Technical Report

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Plan 2003

Costs for management of the radioactive waste products from nuclear power production

Svensk Kärnbränslehantering AB

June 2003

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Preface

According to the "Act on the financing of future expenses for spent nuclear fuel etc" (1992:1537), it is the responsibility of the reactor owners to prepare a calculation of the costs for all measures that are needed for the management and disposal of spent nuclear fuel discharged from the reactors and radioactive waste deriving from it and to decommission and dismantle the reactor plants. This cost calculation shall be submitted annually to the Government or the authority designated by the Government. SKB prepares this cost calculation on behalf of the nuclear power utilities.

The present report, which is the twentysecond annual cost accounting, gives an updated compilation of the necessary costs. As in previous years' reports, costs are reported both for the system in total and for the parts to be included in the basis for fees in accordance with the Financing Act. The former costs have been based on a scenario concerning reactor operation that ties in with the reactor owners' current long-term planning.

Stockholm, June 2003
Swedish Nuclear Fuel and Waste Management Co

Claes Thegerström
President

Summary

The companies that own nuclear power plants in Sweden are responsible for adopting such measures as are needed in order to manage and dispose of spent nuclear fuel and radioactive waste from the Swedish nuclear power reactors in a safe manner. The most important measures are to plan, build and operate the facilities and systems that are needed, and to conduct related research and development.

The so-called *Financing Act* (1992:1537) is linked to this responsibility and prescribes that a reactor owner, in consultation with other reactor owners, shall calculate the cost for management and disposal of the spent fuel and radioactive waste and for decommissioning and dismantling of the reactor plant. The reactor owner shall annually submit to the regulatory authority the cost data that are required for calculation of the fees to be imposed on electricity production during the ensuing year and of the guarantees that must be given as security for costs not covered by paid-in fees.

The reactor owners have jointly commissioned SKB to calculate and compile these costs.

This report presents a calculation of the costs for implementing all of these measures. The cost calculations are based on the plan for management and disposal of the radioactive waste that has been prepared by SKB and is described in this report.

The following facilities and systems are in operation:

- Transportation system for radioactive waste products.
- Central interim storage facility for spent nuclear fuel, CLAB.
- Final repository for radioactive operational waste, SFR 1.

Plans also exist for:

- Canister factory and encapsulation plant for spent nuclear fuel.
- Deep repository for spent nuclear fuel.
- Final repository for long-lived low- and intermediate-level waste.
- Final repository for decommissioning waste.

The cost calculations also include costs for research, development and demonstration, as well as for decommissioning and dismantling the reactor plants.

This report is based on the proposed strategy for the activities which is presented in SKB's RD&D-Programme 2001 and in the supplementary account to RD&D-Programme 98 which SKB submitted to the regulatory authority. The latter describes the selection of the sites where SKB wishes to proceed with investigations in conjunction with the site investigation phase. The site selections are also reflected in the calculation in that the reference scenario includes a siting of the deep repository to one of the selected sites. The choice has hereby been made on the basis of what best illustrates various cost aspects and should not be regarded as a prioritization in other respects. SKB proposes

that deep disposal be implemented in stages, starting with an initial stage[1] in which approximately 200–400 canisters are deposited. This will be followed by an evaluation before the start of the regular operation.

As a basis for determining fees and the need for guarantees, three amounts are to be reported to the authority:

- *basis for fees,*
- *basis for basic amount,*
- *supplementary amount.*

The basis for fees is supposed to include all costs for managing and disposing of the spent nuclear fuel and radioactive waste that is calculated to have been produced up to and including the fee year, i.e. 2004, or during at least 25 years of operation of the reactors. The amount must also include costs for decommissioning and dismantling the reactors and for conducting the necessary research and development. The *basis for fees* also includes a supplementary amount for uncertainties up to a certain level.

The *basis for basic amount* is supposed to include the above costs, but is limited, with regard to spent fuel and radioactive waste, to the waste quantities estimated to exist at the end of the current year, i.e. at 31 December 2003. This amount provides a basis for determining the size of *Guarantee I*.

The *supplementary amount* comprises the difference between the *basis for fees* and an upper limit for the amount which the reactor owner must guarantee at the present time. According to the Financing Act, the *supplementary amount* shall cover "reasonable costs of additional measures due to unforeseen events". This amount comprises the basis for estimating the size of *Guarantee II*.

The basis for the calculation of the above amounts is a so-called *reference scenario* based on the reactor owners' current operational planning. With the exception of Barsebäck 1, this entails operation of the reactors for 40 years. The *reference scenario* thus includes the total system, even with space for radioactive waste that does not fall under the Financing Act. The costs of the *reference scenario* are calculated according to a probable scenario and thus without regard for the uncertainties covered by the other amounts above. Altogether, the future costs for the *reference scenario amount* to SEK 49.6 billion.

The results of the calculation are presented below. With regard to the date for decommissioning of the reactors, two cases are presented:

Case A	The earliest decommissioning date for a reactor is determined by the reference scenario's operating time of 40 years. The risk of increased costs due to a changed operating time is covered by *Guarantee II*.
Case B	The shutdown dates for the reactors coincide with the expiry of the *earning time,* i.e. after 25 years of operation. For the reactors that have achieved full earning time, a shutdown date of 31 December 2004 is set this year. Case (B) is by definition a fixed premise. Variations are not studied.

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[1] The scope of the initial operation is stipulated in SKB's current operational plans as 200–400 canisters. The reference scenario in the calculation is currently based on 400 canisters.

	Case A	Case B
Basis for fees	SEK 46.5 billion	SEK 47.7 billion
Basis for basic amount	SEK 45.1 billion	SEK 46.8 billion
Supplementary amount at 90% confidence level	SEK 9.0 billion	SEK 8.8 billion
Same at 80% confidence level	SEK 5.5 billion	SEK 5.4 billion

Contents

Definitions

BWR	Boiling Water Reactor.
CLAB	Central Interim Storage Facility for Spent Fuel.
HLW	High-level waste.
ILW	Intermediate-level waste.
LILW	Low- and intermediate-level waste.
LLW	Low-level waste.
NPP	Nuclear Power Plant.
PWR	Pressurized Water Reactor.
RD&D	Research, Development and Demonstration.
SFR 1	Final Repository for Radioactive Operational Waste.
SFR 3	Final Repository for Decommissioning Waste.
SKB	Swedish Nuclear Fuel and Waste Management Co.
SKI	Swedish Nuclear Power Inspectorate.
TWh	Terawatt-hour. Unit of energy equal to a billion kWh.
MWh	Megawatt-hour Unit of energy equal to a thousand kWh.
MWd	Megawatt-day. Unit of energy equal to 24,000 kWh.
tU	Tonne of uranium. Quantity of spent fuel defined as the weight of uranium contained in the fuel assemblies when they are placed in the reactor.
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 output during every hour of the year (normally between 75% and 90%).
Burnup	A value which here gives the quantity of energy obtained from the fuel when it is taken out of the reactor for transport to CLAB, normally expressed in MWd per kg of uranium (MWd/kgU).
Case A	Refers to a decommissioning plan for the reactor plants that relates to a mean operating time of 40 years and where variation analyses are performed with respect to this operating time. The condition

	pertains solely to the scheduling of the decommissioning date for the reactor plants and does not influence the so-called “earning time” stipulated in the Financing Act, see Section 1.1.
Case B	Refers to a decommissioning plan for the reactor plants that relates to a foreseen shutdown coinciding with the expiry of the so-called earning time of 25 years as defined in the Financing Act. No variation analyses are performed of the shutdown dates (fixed premise).

1 Cost calculations according to Financing Act

1.1 Financing Act

The companies that own nuclear power plants in Sweden are responsible for adopting such measures as are needed in order to manage and dispose of spent nuclear fuel and radioactive waste from the Swedish nuclear power reactors in a safe manner. The most important measures are to plan, build and operate the facilities and systems that are needed, and to conduct related research and development.

The *Financing Act* (1992:1537) is linked to this responsibility and prescribes that a reactor owner, in consultation with other reactor owners, shall calculate the costs for disposal of the spent fuel and radioactive waste and for decommissioning and dismantling of the reactor plant. The reactor owner shall annually submit to the regulatory authority the cost data that are required for calculation of the fees to be imposed on electricity production during the ensuing year and of the guarantees that must be given as security for costs not covered by paid-in fees.

The reactor owners have jointly commissioned SKB to calculate and compile these costs.

Paid-in fees are transferred to the *Nuclear Waste Fund*, whose assets are deposited in an interest-bearing account at the National Debt Office or invested in treasury bills. The reactor owner is entitled to obtain compensation from the fund for waste disposal and certain other costs stipulated in the Financing Act.

The future costs are based on SKB's current planning regarding the design of the system, including the timetable for its execution. The present report summarizes this planning under the designation *reference scenario*. SKB's planning includes in several cases alternative proposals for solutions, for example in cases where development work or collection of background data for decisions is under way. In the *reference scenario*, however, a specific solution must be formulated in order to provide a clear and concrete basis for the cost calculations. This formulation should nevertheless not be regarded as a final commitment on the part of SKB.

At the calculation of future costs as basis for determining the fees and guarantees, uncertainties regarding future events must be considered. This is done by applying a large number of variations regarding both technology and execution to the *reference scenario*. More about this in Chapter 5.

In principle, fund assets shall, at any given time, cover planned future costs for decommissioning and dismantlement of the reactor plants and for the facilities that are required to manage and dispose of already existing quantities of spent fuel and radioactive waste. A gradual build-up of the fund to this level is, however, permitted during the first 25 years of operation, known as the *earning time*.

The reactor owner must pledge two types of guarantees. *Guarantee I* is supposed to cover forfeited fees and cases where funds have to be paid into the fund in another manner if the reactor is shut off prior to the expiry of the earning time, i.e. before the reactor reaches an operating time of 25 years. This guarantee is gradually reduced as the reactor's operating time approaches 25 years. Thus, the concept *Guarantee I* ceases to exist in 2010 when the youngest reactor has been operated for 25 years. *Guarantee II* applies in the case where the assets in the Nuclear Waste Fund will not suffice as a consequence of unforeseen events. A shortage of funds will not arise in this case for a long time to come, and for this reason *Guarantee II* will be in force for a long time.

1.2 Operating scenario for reactors

1.2.1 Reference scenario

The plan drawn up by SKB for the management system, which gives different investment and operating phases as well as design-basis data for the facilities, is based on historical production data and currently prevailing conditions as well as forecasts of future events. The forecasts are based essentially on the reactor owners' planning for future reactor operation.

The power utilities estimate today that the operating time for the reactors could amount to 60 years or more[2]. SKB refrains from weighing in this estimate in the calculation this year, but instead retains an operating time of 40 years as a mean value. Design and production capacity for different facilities in the system are based on this, which also gives the earliest date for decommissioning of the reactor plants. As mentioned previously, waste management principles, facility design, execution plan and other activities related to this scenario fall under the designation *reference scenario*.

Allowance is also made in SKB's waste management plan for other radioactive waste arising in Sweden, mainly from Studsvik. The costs for this are included in the account, but only comprise a percent or so of the total cost.

The costs to be used in the calculation of the annual fee according to the Financing Act are based on the *reference scenario*, but with deduction of costs related to **future** spent fuel and radioactive waste estimated to arise after the earning time for the reactor, i.e. after 25 years of operation. In addition, a deduction is made for costs which for other reasons are not to be included under the Financing Act due to the fact that they are financed in other ways, for example costs for management and disposal of the Studsvik waste.

1.2.2 Two cases with reference to the decommissioning date

In determining the need for fees to be paid into the *Nuclear Waste Fund*, the distribution of the future costs in time comprises an essential factor. This is related to the fact that the fund assets are expected to yield a certain annual return which is to be credited to the fund. In this respect, expenditures for management and disposal of spent fuel and radioactive waste are largely independent of the operating times for the reactors. The programme drawn up by SKB is followed here, e.g. with a given starting date for deposition and a given deposition rate.

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[2] Except for Barsebäck 1, which was taken out of service on 30 November 1999.

The same is not true of the costs of decommissioning and dismantlement of the reactors. The outcome in time, primarily with regard to the earliest date, is directly related to the shutdown dates for the reactors. Two cases have been put forth by SKB and SKI in recent years as a basis for fees. The cost-related effects of these two cases are presented in this report. They are called case A and case B.

Case A The earliest decommissioning date for a reactor is determined by the reference scenario's 40 years. This is the most likely case for calculation of the basis for fees. The effect of departures from this date, which may be more or less probable and entail a shorter or longer operating time, are analyzed in the model for analysis of uncertainties that is applied generally in the calculation. The risk of increased costs due to a changed operating time is covered by *Guarantee II*.

Case B The shutdown dates for the reactors coincide with the expiry of the *earning time,* i.e. after 25 years of operation. For those reactors that have already reached full earning time, a shutdown date of 31 December 2004 is set this year. Case B is by definition a fixed premise, which means that no variations of reactor operation are studied. In Case B, the decommissioning date for the older reactors will largely be determined by the time it takes to complete facilities for management and disposal of the radioactive decommissioning waste. During the time from shutdown until this has occurred, maintenance and service operation is required at the NPP. Funds for this are set aside in the *Nuclear Waste Fund* and are thus included in the fee.

Cases A and B represent two different cost levels for decommissioning and for the final repository for the decommissioning waste. The amounts are shown in Table 6-1.

Since it is only the decommissioning timetable that distinguishes the two cases, the quantity of fuel and radioactive waste to be disposed of is the same. The other costs for the facilities are therefore the same in both cases.

1.3 Amounts to report under the Financing Act

As a basis for calculating fees and judging the need for guarantees, three amounts are to be reported to the authority:

- *basis for fees,*
- *basis for basic amount,*
- *supplementary amount.*

The *basis for fees* is supposed to include all costs for managing and disposing of the spent fuel and radioactive waste expected to have been produced up to and including the fee year, i.e. 2004, or at least after 25 years of operation of the reactors[3] . The amount is also supposed to cover costs for decommissioning and dismantling the reactors and conducting the necessary research and development. The *basis for fees* also includes a supplementary amount for uncertainties up to a certain level. These additional costs are

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[3] The reactors that had not reached an operating time of 25 years in the present calculation are Ringhals 3 and 4, Oskarshamn 3 and all the Forsmark reactors.

obtained in the statistical calculation method that is employed and is described in Chapter 4. Finally, the *fee-determining amount,* is obtained by adding certain costs for regulatory supervision etc. These costs are added by the regulatory authority in connection with the calculation of fees and are not included in the present report.

The *basis for basic amount* is supposed to include the above costs, but is limited, with regard to spent fuel and radioactive waste, to the waste quantities estimated to exist at the end of the current year, i.e. 31 December 2003. The *basic amount*, is then obtained in the same manner as above by certain additions on the part of the regulatory authority. The difference between the *basic amount* and the current content of the Nuclear Waste Fund determines the appropriate size of *Guarantee I*.

The *supplementary amount* comprises the difference between the *basis for fees* and an upper limit for the amount which the reactor owner must guarantee at the present time. According to Chapter 3, clause 3 of the Financing Act, the *supplementary amount* shall include "reasonable costs for additional measures due to unforeseen events". The upper amount limit includes uncertainties with a lower probability of occurring and with greater consequences than is included in the *basis for fees*. Otherwise, the same statistical calculation method is employed. The *supplementary amount* determines the appropriate size of *Guarantee II.*

2 Energy production and waste quantities

The present chapter gives an account of the assumed energy production and the quantity of spent fuel and radioactive waste accommodated within the *reference scenario*. The account distinguishes between the quantities that are attributable to the operational plan and the reduced quantities that are used to calculate the *basis for fees*. The fundamental difference between these quantities has been described in Chapter 1.

Forecasts of future energy production and the associated quantity of spent fuel for each reactor are prepared by the reactor owners on the basis of their current operational plans. Account is thereby taken of anticipated future maintenance and modification work and possible future disturbances in operation. In calculating the quantity of fuel, *burnup* is also taken into account (see definitions on page 11). The forecasts differentiate between the energy production and the quantity of fuel attributable to it according to the Financing Act, which is supposed to serve as a basis for calculating the fee.

Energy production in the Swedish nuclear power plants were totally 66 TWh during 2002, which is equivalent to an average capacity factor of 84% if reactor O1, which was shut down for renovation during 2002, is excluded from the calculation. Energy production during 2001 was 69 TWh and the corresponding average capacity factor was 83%. The equivalent values for 1999 were 70 TWh and 80% and for 2000 55 TWh and 66%. The relatively low energy production for 2000 was due partly to an unusually high availability of hydropower, which led to some output reductions at the plants, but also to extended shutdowns for maintenance work in a couple of cases.

Table 2-1 gives energy production and spent fuel for the *reference scenario* in total and for the portion that is to serve as a basis for fee calculation, i.e. operation of all reactors through 2004, but for at least 25 years.

Most of the spent fuel will be interim-stored in CLAB and then directly disposed of. In addition to the fuel in Table 2-1, approximately 20 tonnes of fuel from Ågesta and 23 tonnes of Mox fuel originating in german must also be dealt with. The latter fuel replaces 57 tonnes of Swedish fuel previously shipped to Cogema. In 1989, SKB transferred the right to reprocessing at Cogema to eight german companies. 140 tonnes of fuel have also been sent to BNFL for reprocessing, from which no waste will be returned.

Besides spent fuel, the Swedish nuclear power programme gives rise to low- and intermediate-level operational waste from the nuclear power plants and from CLAB and the encapsulation plant. When the plants are decommissioned they give rise to decommissioning waste. The activity content of the different waste types varies greatly. The type of management and disposal required varies with the type of waste. Table 2-2 summarizes the radioactive waste products to be disposed of. The waste quantities are reported in detail in Appendix 1.

The *reference scenario* includes 4,500 canisters, which is a rounded-off figure that is currently exceeded by the quantity obtained from the energy production shown in Table 2-1. The number of canisters is fixed to provide a stable design basis that is not affected by small fluctuations in the reactor owners' forecasts. This solution does not in any way influence the calculation of the *basis for fees*, which at present only includes approximately 3,150 of the total number of expected canisters.

Table 2-1. Electricity production and fuel consumption at all nuclear power plants.

Start commercial operation		Thermal capacity/ net capacity MW	Energy production		Fuel through 2002 t U	Total acc. to reference scenario			Total as basis for fees		
			through 2002 TWh	appr. annual mean value TWh		Operation through	Energy production TWh	Spent fuel t U	Operation through	Energy production TWh	Spent fuel t U
B1 (BWR)	1 July 1975	1,800/600	93		425	30 Nov 1999	93	425	30 Nov 1999	93	425
B2 (BWR)	1 July 1977	1,800/600	100	4.4	456	30 June 2017	166	682	31 Dec 2004	109	487
R1 (BWR)	1 Jan. 1976	2,500/830	123	6.1	512	31 Dec 2015	204	755	31 Dec 2004	136	550
R2 (PWR)	1 May 1975	2,570/870	135	6.4	469	30 Apr 2015	215	686	31 Dec 2004	148	504
R3 (PWR)	9 Sept 1981	2,780/920	125	6.8	416	8 Sept 2021	257	778	8 Sept 2006	151	487
R4 (PWR)	21 Nov 1983	2,780/920	120	6.8	416	20 Nov 2023	267	805	20 Nov 2008	161	526
O1 (BWR)	6 Feb 1972	1, 375/440	72	3.5	376	5 Feb 2012	104	466	31 Dec 2004	79	395
O2 (BWR)	15 Dec 1974	1,800/600	110	4.6	450	14 Dec 2014	165	615	31 Dec 2004	119	482
O3 (BWR)	15 Aug 1985	3,300/1,160	144	8.9	527	14 Aug 2025	346	1,084	14 Aug 2010	212	715
F1 (BWR)	10 Dec 1980	2,930/970	147	6.8	590	9 Dec 2020	289	1,015	9 Dec 2005	169	660
F2 (BWR)	7 July 1981	2,930/970	145	6.8	564	6 July 2021	292	1,013	6 July 2006	171	650
F3 (BWR)	22 Aug 1985	3,300/1,160	146	8.1	533	21 Aug 2025	360	1,148	21 Aug 2010	218	741
BWR total		21,735/7,330	1,080	49	4,434		2,021	7,203		1,306	5,106
PWR total		8,130/2,710	380	20	1,300		739	2,268		460	1,517
All NPPs total		29,865/10,040	1,460	69	5,734		2,760	9,471		1,766	6,622

Table 2-2. Main types of radioactive waste products to be disposed of.

Product	Principal origin	Unit	Acc. to reference scenario		Basis for fees	
			No. of units	Volume in final repos. m³	No. of units	Volume in final repos. m³
Spent fuel	Spent fuel	canisters	4,500	19,000	3,200	13,200
Alpha-contaminated waste	LILW from Studsvik	drums and moulds	13,400	7,500	13,400	7,500
Core components	Reactor internals	long moulds	1,400	9,700	1,400	9,700
LILW	Operational waste from NPPs and treatment plants	drums and moulds	25,800	49,000	18,100	34,300
Decommissioning waste	From decommissioning of NPPs, treatment plants and Studsvik	ISO cont.	12,000	179,000	12,000	179,000
Total quantity, approx.			57,000	264,000	48,000	244,000

3 System for management of radioactive waste products

3.1 General overview

The waste management system on which the calculations have been based is called the *reference scenario*. For calculation of the *basis for fees*, the scope of the system is reduced in view of the fact that the quantity of fuel and other waste products to be managed is smaller, see Section 1.2. Numerous uncertainties are also taken into account, see Chapter 4.

This chapter describes the *reference scenario* with a scope based on operation of the reactors for 40 years. The description does not include those possible future deviations from the reference scenario that comprise the basis for calculation of the supplementary amount. Such deviations are dealt with in Chapter 5. The facilities, systems and measures included are described in brief.

The block diagram in Figure 3-1 shows how the waste products pass through the storage and treatment facilities before being deposited in the various final repositories.

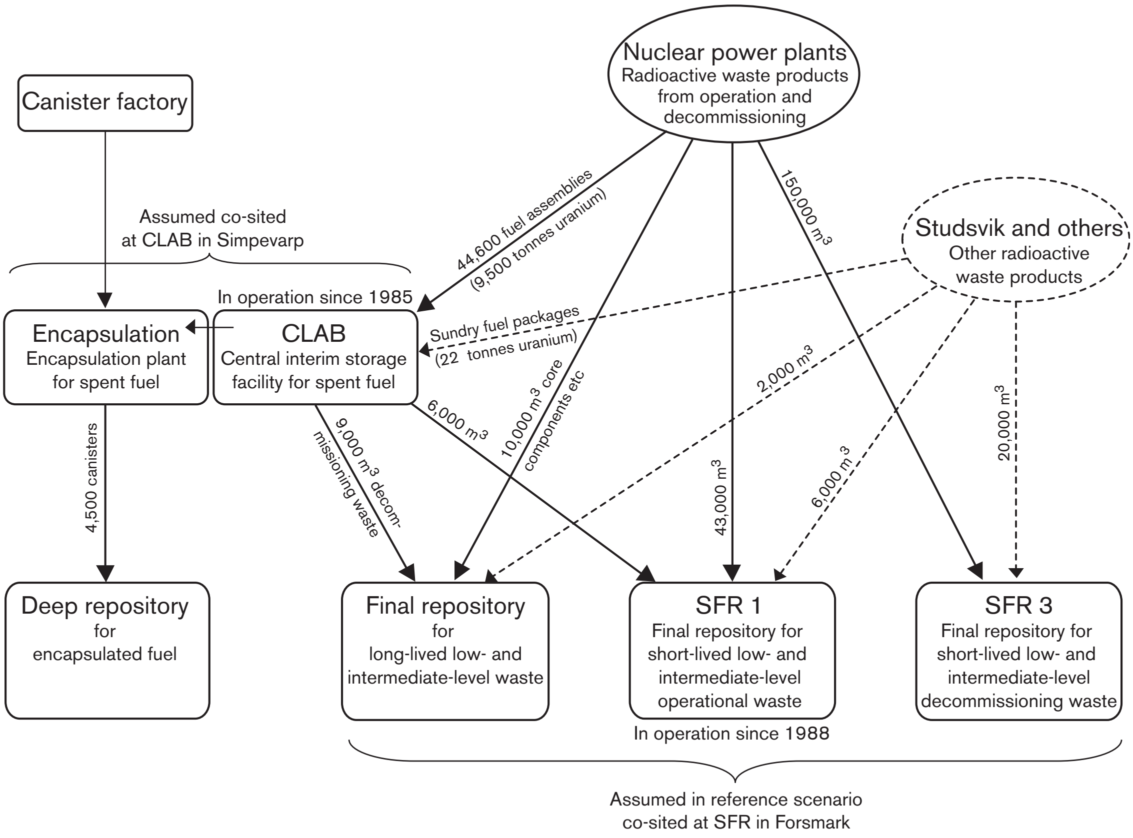


Figure 3-1. *Block diagram with transport flows showing management of the waste products from nuclear power (rounded-off data apply to reference scenario with reactor operation for 40 years).*

RD&D-Programme 2001 presented a programme and plans for activities regarding canister, encapsulation plant and deep repository. Based on this, rough timetables have been prepared for future facilities as a basis for the cost calculations. They indicate that the encapsulation plant and the deep repository will be built so that deposition of encapsulated fuel can begin in 2015. Deep disposal will be carried out in stages. In the first stage, initial operation, 200–400 canisters will be deposited. An evaluation will then take place before the start of the regular operation. It is assumed that regular operation will start in 2023. The reference scenario in the calculation is currently based on 400 canisters.

Figure 3-1 shows which facilities are included in the *reference scenario*. A couple of the facilities are in operation, which provides a good basis for the cost calculations. Other facilities are in various stages of development and design, where individual processing and handling systems are also being tested on a full scale. The cost calculations for these facilities have been based on drawings, specifications, staffing plans etc and on experience from manufacture and use of developed prototype equipment.

3.2 Research, development and demonstration – RD&D

SKB's work with research, development and demonstration (RD&D) is aimed at gathering the necessary knowledge, material and data to realize the final disposal of spent nuclear fuel and other long-lived radioactive waste. A programme for this work is presented by SKB every three years. The most recent RD&D programme was presented in September 2001 (English version, ref 1) and a review report from SKI was presented in March 2002 (English version, ref 2).

In 1999, SKB compiled and presented a safety assessment, SR 97 (English version, ref 6), which shows that the prospects for building a safe deep repository for spent nuclear fuel in Swedish granitic bedrock according to the KBS-3 method are very good. The regulatory authorities presented their joint review of SR 97 in November 2000 (English version, ref 7). In summary, it was concluded that no circumstances had emerged in SR 97 to indicate that disposal according to the KBS-3 method has any significant drawbacks with respect to safety and radiation protection. As a consequence, in conjunction with the preparation of PLAN 2001, SKB decided that alternative methods should no longer be included among the variations in analysis of the calculation-related effect of unforeseen events (calculation of *supplementary amount*).

The RD&D work is aimed at the measures needed to carry out construction of an encapsulation plant for spent nuclear fuel and a deep repository for encapsulated fuel. Besides the design work and the safety assessments, relatively extensive supportive research and development is needed, with the emphasis on development of methods and background material for safety assessments.

An important component in the RD&D work is the Äspö Hard Rock Laboratory (HRL). It is used to test, verify and demonstrate the investigation methods that will later be used for detailed studies of candidate sites for the deep repository, as well as to study and verify the function of different components in the final repository system. It is also used to develop and test technology for deposition. A schematic diagram of the HRL is shown in Figure 3-2.

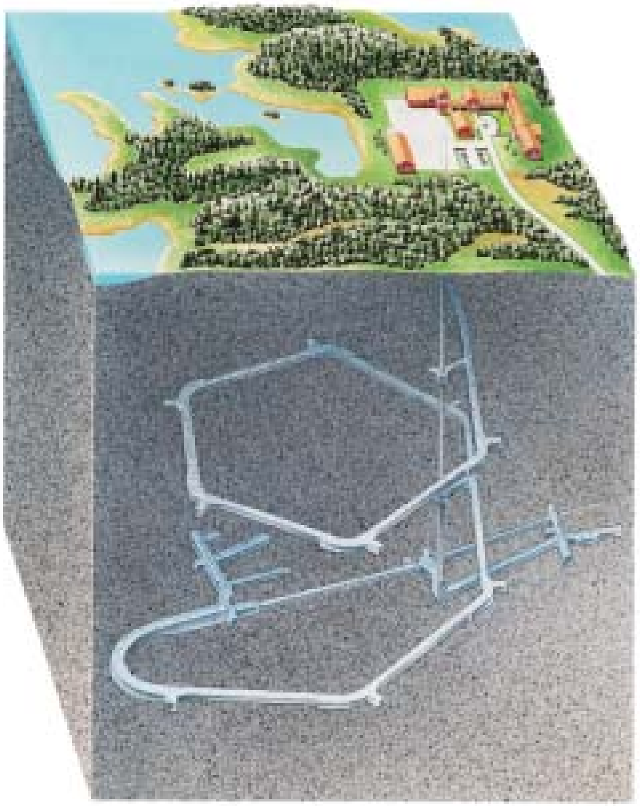


Figure 3-2. *Schematic model of Äspö HRL.*

The various tests of technology and methods conducted in Äspö involve trials of a prototype deposition machine, testing of method for lowering of bentonite buffer and canisters in the bored holes, and backfilling and plugging of deposition tunnels. Furthermore, a long-term test is being conducted regarding retrieval of deposited canisters and setup of a full-scale demonstration facility. Figure 3-3 shows the demonstration facility during emplacement of a canister.

Another important component in the RD&D activities is the Canister Laboratory, where development of methods for sealing and inspection of the copper canister is carried out. Different types of canister handling equipment are also tested and verified on a full scale in the laboratory. In the future, the laboratory will also be able to be used for training of operators for the encapsulation plant.

Trial fabrication of canister components such as copper tubes, lids, bottoms and inserts with lids has been going on since 1996. Different fabrication methods are being tested at a number of companies in Sweden and abroad.

In the *reference scenario* it is assumed that research, development and demonstration will continue on Äspö until deposition in regular operation is commenced. A small group of scientists who conduct research and development in the geosciences will then be transferred to the deep repository's operating organization. Development and training will be pursued at the Canister Laboratory until the encapsulation plant is put into operation.

Early costs for the deep repository project – i.e. site investigations, design and detailed characterization – are presented in the cost compilation under the heading "Deep repository".

Principal data:

Height	4.6 m
Width	3.7 m
Length	11.8 m
Weight without radiation protection tube	90 tonnes
Weight with radiation protection tube and canister	140 tonnes
Speed	1–10 m/min
Power supply	cable
Capacity, main lift	30 tonnes
Capacity, auxiliary lift	5 tonnes
Capacity, lift for bentonite plug in machine	1 tonnes

Figure 3-3. *Demonstration facility in the Äspö HRL with deployed deposition machine.*

3.3 Transportation

A distinction is made in the calculation between sea transport with associated terminal handling and overland transport by road or rail. The former is presented under the heading “Transportation system” while the latter is included in the concerned facilities.

The transportation system for sea transport is composed of the following main components: the ship M/S Sigyn, transport casks and containers, and terminal vehicles. The system is designed to be used for all types of nuclear waste.

M/S Sigyn has a payload capacity of 1,400 tonnes and is built for roro handling. Loading by crane is also possible. Operation and maintenance of the ship is entrusted to Rederiaktiebolaget Gotland.

As of year-end 2002, a total of 3,880 tonnes of fuel had been transported from the NPPs to CLAB and about 29,400 m^3 of LILW to SFR.

Casks designed to meet stringent requirements on radiation shielding and to withstand large external stresses are used for shipments of spent fuel and core components. One cask holds about 3 tonnes of fuel. Radiation-shielded steel containers are used for transporting ILW to SFR. They hold about 20 m^3 of waste, and the maximum transport weight per container is 120 tonnes. Standard freight containers can be used for LLW from operation as well as for most of the decommissioning waste. At present, the system includes 10 transport casks for spent fuel, 2 for core components, and 27 radiation-shielding containers for ILW.

During loading and unloading, the casks/containers are transported short distances between storage facilities and the ship by special terminal vehicles, see Figure 3-4. At present, five vehicles are used.

***Figure 3-4**. Terminal vehicle with fuel transport cask.*

Transport of canisters with spent fuel from the encapsulation plant at CLAB to the deep repository is assumed in the reference scenario to take place by sea to the harbour in Forsmark (see Section 3.6.1 with regard to siting). The deep repository is assumed to be sited immediately adjacent to the harbour. Siting alternatives for the deep repository that eliminate the need of sea shipments for this type of transport or require further transport from the harbour by rail to the deep repository are not taken into account in the reference scenario, but are included in the variations presented in Chapter 5.

The encapsulated fuel will be carried in transport casks of a type similar to those used for the fuel today. Other LLW and operational waste from CLAB, the encapsulation plant and Studsvik is planned to be transported in specially designed transport containers.

The costs for the transportation system are based on experience to date. The future costs taken into account recurrent needs for new acquisition of both ship and transport casks/containers.

3.4 Central interim storage facility for spent nuclear fuel, CLAB

The central interim storage facility for spent nuclear fuel, CLAB, is situated adjacent to the Oskarshamn power station. The facility, which started operation in 1985, was originally designed to store some 3,000 tonnes of fuel (uranium weight) in four pools. The introduction of new storage canisters has increased the capacity of these pools to about 5,000 tonnes.

At year-end 2002, the facility contained fuel equivalent to 3,880 tonnes of uranium. Core components and reactor internals are also kept in the facility prior to ultimate disposal in the final repository for long-lived LILW.

CLAB consists of an above-ground complex for receiving fuel and an underground section with the storage pools. The above-ground complex also contains equipment for ventilation, water purification and cooling, waste handling, electrical systems etc plus premises for administration and operating personnel. Reception of fuel and all handling takes place under water in pools.

The storage pools are located in a rock cavern and made of concrete with a stainless steel lining. The pools are designed to withstand earthquakes.

To increase the storage capacity at CLAB, an additional rock cavern, CLAB 2, is currently being built with storage pools of the same size as the existing ones. Blasting of the rock cavern and tunnels is finished and building and installation work is under way. CLAB 2 is scheduled to be commissioned in mid-2004.

The permanent workforce during operation is currently about 40 persons. In addition there are service personnel, who are mainly taken from OKG’s (the nearby located power plant) regular base organization. On average, this personnel complement is equivalent to about 60 full-time employees. During periods when less fuel is being taken in or out of the facility, the workforce can be reduced.

After all fuel and other waste has been removed from CLAB, the above-ground facilities will be dismantled along with those parts of the storage pools that have become radioactive. The radioactive decommissioning waste will be sent to the final repository long-lived LILW.

The costs for CLAB are based on experience to date.

Handling of transport cask in the receiving section.

CLAB with two rock caverns.

CLAB underground storage pools.

Figure 3-5. *CLAB.*

3.5 Encapsulation of spent fuel

3.5.1 Canister factory

Preliminary studies have been made of the design of a factory for fabrication of canisters for deep disposal of spent nuclear fuel.

The current canister design consists of an outer 50 mm thick corrosion barrier of copper in the form of a tube with lid and bottom, see Figure 3-6. The specified copper grade consists of high-purity oxygen-free copper with a small addition of phosphorus. Inside the copper tube is the cast iron insert with channels for the fuel assemblies. The insert also serves as the pressure-bearing component in the design. The insert is made of spheroidal graphite iron. The lid for the insert is made of rolled steel plate.

Two methods for fabrication of the copper tubes have been studied. In the previous study, the fabrication method involving roll forming of rolled plate was studied. The plate is rolled to tube halves, which are then welded together by longitudinal electron beam welding (EBW). A later study examined two alternative methods: pierce and draw processing or extrusion of the copper tube, where the tube is formed in one piece. Copper lids and bottoms are finish-machined from preformed forged blanks. The copper bottom is then EB-welded onto the tube. Welds are inspected by ultrasonic and radiographic nondestructive testing. The costs of the two methods are comparable.

The cast spheroidal graphite iron inserts are delivered cast and rough-machined to the factory for finish machining. Blanks for insert lids are cut out of rolled steel plate and finish-machined.

50 mm copper

Estimated weight (kg):

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

Figure 3-6. Copper canister with cast iron insert.

After cleaning, the insert is lowered into the copper tube and the canister is readied for delivery.

With premises for maintenance shop, offices and inspection laboratory, the factory building covers about 7,000 m^2. The staff requirement is estimated at 30 persons.

3.5.2 Encapsulation plant

Before the spent fuel is emplaced in the deep repository it will be encapsulated in a durable canister. Encapsulation is planned to take place in a new plant adjacent to CLAB.

It is proposed that the canister be made with a cast iron insert, providing mechanical strength, and an outer shell of copper, providing corrosion protection, see Figure 3-6. The canister holds up to 12 BWR assemblies with boxes or 4 PWR assemblies.

The encapsulation plant will contain the following functions:

- Arrival section with quality inspection of delivered canister parts.
- Encapsulation section for emplacement of fuel in canister, sealing of canister and quality inspection.
- Dispatch section for canisters. Transport will take place in radiation-shielded transport casks.
- Auxiliary systems with cooling and ventilation systems as well as electrical and control equipment.
- Personnel and office premises plus storerooms.

The plant is designed for an annual production capacity of 200 copper canisters. The long-term production rate at the plant will, however, be limited by the fuel input rate, which will in turn be limited by the minimum storage time in CLAB needed for the fuel to decay to a suitable level. In the *reference scenario* with operation of the reactors for 40 years, the average annual production rate will be around 160–170 canisters. Altogether in the *reference scenario*, approximately 4,500 canisters will be filled and sealed in the encapsulation plant.

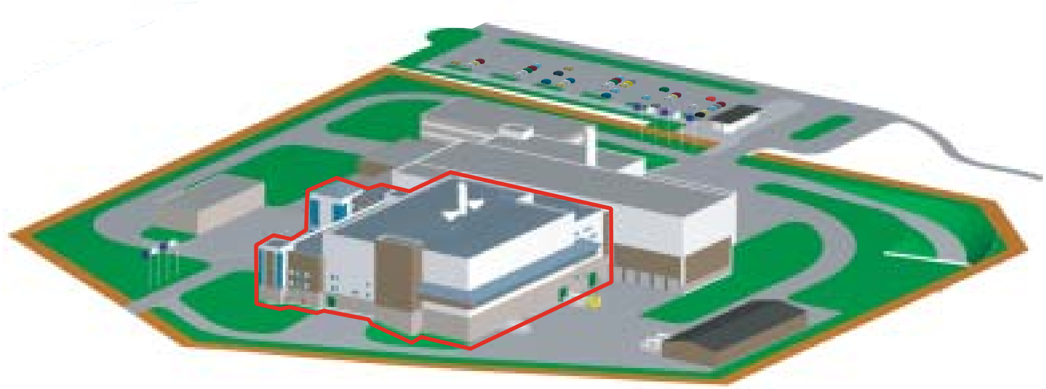


Figure 3-7. *Encapsulation plant for spent fuel integrated with CLAB.*

The plant will mainly be operated in the daytime. The calculations take into account the coordination advantages that are gained in terms of staffing by having the encapsulation plant co-sited with CLAB.

During the initial deposition period starting in 2015, it is assumed that 200–400 canisters will be completed for deposition over a number of years. The remaining canisters will be fabricated starting in 2023. The reference scenario in the calculation is currently based on an initial operation of 400 canisters.

After completed encapsulation, the plant will be decommissioned and radioactive decommissioning waste will be transported to the final repository for long-lived LILW.

In a calculation of costs within the framework of the Financing Act, whereby the quantity of fuel is about 30% less, the overcapacity in CLAB is used for storage of core components etc. It is assumed that pre-disposal treatment of these components will take place in the encapsulation plant, and costs for the required systems are included in the *basis for fees*. In the reference scenario, this treatment takes place next to the special interim store that is created.

3.6 Deep repository for spent fuel

3.6.1 Siting and site investigations

As described in RD&D-Programmes 98 and 2001, the work of siting and designing the deep repository is being pursued stepwise with feasibility studies, site investigations, construction and detailed characterization. The costs of siting and site investigations are reported in Table 6-1 under those headings. Detailed characterization will be carried out in parallel with the construction of the repository's different underground sections.

In the supplement to RD&D-Programme 98 (ref 4), SKB has selected and proposed three sites for further investigations. These sites are situated in the municipalities of Östhammar, Oskarshamn and Tierp. Based on SKB's proposal and the decisions of the Government and the concerned municipalities, Forsmark in the municipality of Östhammar and Simpevarp in the municipality of Oskarshamn have been selected for site investigations. On 9 April 2002, the municipal council in Tierp decided not to proceed with a site investigation.

SKB has chosen a *reference scenario* where the repository will be sited at one of the two sites where site investigations are conducted. Since neither of the sites has priority status, the choice has fallen on the designated site in the municipality of Östhammar, since the location represents a good compromise from the viewpoint of transportation. Since it is separated from the site where the encapsulation plant is envisaged to be located (at CLAB), the costs of sea transport must continue to be accounted for.

The case where all sites are abandoned for yet another site is also being studied, but only as a basis for determining the need for *Guarantee II*.

The site investigations are aimed at obtaining detailed data on the rock for further safety assessments and design studies and as a basis for licensing of the deep repository. Field investigations based on test drillings were commenced during 2002. Different types of investigations will be pursued continuously on these two sites during 2003 and continue up until site selection and submission of an application. The initial investigations are expected to be completed and a preliminary safety evaluation presented for the two sites during 2004.

3.6.2 Facilities under ground

According to RD&D-Programme 2001, the deep repository is planned to be situated at a depth of about 500 m below the ground surface. The repository level will be reached via hoist shaft or ramp. A combination of shaft and ramp is considered in the *reference scenario* in line with a completed study of the choice of descent alternative. An overview of the deep repository is shown in Figure 3-8.

The layout of the deep repository allows for the fact that the fuel will be deposited in stages. 200–400 canisters will be deposited in the first stage. The reference scenario in the calculation is currently based on 400 canisters. It is assumed that a separate repository section is arranged for them.

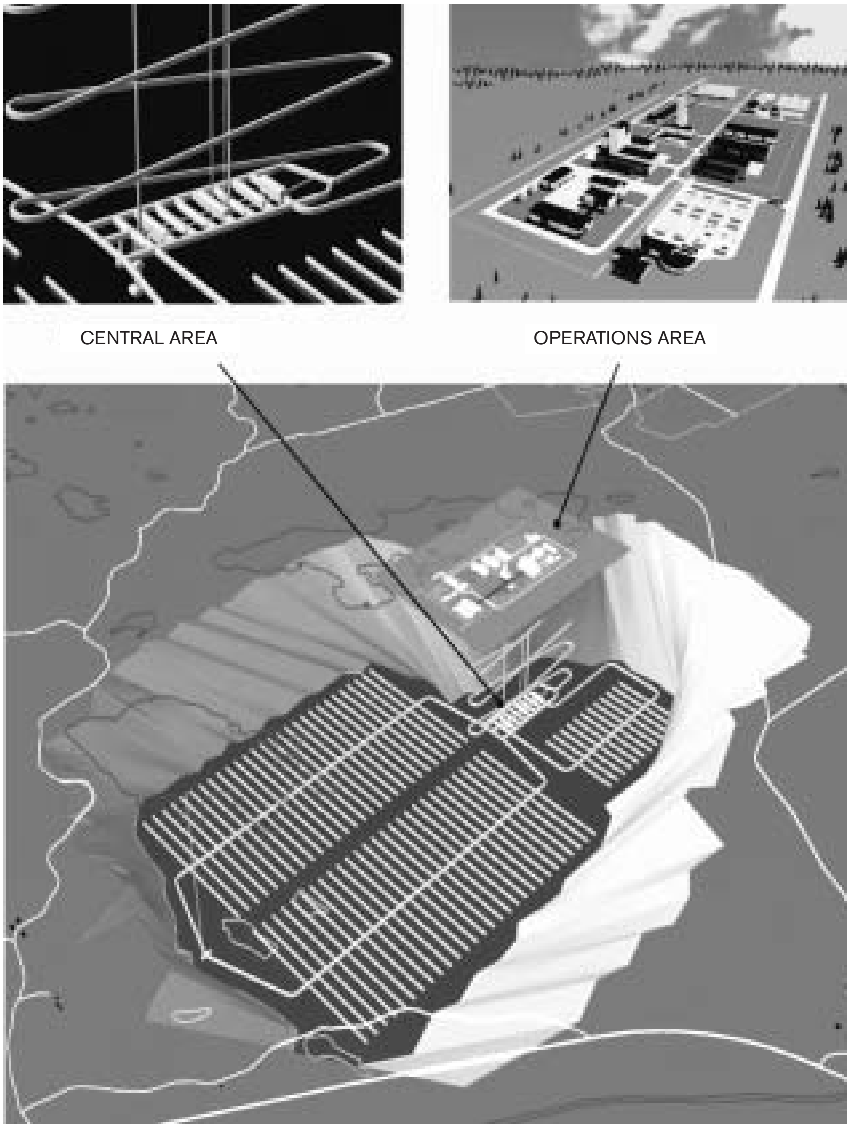


Figure 3-8. *Deep repository – overview.*

In the spiral ramp alternative, the deep repository's central area under ground with various service facilities will be located directly below the operations area on the surface. The central area is adapted to the assumed conditions for transport of canisters in transport casks down to the repository level and to the fact that unloading of transport casks will take place there.

The positioning of the different deposition areas in the deep repository will be determined by the geological conditions on the chosen site. The layout in Figure 3-8 is schematic with two consolidated deposition areas, one for each of the two deposition stages. In reality, a number of rock blocks will need to be used, necessitating a division into several deposition areas. The extra cost entailed by this in the form of longer transport tunnels and more transport work is taken into account in the calculation.

The copper canisters with fuel are placed in vertical holes bored in the bottom of the tunnel, where they are surrounded by a 35 cm thick layer of compacted bentonite.

The distance between the canisters and between the deposition tunnels is determined by the temperature expected to develop around the canister, especially the temperature on the canister surface and in the surrounding bentonite. This is determined by the fuel's decay heat, the thermal properties of the rock and the bentonite, and the initial temperature of the rock. The latter is determined to a large extent by the selected siting. A canister spacing of 6.0 m and a tunnel spacing of 40 m have been chosen in the reference scenario. In order to allow for rock formations that are unsuitable for deposition, costs for 5% extra tunnel length have been included in the *reference scenario*.

The illustration shows the alternative with an operations area and a ramp for transporting heavy and bulky goods. In order to shorten the construction time by about 18 months, a skip shaft is sunk in parallel with the excavation of the ramp.

During the operating period, the skip shaft will be utilized for transport of blasted rock and backfill material, while the ramp will mainly be used for hauling transport casks with canisters. In this way, safety on the ramp is improved, since most of the transport work takes place by rock hoist (skip) during the operating period.

Furthermore, the combined hoist and ventilation shaft has been divided into three shafts for practical reasons.

The copper canisters are transported from the encapsulation plant at CLAB to the deep repository in special transport casks. The transport casks are brought down to the repository level, where canisters are transferred to radiation protection tubes and then transported to the deposition tunnel in question.

Prior to deposition of the canister, the bottom pad and the rings of bentonite are placed in the deposition hole by separate handling equipment.

When the deposition machine is situated above the deposition hole, the canister is raised to a vertical position and lowered into the hole, after which the remaining compacted bentonite blocks are placed in the deposition hole on top of the canister. The whole canister lowering sequence is radiation-shielded.

The deposition tunnels are backfilled with a mixture consisting of bentonite and crushed rock. The proportions in the *reference scenario* are 15/85.

During regular operation, excavation of new deposition tunnels is carried out simultaneously with deposition of canisters and backfilling of deposition tunnels. The rock excavation activities will be separated from the deposition work due to the fact that these activities will take place in the two separate deposition areas.

Deposition of canisters proceeds at roughly the same rate as production in the encapsulation plant, see Section 3.5. Backfilling in the deposition tunnels proceeds tunnel-by-tunnel and at the same rate as deposition. After concluded deposition and backfilling of the deposition tunnels, transport tunnels, other rock caverns, shafts and ramp are backfilled up to ground level.

3.6.3 Facilities above ground

The deep repository's above-ground operations area will contain a number of buildings and service functions, see Figure 3-9. Its size will be dependent on site-specific conditions and the final design of certain functions, for example transport between the ground surface and the repository level, which can take place by shaft or ramp.

In the *reference scenario*, it has been assumed that the operations area contains the following buildings:

- Information building with restaurant.
- Office and workshop building.
- Operations building.
- Storage building.
- Garage building.
- Service buildings for raw water treatment, sanitary sewerage, heating plant, etc.
- Ventilation building.
- Reception building for transport casks with canisters.
- Production building for high-pressure compacting of bentonite and preparation of backfill materials.

Above-ground installations include harbours for receiving transport casks with canisters as well as bentonite and other material. In the *reference scenario* it is assumed that the harbour in Forsmark (SFR) will be able to be utilized for reception of transport casks with canisters in the same way as M/S Sigyn brings waste for SFR to Forsmark. The existing harbour in Hargshamn (located some 20 km south of Forsmark) is intended to be used to receive bentonite after construction of a storage building for bentonite.

Approximately 200 persons will be employed at the deep repository during the operating phase.

Figure 3-9. Model of operations area at deep repository.

3.7 Final repository for long-lived low- and intermediate-level waste

The final repository for long-lived LILW is mainly intended to contain core components and reactor internals, plus long-lived LILW from Studsvik. In the reference scenario, the short-lived decommissioning waste from CLAB and the encapsulation plant is also deposited in this repository.

The site of the repository has not been decided and will not have to be decided for a long time to come. It is assumed that the waste will be interim-stored in radiation-shielded casks, which will be simpler to handle after their radiation has decayed. Interim storage can be arranged in different ways, but it is assumed in the *reference scenario* that it will take place in a rock cavern in SFR. After the waste has been removed for final disposal the emptied cavern will be included in SFR 3, see below. The final repository for long-lived LILW may be co-sited with one of the other final repositories. For calculation purposes, a co-siting with SFR 1 is assumed in the *reference scenario*. The repository will be built at a depth of 300 m and connect to existing ramps.

The repository consists of rock vaults in which the waste is stacked in concrete cells, which are then backfilled with porous concrete. After backfilling, the cells are covered with concrete planks and sealed. All handling is done by remote-controlled overhead crane. Finally, the space between the concrete cells and the rock is filled with crushed rock and the openings of the rock cavern are sealed with concrete plugs. This takes place later in conjunction with sealing and closure of the repository.

The waste consists primarily of cubical concrete moulds with sides of 1.2 m or of the types of containers that will be developed for interim storage or embedding of core components and reactor internals. In the calculation of the waste volume in the final repository in the *reference scenario*, a unit mould with sides measuring 1.2/1.2/4.8 m is used, as previously.

See Section 3.8 regarding the workforce during operation.

3.8 Final repository for reactor waste, SFR 1

A final repository for short-lived operational waste from the nuclear power plants called SFR 1 has been in operation since 1988 adjacent to the Forsmark Nuclear Power Station. The repository is located beneath the Baltic Sea, covered by about 60 metres of rock. Two 1 km long access tunnels lead from the harbour in Forsmark out to the repository area. Radioactive waste from CLAB and similar radioactive waste from non-electricity-producing activities, including Studsvik, is also disposed of in SFR. In the *reference scenario* it is also assumed that operational waste from the encapsulation plant will be received and disposed of in SFR 1 in the future.

SFR 1 consists of four 160 m long rock vaults and one 70 m high cylindrical rock cavern containing a concrete silo. The waste containing most of the radioactive substances is placed in the silo. Figure 3-10 shows a sketch of SFR 1 and pictures from different repository disposal chambers.

For the *reference scenario* with 40 years of operation of the reactors, it is estimated that SFR 1 will receive a total of about 50,000 m^3 of waste. The need for an extension of SFR 1 with a certain type of storage chamber is currently being investigated, but this space is not included in the present calculation. The capacity of SFR 1 is currently 63,000 m^3.

The concrete silo stands on a bed of sand and bentonite. Internally it is divided into vertical shafts, where the waste is deposited and embedded in a cement mortar. The space between the silo and the rock has been filled with bentonite. When the silo is full, the space above the silo will be filled with a sand-bentonite mixture.

Certain waste categories are embedded in cement mortar after they have been deposited in the rock vaults. It is also possible to pour more concrete around the waste when the facility is closed.

Handling of intermediate-level waste packages in the silo repository and in one of the rock vaults takes place by remote control, while low-level packages in the other rock vaults are handled by forklift truck.

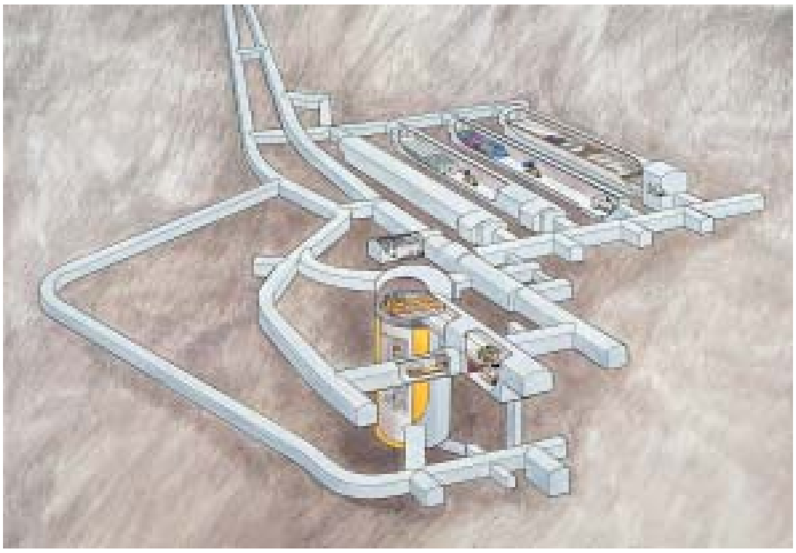
An operations group consisting of six persons is in charge of operation and maintenance. In addition, support services are provided by the regular base organization of Forsmark power plant. External contractors are also engaged for parts of the maintenance work. Altogether, operation and maintenance of SFR requires about 12 full-time equivalents per year. In the *reference scenario* it is assumed that SFR 3 and the final repository for long-lived LILW will be connected to SFR 1. It is nevertheless assumed that the staffing requirement on the site can be kept to the same level as today, so that in the future it will be more of a question of distributing a virtually constant operating cost between the different repositories. The significance of this is that costs pertaining to the management and disposal of operational wastes from NPPs, i.e. costs that must not be included in the basis for fee, can be distinguished and excluded.

Based on the planning assumptions in the *reference scenario*, it is assumed that the facility will be closed and decommissioned along with other facilities on the site, i.e. SFR 3 and the final repository for long-lived LILW.

Approximately 29,400 m^3 of waste had been deposited in SFR by year-end 2002.

View of the above-ground complex.

Rock vault for ILW.



View over top of silo.

Figure 3-10. *SFR 1.*

3.9 Decommissioning of nuclear power plants

3.9.1 Shutdown and dismantling of the reactor plants

The measures required for managing and disposing of the radioactive waste products from nuclear power plants also include decommissioning of the facilities after they have been taken out of operation (ref 8).

The timetable for decommissioning the power plants is influenced by a number of different factors. Dismantling can be carried out safely a short time after shutdown, but there may be advantages to deferred dismantling. The earliest time for dismantling, after the different reactors have been shut down and the spent fuel has been transported to CLAB, is linked to the construction of facilities for management of the decommissioning waste and the processing of permit and licence applications. In the *reference scenario*, decommissioning after 40 years of operation of the two oldest reactors, Oskarshamn 1 and 2, gives 2016 as the earliest year for the start of dismantling.

With regard to resource utilization and the receiving capacity of interim stores and final repositories, it is desirable to stagger the start of dismantling of different reactor plants. In the *reference scenario*, a minimum of one year is assumed between the start of dismantling of reactors at the same station. Two integrated nuclear power units cannot begin to be dismantled until both have been shut down and all fuel has been removed.

During the period from when the reactor has been taken out of service until the start of dismantling, fuel is removed, decontamination[4] takes place and preparations are made for dismantling. This period is called *shutdown operation* as long as fuel is left in the plant and *service operation* thereafter. During the period with service operation, which varies in length depending on the decommissioning timetable, the workforce will be reduced to a very low level. The actual dismantling work is expected to take five years per unit and employ an average of a couple of hundred persons.

The radioactive waste from decommissioning is all LLW and ILW. However, the activity level varies considerably between different parts. It is assumed that the waste with the highest activity, the core components and reactor internals, will be interim-stored as needed (see Section 3.7) before being emplaced in the deep repository for long-lived LILW. Other radioactive decommissioning waste will be transported directly to SFR 3, see below, and deposited there. A large quantity of the decommissioning waste can be released for unrestricted use, after decontamination if necessary.

3.9.2 Final repository for radioactive waste from decommissioning, SFR 3

The short-lived decommissioning waste from the NPPs and from Studsvik and Ågesta is planned to be deposited in a repository called SFR 3. This repository is planned to be located adjacent to SFR 1. It will consist of rock vaults of a type similar to those in SFR 1. Most of the decommissioning waste can be transported in standard freight containers, which are placed in rock vaults without being emptied. A total of about 170,000 m^3 of decommissioning waste will be stored in SFR 3.

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[4] Washing or other manner of cleaning to remove superficial radioactive contamination.

Core components and reactor internals from decommissioning of the NPPs are planned to be deposited in the final repository for long-lived LILW, see Section 3.7.

See Section 3.8 regarding the workforce during operation.

The operating time at SFR 3 is determined by the timetable for decommissioning of the reactor plants. Closure of the repository will take place jointly with other repositories at SFR.

4 Calculation methodology

4.1 Calculation of reference costs

The cost of the *reference scenario* – i.e. the costs of all facilities, even those not covered by the Financing Act, but without an allowance for uncertainties – is calculated according to the traditional deterministic method. By this is meant a method based on given, fixed assumptions. In the PLAN calculation, the premises regarding both technical design and external factors are defined with the so-called general conditions (described in greater detail in next chapter). The analysis starts with functional descriptions of each facility, resulting in layout drawings, equipment lists, staffing forecasts, etc. For facilities and systems that are in operation, this material is highly detailed, while the degree of detail is lower for future facilities.

A base cost is calculated for each cost item, including:

- quantity-related costs,
- non-quantity-related costs,
- secondary costs.

Quantity-related costs are costs that can be calculated directly with the aid of design specifications and with knowledge of unit prices, e.g. for concrete casting, rock blasting and operating personnel. Experience gained in the construction of the nuclear power plants, CLAB and SFR 1 has been drawn on in estimating both quantities and unit prices.

All details are not included in the drawings. These non-quantity-specified costs can be estimated with good accuracy based on experience from other similar projects.

The final item included in the base costs is secondary costs. These include costs for administration, design, procurement and inspection as well as the costs for temporary buildings, machines, housing, offices and the like. These costs are also relatively well known and have been calculated based on the estimated service requirement during the construction phase.

4.2 Management of uncertainties

4.2.1 The successive principle – a probabilistic calculation method

A so-called probabilistic method that uses standard statistical methods to make allowance for the variations and uncertainties that must be taken into account in estimating the cost of a project, especially in an early phase, is employed for calculation of both the *basis for fees* and the *supplementary amount* (see Chapter 1). The method is based on a calculation principle called “the successive principle” (ref 9), which has been developed specially as a tool for management of this type of uncertainties.

Each cost item or variation is regarded as a variable that can assume different values with a varying degree of probability (stochastic variable). A suitable function that defines this probability distribution (distribution function) is chosen for each cost item and variation.

A central aspect of the application of the "successive principle" is the methodology for structuring the calculation and setting up its probability distributions. This is done by means of highly subjective judgements, which are made by a specially composed "analysis team". This group should consist of persons with different qualifications and otherwise be of heterogeneous composition with regard to age, occupation, etc. This is to obtain an optimal interaction in the group and minimize the risk of a systematic bias in the conclusions it arrives at. The number of participants can vary according to the nature of the project. The analysis team that is participating in SKB's calculation work includes around 15 persons.

The total cost is then obtained by adding up all the cost items according to the rules that apply to addition of stochastic variables. The results are then presented as a distribution function indicating the probability associated with a given cost. The probability, expressed as a percentage, is called the degree of confidence. A degree of confidence of 50% means, for example, that there is an equal probability that the actual value will exceed or fall short of the calculated value. The degree of confidence chosen for presentation of the results is dependent on the purpose of the calculation. The 50% level is used for the *basis for fees*, which is supposed to reflect a probable cost outcome. The *supplementary amount* is determined on the basis of a higher degree of confidence, 80% or 90%.

The method also provides indications of where the major uncertainties are. They can then be broken down and studied in greater detail, after which the calculation is repeated, leading to reduced uncertainty. This "successive" convergence towards an increasingly accurate result has given the method its name.

4.2.2 Brief description of the applied methodology

In the case of the PLAN calculation, the statistical summation of the different outcomes that arise in the application of the "successive principle" must be done in a way that takes into account certain special and important conditions. The most important one is the relatively high proportion of timetable dependencies contained in the variations. With the discountings that are done, the effect of this in some cases is that the minimum and maximum values change place or even have the same position relative to the most likely value. Another factor that must be taken into account is that there may be some dependencies between variables – a situation that should not normally occur when the "successive principle" is applied. These and other phenomena are easiest to manage by performing the summation in a Monte Carlo simulation. The calculation takes place in a number of cycles where each cycle can be said to represent one "execution" of the project and where the outcome for each variation is given by random numbers. The total outcome is obtained as the result of a large number of calculation cycles. In the PLAN calculation, the simulation is done in 2,000 cycles, which provides a sufficiently small margin of error.

The application of the method is illustrated schematically in Figure 4-1. The following description relates to the numbers in the figure.

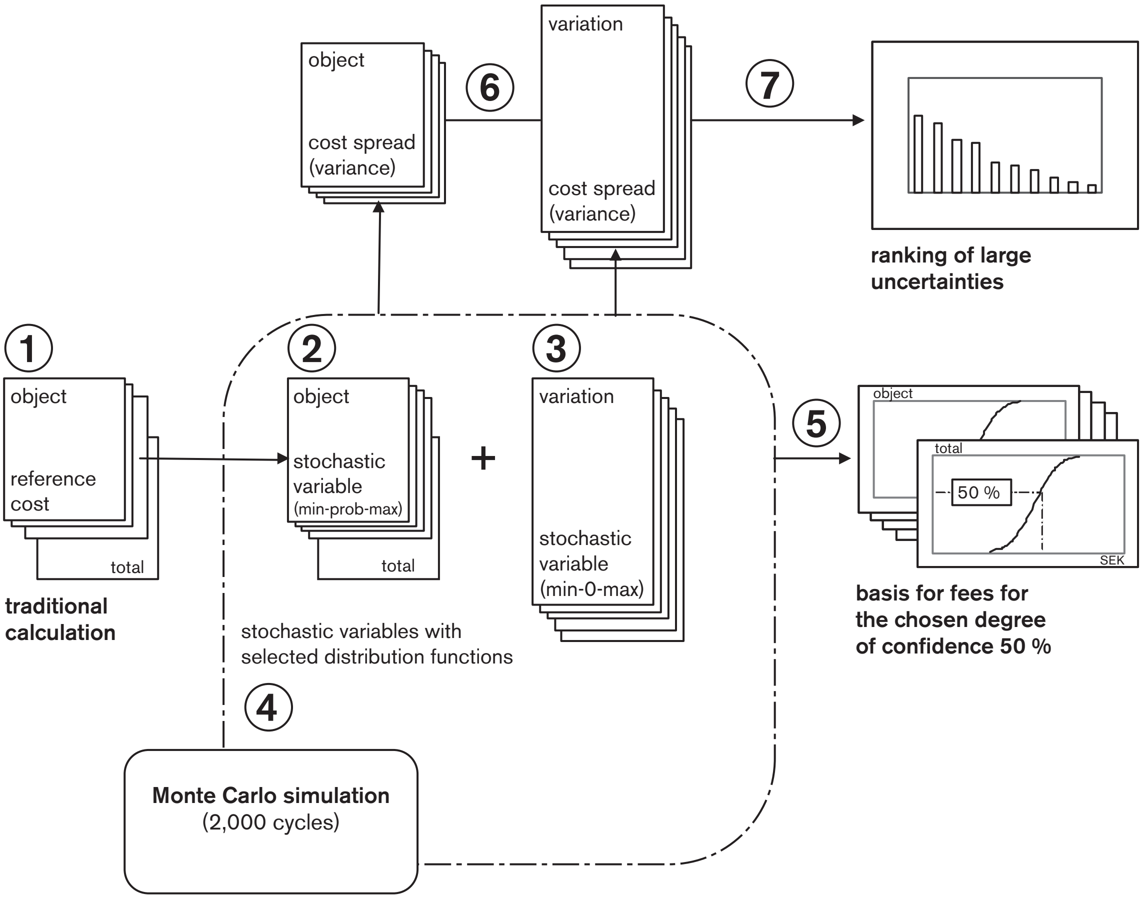

Figure 4-1. *Schematic description of calculation steps (numbers refer to description in text).*

The input values in the calculation are obtained from the "most likely" cost for each calculation object and for the total **(1)**. The most likely costs are calculated on the basis of the reference scenario by means of a traditional deterministic calculation, but without allowances for variations and uncertainties. Deviations can occur from the *reference scenario* if another facility design is judged to be more most likely in the future execution. The subdivision into calculation objects corresponds in principle to the different cost categories for each different facility, i.e. investment, operation, closure etc.

The next step is to determine what variations and uncertainties are to be included in the cost calculation. They may be of the type that affect calculation objects in several parts of the waste system **(3)**, e.g. changed timetable or changed number of canisters, or they may only affect single calculation objects **(2)**, e.g. uncertainty in workforce or canister cost. Each variation is defined in terms of scope and an assessment is made of which calculation objects are affected by the variation. In specifying the scope, a range of values is given which has a given probability of encompassing the actual value. The variations are described in greater detail in Chapter 5.

Subsequently, the cost influence on different calculation objects of the variations chosen to be included is evaluated. Since both the calculation objects and the variations have been defined not only with their respective most likely costs but also with a range of values (lowest and highest cost related to a given probability), the component cost items can be described as stochastic variables with associated distribution functions. The functions are chosen so that the probability distribution fits the character of the variation as closely as possible. Thus, special properties of the variation are taken into account, such as a pronounced skewed distribution of the outcome or an either-or value (discrete distribution).

Finally, the outcome is calculated and summed in the Monte Carlo simulation.

The result gives, for each object as well as for the system as a whole, a mean value and a standard deviation of the cost, which together define a distribution function **(5)** from which the cost can be obtained for the chosen probability (degree of confidence). In addition, partial results **(6)** are drawn off during the course of the calculation procedure which enable the uncertainties in the analysis to be evaluated and ranked **(7)**.

Since several of the variations included in the calculations greatly influence the timetable, the final result varies with different discount rates. The calculations are therefore carried out as a number of present-value calculations with different values for the discount rate.

The amount used as a basis for determining the *supplementary amount* is calculated in the same manner as the basis for fees. Variations with a greater system and timetable influence are then also included.

5 Uncertainties taken into account in the calculation

5.1 General

As described in Chapter 4, uncertainties are managed according to the successive principle by first being neutralized by a definition of so-called “general conditions” that fix the calculation premises. In a second process, variations around these general conditions are defined and costed. This is done primarily in a specially composed analysis team. Finally, a statistical summation is made of the uncertainties by means of a Monte Carlo simulation.

Two sets of general conditions with associated variations have been defined for the PLAN calculation. The complete list is very extensive, more or less comprehensive.

The first category includes variations that are more or less common in this type of civil engineering. Variations of this type are included in the calculation from which the *basis for fees* is obtained. These variations are described in Section 5.2 below.

The second category consists of more extreme variations with low probability of occurring. Variations of this type are included, along with variations in the first category, in the calculation from which the *supplementary amount* is obtained. These variations are described in Section 5.3 below.

It should also be pointed out that there are uncertainties that are not taken into account in the present calculation. They are called “fixed premises”. These include such disparate premises as, for example, the operating time of the reactors, the social order, and the future trend with regard to the yield on fund assets. These uncertainties are taken into account when deciding what degree of confidence is to be assigned to the final amount.

5.2 Uncertainties taken into account in basis for fees

Below is an overview of uncertainties and associated variations included in the *basis for fees*. For clarity they are divided into the following groups:

- operating conditions for the NPPs,
- management and disposal concept,
- technology,
- siting,
- timetable dependencies,
- general calculation premises,
- object-specific variations.

If nothing else is said, the values specified below are assumed to bound a confidence interval of 80%, i.e. the value is expected to fall within the specified limits with a probability of 80%. The limit values are thus not strict minimum or maximum values, but merely define the probability function assigned to the uncertainty in question.

Operating conditions for the NPPs

No variations are taken into account within the *basis for fees.*

Management and disposal concept

Pertains solely to the repository for long-lived LILW. The repository is in a very early phase of development, so the variation has been given a relatively wide span: low value –30% and high value +100%, estimated on the investment cost.

Technology

Canister design and the layout and execution principles for the deep repository for spent fuel are taken into account in the technology area.

A lower cost for the canister can be obtained with a smaller thickness of the copper shell. 30 mm instead of the stipulated 50 mm is assigned as a low value. A considerably higher cost is obtained for the canister if the insert, which in the probable case consists of spheroidal graphite iron, has to be made of a more durable material.

Regarding the cost of the deep repository for spent fuel, three factors in particular contain significant uncertainties. The first factor of importance is local conditions, with regard to both the fracture structure in the rock and the geographical conditions on the ground surface. This is assumed to influence the design of the underground areas, since the extent of the repository is influenced by the size of the individual rock blocks, and since the accesses, i.e. ramp and shaft, are influenced by repository depth and connections to the ground facilities. To this must be added uncertainties regarding handling equipment etc, which influence the dimensions of rock caverns and tunnels. An example of a high value in this context is an increase in the extent of the repository (all tunnel lengths) by 20%, a repository depth of 700 m, and duplicate ramps. The cross-sectional area of the deposition tunnel also increases.

The second factor of importance for the deep repository is thermal conditions with regard to both the spent fuel, i.e. its decay heat, and the properties in the buffer and in the surrounding rock. These conditions can influence the spacing between the canisters. At most, these types of variations are assumed to give a canister spacing of 10 m as a high value instead of the 6 m chosen in the reference scenario.

The third factor of importance for the deep repository is conditions surrounding the backfilling of deposition tunnels and other rock vaults. Backfilling with a mixture of bentonite and crushed rock in the proportions 15/85 is assumed as the most likely case. The low alternative is backfilling with crushed rock alone, while the high alternative assumes backfilling of the entire repository with natural clay.

Another cost factor that can be assigned to the area of technology, but with a link to *general calculation premises*, is productivity and method development. This is taken into account in the calculation within a number of different areas such as rock construction, manufacturing industry and process, building and installation, and operation of facilities.

These variations are expressed as an expected cost trend, in percent per year, in relation to inflation. The measure of inflation that is used is the index on which the calculation of the real rate of return of fund assets is based, namely the consumer price index, CPI. A value of zero for this variation (which is always the "most likely" value with regard to general variations) entails in this case that productivity and method development leads to a cost trend that equals the CPI. The price increase may exceed the CPI in certain parts of the system, but this is then compensated for by productivity increases in other parts. A positive productivity and method development rate of 2.0% in relation to the CPI is normally set as a low value, while a negative rate of 1.0% is set as a high value.

Siting

For the reasons given in Section 3.6.1, the "most likely" value has been based on a siting of the deep repository for spent fuel to one of the sites chosen by SKB for further site investigations. This is in part to provide a concrete basis for the calculation. No siting alternatives besides these sites are being studied within the framework of *basis for fees*.

Based on today's knowledge level, it is not possible to state with certainty whether any of the sites represents a low or high alternative. But it is highly likely that siting will prove to be of cost-related importance later on, so a standard cost variation is included in this year's calculation with a 10% influence on investments and an allowance for the different transport premises of the different sites. This variation will be updated as data emerge during the site investigation phase.

Timetable dependencies

Timetable-influencing variations cannot normally be singled out as low or high alternatives, since the polarization is influenced by the interest rate chosen for discounting. Postponing activities normally leads to increased costs, since intervening activities are prolonged, and postponement could then be considered a high alternative. However, the purpose of the calculation is to provide a basis for estimating the fee requirement, and discounted costs are utilized in that analysis. With a positive real interest rate, the postponement of activities can, despite real extra costs, lead to a reduction of the basis for fees. Consequently, the alternative is then a low alternative. Since it is necessary that the designations low and high consistently relate to a certain course of events rather than certain relative amounts, a convention is used here. This convention entails that the situation with discounting of the future costs with an interest rate corresponding to the rate of return on fund assets is determinant.

In the calculation of the *basis for fees*, only one time-influencing variation is posited. It relates to the overall timetable strategy. In this variation it is assumed that the starting date for deposition remains fixed at 2015 and that the initial deposition of 400 canisters is completed, but that the subsequent course of events diverges. In the low alternative (low at discounted costs), the remaining deposition activities are postponed, but the final date in the reference scenario (40 years of reactor operation) is retained. This postponement is made possible by the fact that the deposition capacity is increased to 400 canisters per year instead of the 160–170 in the reference scenario. In the high alternative, the programme is brought forward by having regular operation ensue immediately after initial operation. The decay heat in the canister thereby increases, leading to increased canister spacing in the deep repository.

It should particularly be noted that this variation is in part made possible by the fact that today only about 70% of the total number of canisters in the *reference scenario* have to be considered (limitation in the Financing Act). This percentage will gradually increase until all reactors have been taken out of service, a slow process but one whose end will probably be preceded by the fact that the variation as such ceases to be valid.

General calculation premises

Variations in general calculation premises concern the business cycle, currency rates, legislative and regulatory requirements, and the fact that the different individuals responsible for the pricing of different parts of the calculation take different views regarding the complexity and difficulties in execution of the project. This is normally attributed to pessimism (overestimation of difficulties) or optimism (underestimation of difficulties) and is summed up under the heading of realism in cost estimates. This latter variation is divided into a number of separate variations corresponding to the main estimators involved. The tendency to overestimate difficulties when pricing is done this early in a project is judged to dominate[5]. Normally, the low alternative entails a reduction of the concerned costs by 25%, while the high alternative is limited to an increase of 15%.

The variation concerning the business cycle is limited to influencing the investment phase for the encapsulation plant and the deep repository for spent fuel, 2008–2015, and the decommissioning of the NPPs, 2016–2032 for case A and 2015–2023 for case B. The limitation is justified by the fact that this involves large costs concentrated to relatively limited periods. For other costs in the system, it can be assumed that cyclical fluctuations will even out in the long run. The low value is calculated here based on a cost reduction of 15%, while the high value is based on a cost increase of 25%.

Variations in exchange rates only affect products that are purchased directly from abroad and where the effect of the exchange rate variation cannot be assumed to be included in e.g. the business cycle variation or in the variation in the general price level. This applies particularly to purchases of bentonite, copper and possibly special machines.

Regarding the cost influence of changed legislative and regulatory requirements, a distinction is made between specifically nuclear-related changes and changes that apply to construction and industrial activities in general. The former are assumed to influence both investment and operation, while the latter are assumed to only influence the investment costs. The influence is set at –5% and +10% of these costs, respectively.

Object-specific variations

Object-specific variations consist of specified or more general variations in the most likely cost for each object (32 objects). In other words, these variations remain after the general variations described above have been taken into account. Typical such variations relate, for example, to changes in building volume or operating organization, or varying requirements on execution (e.g. deposition).

One area where a large portion of the uncertainty has been covered by object variations is decommissioning of NPPs. This process is divided into six objects, which means that there is only a limited need for general variations in the technical area. For example, the more complex part involving dismantling of the reactor vessel and internals is separated into a separate object. The low alternative with method development and more efficient

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[5] Pricing should not be confused with estimation of the general scope or complexity of the project, where the opposite may be true, i.e. there may be a tendency towards underestimation.

decontamination gives a cost saving of 15%. The high alternative based on an assumed underestimation of the work involved and aggravating circumstances, for example the effects of fuel damage, gives a cost increase of 45%.

5.3 Uncertainties taken into account in the supplementary amount

The grouping of the uncertainties is the same as above. But in contrast to the variations included in *basis for fees*, the confidence interval is broader, normally 90%, which means that the limit values have a lower probability of occurring.

It should once again be emphasized that the variations discussed in preceding sections are also included in the *supplementary amount*. The following variations thus relate to an increase in the number of events taken into account.

Operating conditions for NPPs

A circumstance related to operation of the reactors that justify a variation is the occurrence of fuel damage to an abnormal extent. Only the cost increases in the handling process that arise in the system after the fuel has been transported to CLAB are taken into account here. Extra costs at the NPPs are not included. There is only a high alternative here, giving an increase in the operating cost for CLAB and the encapsulation plant by 10% (canister cost is not affected).

Another circumstance is the shutdown date. The part of the system that can be affected by the operating times for the reactors[6] is the timetable for decommissioning of the NPPs. The reference timetable is based on 40 years of operation of all reactors (except Barsebäck 1). As mentioned in Section 1.2.2, two cases A and B can be distinguished in the calculation of the *basis for fees* and the *supplementary amount*. For case B, the shutdown dates comprise a fixed premise and are not varied. The following therefore only applies to case A.

An earlier shutdown (average for all reactors) means either that dismantlement is brought forward or that additional costs are incurred for service operation during the period between shutdown and dismantlement. A later shutdown, on the other hand, means that the whole cost of the dismantling process is postponed, giving an increased yield on the funds set aside to pay for this. The low alternative is based on an average operating time of 60 years. The high alternative is based on an average operating time of 30 years.

Technology

The variations within the technology area specific for calculation of the *supplementary amount* generally have such an influence on the activities that they lead to a major effect on the timetable. However, the variations are not aimed at the timetable, which is why they are described here under *technology*.

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[6] The part of the system that is dependent on the quantity of spent fuel is not affected, since this quantity is controlled by the conditions in the Financing Act (earning time).

It is, however, assumed that the following two variations will not influence the timetable for the programme.

The KBS-3 method does not specify in detail how the canister with buffer should be applied in the rock, so different methods can be considered. An alternative called deposition in horizontal deposition holes, KBS-3H, is being considered as a variation of vertical deposition, KBS-3V. In this method, the deposition tunnels are replaced by long bored horizontal holes in which the canisters are deposited lying down with a spacing of a metre or so. This variation is related to an event entailing that the method in the reference scenario with holes in the tunnel floor is abandoned and replaced by KBS-3H. The cost effect is obtained after a special analysis where the uncertainties within the actual KBS-3H concept are also weighed in. The KBS-3H method is applied already in initial operation, when the necessary development work has been finished.

The other variation within the technology area that does not lead to timetable changes involves omitting the limitation of the temperature on the canister surface as well as, to a reasonable extent, any limitations of the temperature in the buffer. This gives a low alternative entailing that two canisters can be deposited in each position. This saving is reduced slightly by the fact that the tunnel length that is unsuitable for deposition due to the presence of fractures or other factors increases as a result of the fact that the hole depth is nearly doubled.

Of the variations that influence the timetable, retrieval of canisters is the one with the greatest influence on the programme and also with the greatest effect on the costs with regard to undiscounted amounts. In calculating the present value, however, the cost effect diminishes with a positive real interest rate as a consequence of the resultant considerable delay of the execution of the programme. The variation is limited by the fixed premise that retrieval can only be done once and not later than before regular operation is commenced at the deep repository. As in the case of the variation with KBS-3H above, retrieval is regarded as an event which is in turn analyzed with respect to low and high alternatives.

The “probable case” for the outcome of the event “retrieval” is that a new siting process must be carried out, followed by a new establishment of the deep repository. The total delay of the programme is assumed to be 25 years, although this is offset to some extent by the fact that the deposition rate can then be increased, since the fuel has decayed for a longer time. No division into initial operation and regular operation is made at the new deep repository. The 400 deposited canisters are assumed to remain in the first repository until they can be retrieved and directly (after inspection) disposed of in the new deep repository. A low alternative entails that a new siting and site investigation process is not required, since one of the two other designated sites can be utilized. A high alternative is given by a shorter delay, 20 years, and the fact that the canisters are removed immediately from the first repository, which is subsequently closed and restored. This means that a canister store for these 400 canisters must be arranged.

In the previous section, a variation was described entailing disturbances in operation due to sabotage, theft, etc, i.e. caused by intentional actions by individuals. The *supplementary amount* also includes disturbances in operation due to serious technical defects, accidents, etc. As before, the material damage is not included, since it is indemnified via insurance, but rather only the effect on operation. A high alternative is defined as damage of such scope that it results in an interruption in operation of five years. The damage further occurs at a late stage so the lost time cannot be made up. It is assumed that a full workforce is maintained during the stoppage, indicating that it is not known in advance how long the interruption will be.

Siting

Three variations concerns siting of the deep repository, the encapsulation plant and the final repository for long-lived LILW.

The variation for the deep repository relates to a case where none of the designated areas is accepted, so a new siting process has to be started. The final result is conservatively assumed to be an inland siting in Norrland (in the north of Sweden). The cost effect of the variation is varied with respect to the delay in the programme that arises, with extreme cases of 7 and 25 years.

For the encapsulation plant, a variation is included where the facility is co-sited at the site of the deep repository for spent fuel. If the deep repository is sited in Oskarshamn (Simpevarp), the encapsulation plant will be co-sited at CLAB. In this alternative, external canister shipments are eliminated and replaced by fuel transport from CLAB to the encapsulation plant.

For the final repository for long-lived LILW, a variation is included where the repository is sited separately from other final repositories. This is a high alternative with costs for separate access tunnels to the deposition level, with a separate supply and operating organization, and with an expanded siting and site investigation programme.

Timetable dependencies

Two variations are focused directly on delays in the timetable for the programme.

One variation concerns delays in startup. As a result, the starting deadline of 2015 cannot be met. A delay of 10 years is assumed, resulting in deposition of the first canister in 2025. The reason for the delay is not specified, but it may consist of both technical and political factors. Some of the delay is made up since the encapsulation rate can be stepped up due to the longer decay time for the fuel.

Another timetable-affecting variation concerns the date for dismantling of the nuclear power plants (with no change in the shutdown dates for the reactors). The reference scenario assumes immediate dismantlement, i.e. dismantlement immediately after the reactors have been shut down. Here again, however, a distinction must be made between cases A and B. In case B, the starting date for dismantlement is determined by the earliest start of operation of the final repository that will receive the decommissioning waste. This date is set at 2015. In both cases, the low alternative results in deferred dismantlement. This means that dismantlement is scheduled so far ahead in time that it is completely concluded for all reactors roughly simultaneously with the conclusion of all other activities, for example closure and restoration at the deep repository. The alternative entails that costs for additional service operation for the period between shutdown and dismantlement must be taken into account. For case B, there is also a high alternative with immediate dismantlement entailing that **all** reactors are dismantled starting in 2015.

6 Cost accounting

6.1 General

An account of all costs for management and disposal of the radioactive waste products described in Chapter 2 and for decommissioning and dismantling the reactor plants is given in this chapter. As a basis for the calculation, the system has been described briefly in Chapter 3 and the uncertainties taken into account in calculating the *basis for fees* and the *supplementary amount* have been described in Chapter 5.

The costs for different facilities are reported in the items: investment, operation and maintenance, and decommissioning and backfilling of rock caverns[7] . Normally, only the costs that arise before a facility or part of a facility is put into operation are assigned to the investment costs. But in the deep repository, where construction of the deposition tunnels will proceed continuously during the deposition phase, the costs of this work also have been assigned to the investment costs.

The amounts that will serve as a basis for the Government's decision on fees and guarantees are reported in greater detail in the following sections:

- *basis for fees,*
- *basis for basic amount,*
- *supplementary amount.*

A more detailed definition of the amounts is given in Chapter 1.

Finally, a table is presented showing incurred and budgeted costs through 2003, plus an illustration of how the total cost is distributed among various facilities and activities in the system.

6.2 Future costs

6.2.1 Reference costs and basis for fees

Table 6-1 shows the future costs through 2004 for the *reference scenario* in total according to the operational plan, and the costs that are attributable to the *basis for fees* in accordance with the Financing Act. The latter are taken from the calculation according to the "successive principle" described in Chapter 4 and represent an outcome where there is an equal probability that the actual value will exceed or fall short of the calculated value.

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[7] Previously the concept of reinvestment has also been used. Such costs are now allocated either to investment or to maintenance.

Table 6-1. Table of future costs starting in 2004, January 2003 price level.

Object and cost category	Future costs acc. to reference scenario with operation of reactors for 40 years		Basis for fees acc. to Financing Act[1]
	MSEK	MSEK	MSEK
SKB adm. and RD&D		4,860[2]	4,410
Transport		2,230[2]	1,330 (A)
investment	1,160		1,230 (B)
operation and maintenance	1,070		
Decommissioning NPPs		13,130	14,380 (A)
operation at shutdown reactor units	2,300		15,920 (B)
decommissioning	10,830		
CLAB		4,610[2]	3,960
investment	990		
operation and maintenance	3,220		
decommissioning	400		
Encapsulation plant		7,920[2]	6,940
investment	2,150		
operation and maintenance	5,600		
decommissioning	170		
Deep repository – off-site facilities		250[2]	320
investment and operation	250		
Deep repository – siting, site investigations		1,040[2]	1,160
Deep repository – operating areas (above-ground fac.)		5,420[2]	4,570
investment	1,870		
operation and maintenance	3,440		
decommissioning	110		
Deep repository – spent fuel		8,150[2]	7,720
investment	4,580		
operation and maintenance	1,170		
decommissioning and backfilling	2,400		
Final repository for long-lived LILW		580[2]	700
investment	360		
operation and maintenance	120		
decommissioning and backfilling	100		
Final repository for reactor waste – SFR 1		420[2]	0[3]
investment			
operation and maintenance	420		
decommissioning and backfilling			
Final repository for decommissioning waste – SFR 3		960[2]	1,040 (A)
investment	530		790 (B)
operation and maintenance	240		
decommissioning and backfilling	190		
Total		49,600	46,500 (A) 47,700 (B)

[1] The quantity of spent fuel and radioactive waste is limited to the amount which is estimated to arise through 2004 or at least during 25 years of operating time for each reactor. An allowance for uncertainties is also included.

[2] Also includes costs financed outside the Financing Act.

[3] Decommissioning costs for SFR 1 are included in SFR 3, other costs for SFR 1 are assigned to operation of CLAB.

(A) Alternative where the decommissioning date is controlled by the reference scenario's operation of the reactors for 40 years.

(B) Alternative where the decommissioning date is controlled by a shutdown of the reactors coinciding with the end of the earning time given in the Financing Act (25 years).

The total cost also includes costs that do not fall under the Financing Act (costs for management and disposal of operational waste from the NPPs, Ågesta fuel and waste from Studsvik).

Figure 6-1 shows the reference costs according to Table 6-1 distributed over time. Figure 6-2 shows in the same manner the *basis for fees* for case A and case B. The time distribution for the *basis for fees* is necessarily approximate since the cost flow is affected by the variations in the timetable included in the statistical analysis.

The *basis for fees* amounts to SEK 46.5 billion in January 2003 price level for case A and SEK 47.7 billion for case B.

Since several variations influence the timetable for the waste management system, the present value of the costs has also been calculated for different real interest rate assumptions. To show the importance of the real interest rate, Figure 6-3 shows the *basis for fees* as a function of the chosen real rate of return used in the calculation (discount rate).

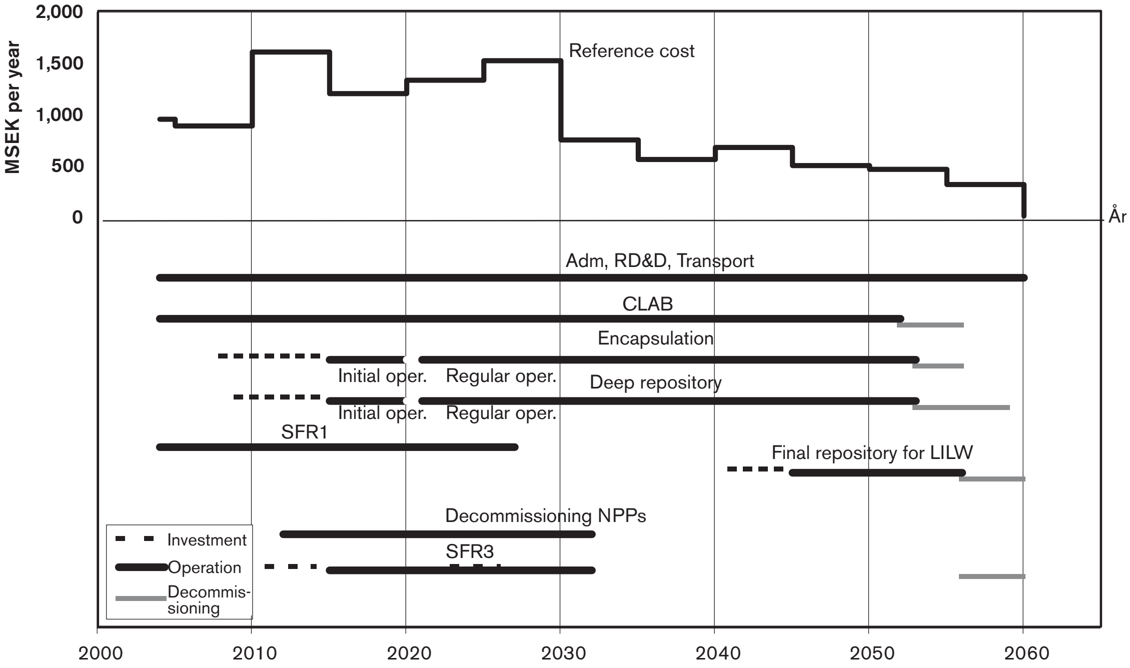

Figure 6-1. *Future costs for the reference scenario with associated timetable. January 2003 price level.*

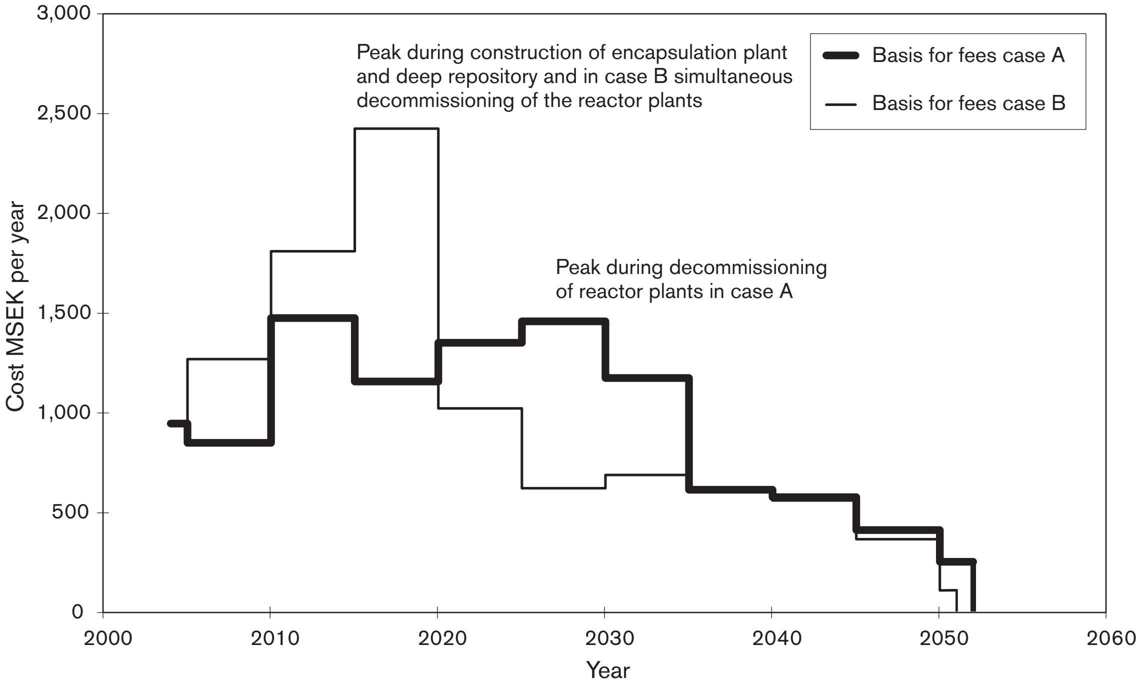

Figure 6-2. Basis for fees. January 2003 price level.

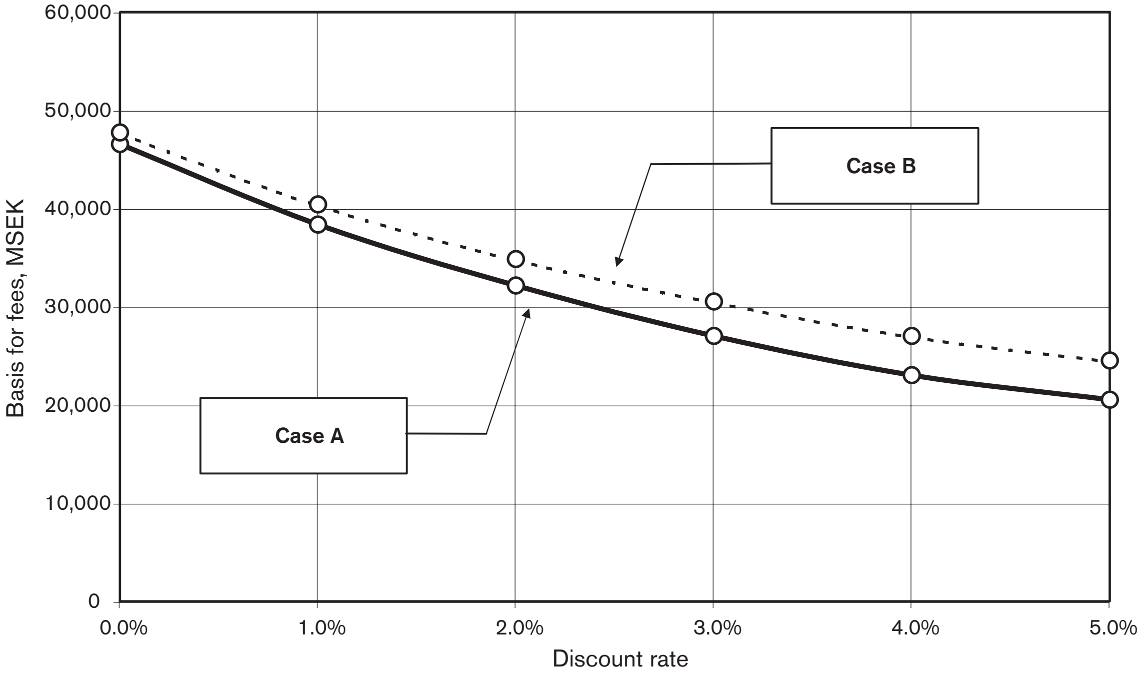

Figure 6-3. Basis for fees as a function of the discount rate. January 2003 price level.

6.2.2 Basis for basic amount

As a basis for determining what guarantees are needed to cover the fees attributable to the earning time that remain to be paid in, i.e. *Guarantee I*, costs for a hypothetical case have been calculated including only the quantity of fuel existing at the end of the current year, i.e. at 31 December 2003. This gives the *basis for basic amount*. This amount includes the cost effect of a reduction of the quantity of fuel by about 700 tonnes of uranium compared with the fuel quantity covered by the *basis for fees*. For case B, the cost saving diminishes due to costs for additional years with service operation at the shutdown reactor.

The *basis for basic amount* is estimated at a total of SEK 45.1 billion for case A and SEK 46.8 billion for case B, which is SEK 1.4 and 0.9 billion lower, respectively, than the *basis for fees*.

6.2.3 Supplementary amount

The *supplementary amount* will be used as a basis for determining the need for *Guarantee II* , which is supposed to cover additional costs as a consequence of unforeseen events. The same calculation methodology has been applied in the calculation of the *supplementary amount* as for the *basis for fees*. The variations that have been applied to the reference scenario are, however, much more comprehensive.

The probability distribution of the costs obtained as a result of the cost calculation according to the statistical method makes it possible to determine an upper amount limit. This is done on the basis of the choice of the degree of confidence deemed to meet the Financing Act’s requirement of a reasonable coverage of costs due to unforeseen events. So far a degree of confidence of 90% has been applied by the regulatory authority in estimating *Guarantee II*, which means that the upper amount limit obtained in this way is considered to cover costs with 90% probability.

The *supplementary amount*, which constitutes the difference between the upper amount limit and the *basis for fees*, has been calculated to be SEK 9.0 billion at a confidence level of 90% for case A and SEK 8.8 billion for case B. If a confidence level of 80% is chosen, supplementary amount of SEK 5.5 and 5.4 billion, respectively, are obtained.

6.3 Previously incurred costs

Table 6-2 shows costs incurred through 2002 in current money terms and bugeted costs for 2003.

Table 6-2. Incurred and budgeted costs through 2003, current money terms (excluding reprocessing costs).

	Incurred through 2002 MSEK	Budgeted for 2003 MSEK	Total through 2003 MSEK
SKB administration	874	145	1,019
RD&D	3,522	291	3,813
Transport	766	28	794
CLAB	4,234	235	4,469
Encapsulation plant	193	0	193
Deep repository, siting Site investigations	733	285	1,018
SFR 1	1,320	39	1,359
Total	11,642	1,023	12,665

The distribution of the total cost among different parts of the system is shown in Figure 6-4. The total cost consists of incurred costs plus estimated future costs. The distribution is based on January 2003 price level, whereby incurred costs have been adjusted upwards with index.

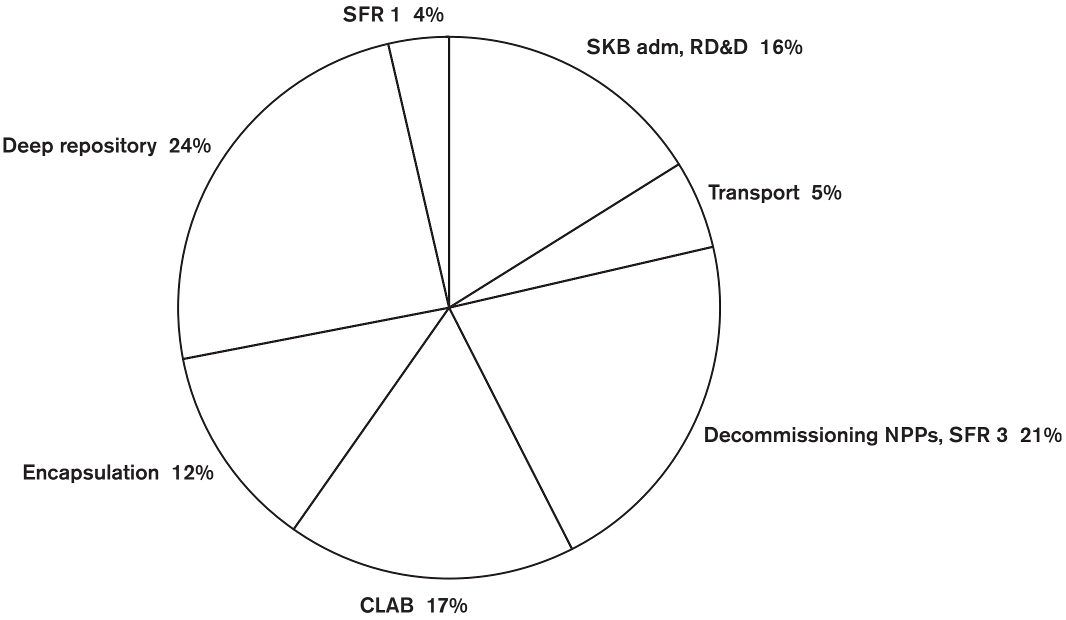

Figure 6-4. *Distribution of the total cost (incurred and future) for the alternative with 40 years of operation of the reactors (excluding costs for reprocessing).*

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Programme for research, development and demonstration of methods for the management and disposal of nuclear waste
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Ref 2 SKI's evaluation of SKB's RD&D-Programme 2001
SKI Report 02:33
Review Statement September 2002

Ref 3 SKB RD&D-Programme 98
Treatment and final disposal of nuclear waste
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Ref 4 Integrated account of method, site selection and programme prior to the site investigation phase Supplement to SKB RD&D-Programme 98
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Ref 5 SKI's evaluation of SKB's RD&D-Programme 98
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Proactive Management of Uncertainty using the Successive Principle
Polyteknisk Press, Denmark 2000

Detailed list of radioactive waste products for disposal according to the reference scenario with operation of the reactors for 40 years

Values in parentheses are design-basis quantities for *basis for fees*, i.e. operation through 2004 or for at least 25 years of operation.

Waste category	Unit	Dimensions m	Number of units	Volume in final store m^3	Final repository
Spent BWR fuel	assembly	0.14/0.14/4.383	39,730 (27,720)	19,100 (13,200)	Deep rep. fuel
Spent PWR fuel	assembly	0.21/0.21/4.103	4,900 (3,280)		
Other spent fuel (MOX, Ågesta, Studsvik)	various		640 (640)		
Reactor internals and core components	mould	1.2/1.2/4.8	1,400 (1,400)	9,700 (9,700)	Final rep. long-lived
Oper. waste from CLAB and encapsulation plant to silo	mould	1.2/1.2/1.2	3,200 (2,240)	5,500 (3,850)	SFR 1
Oper. waste from CLAB to rock vault	mould	1.2/1.2/1.2	300 (210)	520 (360)	SFR 1
Waste from Studsvik to silo	drum	0.6/0.9	350 (350)	130 (130)	SFR 1
	mould	1.2/1.2/1.2	60 (60)	110 (110)	SFR 1
Waste from Studsvik to rock vault	drum	0.6/0.9	8,350 (8,350)	3,010 (3,010)	SFR 1
	mould	1.2/1.2/1.2	60 (60)	110 (110)	SFR 1
	ISO cont.		120 (120)	2,300 (2,300)	SFR 1
Waste from Studsvik to rock vault	drum	0.6/0.9	4,320 (4,320)	1,500 (1,500)	Final rep. long-lived
	mould	1.2/1.2/1.2	180 (180)	300 (300)	Final rep. long-lived
Operational waste from NPPs to silo	drum	0.6/0.9	4,330 (3,030)	1,560 (1 090)	SFR 1
	mould	1.2/1.2/1.2	4,690 (3,280)	8,120 (5 680)	SFR 1
Operational waste from NPPs to rock vault	drum	0.6/0.9	5,950 (4,170)	2,140 (1,500)	SFR 1
	mould	1.2/1.2/1.2	5,770 (4,040)	9,970 (6,980)	SFR 1
	ISO cont.		590 (410)	11,270 (7,890)	SFR 1
	container	3.3/1.3/2.3	990 (690)	9,860 (6,900)	SFR 1
Decomm. waste from NPPs to rock cavern	ISO cont. mm		10,000 (10,000)	150,000 (150,000)	SFR 3
Decomm. waste from Studsvik to rock cavern	ISO cont.		1,400 (1,400)	20,000 (20,000)	SFR 3
Decomm. waste from CLAB and encapsulation plant to rock cavern	container	2.4/2.4/2.4	630 (630)	8,700 (8,700)	Final rep. long-lived
Total, approx.			98,000 (77,000)	264,000 (243,000)	

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