

Costing and Financing of the Swedish Waste Management System - 14540

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ABSTRACT

In Sweden a company that has a licence to own a nuclear power plant is responsible for adopting whatever measures are needed for safe management and disposal of spent nuclear fuel and radioactive waste deriving from it and for decommissioning and dismantling of the reactor plants after they have been taken out of service. The most important measures are to plan, build and operate the facilities and systems that are needed for this, and to conduct related research and development. The financing of these measures is based on payment by the licensees of nuclear waste fees to a state-administered fund (Nuclear Waste Fund), primarily during the period the reactors are in operation, but also later if need be. In addition to these fees, the licensees must pledge certain guarantees to the state. According to the regulatory framework, such a cost accounting shall be submitted to the regulatory authorities every third year.

The future costs are based on Swedish Nuclear Fuel and Waste Management Co's (SKB) current planning regarding the design of the system and the timetable for its execution. The latest cost calculation is based on the proposed plan of activities that has been presented in SKB's RD&D Programme 2013.

SKB calculates the costs for two scenarios. The first, the reference scenario, is based on an operating time of 60 years for all operating reactors except three reactors. The second scenario is based on the scenario given by the Financing Act, i.e. 40 years of operating time with a minimum remaining operating time of six years. This scenario is used only for financing issues.

INTRODUCTION

The financing system for management of radioactive waste from nuclear power reactors has now been in action since 1982. The financing system has been developed over time but the main features, like division of responsibilities, have remained the same. Details of how to estimate the costs and the inherent uncertainties have evolved over time. The current paper describes the main features of the current system.

FINANCING SYSTEM

Financing System and Current Regulatory Framework

A company that has a licence to own a nuclear power plant is responsible for adopting whatever measures are needed for safe management and disposal of spent nuclear fuel and radioactive waste deriving from it and for decommissioning and dismantling of the reactor plants after they have been taken out of service.

The most important measures are to plan, build and operate the facilities and systems that are needed for this, and to conduct related research and development. The financing of these measures is based on payment by the licensees of nuclear waste fees to a state-administered fund, primarily during the period the reactors are in operation, but also later if need be. In addition to these fees, the licensees must pledge certain guarantees to the state.

WM2014 Conference, March 2 – 6, 2014, Phoenix, Arizona, USA

The fees are paid to the Nuclear Waste Fund, which deposits the assets in an interest-bearing account at the National Debt Office, in treasury bills or in debt instruments bearing account at the National Debt Office, in treasury bills or in debt instruments. Paid-in fees shall be used to reimburse the costs the fees are intended to cover. In practice, this means that the licensee is entitled to obtain compensation from the fund for his costs to meet his obligations as described in the above paragraph.

The system of nuclear waste fees and guarantees is regulated in the Financing Act [1] with associated Ordinance [2]. The content of both of these statutes is hereinafter called the regulatory framework.

A licensee/reactor owner pays fees based on electricity produced (öre/kWh). Today there are three reactor owners in this category: Forsmark Kraftgrupp AB, OKG Aktiebolag and Ringhals AB. Barsebäck Kraft AB can be ordered to pay a certain annual amount (the two reactors in Barsebäck were shut down in 1999 and 2005).

The regulatory framework further distinguishes between residual products on the one hand and radioactive operational waste on the other. Residual products are defined as “nuclear material that will not be reused and nuclear waste that does not constitute operational waste”. The nuclear waste fee shall cover costs for management and final disposal of residual products, but not costs for management and final disposal of operational waste. Those costs are borne directly by the licensee.

A licensee shall, in consultation with the other licensees, calculate the costs for management and disposal of the spent nuclear fuel and the radioactive waste, as well as for decommissioning of the reactor plants. The licensees have commissioned SKB to carry out and compile these calculations.

The Government has decided that the calculations shall be submitted to the Swedish Radiation Safety Authority, which prepares proposals for fees and guarantees based on these figures. Decisions on the size of fees and guarantees are made by the Government. An exception is the guarantee pledged by Barsebäck Kraft AB. This guarantee is determined by the Swedish Radiation Safety Authority. Fees shall be charged and guarantees pledged as needed both during the time the reactors are in operation and after permanent shutdown up until the reactor plants have been dismantled and all residual products disposed of.

The quantity of spent nuclear fuel and radioactive waste to be disposed of is dependent on the operating time of the reactors. The regulatory framework stipulates that the cost calculations shall assume an operating time of 40 years for each reactor that is currently in operation. A minimum limit is stipulated entailing that a remaining operating time of at least six years shall be applied unless there is reason to assume that operation may cease before then.

Aside from the payment of fees, a licensee must pledge two kinds of guarantees. One type of guarantee covers fees that have not yet been paid in. The other type of guarantee relates to unplanned events. The guarantees become payable if the licensees fail to fulfil their obligation to pay fees and the assets in the fund are deemed to be insufficient.

According to the regulatory framework, the cost accounting shall be submitted to the regulatory authority at certain intervals, every three years.

Amounts to Report under the Financing Act

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

- the remaining basic cost (basis for fees),
- basis for financing amount (basis for determining the amount of the guarantee that relates to fees stipulated but not yet paid),
- supplementary amount (basis for determining the amount of the guarantee that relates to unplanned events and that becomes payable if fee payments are not made and the guarantee according to the second bullet point is not sufficient).

The remaining basic cost shall include all future costs for managing and disposing of the residual products that are expected to arise during the fee-determining operating time of 40 years (or at least six remaining years of operation). The amount shall also cover costs for decommissioning the reactors and conducting the necessary research and development. The remaining basic cost includes an allowance for unforeseen factors and risk to a given level. These contingency amounts are obtained by means of a probability-based uncertainty analysis which SKB uses. The total basis for fees is finally obtained by adding an additional amount relating to certain costs for regulatory supervision and other items, called extra costs. These amounts are added by the regulatory authority in connection with the calculation of fees and are not included in the present report.

The basis for the financing amount shall include costs calculated in the same way as the remaining basic cost but with the limitation that the quantity of spent nuclear fuel and radioactive waste refers to the quantities projected to exist at the time the calculation begins. Based on these quantities, the total financing amount is then obtained in the same way as the fee basis, i.e. certain additions are made for unforeseen items and risk and for extra costs, the latter by the regulatory authority. The difference between the financing amount and the current content of the Nuclear Waste Fund, plus expected return, provides a basis for estimating the size of the guarantee to be pledged for fees determined but not yet paid. This estimate is made by the regulatory authority.

The supplementary amount constitutes the difference between costs included in the remaining basic cost and the upper limit for costs for which the reactor owner is currently required to pledge a guarantee. In SKB's model, this upper limit is not just based on the uncertainties that serve as a basis for the fee, but also on a number of exceptional events with greater consequences than what is included in the basic cost. Otherwise, the same probability-based calculation method is employed. The supplementary amount constitutes the basis for determining the size of the guarantee for unplanned events.

At the end of 2012 there was about SEK 49 billion in the nuclear power companies' shares of the Nuclear Waste Fund (market value). In addition, some Swedish kronor (SEK) 34 billion (current price level) has been spent building and operating today's system and for the research and development work. During the period 2012 to 2014, the average fee is 2.2 öre (100 öre = 1 Swedish krona=0.15 US dollars) per kilowatt-hour of electricity produced for the nuclear power plants that are in operation. Barsebäck Kraft AB pays an annual fee of SEK 842 million.

SKB'S WASTE MANAGEMENT SYSTEM

Figure 1 provides an overview of SKB's system for management and disposal of radioactive waste and spent nuclear fuel.

The Swedish system can be divided into two main parts: the system for management of low- and intermediate-level waste, and the system for management of the spent nuclear fuel (the

KBS-3 system). The facilities in the former system are operated by both SKB and the waste producers. All facilities in the KBS-3 system will be operated by SKB.

SKB is responsible for the transportation system, which is the same for both low- and intermediate-level waste and spent nuclear fuel. The shipments go by sea, since all nuclear power plants and nuclear waste facilities are situated on the coast. The transportation system consists of a specially built ship, different types of transport containers for different waste types, and special vehicles for loading and unloading.

The ship, m/s Sigrid, can carry twelve fuel and waste containers instead of ten as before. Normally, the ship, which is operated by a contractor, makes between 30 and 40 trips per year between the nuclear power plants, Studsvik, the final repository for short lived radioactive waste (SFR) and the interim storage for spent nuclear fuel (Clab).

SKB's system

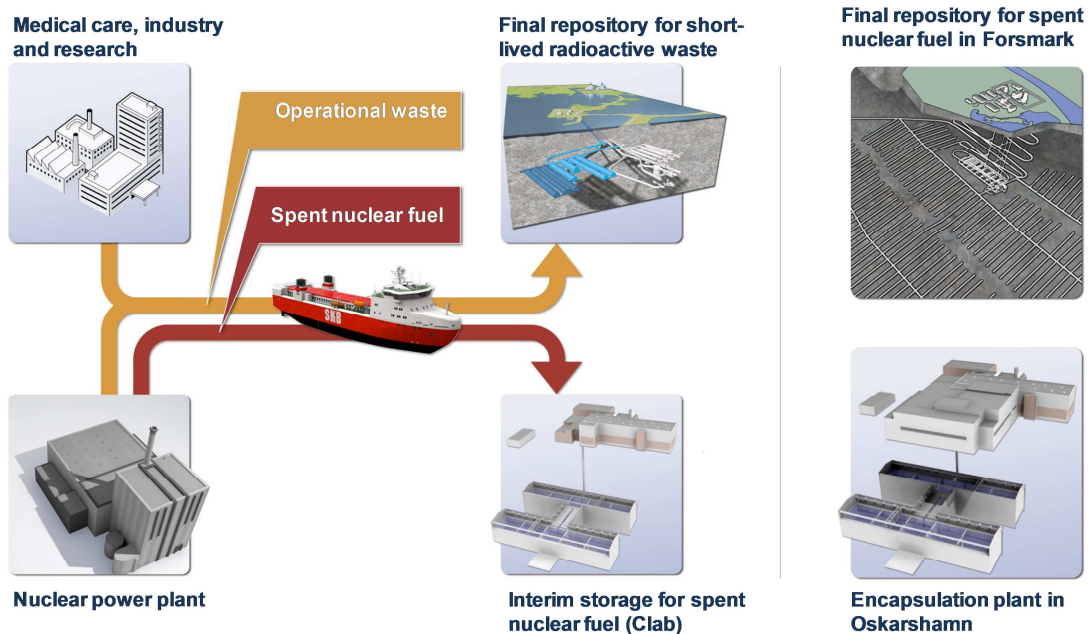


Fig. 1. Overview of the SKB's system for management and disposal of the residual products of nuclear power and other radioactive waste

SKB'S CALCULATION MODEL

The previous section outlined the costs SKB has to report to the Authority according to the Financing Act. These costs are based on an assumed operating time of 40 years for each reactor (a minimum remaining operating time is set to six years). The costs reported to the authority are derived from the cost estimate based on the reactor owners' current planning, the reference scenario. This scenario gives the reference cost.

The cost calculations are carried out in four steps, schematically illustrated in Figure 2.

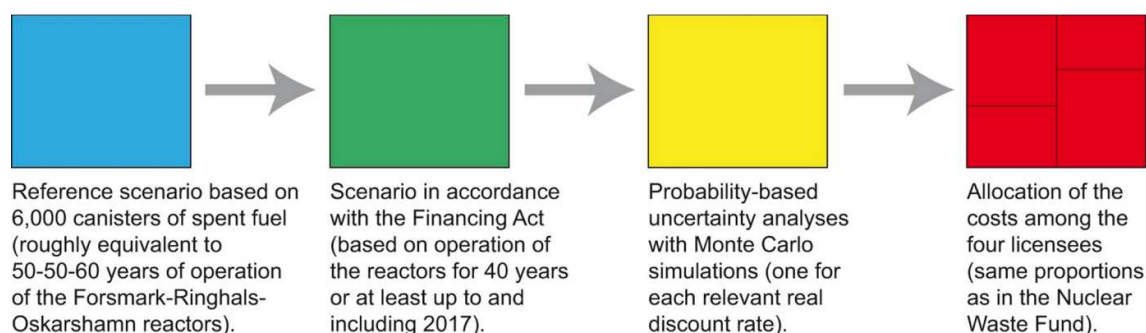


Fig. 2. The four steps in SKB's calculation model.

Step 1 (blue box)

The future costs are based on SKB's regarding the design and execution of the system. The current design is called the reference design while its execution – which includes timetables, waste quantities and other planning – is called the reference scenario. The reference scenario is based on the proposed plan of the activities that has been presented in SKB's Research, Development and Demonstration (RD&D) Programme 2013. It is made clear there that the quantity of spent nuclear fuel and radioactive waste is to be based on an operating time of 60 years for all reactors in Forsmark, Oskarshamn and Ringhals except two reactors, Ringhals 1 and Ringhals (50 years). The quantity of nuclear fuel is rounded off to the equivalent of 6,300 copper canisters.

A cost calculation based on the current state of planning within SKB serves as a basis for the costs presented to the in the plan report. This primarily applies to the design of the system which today constitutes the main alternative in SKB's development work and is referred to as the reference design, but here also includes assumptions concerning future events where decisions have not yet been made. These assumptions are necessary in order for a complete cost calculation basis to be compiled. They are presented in greater detail in the next section.

The reference design, together with these assumptions, comprises what we call the reference scenario. This in turn serves as the basis for the calculation of the reference cost.

The costs also include costs for research, development and demonstration (RD&D), as well as SKB's central functions. The latter include general functions such as corporate management, business support, communications, environment, overall safety matters, etc. Other costs include costs for decommissioning of the reactor plants as well as at-plant facilities for interim storage or final disposal of radioactive waste.

Step 2 (green box)

The Financing Act and the associated Ordinance stipulate a number of conditions whose effect is that the scope of the programme is limited somewhat in comparison with the reference scenario. This applies above all to the operating time for the reactors, which comprises the basis for the estimate of the quantity of spent nuclear fuel and radioactive waste. A minor limitation also follows from the fact that the cost calculation shall pertain to the management and disposal of residual products, which, according to the definition in the Financing Act, excludes operational waste. Among other things, the cost of today's SFR is not included in the calculations.

According to the regulatory provisions, the fee-determining operating time of the reactors shall be 40 years, but with a minimum of six remaining years of operation. The quantity of nuclear fuel in this scenario is rounded off to the equivalent of 4,600 copper canisters.

In this step SKB also takes into account for future real price changes in the cost estimates that are reported under the Financing Act. The real price changes refer to the price and productivity in the project differs from the development of society at large. The latter is expressed as the consumer price index. These changes are dependent on factors in society at large over which SKB has no control. The estimates take into account the real price change through a number of conversion factors referred to herein as external economic factors, EEF. These include the trend in payroll costs (including productivity), costs of input materials and machinery, as well as currency exchange rates. By “real” price increases is meant price increases in addition to the general rate of inflation as expressed by the consumer price index. The real price and cost trend is defined in the calculation by a trend line for each EEF. The trend lines are plotted based on historical data.

The external economic factors selected to be in the calculation consists of a limited number of observable macroeconomic variables. The very large number of variables in a project of this nature is reduced to eight factors which represent a relatively strong aggregation.

Step 3 (yellow box)

The regulatory framework prescribes that the cost accounting should pertain to both expected costs and additional costs to cover the possible effect of unplanned events. This means that some form of uncertainty analysis based on probability theory should be carried out. Since the mid-90s, SKB has used a method called “The successive principle” or simply “successive calculation”. The method is described thoroughly in [3].

A central aspect of the application of the “successive principle” is the methodology for structuring the calculation and setting up probability distributions for the variations/uncertainties included in the analysis. This is done by means of judgements made by a team specially composed for this purpose. SKB has chosen to call this team the “analysis group”. The analysis group composition is broad, with participants from both areas of nuclear-related as from areas that are completely independent of this activity.

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 result that is obtained is also a stochastic variable, which means that each amount that can be determined is associated with a given probability. In our case, this association is expressed as the “probability that a given amount will not be exceeded”. This is designated in the model as the “confidence level” for the amount. A confidence level of 50% means, for example, that the probability that the actual value will not exceed the predicted value is 50%. Current fees have been based on a confidence level of 50 %.

The guarantee that has to be pledged for unplanned events is determined on the basis of a much higher confidence level. The current level is 90%.

The method also provides indications of where the major uncertainties are. They can then be broken down and analyzed 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.

Step 4 (red box)

Payments to the Nuclear Waste Fund are made under four main headings, one for each licensee. The future costs must therefore be divided among them. The division of costs is based on agreements between the licensees.

RESULTS OF THE COST ESTIMATES

Figure 3 gives an overview of the results of the different cost estimates.

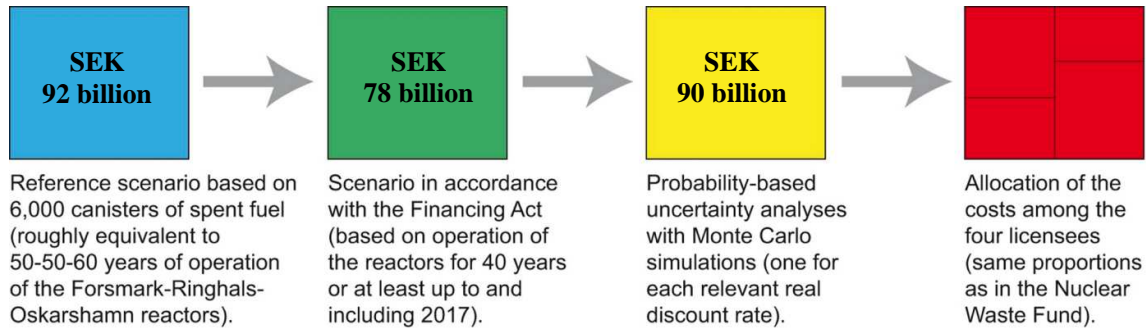


Fig. 3. The four steps in SKB's calculation model with total cost for the reference scenario and the scenario according to the Financing Act. The cost SEK 90 billion includes an allowance of 12 billion SEK for unforeseen factors and risk.

Future Costs – Reference Scenario

Figure 4 shows how the future costs for the reference scenario are distributed in time with associated time table. The first peak in the cost distribution is the costs for investments in the encapsulation plant and the final repository for spent fuel and the second peak is the costs for decommissioning of the power plants.

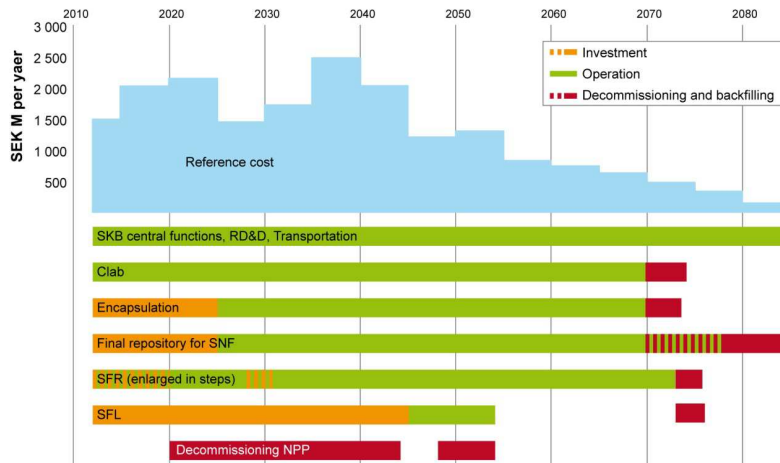


Fig. 4. Future cost distribution in time for the reference scenario with associated timetable. Price level January 2010.

Scenario According to the Financing Act

The fee is calculated based on the remaining basic cost and additional costs for the authority, state, municipalities and organizations. The latter is calculated by the authority and is not included in the costs presented in this chapter. The remaining basic cost includes costs for uncertainties and risks and is the mean value from the results from the Monte Carlo simulation.

Figure 5 shows the cost function by which the remaining basic cost is determined. The function is the result from the Monte Carlo simulation. The figure shows un-discounted costs.

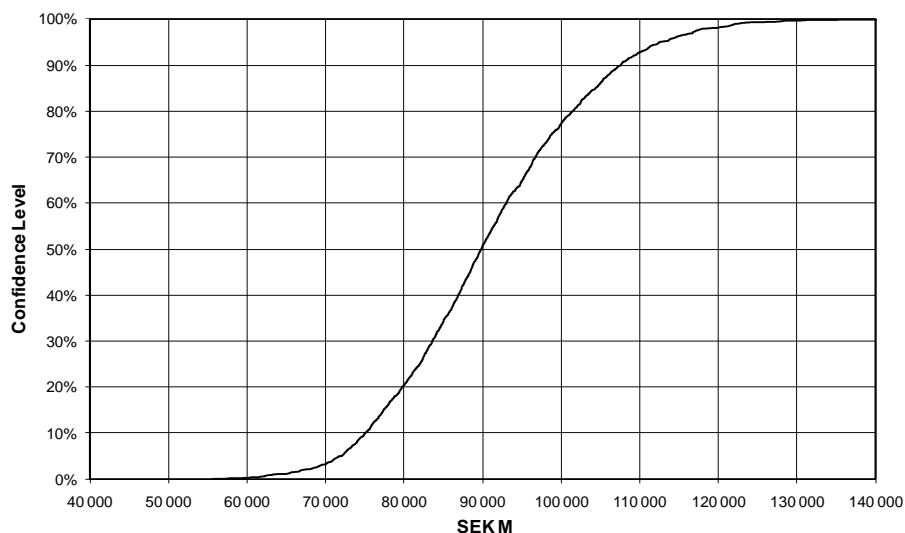


Fig. 5. The cost function for the remaining basic cost (undiscounted amount).

The remaining basic cost is estimated at a total of SEK 89.8 billion, median 50 % value in Figure 5. The cost includes an allowance of SEK 12 billion for unforeseen factors and risk.

Fees and Financial Guarantees

Swedish Radiation Safety Authority (SSM) submitted their proposal for fees and financial guarantees for the period 2012-2014 in October 2011. The Government decision was made in December 2011. The Government's decision is presented in the table below.

Table 1. Fees and guarantees for the years 2012-2014, the Government decision.

	Fee	Guarantee for Financing amount MSEK	Guarantee for Supplementary amount MSEK
Forsmark	2,1 öre/kWh	4 015	3 020
Oskarshamn	2,0 öre/kWh	2 675	2 250
Ringhals	2,4 öre/kWh	4 170	3 210
Barsebäck	842 MSEK/year	3 410	-

Figure 6 shows the historic development of the average annual fees to the Nuclear Waste Fund. The average fee is given in current money terms and adjusted for inflation to 2012 money value.

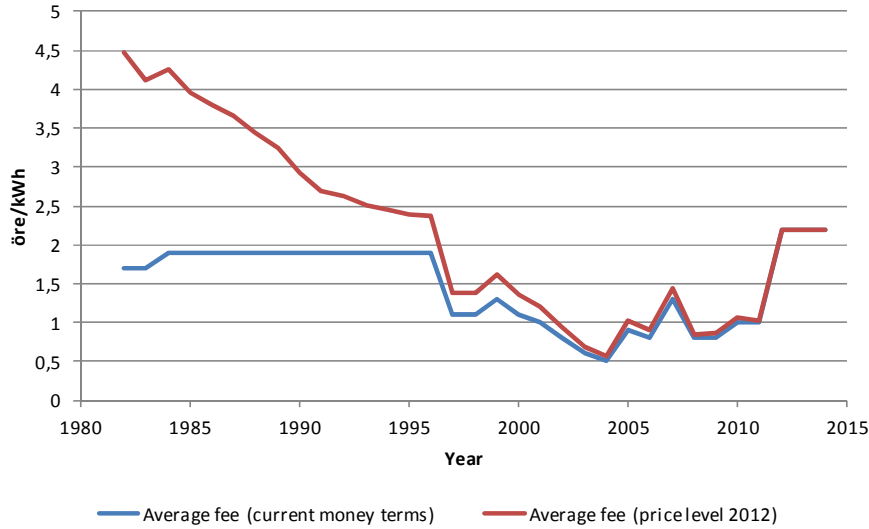


Fig.6. Historic development of average fee.

Figure 7 gives the total of the Guarantee for Financing amount and Guarantee for Supplementary amount for all nuclear owners since these were introduced in 1997.

For the calendar year 1997 the Government decided that there should be no Guarantee for Supplementary amount because the principles for determining the Guarantee were not sufficiently analysed. The increase of the Guarantee for Supplementary amount in 2005 is due to revised uncertainties used in the calculation.

Except for the years 2008 and 2009 the Guarantee for Financing amount has been based on discounted costs.

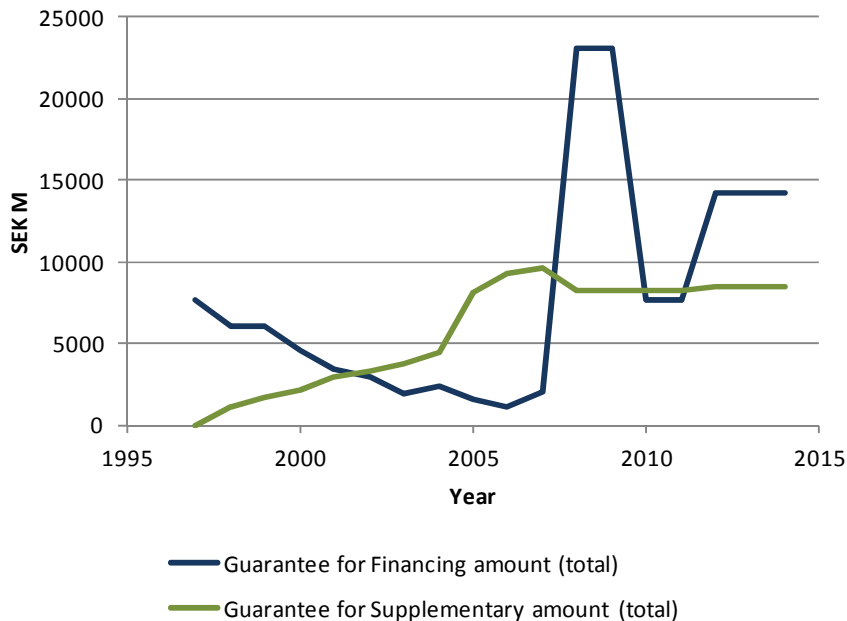


Fig. 7. Historic development of the total of Guarantee for Financing amount and Guarantee for Supplementary amount in current money terms.

CONCLUDING REMARKS

The Swedish financing system was created in the early eighties and it has been successively developed. The current amount in the Nuclear Waste Fund covers the estimated costs for SKB's activities for more than 25 years into the future. The fee together with the return on investment on the money in the fund should cover the remaining costs. In addition the power utilities provide guarantees for remaining basic costs and unforeseen events. The power utilities that own SKB are large and stable corporations. But the most important factor to make the system robust are the updated cost estimates and updated decisions regarding fees and guarantees every third year. Hence, uncertainties in cost estimates can be corrected for successively.

REFERENCES

1. Act (2006:647) on Financial Measures for the Management of Waste Products from Nuclear Activities
2. Ordinance (2008:715) on Financial Measures for the Management of Waste Products from Nuclear Activities.
3. Lichtenberg S, Proactive Management of Uncertainty using the Successive Principle, (2000)