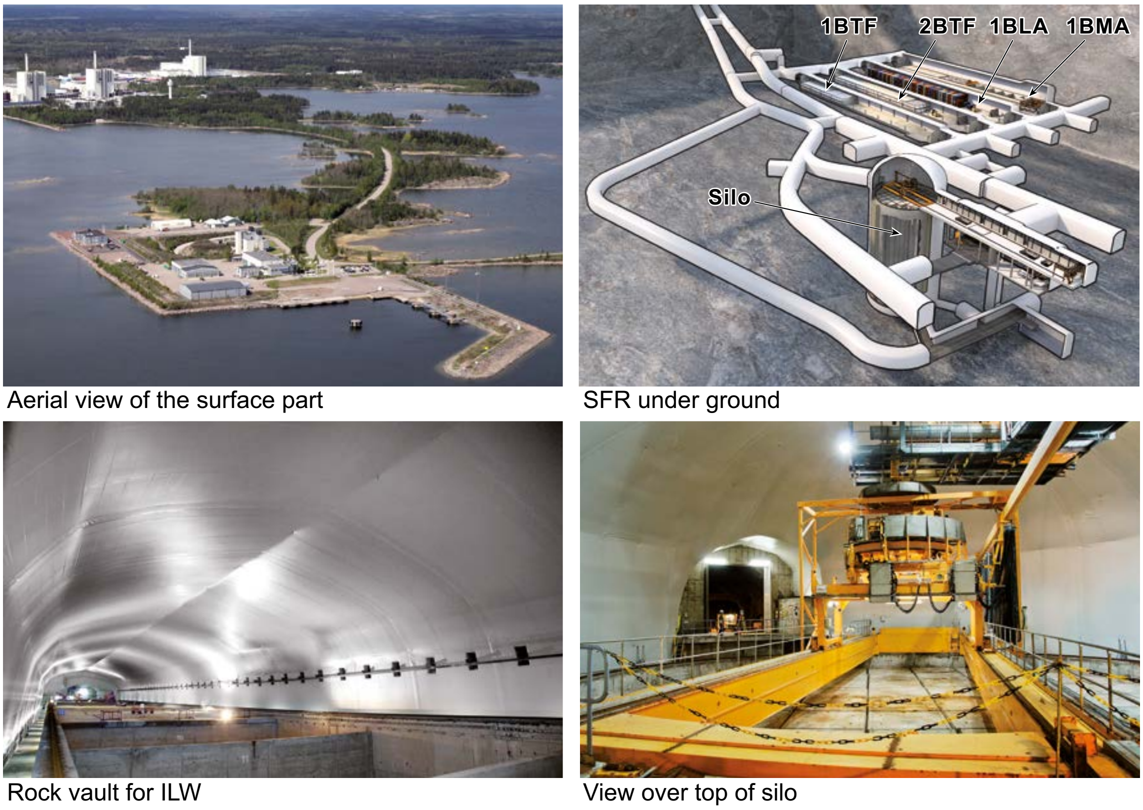


Figure 3-4. *SFR.*

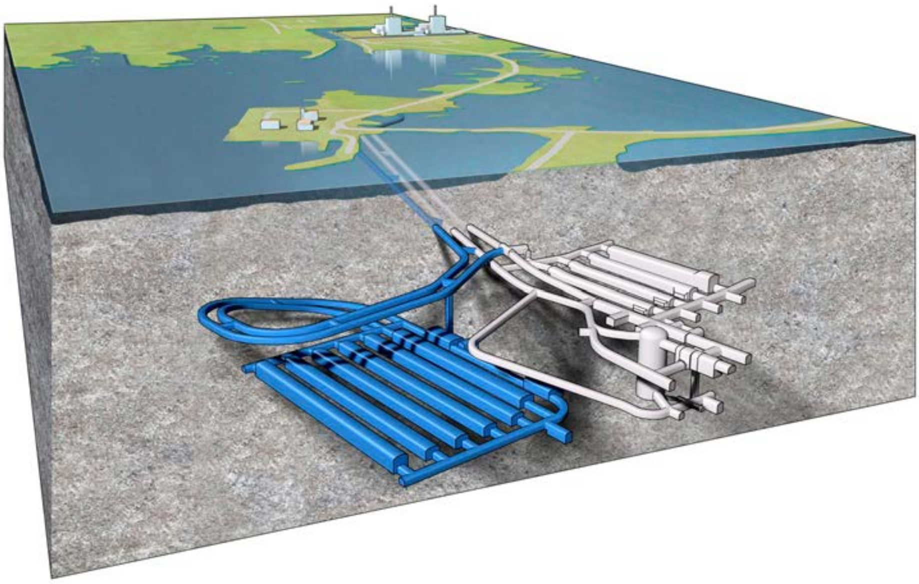


Figure 3-5. *SFR with the planned extension.*

Certain categories of waste deposited in the rock vaults are embedded after deposition. It is also possible to encase the waste in concrete at the time of the sealing of the facility.

Handling of the intermediate-level waste packages, which are placed either in the silo or in one of the rock vaults, is performed by remote control. Low-level waste, which is deposited in the other rock vaults, is handled by fork-lift trucks.

For the reference scenario it is estimated that SFR will receive a total of approximately 70,000 m^3 of operational waste, including radioactive waste from other activities as mentioned in Section 3.1. The capacity of the present SFR is approximately 60,000 m^3. It is in other words necessary to expand the capacity for operational waste – a need that will be met within the framework of the planned expansion to accommodate decommissioning waste.

It is assumed that most of the decommissioning waste could be packed into standard containers, which would then be transported to SFR and deposited in rock vaults. In all, it is estimated that some 140,000 m^3 of waste could be deposited in this way. A minor quantity of the decommissioning waste consisting of core components and reactor internals is planned to be deposited in SFL, which in the reference scenario is assumed to be built adjacent to SFR, see Section 3.2.3.

SKB took over operation of SFR under its own management in 2009 after its operation had been previously contracted to Forsmarks Kraftgrupp AB. Operation and maintenance are currently carried out by a team of some 40 personnel. In addition, external contractors are engaged for certain parts of the maintenance work. Altogether, it is estimated that the operation and maintenance of SFR will in the long term require a total of between 20 and 30 man-years. This also includes operation of the future SFL.

In the reference scenario SFR and SFL are assumed to be closed and sealed at the same time. That time is dependent of when all decommissioning waste from Clink has been disposed of.

3.3.2 Facilities at the nuclear power plant sites

Those facilities, for handling of nuclear waste that exist today at our nuclear power plant sites are intended for the disposal or interim storage of low- and intermediate-level waste. These facilities are covered either by a licence to own a reactor facility or by a licence that has been specially issued. Only the latter facilities are included in the cost calculations for the reference scenario.

Those operated on the basis of a special licence are at present:

- A near-surface repository for very low-level operational waste at Forsmark (Svalören).
- An interim storage facility for core components at Forsmark.
- A near-surface repository for very low-level operational waste at Oskarshamn (MLA).
- A dry-rock interim storage facility at Oskarshamn for short-lived operational waste from OKG and for long-lived waste (core components) from all nuclear power plants (BFA).
- A near-surface repository for very low-level operational waste at Ringhals.
- An interim storage facility for operational waste at Ringhals (referred to as the Mould Store).

3.3.3 SFL – Repository for long-lived waste

The repository for long-lived waste, called SFL, is mainly intended to contain core components and reactor internals, plus long-lived radioactive waste from SVAFO and Studsvik[8]. This final repository is the facility that will be commissioned last of all (assumed to be in 2045).

The siting of SFL is still an open issue. One possibility is for SFL to be co-located with one of the other repositories. In the reference scenario it is assumed that a co-location with SFR will be made. It should be pointed out that this is only a precondition for the cost calculation. Work is at present in progress on developing possible disposal concepts for SFL. For the purpose of the cost calculation, it is assumed that the repository will be constructed at a depth 300 m with a connection to existing ramps. SFL's disposal volume will be relatively small in comparison to SKB's other repositories. The total disposal volume is estimated to be 16,000 m^3.

According to the design that serves as a basis for the cost calculation, the disposal facility consists of rock vaults in which the waste is stacked in concrete shafts and encased in porous concrete. The shafts are successively covered with concrete planks and cast over. All handling is remote controlled by means of an overhead crane. As part of closure operations, the spaces between the concrete shafts and the rock are filled with crushed rock and the openings to the rock caverns are sealed with concrete plugs.

As regards manpower during operation, see Section 3.3.1.

Figure 3-6. *M/S Sigrid and transport casks for short-lived radioactive waste (ATB) and for core components (TK).*

[8] It is assumed that the long-lived waste from the NPPs will be interim-stored in containers, whereby decay will facilitate the subsequent continued handling. Interim storage can be arranged in different ways, but in the reference scenario it is assumed to take place in the extended SFR.

3.4 Description of facilities within the KBS-3 System

3.4.1 RD&D – Research, development and demonstration

The purpose of SKB's work on research, development and demonstration, RD&D, is to gather the knowledge required to realize the final disposal of spent nuclear fuel and long-lived radioactive waste. The programme for this work is presented by SKB every three years. The latest programme, RD&D Programme 2013, was submitted to the Government in September 2013.

During 2013, SKB and Posiva (the Finnish nuclear waste management company) started an in-depth cooperation, the goal of which is to develop common technical solutions for a disposal system prior to operation. A "Letter of Intent" was signed in autumn 2013.

So far, the RD&D Programmes have been focused mainly on the management and disposal of spent nuclear fuel. An increasingly part, however, is nowadays devoted to the handling of low and intermediate-level waste. The programmes also include method studies and the follow-up of NPP decommissioning experience. Within the system for low- and intermediate-level waste, RD&D activities are focused above all on the handling of long-lived waste.

Since most of the RD&D-related activities are included in the KBS-3 System, the activities are described in the section concerning this system.

One important component in the RD&D activities is the Äspö Hard Rock Laboratory located in the vicinity of the nuclear power plant in Oskarshamn, Figure 3-7. The laboratory is used to test, verify and demonstrate the investigation methods that have been used in the site investigations and which will later be used for detailed investigations of the Spent Fuel Repository in Forsmark. The laboratory is also used to study and verify the function of different components in the final repository system.

Another important purpose is to develop and demonstrate ways of building and operating the Spent Fuel Repository. As part of this work, SKB has conducted tests of prototype deposition machines, development of the horizontal deposition alternative, testing of methods for lowering the bentonite buffer and canisters into the drilled deposition holes, as well as backfilling and plugging of the deposition tunnels. A full-scale prototype repository has been built, and testing has been carried out on the retrieval of canisters from a deposition hole. Figure 3-8 shows the latest design of the deposition machine for the handling of canisters containing spent nuclear fuel.

In the future, the laboratory will be used to train personnel who will be working in the Spent fuel Repository. As a consequence, the facility will remain in operation roughly up until the time that the Spent Fuel Repository becomes operational.

Another important component in the RD&D activities is the Canister Laboratory in Oskarshamn where methods are developed for the sealing and inspection of the copper canisters. The laboratory is also used for the full-scale testing and verification of different types of canister handling equipment. The laboratory will also be used for the training of personnel prior to the start of operations in the encapsulation part of Clink.

The test fabrication of canister components such as copper tubes, lids, bottoms and inserts with lids has been in progress since 1996. Fabrication is being tested using a variety of methods at a number of companies in Sweden and abroad.

SKB has been conducting research and development at the Bentonite Laboratory since 2007. The laboratory is situated adjacent to the Äspö Hard Rock Laboratory and supplements the experiments that are conducted there. The laboratory is used to test the properties of the bentonite and developing methods for backfilling the repository tunnels and constructing the plugs that will be used to seal the deposition tunnels in the planned Spent Fuel Repository.

In the reference scenario, it is assumed that research, development and demonstration will continue on Aspö until the deposition activities are started. Development and training activities will continue at the Canister Laboratory until the encapsulation part of Clink becomes operational.

The costs of earlier activities within the Spent Fuel Repository project, such as site surveys, design and detailed investigations, are reported in the cost compilation under the heading "Spent Fuel Repository".

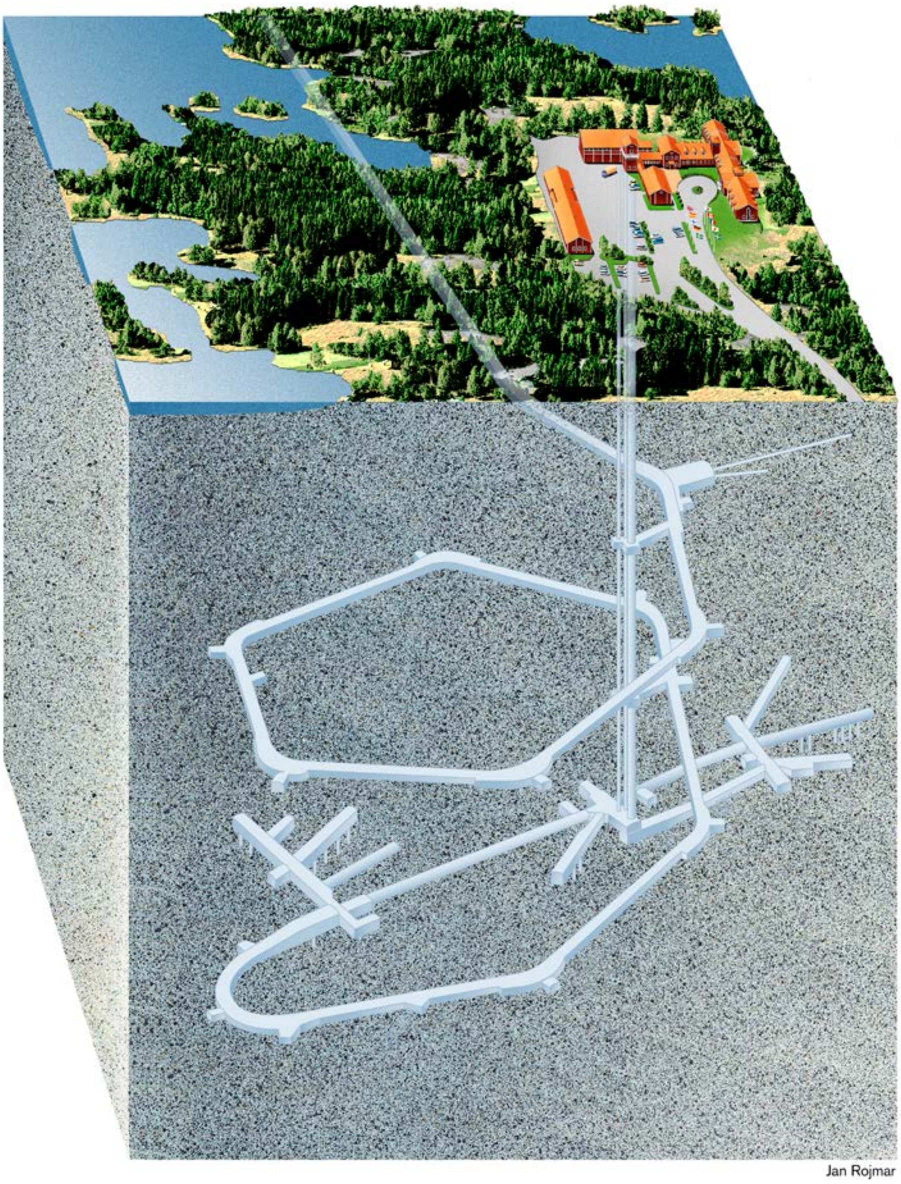


Figure 3-7. The Äspö Hard Rock Laboratory.

Figure 3-8. Deposition machine for handling canisters in the repository

3.4.2 Clab – Central interim storage facility for spent nuclear fuel

Clab is located at the Oskarshamn NPP site. The spent nuclear fuel is stored on an interim basis in water pools. The facility, which became operational in 1985, was originally designed to store some 3,000 tonnes of fuel (uranium weight) in four pools. The capacity of these pools was subsequently extended to approximately 5,000 tonnes by the introduction of new storage canisters, which allow closer packing. The storage volume was again increased in 2008 when a second rock cavern with storage pools was put into operation. SKB is at present licensed to store 8,000 tonnes of fuel in the facility.

At year-end 2013/2014, the facility is expected to contain some 5,740 tonnes of spent nuclear fuel. The pools can hold a total of 11,000 tonnes of fuel. An increase in the storage capacity will require a new licence.

In addition to spent nuclear fuel, the facility currently contains, on an interim basis, control rods from BWRs and core components.

Clab consists of a surface section for fuel reception and an underground section containing storage pools. The surface section also contains equipment for ventilation, water purification and cooling, waste handling, electrical systems, etc as well as premises for administration and operating personnel. The reception of fuel and all handing procedures take place in the pools under water.

The storage pools, which are located in rock caverns and made of concrete with a stainless steel lining, are design to withstand earthquakes.

The facility is operated by SKB's own personnel. The permanent workforce with the facility in full operation is approximately 100.

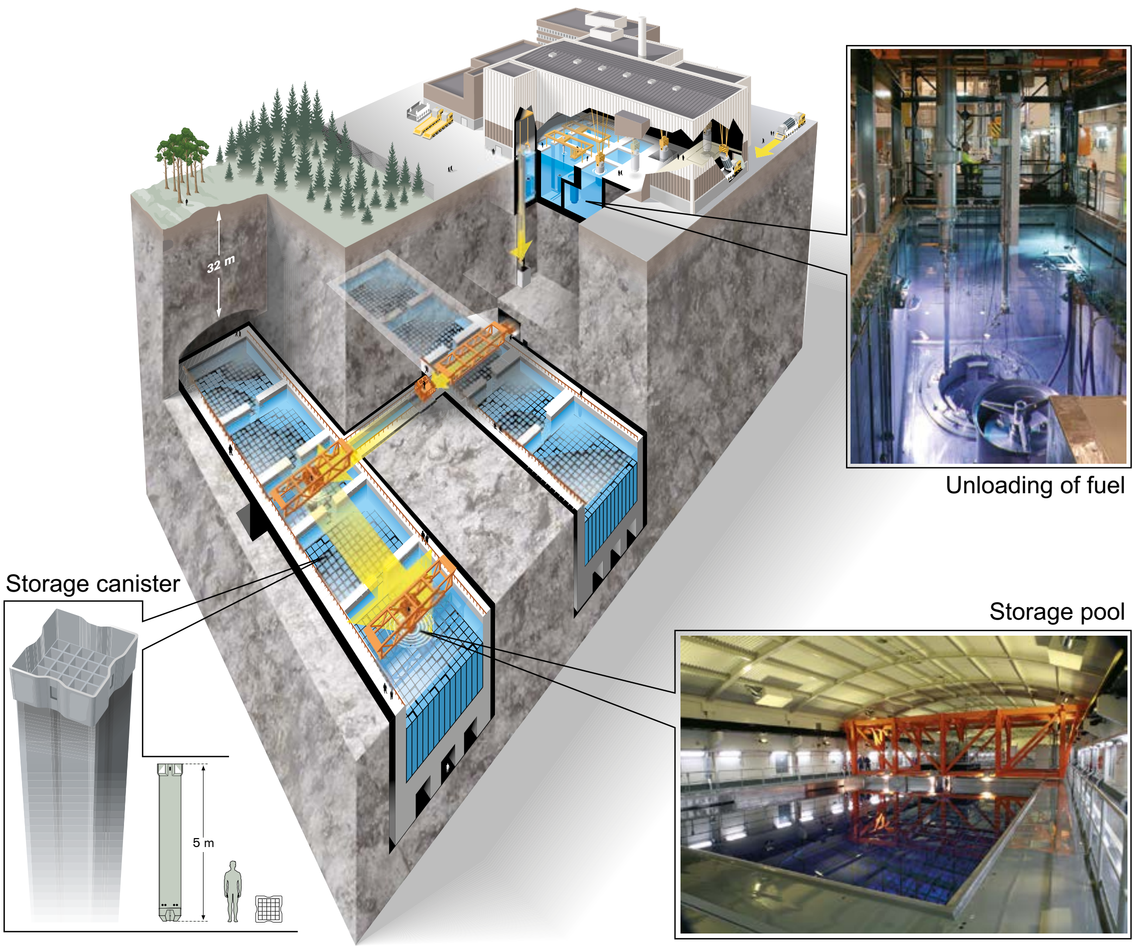


Figure 3-9. *Clab.*

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.

The cost calculations for Clab are based on experience gained to date and updated reviews of the future requirements of the facility in terms of maintenance and reinvestments.

3.4.3 Facilities for the encapsulation of spent nuclear fuel

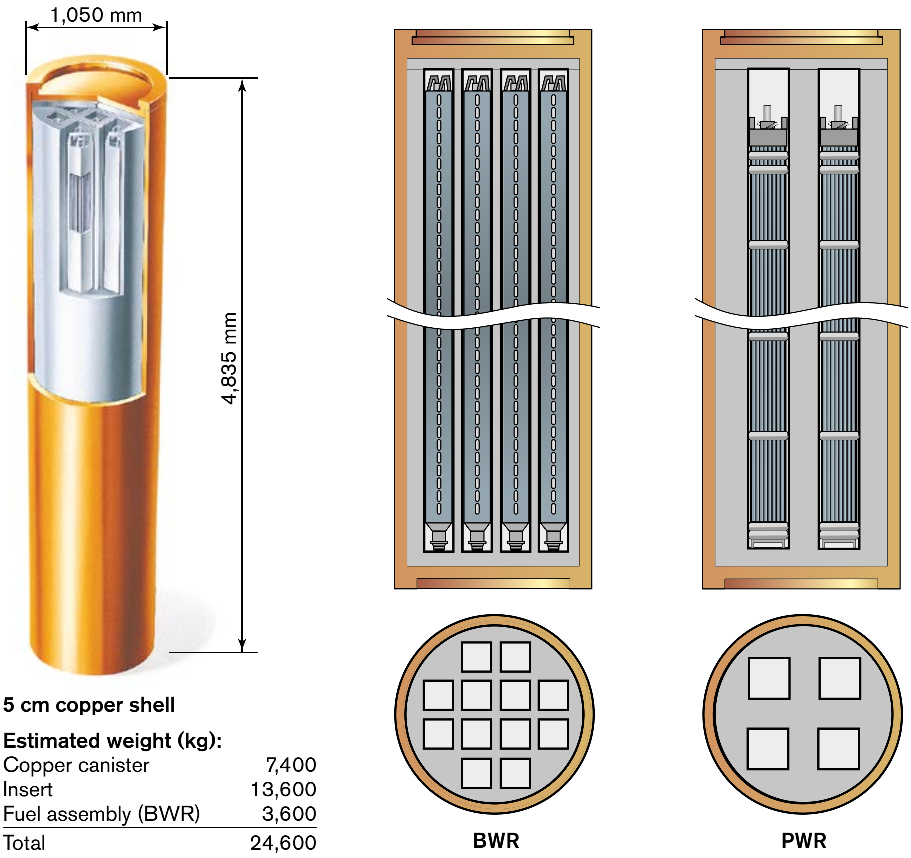
Canister factory

The term "canister factory" refers in this report to a facility in which the various parts of the canister are finely machined and assembled into a finished canister.

The canister in the reference design consists of an outer 5 cm-thick corrosion barrier of copper in the form of a tube with a lid and a bottom, see Figure 3-10. The specified copper grade is a high-purity, oxygen-free copper with a small phosphorous additive.

Inside the copper tube there is a cast-iron insert with channels for the fuel assemblies. The insert also serves as the pressure-bearing component in the structure. The lid of the insert is made of rolled steel plate.

Components such as tubes, lids and bottoms made of copper as well as inserts of nodular iron with steel lids are delivered to the factory. These components are finely machined in the canister factory to the correct final dimensions. After the final dimensions have been checked, the copper bottom is welded on to the copper tube. Non-destructive testing methods such as ultrasonic sounding and radiography are used to inspect the welds. After cleaning, the insert is lowered down into the copper tube and, together with the steel lid and the copper lid, delivered as a "package" to Clink. The canister is accompanied by a detailed certificate containing material and fabrication documentation.



Estimated weight (kg):

Copper canister	7,400
Insert	13,600
Fuel assembly (BWR)	3,600
Total	24,600

Figure 3-10. *Copper canister with cast-iron insert.*

The canister factory is planned to be housed in a building approximately 7,000 m^2 in size with premises for maintenance shops, offices and an inspection laboratory. The manpower requirement is estimated to be about 20.

Central facility for the handling, interim storage and encapsulation of spent nuclear fuel, Clink

Before the spent nuclear fuel is deposited in the final repository, it will be encapsulated in the canister described above, which has sufficient capacity to hold up to 12 BWR elements or 4 PWR elements. Encapsulation is planned to be conducted at a new facility located adjacent to Clab. Once this encapsulation section is directly connected with Clab, the two parts will be operated as an integrated facility under the name Clink.

Clink will contain a number of stations for various work phases.

- Arrival section with quality control of the canister components delivered.
- Encapsulation section with the steps:
  - Verification of decay heat output, documentation, and sorting of the fuel from the storage pools. Transfer of fuel assemblies to a transfer container.
  - Drying of fuel and lowering of individual fuel assemblies into the copper canister insert followed by fitting of the steel lid on to the insert.
  - Change of atmosphere in the insert, which entails replacing air by an inert gas. Cleaning of joint surfaces and fitting of copper lid to the copper canister.
  - Welding of the canister lid by means of friction stir welding.
  - Non-destructive testing of weld joints and cooling of the canister. Testing is planned to be carried out after both welding and machining.
  - Machining of weld joints.
- Terminal building or dispatch section for finished canisters. Canisters will be transported to the final repository in radiation-shielded transport casks.
- Auxiliary systems with both cooling and ventilation systems as well as electrical and control equipment.
- Personnel and office premises as well as storerooms.

Figure 3-11. *Clink with encapsulation section for spent nuclear fuel (marked in the figure).*

The facility is designed for an annual production capacity of 200 canisters. However, the long-term production rate at the facility is dependent of the fuel input rate, which is in turn determined by the minimum storage time needed in Clab in order for the fuel to decay to a suitable level. In the reference scenario, with a total of 6,200 canisters, the production rate during the greater part of the operating period will be approximately 180 canisters per year, decreasing to 100 towards the end of the period.

Encapsulation will take place during the daytime. When estimating the manpower requirements, consideration has been given to the synergies to be gained in terms of organization and staffing by integrating the encapsulation section with Clab and operating the two parts of the facility as one integrated unit, Clink.

SKB plans to apply for permission to start trial operation of Clink at year-end 2027/2028. The trial operation is envisaged to start a year later and an application for routine operation is planned to be submitted at year- end 2029/2030. It is anticipated that the licence will be granted half-way through 2030.

On completion of encapsulation, the facility will be decommissioned and radioactive decommissioning waste will be transported to SFR.

3.4.4 Spent Fuel Repository

SKB has applied to construct the Spent Fuel Repository at Söderviken, south-east of Forsmark NPP, Figure 3-12. The facility consists of an above-ground (surface) part and an underground (subsurface) part.

Underground part

The underground part consists of a central area and a repository area, together with connections to the surface part in the form of shafts for lifts and ventilation, and a ramp for vehicle transport. According to the KBS-3 method, the final repository will be located within a depth range of 400–700 m below the ground surface.

Figure 3-12 shows the planned repository area based on the results of the site investigation. The area is located within a delimited area of rock known as a tectonic lens. In order to avoid water-bearing structures and limit the rock stresses, the repository level has been set at 470 m. The spacing between the canisters and between the deposition tunnels is determined by the temperature that is expected to develop around the canister, especially that of the surrounding bentonite, the function of which is dependent on the temperature not becoming too high. Bentonite is a clay that swells when it absorbs water, and its purpose is to protect the canister and retard the possible discharge of radioactive substances. The distance between the canisters is thus determined by the decay heat of the fuel, the thermal conductivity of the rock and the bentonite, and the initial temperature of the rock. A canister spacing of 6.0 m and a tunnel spacing of 40 m have been chosen in the reference scenario. The extent of the repository shown in the figure also includes 13% spare capacity to allow for deposition holes that cannot for some reason be used.

The reference design is based on an alternative incorporating a consolidated operations area above ground and a spiral-shaped ramp for the transportation of heavy and bulky items. In addition, there are a number of shafts for the purpose of transportation, utilities and ventilation. In order to shorten the construction period, the lift shaft for rock spoil – referred to as a skip shaft – will be driven in the form of a sunk shaft (from the ground surface downwards) at the same time as the ramp. During the operating period, the skip shaft will be used for the transportation of rock spoil and backfill. The main use of the ramp will later be for the transportation of transport casks containing the canisters.

The central area contains functions for operation of the underground part of the facility, and is situated immediately below the operating area on the ground surface. It consists of a series of parallel halls with different purposes. The halls are interconnected both by the tunnels that serve as the transport routes in the central area and by local tunnels for communication and service.

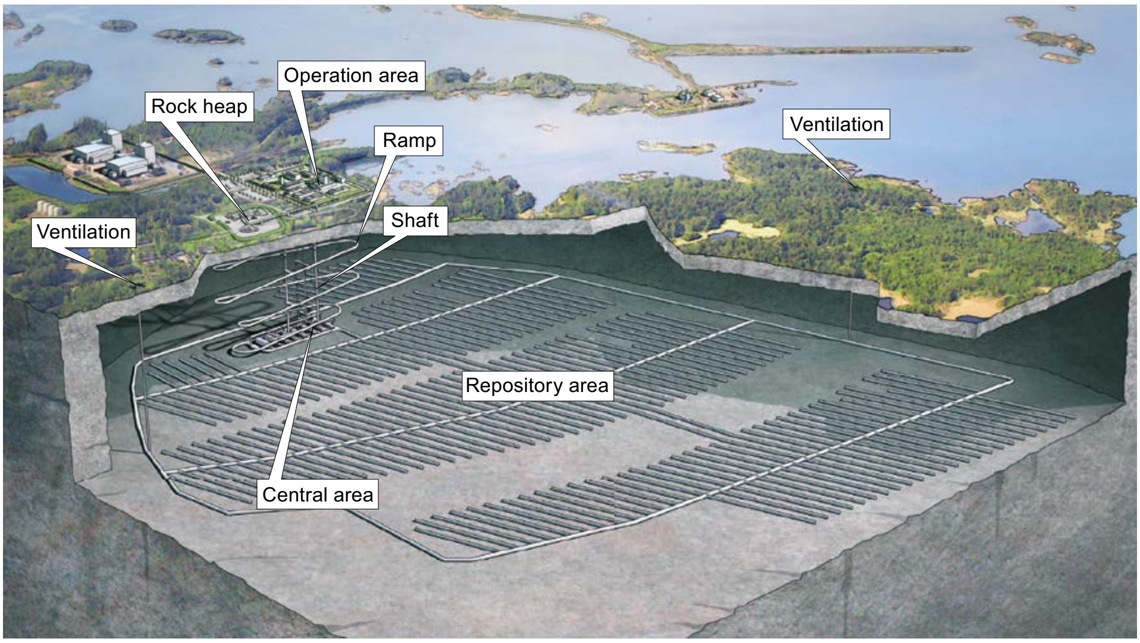


Figure 3-12. *Main parts of the Spent Fuel Repository.*

Surface part

The surface part comprises the operations area, rock heap, ventilation stations and stores, see Figure 3-13. Most parts of the facility are collected in a large operations area that is subdivided into an outer and an inner operations area. The inner operations area is used for conducting the nuclear activities while the outer area contains the production plant for buffer and backfill, and a number of buildings intended for operational functions, service and maintenance, and personnel.

The inner operations area contains the buildings that serve as access routes to the subsurface part of the facility, and therefore consists of a monitored area with special access and exit control facilities. The inner operations area also contains a terminal building that serves as a reception and transfer loading area for the canister transport casks. In the reference scenario, these casks are transported from Clink to the harbour at Oskarshamn NPP and from there by M/S Sigrid to the harbour in Forsmark at SFR. The casks are then transported by terminal vehicles to the terminal building, where they are stored on an interim basis before being transported down to the subsurface part of the repository, where the canisters are unloaded from the casks and transferred to the deposition machine.

The rock heap is an interim storage where blasted rock is stored until it can be sold. It is located near the operations area and the rock material is transported to the heap on a conveyor belt from the skip building in the internal operations area.

In the outline drawing in Figure 3-13, an indication is given of the planned locations of two ventilation stations for the exhaust air from the rock caverns.

In addition to the surface parts described above, there is a store for bentonite and backfill situated at the receiving harbour in Hargshamn, some 30 km south of Forsmark. Here, the material for production of the buffer and backfill is stored before being transported to the production plant in the outer operations area.

Activities and functions

Once the facility has been built and the commissioning conditions have been met, and approved by the regulatory authorities, the nuclear activities will commence with a first stage, referred to as trial operation. The principal operating activities are rock works, deposition and the production/transport of buffer and backfill material. These activities will in principle be conducted simultaneously, but in different parts of the subsurface facility. This means that the canisters will be deposited in one part of the repository at the same time as new deposition tunnels are being blasted and excavated in another part.

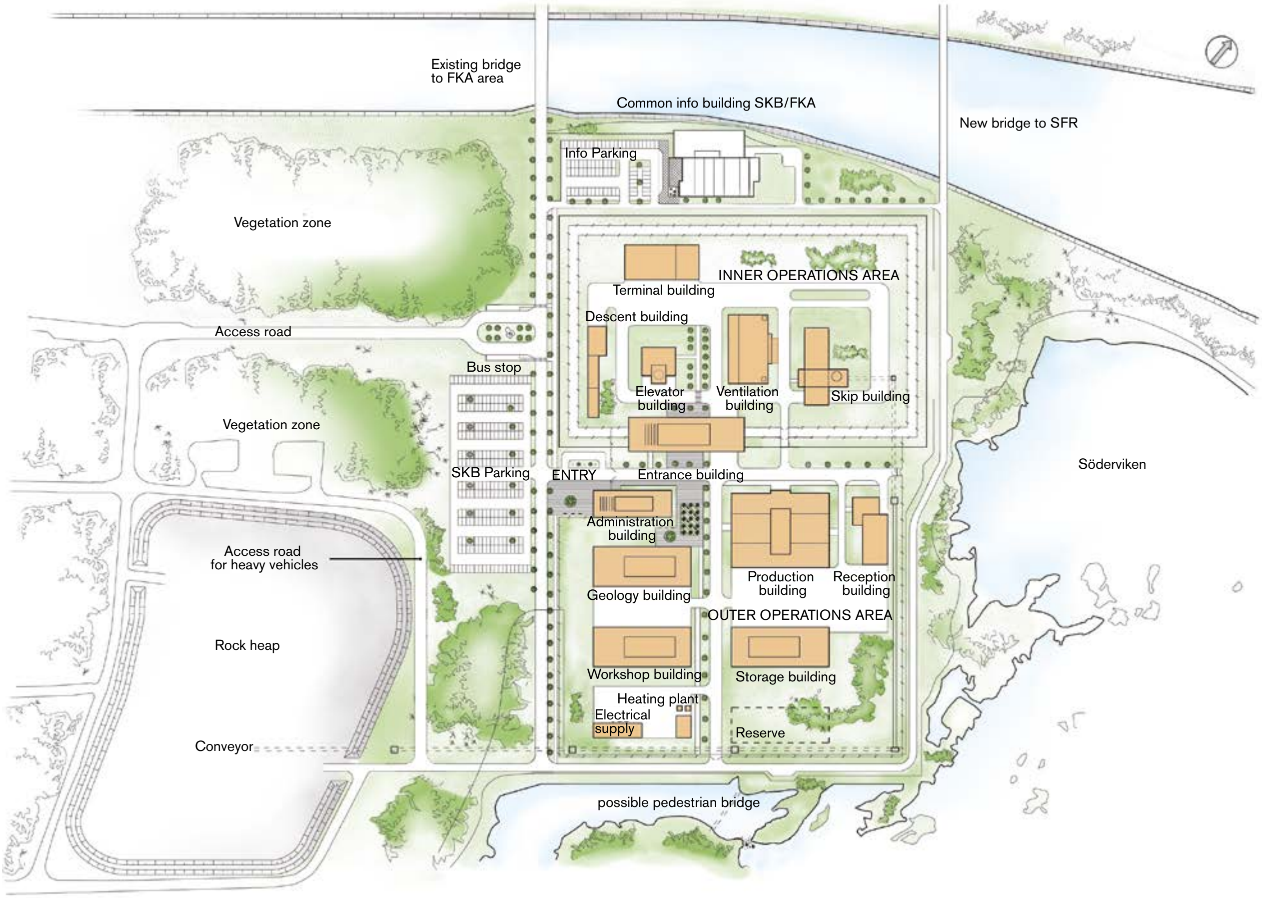


Figure 3-13. *Spent Fuel Repository in Forsmark – surface part.*

The deposition tunnels will be blasted and excavated as deposition gradually proceeds. However, deposition may start already when trial operation begins. This is possible because while the facility is being constructed, a number of deposition tunnels and associated transport and main tunnels will be driven at the same time. These are the transport and waste handling tunnels that are situated directly adjacent to the deposition tunnels and link them together. The deposition rate will be gradually increased after the trial operation phase in order to approach the rate that will apply during routine operation. The experience from the trial operation phase will be evaluated to serve as a basis for obtaining a licence for routine operation.

A total of just over 200 personnel will be employed at the Spent Fuel Repository.

Rock works

The term rock works is understood to mean all activities required in order to blast tunnels and bore the deposition holes, including preparatory works and detailed investigations. The works also include providing tunnels with temporary installations for ventilation, electricity, lighting and drainage. The rock works will be conducted for the most part using standardised equipment for blasting and for boring. Equipment developed specially for the purpose is used for boring of deposition holes. The rock works in a deposition tunnel are considered to be finished when the tunnel is ready for canister deposition.

Rock spoil is transported by dumper trucks from the blasting site in the repository area to the loading station in the central area. The spoil passes through the loading station crusher and silo, and is then conveyed by skip to the operations area and from there to the rock heap.

Deposition

Deposition consists of the preparatory works for deposition, placing of the bentonite buffer in the deposition hole, deposition of the canister as well as backfilling and plugging of the deposition tunnel, see Figure 3-14.

Backfilling of the deposition tunnel is started when the last canister in a deposition tunnel has been deposited. In simple terms, the backfilling works entail the tunnel being filled with blocks of swelling clay. The space closest to the rock surface is filled with pellets made of the same material as the blocks. Once the deposition tunnel has been completely backfilled, it is sealed by casting a concrete plug into the tunnel entrance. These concrete plugs have no long-term function once the entire repository has been sealed.

Buffer and backfilling

The buffer surrounds the deposited canister and is one of the barriers in the repository. The buffer consists of compacted bentonite. Above and below the canister the buffer consists of blocks, whereas along the canister mantle surface it consists of rings. In addition, there are pellets or granules (grains) of bentonite to fill the gaps between the blocks/rings and the rock in the deposition hole.

The backfill replaces the excavated rock in the deposition tunnels. At a later stage backfilling of remaining tunnels and spaces in the subsurface part will be done. The backfill in the deposition tunnels consists of compacted blocks of bentonite that are stacked in the tunnels. Pellets of the same material are used to fill gaps between blocks and the tunnel wall.

Bentonite is shipped into the harbour at Hargshamn, where it is stored in bulk in storerooms. From there it is transported to the production building in the outer operations area where production of the buffer and backfill take place by compressing the bentonite into blocks, rings and pellets with a high level of density.

The finished blocks for the buffer and backfill are then transported into the inner operations area via the access building and from there to the skip building. Transport down to the central area is done by skip and from there by vehicle out to the point of use in the deposition tunnel.

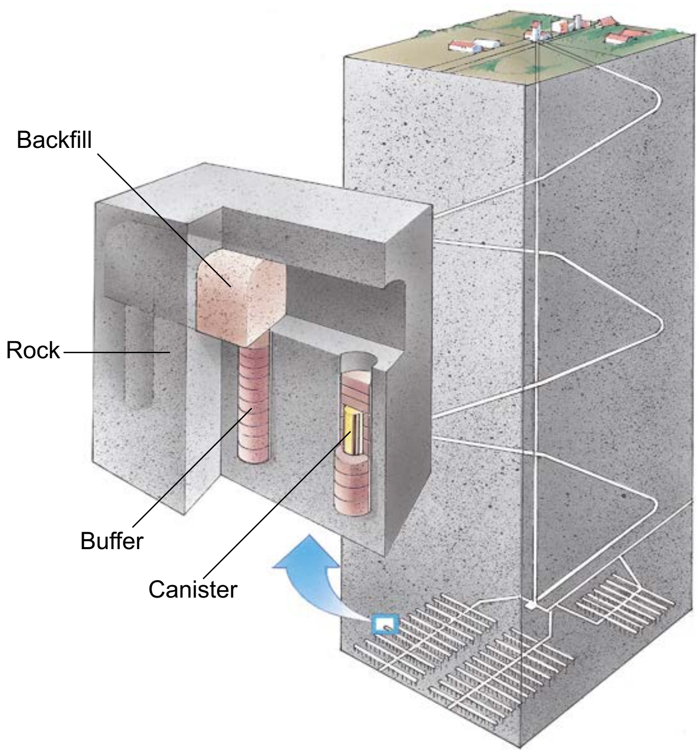


Figure 3-14. *KBS-3.*

3.5 Description of the transport system

In the cost calculation, a distinction is made between sea transport with associated terminal handling and land transport by road. Sea transport is reported under the heading Transport systems while land transport is included in the facilities described.

The system for sea transport consists of three main components: the ship M/S Sigrid, the transport casks and terminal vehicles. This system is designed to be used for spent nuclear fuel and all types of nuclear waste.

M/S Sigrid, is a new ship that replaces M/S Sigyn (built in 1982). As with M/S Sigyn, the new ship is double bottomed and has a double shell. The design would protect the cargo in the event of a grounding or collision. M/S Sigrid has a better fuel economy and has less of an environmental impact than her predecessor. She has the capacity to carry 12 fuel and waste casks instead of the previous ten.

For the transport of spent nuclear fuel and core components from the NPPs to Clab, use is made of casks that have been designed to meet the requirements for radiation shielding and to withstand large external forces. A transport cask of this type has room for about 3 tonnes of fuel. For the transport of intermediate-level waste to SFR, radiation-shielded steel casks are used. They have capacity for approximately 20 m^3 of waste and the maximum transport weight per cask is 120 tonnes. In the case of low-level operational waste, as well as for most decommissioning waste, standard casks can be used. At present, the system has ten transport casks for spent nuclear fuel, two for core components and 27 radiation-shielded casks for intermediate-level radioactive waste.

When the casks are loaded and offloaded, they are transported limited distances between store and ship on special terminal vehicles, see Figure 3-6. At present, five such vehicles are in use.

The transport of canisters containing spent nuclear fuel from Clink to the Spent Fuel Repository is assumed in the reference scenario to be effected by sea transport to the harbour in Forsmark. During this transport, the canisters with spent nuclear fuel are placed in casks of the same type as those used for spent nuclear fuel today. Further transport to the operations area will be made by terminal vehicle.

The costs of the transport system are based on experience gained to date. Consideration has been given in the future costs to the need for new acquisitions of ships and vehicles, as well as transport casks.

3.6 Cost accounts

3.6.1 Future costs

The future costs for different facilities and activities in the reference scenario are shown in Table 3-5. For each facility and activity, a specification is given as to whether the costs refer to *investment, operation and maintenance, backfilling* and/or *decommissioning and enclosure*. Costs for backfilling refer only to the deposition tunnels. 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). On the other hand, in the case of the Spent Fuel Repository, where extension of the number of deposition tunnels will take place on a continuous basis throughout the deposition phase (operating phase), the costs for this work are also included in *investment*. The cost estimates in Table 3-5 are based on current data for the reference scenario and cover neither an allowance for uncertainty and risk nor an adjustment for future real price changes (adjustment for EEF).

The reference cost amounts to a total of SEK 99.2 billion. Of this, SEK 75.6 billion is within SKB's sphere of operations and is therefore common for the licence holders (joint costs). The remainder are costs for activities in which each licence holder has an individual cost responsibility (separable costs).

Figure 3-15 shows the reference cost distributed over the course of 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.

Table 3-5. Compilation of future costs for the reference scenario from and including 2015, at the January 2013 price level.

		Cost per type of cost, SEK million	Cost per facility, SEK million
SKB's central functions and RD&D		9,900	9,900
Transport system	investment	1,400	3,100
	operation and maintenance	1,700	
Clab	reinvestments	2,120	11,130
	operation and maintenance	8,250	
	decommissioning	760	
Encapsulation	investment	4,340	15,650
	operation and maintenance & reinvestments	11,070	
	decommissioning	240	
Spent Fuel Repository			
– above-ground	investment and decommissioning	5,460	28,750
	operation and maintenance (entire facility)	5,930	
	reinvestments (entire facility)	2,430	
– other rock openings	investment	2,410	
	investment and closure	1,440	
– main and deposition tunnels	investment	6,830	
	decommissioning, backfilling and closure	4,250	
SFL	investment	860	1,520
	operation and maintenance & reinvestments	280	
	decommissioning and closure	380	
Interim storage facility and near-surface repositories at NPPs	investment, operation and decommissioning	120	120
SFR (operational waste)	operation and maintenance & reinvestments	1,000	1,000
SFR (decommissioning waste)	investment	2,260	4,590
	operation and maintenance & reinvestments	1,970	
	decommissioning and closure	360	
Decommissioning of NPPs		23,390	23,390
Total reference cost (excluding adjustment for EEF and allowance for unforeseen factors and risk)			99,150

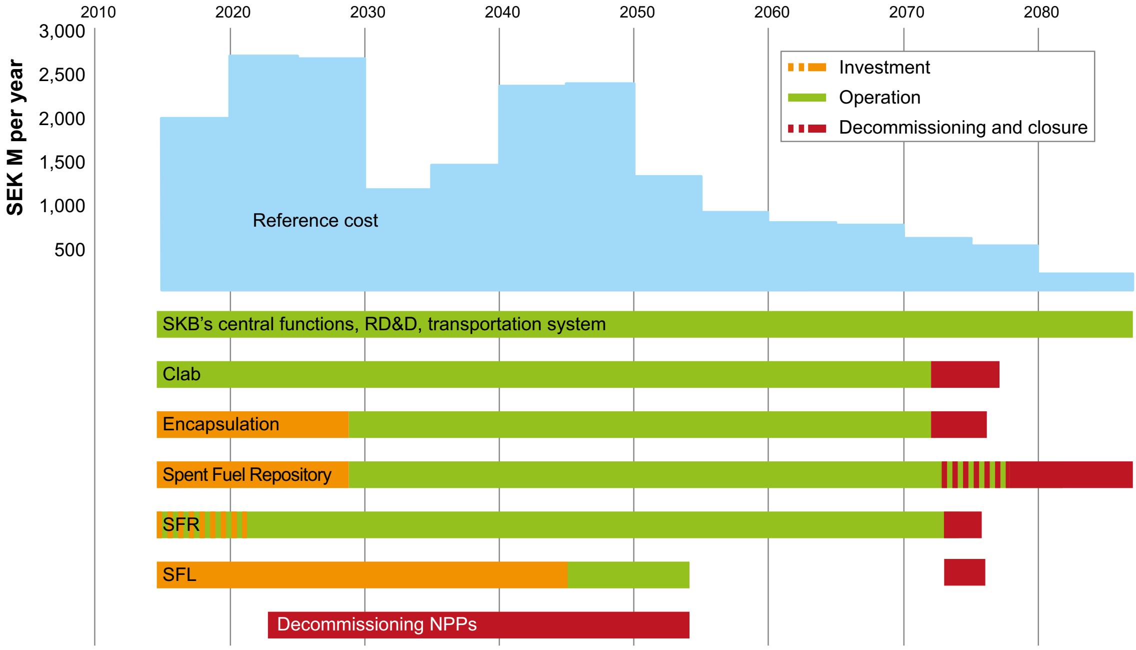


Figure 3-15. *Time distribution of the future costs for the reference scenario and outline time schedules for the facilities, 2013 price level.*

3.6.2 Incurred and budgeted costs

Table 3-6 shows, at the current price level, incurred costs up to and including 2012 and a forecast for the cost outcome in 2013 as well as budgeted costs for the year 2014. (The reference cost reported in Section 3.6.1 contains the costs from and including 2015.)

The costs for reprocessing that occurred in an earlier phase of planning for management of spent nuclear fuel are not included in the table.

Figure 3-16 shows how the total cost, incurred and future, has been allocated to the various facilities. The distribution is based on the January 2013 price level, whereby previously incurred costs have been adjusted upwards with the Consumer Price Index, CPI.

Table 3-6. Costs incurred up to and including 2012 and a forecast for the outcome in 2013 and budgeted for 2014, current price level.

	Incurred up to and including 2012, SEK million	Outcome 2013 (forecast), SEK million	Budget for 2014, SEK million	Total up to and including 2014, SEK million
SKB central functions	3,237	295	303	3,835
RD&D	6,794	259	242	7,295
Transport				
– investment/reinvestment	533	101	30	664
– operation	865	42	40	947
Clab				
– investment/reinvestment	3,947	88	121	4,156
– operation	2,422	204	207	2,833
Encapsulation				
– investment	379	65	54	498
Spent Fuel Repository (siting, site investigations and design)	3,779	289	270	4,338
SFR				
– investment/reinvestment	1,147	7	13	1,167
– operation	1,145	166	179	1,490
Total	24,248	1,515	1,459	27,222

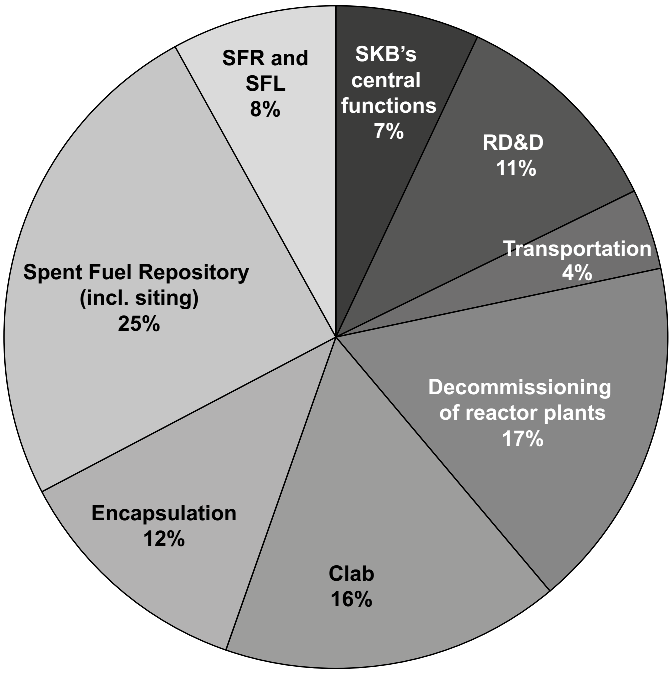


Figure 3-16. *Distribution of the total cost (incurred and future) for the reference scenario (January 2013 price level).*

4 Costs according to the Financing Act

4.1 Operating scenarios for the reactors

To obtain data for calculating the amounts that are requested according to the Financing Act (see Chapter 1) a number of calculations with a variety of scopes and assumptions need to be made. All these calculations are based on the reference calculation, i.e. the one founded on the reference scenario and which is presented in Chapter 3.

The most important factors for the various calculations are the assumptions that are made on the question of reactor operating times and the quantities of spent nuclear fuel that follow from this. The reference scenario is based on current plans of the nuclear power companies. Cost calculations in accordance with the Financing Act should, however, be based on operating times prescribed in the Financing Ordinance. Two operating scenarios are of particular interest. A third, which is not presented in Plan 2013, is used as a distribution of the costs between the licence holders.

One of the operating scenarios is used as a basis for calculation of the remaining basic cost, which serves as a basis for calculating the magnitude of the nuclear waste fees (see Chapter 1). In the Financing Ordinance it is prescribed that the cost calculations shall be made on the basis of the assumption that each of the reactors in operation today should be operated for 40 years. In the case of reactors that have been in operation for at least 34 years it should, however, be assumed that the remaining operating time is six years unless there is reason to suspect that operation may cease beforehand. For Plan 2013, which is intended to serve as a basis for fees and guarantees for the period 2015–2017, this means that all current ten reactors are assumed to be in operation at least up to and including 2020. Figure 4-1 illustrates the future assumed operating times according to the Financing Act and the planned operating times for the reactors.

The second operating scenario serves as a basis for calculation of the financing amount with reconciliation at the beginning of the first fee year covered by the calculation, in our case 31 December 2014. Reconciliation means that an inventory is made of the total quantity of spent nuclear fuel at any given point in time, including the fuel then in the reactor cores. The costs will then be calculated on the assumption that it is only this quantity of spent nuclear fuel that is to be taken care of.

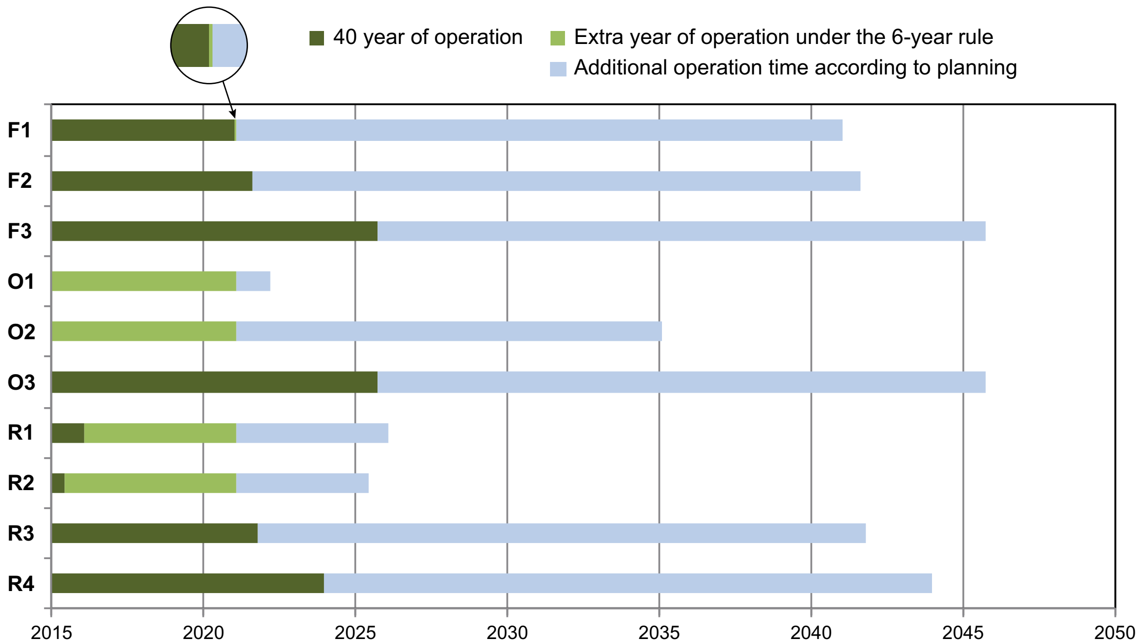


Figure 4-1. *Assumptions on the future operating times according to the Financing Ordinance and the planned operating times for the reactors.*

Otherwise, the same assumptions apply for the cost calculation as in the first operating scenario. The calculation providing the basis for the financing amount is dealt with in standard terms on the basis of the calculation for the remaining basic cost.

Table 4-1 shows operating data and fuel quantities for the 40-year operation scenario. For the sake of comparison, the quantities in the reference scenario are also shown in Table 4-2.

The cost accounting is relatively detailed for the 40-year scenario (Section 4.3.2). In the case of the basis for the financing amount, i.e. the reconciliation on 31 December 2014, only the total amount is given (Section 4.3.3).

Table 4-1. Operating data plus electricity production and fuel quantities according to the Financing Ordinance.

Start of commercial operation	Thermal capacity	Energy production		Fuel	Operating time	Total for the 40-year scenario		
	Net output MW	Up to and including 2013 TWh	Mean value from and including 2014 TWh/yr	Up to and including 2013, tonnes of uranium	according to Financing Act yr	Operation up to and including	Energy production TWh	Spent nuclear fuel tonnes of uranium
F1 (BWR) 1980-12-10	2,928 / 984	228	7.5	823	40.1	2020-12-31	282	984
F2[1] (BWR) 1981-07-07	2,928 / 990	222	7.5	803	40.0	2021-07-06	282	984
F3 (BWR) 1985-08-22	3,300 / 1,170	244	8.8	817	40.0	2025-08-21	347	1,097
O1 (BWR) 1972-02-06	1,375 / 473	100	3.5	371	48.9	2020-12-31	124	441
O2 (BWR) 1974-12-15	1,800 / 638	154	6.4	533	46.1	2020-12-31	199	645
O3 (BWR) 1985-08-15	3,900 / 1,400	226	11.2	766	40.0	2025-08-14	356	1,131
R1 (BWR) 1976-01-01	2,540 / 855	181	6.4	671	45.0	2020-12-31	225	805
R2 (PWR) 1975-05-01	2,652 / 866	194	6.3	595	45.7	2020-12-31	239	723
R3 (PWR) 1981-09-09	3,135 / 1,051	205	8.2	655	40.0	2021-09-08	267	824
R4 (PWR) 1983-11-21	2,775 / 935	196	7.3	620	40.0	2023-11-20	269	824
B1 (BWR) 1975-07-01	1,800 / 600	93		423		1999-11-30	93	423
B2 (BWR) 1977-07-01	1,800 / 600	108		442		2005-05-31	108	442
BWR total	22,371 / 7,710	1,556	51	5,649			2,017	6,953
PWR total	8,562 / 2,852	595	22	1,871			775	2,372
All NPPs total	30,933 / 10,562	2,152	73	7,520			2,792	9,325

[1] Forsmark 2 has since 2012 a permit for trial operation to max. 3,253 MW thermal capacity which is equivalent to 1,120 MW of net electrical output. The higher output was achieved in spring 2013. Plan 2013 is based on a forecast made earlier for F2.

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

	Quantity to be disposed of		Final repository
Spent BWR fuel Spent PWR fuel Other spent nuclear fuel (MOX, Ågesta, Studsvik)	4,560 canisters	(6,200)[1]	Spent Fuel Repository
Operational waste from NPPs	44,200 m^3	(53,200)	SFR
Decommissioning waste from NPPs	73,300 m^3	(73,300)	SFR
Operational and decommissioning waste from NPPs (near-core components)	3,700 m^3	(3,700)	SFL
Operational waste from Clab and the encapsulation plant	2,500 m^3	(3,400)	SFR
Decommissioning waste from Clab and the encapsulation plant	400 m^3	(400)	SFR
Operational waste from SVAFO and Studsvik	11,500 m^3	(11,500)	SFR
Decommissioning waste from SVAFO and Studsvik	13,000 m^3	(13,000)	SFR
Waste from SVAFO and Studsvik	11,800 m^3	(11,800)	SFL
Total short-lived radioactive waste	144,900 m^3	(154,800)	SFR
Total long-lived radioactive waste	15,500 m^3	(15,500)	SFL

[1] According to reference scenario in Chapter 3.

4.2 Changes compared with the reference scenario

This section concerns changes in relation to the description of the reference scenario in Chapter 3.

Different assumptions regarding the reactor operating times are the most important factor affecting the assumed quantities of spent nuclear fuel and radioactive waste. The assumed operating time also affects the deposition rate for the canisters of spent fuel.

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

- The number of canisters with spent nuclear fuel is reduced from the 6,200 specified in the reference scenario. Calculation of the remaining basic cost is instead founded on 4,560 canisters. The basic starting point for calculating the financing amount is that a total of 3,775 canisters will be deposited.
- The total operating time for the Spent Fuel Repository and Clink decreases. This means that the starting point for calculation of the remaining basic cost is a 17-year shorter operating time than in the reference scenario, and in the calculation of the basis for the financing amount a 21-year shorter operating time. The shorter time schedules also have an impact on the cost calculations for other facilities, primarily SFR.
- 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 of 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 sources other than licence holders (SVAFO, etc) are not included in the calculation. These costs are financed in an other way.

4.3 Costs

4.3.1 General

The costs in this chapter refer to the amounts that licence holders are obliged to report to the regulatory authority in accordance with the Financing Act. The cost items included have been described in previous sections, but two items should be highlighted in order to emphasize the difference between the amounts specified here and those reported for the reference cost in Chapter 3:

- The costs refer only to the licence holders' future costs from and including 2015 for the management and disposal of spent nuclear fuel and the type of radioactive waste that is not operational waste. The price level is January 2013. The costs are adjusted for future real price changes in accordance with the method for the application of external economic factors, EEF.
- An allowance for unforeseen factors and risk has been calculated using the method described in Section 2.3. For the remaining basic cost and the basis for the financing amount, the allowance has been arrived at by setting the mean value from the statistical analysis as the remaining basic cost. The supplementary amount has been obtained by choosing a given confidence level and applying it to the probability distribution that constitutes the outcome of the uncertainty analysis. The question as to which confidence level is used is described below in connection with the presentation of the amount.

Both the adjustment for EEF and the allowance from the uncertainty analysis are separately reported in Table 4-3, and thereafter added to the cost on a total level. This is partly in order to facilitate comparison with Table 3-5, which contains the same cost items referring to the reference scenario but where these allowances do not exist.

The fact that the allowance for unforeseen factors and risks is added only to the total amount is also due to the fact that the calculation method used assesses the total uncertainty. If in the calculations each object were to be analysed individually, the "statistic" impact of the fact that the probability for negative or positive events occurring at the same time for most or all object is very low would be lost. Nor can an allowance for unforeseen factors and risks calculated in this way be tied to individual objects other than by some form of standard distribution (for example by proportioning).

As regards an overall picture of the costs for the management and disposal of residual products and other radioactive waste, including costs incurred and budgeted costs for the present year, reference is made to Figure 3-16 in Section 3.6.2.

4.3.2 Remaining basic cost

Table 4-3 shows a compilation of the calculated future costs that are attributable to the remaining basic cost and which serves as the basis for calculating fees.

The costs for the different objects reported in the table above contain no allowance for unforeseen factors and risk. This allowance and the impact of EEF are reported as lump sums at the foot of the table.

The calculated costs for different facilities are presented under the items *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 for major reinvestments when a facility has reached a significant age (e.g. Clab). However, in the case of the Spent Fuel Repository where extension of the number of deposition tunnels will proceed continuously throughout the deposition phase (operating phase), the cost of this work will also be included in investment.

The calculated remaining basic cost amounts to a total of SEK 100.8 billion, SEK 18.0 billion of which is allowance for unforeseen factors and risk. Of this amount, some 70% falls within SKB's sphere of activity and is thus borne jointly by the licence holders (referred to as joint costs). The remaining approximately 30% comprises costs for activities in which each licence holder has an individual cost responsibility and does not share the costs with other licence holders (separable costs). The separable costs are attributable to costs for the decommissioning of licence holders' NPPs. However, management and disposal of the radioactive decommissioning waste falls within SKB's sphere of responsibility.

Table 4-3. Remaining basic costs from and including 2015, price level January 2013.

		Cost per cost category SEK million	Cost per facility SEK million
SKB central functions and RD&D		8,630	8,630
Transportation system	Investment	1,090	2,350
	operation and maintenance	1,260	
Clab	Reinvestments	1,560	8,220
	operation and maintenance	5,900	
	decommissioning	760	
Encapsulation	Investment	4,170	12,250
	operation and maintenance & reinvestments	7,840	
	decommissioning	240	
Spent Fuel Repository			
– above-ground	investment and decommissioning	5,480	21,940
	operation and maintenance (entire facility)	3,790	
	reinvestments (entire facility)	640	
– other rock openings	Investment	2,410	
	decommissioning and closure	1,440	
– main and deposition tunnels	Investment	4,900	
	decommissioning, backfilling and closure	3,280	
SFL	Investment	780	1,380
	operation and maintenance & reinvestments	260	
	decommissioning and closure	340	
Interim storage facilities and near-surface repositories at NPPs	investment, operation and decommissioning	–	–
SFR (operational waste)	operation and maintenance & reinvestments	–	–
SFR (decommissioning waste)	Investment	2,050	3,930
	operation and maintenance	1,540	
	decommissioning and closure	340	
Decommissioning of NPPs	Dismantling and decommissioning	22,750	22,750
Total cost “Calculation 40”			81,450
Adjustment for EEF			1,290
Allowance for unforeseen factors and risks			18,010
Total remaining basic cost			100,750

Figure 4-2 shows the costs according to Table 4-3 distributed over the course of time. The allowance for unforeseen factors and risk is not included in the chart. 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. It shows, for example, that the two cost peaks in the chart stem on the one hand from investments in the encapsulation part in Clink and in the Spent Fuel Repository, and on the other from the decommissioning of NPPs.

The graph in Figure 4-3 shows the present value of the remaining basic cost as a function of which discount rate being used for discounting to this present value. The graph presents the total amount, which means that the allowance for unforeseen factors and risk is included. Production of the graph has been made possible in that separate Monte Carlo simulations were made for the discount rates 1, 2, 3, 4 and 5%.

4.3.3 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 composed of 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 2013, this applies only to the residual products that exist on 31 December 2014. This means, among other things, that the number of canisters decreases to 3,775 compared with the 4,560 that serve as the basis for calculation of the remaining basic cost.

The part of the financing amount based on SKB's calculations amounts to SEK 95.4 billion, which is SEK 5.0 billion lower than the remaining basic cost.

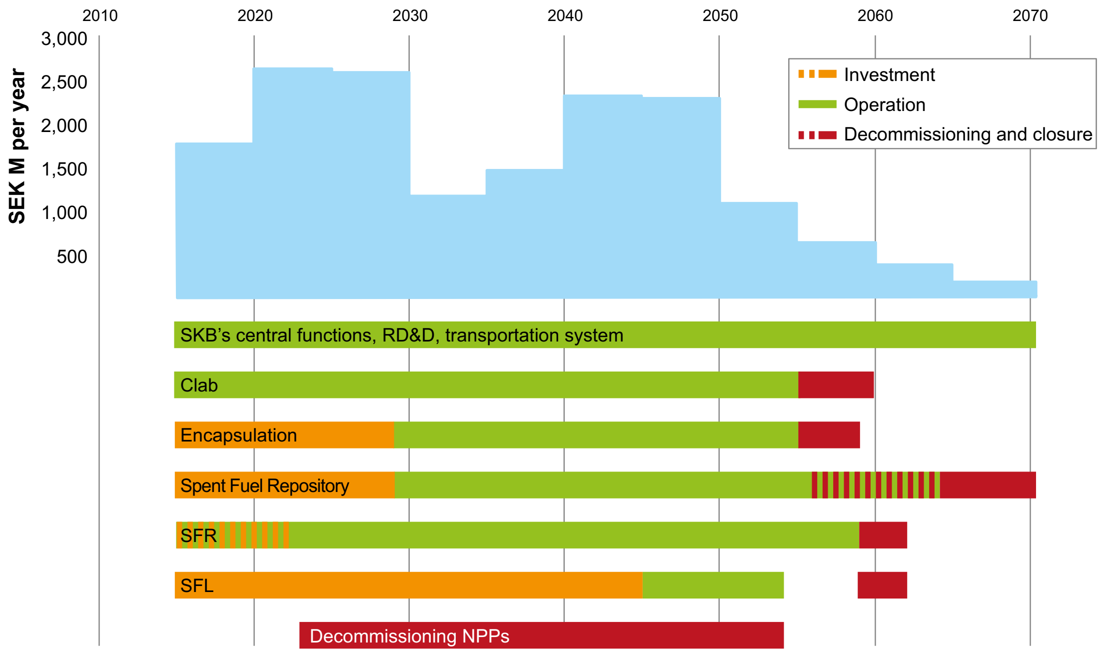


Figure 4-2. *Remaining basic cost, excluding the allowance for unforeseen factors and risk, distributed over time, and the associated time schedule for the facilities at the January 2013 price level.*

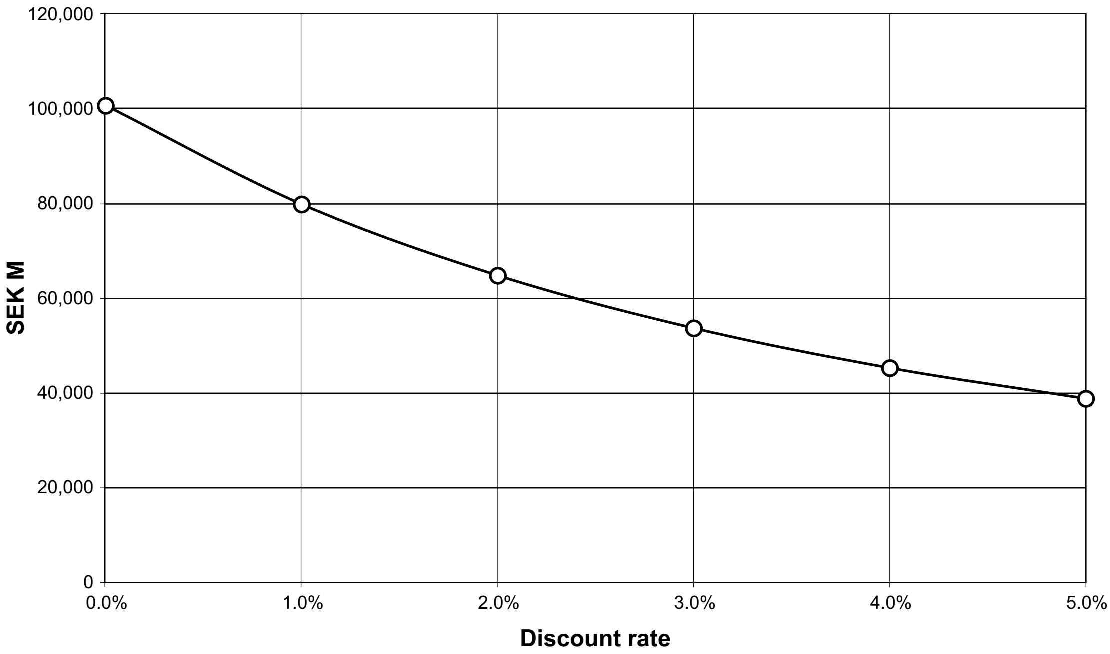


***Figure 4-3.** Present value of the remaining basic cost as a function of the discount rate at the January 2013 price level.*

4.3.4 Supplementary amount

The supplementary amount forms the basis for a second type of guarantee that the licence holders have to provide in addition to the guarantee of which the financing amount forms the basis. The supplementary amount is calculated in basically the same way as the remaining basic cost, but with three fundamental differences.

- The amount shall serve as a basis for guarantees which shall, to a reasonable level, cover costs for unforeseen events. The uncertainty analysis therefore includes events and uncertainties that are attributable to more fundamental deviations from the chosen system for managing nuclear residual products than those included in the calculation of the other amounts.
- The supplementary amount is set as the difference between an amount that represents this upper reasonable limit and the remaining basic cost. SKB is of the opinion that a confidence level of 80% is one that corresponds to the "reasonableness" that the Financing Act stipulates.
- The supplementary amount concerns only those parts of the overall 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 80%, been calculated to be SEK 11.1 billion.