SKI Report 02:22

Research

An Analysis of the Authorities' Expected Costs Related to the Decommissioning Programme

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SKI Perspective

Background

The nuclear power utilities pay, since 1981, a fee to the Swedish Nuclear Waste Fund. This financing system was resolved by the Swedish parliament for the future expenses for the safe management of spent nuclear fuel and for the decommissioning and dismantling of the Swedish nuclear reactors. Hence, assuring appropriate financial contributions to the Swedish Nuclear Waste Fund is crucial for the sustainability and long term credibility of this financing system.

A deficit situation may arise if the level of accruals to the fund becomes insufficient in relation to future disbursements. Hence, it is important that provision to the fund accurately reflects the real cost of performing the necessary work in the future. SKI strive to enhance the overall quality of the calculation of fees to the fund, as well as the guarantees given by the industry, and is therefore conducting pro-active work by applied studies on some major cost items. One central criterion for these studies is that the studied cost item, or cost items, shall have a significant impact on the funding and/or guarantees. In this perspective it is vital that uncertainties in the estimated costs of governmental supervision are calculated in an efficient and appropriate way. It may be anticipated that the future costs for the future supervision made by SKI and SSI is one of the major cost areas where even more detailed analysis will be requested, by e.g. the government, public or the industry, in the years to come.

Purpose of the project

The future authorities expected cost has up to now been based on deterministic data from joint work within SKI and SSI. The deterministic origin has been a major drawback, since SKB calculates costs based on probabilistic figures. A new approach will help SKI to fully incorporate future cost for supervision by SKI and SSI into the SKB calculation. Hence, this non-deterministic approach for the analysis of the authorities expected cost give newer and better estimates of the total cost structure. The primarily aim of the project was, in this context, to demonstrate that a probabilistic approach also is applicable for the authorities expected costs.

A secondary objective of this study has been to derive a probabilistic estimate of the cost level. Ultimately, a third objective was to measure the level of uncertainty in the authorities expected costs. The level of uncertainty is measured by the standard deviation. Now the derived standard deviation gives SKI a possibility to analyse and present data in a more structured and concrete way, and the work to define an appropriate level of the guarantees will be facilitated.

Results

The report gives estimates on the magnitude of the future cost for supervision, and in conjunction the level of uncertainty gives input to a more accurate basis for calculation of guarantees.

This applied study demonstrates that is accessible to evaluate and predict the future cost for supervision by a probabilistic approach.

Continued work

The report identifies some avenues for future studies. First it may be recommended to develop studies of the differences in future cost levels between Sweden and the rest of the European Union. In particular labour rates and worked hours are items with significant uncertainties. In due course it may be appropriate to assume that the wage level and labour conditions will equalise on a pan-European basis. Such development may have a substantial impact upon the present cost calculation making it to a highly prioritised area of future studies.

In this study a normal monetary approach has been applied with exchange rate conversion to SEK. The effects of the new unified European currency union upon prices and wages has not yet been seen. Nevertheless, it may be anticipated that there will be mitigating external forces derived from reduced exchange-rate fluctuations and more efficient exchange-rate conversions between among other things EURO and USD. In a short time perspective it is also assumed that a more efficient political process may reduce the difference in cost levels between member countries and/or geographical areas within Europe. In the longer run this may contribute to better estimates of the authorities future expected cost for supervision.

Effects on SKI work

SKI will be able to use the conclusions from this study in the ongoing monitoring of the yearly cost estimates presented by the nuclear industry in two ways. Firstly, the present study gives no indication that the previous used estimated cost figure have been too conservative. On the other hand, there is a clear indication on the contrary. Secondly, by this applied study, SKI has got an estimate on the total uncertainty level in the authorities expected cost for supervision. By this SKI would be able to make even better and more accurate estimates for the proposed levels of the guarantees.

Project information

At SKI Staffan Lindskog have been responsible to supervise and co-ordinate the project.

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The general aims of this analysis
The analysis serves two general aims. These are:
(1) To establish a neutral value of the authorities' total expected future costs arising from the decommissioning programme and identify the related uncertainties and their primary sources. The result is measured as a Net Present Value figure (NPV).
(2) To test the suggested procedure under development.

The analysis procedure follows the basics of the suggested estimate procedure[1].

The project and its nature
This analysis deals with a programme of an unusually long duration. The timing itself is highly uncertain. In addition, R & D is still to be finished.

The scope of the analysis and preconditions
I Costs from January 1 2003 arising from all necessary activities of SKI and SSI and which directly or indirectly relate to the decommissioning programme. They include activities at the power plants after the operating period and until the end of the decommissioning period, and similar activities at CLAB and other communal or shared facilities, as well as related administration, R & D, etc.
II Any future 'wage inflation'.
III Events not known today, as well as effects on the programme of minor and medium-scale unplanned events.
IV Effects of major force majeure events are excluded, for example, a serious nuclear accident in Sweden or elsewhere.
V Activities and obligations related to nuclear power plants in operation as well as other applications of nuclear materials (e.g. at hospitals) are excluded from the study.
VI The price level is SEK as at 2002-01-01.
VII The discount factor as recommended by KAFS and used in the present decommissioning funding is also used here. Hence, it operates at an annual rate of 4% until 2020, and 2.5% thereafter.
VIII This analysis is limited to the AUB scenario. The parallel GB estimate can be derived from the results of this estimate, subject to minor adjustments.

Our basic findings

The total Net Present Value is calculated at

Mean Value(M):	2912	MSEK
Standard Deviation (S):	980	MSEK

[1] An estimate procedure for the decommissioning programme as a whole is under development as a research assignment performed for SKI by Lichtenberg & Partners.

Uncertainty Profile:

The main sources of uncertainty are the following:

No	Name	Priority	
1	K3 Redefinition of future wage level	35%	*of overall uncertainty*
2	A Politics, org., share of activities, etc.	17%	
3	D Internationalisation, economy	7%	
4	G Future real interest rate	7%	
5	K4 Unknown activities & unplanned events	6%	
6	B Technological advances	5%	
7	C Permanent storage for long-term waste (SFL)	5%	
8	E Costs of office facilities	2%	
9	F Environment & nature	2%	
10	H1 Evaluation uncertainty	2%	
	All other sources of uncertainty	12%	
		100%	

Primary conclusions

In the light of many years of practical experience, this result can be seen as a neutral, realistic prognosis within the conditions indicated above and further developed in Chapter 1.

The level of uncertainty is rather high for good reasons. It is natural to attempt to reduce this uncertainty. The ‘top-ten list’ shown overleaf indicates the issues on which such efforts should focus.

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Chapter 1
Statement of purpose and the analysis procedure

The analysis serves two general aims

(1) To establish a neutral value of the authorities' total expected future costs arising from the decommissioning programme and identify the related uncertainties and their primary sources. The result is measured as a Net Present Value figure (NPV).
(2) To test the suggested procedure under development.

On the analysis procedure

The basics of the suggested procedure[2] has been followed to ensure a reliable, unbiased and efficient result. It rests on the foundation of the Successive Principle, whose efficiency has been proved over many years. A carefully balanced analysis group has been established. During two analysis sessions, on February 14-15, the group identified and organised all aspects of general uncertainty, then evaluated the durations of and allowances related to activities, using specific procedures for unbiased results. Finally, the total results were calculated from these data, using modern statistical principles.

Analysis participants

No individual member of the analysis group is responsible for the analysis result, as this was established as a group effort. The primary facilitator is responsible for the correct implementation of the procedure. The participants, in alphabetical order, are:

Tuija Grönros, SKI
Bengt Hedberg, SKI
Staffan Lindskog, SKI (analysis sponsor)
Dan Persson, Fortifikationsförvaltningen
Hans Rahm, Professor Emeritus, KTH
Roger Sprimont, independent industrialist
Benny Sundström, SKI
Peter Marks von Würtemberg, Försvarets materielkommando, FMK
and
Steen Lichtenberg, consultant, Lichtenberg and Partners (primary facilitator)
Lorens Borg, consultant, SuccessivPrincipen i Ystad (assistant facilitator)

As the list shows, half of the group members are external to SKI.

[2] The procedure under development as a research assignment.

Chapter 2 On the scope and preconditions of the analysis

On the subject

This analysis deals with a programme, which lasts an unusually long period of time. The timing itself is most uncertain. The estimate will later be integrated into the ongoing process of building up the decommissioning fund (Kärnavfallsfonden). This fact imposed some restrictions on this analysis.

This estimate analysis is limited to the AUB scenario. The parallel GB estimate can be derived from the results of this estimate, subject to minor corrections.

No reductions have been made for the authorities' costs, which may already have been included in SKB's estimate.

All major uncertainties are included, including the future real interest rate, but excluding major force majeure events and a few others indicated below.

Scope: the analysis includes e.g.

(1) Costs from January 1 2003 related to all necessary activities of SKI and SSI, which indirectly or directly relate to the decommissioning programme. They include activities at the power plants after the operating period and until the end of the decommissioning period, and similar activities at CLAB and other communal or shared facilities, as well as the related administration, R & D, etc.
(2) The expected operating periods of the power plants, including Barsebäck 1+2 and expected mothballing periods. Other activities follow the overall timing as suggested by SKB.
(3) Any future 'wage-inflation'.
(4) Events not known today, as well as effects on the programme of minor and medium-scale unplanned events.
(5) Basic research, including studies and experience gained from any 'minor' unplanned events in other countries; administration; and emergency capacity in so far as it relates to the decommissioning programme.
(6) Any future rationalisation potential, and other progress.

Limitations: do not include e.g.

(11) Effects of major force majeure events, such as a serious nuclear accident.
(12) Activities and duties related to nuclear power plants in operation as well as other applications of nuclear materials (e.g. at hospitals).
(13) Emergency services and capacity kept ready for any accident not related to the decommissioning programme.
(14) Resources used by the police and authorities other than SKI and SSI.
(15) Direct costs during the remaining operating periods of the individual power plants.
(16) Possible income, residual value or other capital values.

Other preconditions

(A) The price level is fixed in SEK as at 2002-01-01.
(B) The discount factor as recommended by KAFS and used in the present decommissioning funding is also used here. It will operate at an annual rate of 4% until 2020, and 2.5% thereafter. An uncertainty margin has been added to this discount factor: a minimum of 2.5% for all years, and a maximum of 4.5% for all years.

(C) 40 years' operating period from commercial start for each plant is considered here as an absolute maximum.

A summary of the update of the SKI-PM 99:58 estimate

This analysis	***The base estimate in SKI PM 99:58***
The AUB scenario only	The AUB scenario and the GB scenario
NPV using the discount rate decided by KAFS as a base value	The costs, non-discounted
Operating periods and 'mothballing periods' as expected, including Barsebäck. However, the operating periods are limited to maximum 40 years.	25 years of operation and approx. 5 year-mothballing periods.
Price level as per 2002-01-01.	Price level as per 1999-01-01.
Maximum available workforce on the payrolls, allowing for all sorts of absence.	Net available workforce.
Expected future wage level, incl. consideration of internationalisation, any lack of qualified human resources, etc.	The present wage level estimated at an average gross wage of 560 KSEK + 70 for location + 100 for travel and other costs, totalling 730 KSEK per year per employee.
Necessary activities not known today, as well as unplanned events, are included, except major force majeure events.	Necessary activities not known today, as well as unplanned events, are excluded.
Total costs.	The costs reduced by excluding those already included in SKB's estimate.
All relevant costs from 2003-01-01.	All relevant costs from 2001-01-01.

Major key figures from SKI PM 99:58 in MSEK (1999-01-01)

Power plants	417	
SFR-3	70	
Total, power plants, etc.		487
CLAB	120	
Encapsulation plant	179	
Permanent storage (SFL)	307	
Related R & D	424	
Emergency capacity	81	
Support functions	269	
Information	137	
Total, other facilities		1517
Total, specific activities		2004
Administration & miscellaneous 15 MSEK/yr from 2000 to 2010		150
Total		2154
Total, abbreviated (see page 1 in SKI PM 99:58)		2150

Other useful key figures

(1) The average closing date for the power plants is 2005-07. This represents 25 years of operation.

(2) The related Economic Point of Gravity (EPG) of their decommissioning is 2012-07. (according to scenario 25+5).

(3) The cost of one additional year of mothballing all the reactors is roughly 15 MSEK.

Chapter 3
Identification and organisation of the overall uncertain aspects

Aspects or factors that might have an overall influence on the schedule (for better or for worse) are identified using brainstorming techniques.

In the four following pages the identified keywords are classified into separate groups.
For every group, a base case definition is established as a basis for the subsequent evaluation of the costs individual activities.

The base case definitions are specifically defined to relate directly to the basic key figures from SKI PM 99:58, to allow these figures to be used reliably.

Some ‘best case’ and ‘worst case’ scenarios are then outlined as a basis for the final overall corrections, which transfer the basic result into the preconditions of this analysis. See the two right-hand columns.

Groups/keywords	Base case reference	Opportunities	Potential risks
A POLITICS/ SOCIETY / ORGANISATION/ MANAGEMENT A1 POLITICS/ SOCIETY ❖ General opinion/attitudes/ambition level ❖ Future demand for energy in Scandinavia ❖ The nuclear power rearmament/laws and deals in particular ❖ Interest groups/NGOs/lobbying ❖ Re-prioritising of obligations of authorities ❖ Political pressure and related re-prioritising ❖ The political decision-making process ❖ SKI's tasks/authority/size ❖ Effect of SKI and SSI ❖ Employment issues ❖ Foreign ownership of power plants	• The situation 1996-1999 and implementation of present plans is assumed	• More efficient cooperation or merging SKI and SSI may reduce costs. • Re-definition of energy plans may be advantageous	• Political turbulence may increase the costs • A turbulent political decision-making process
A2 ORGANISATION & MANAGEMENT, SKI ❖ The degree of external assistance ❖ Info/confidentiality policy versus openness ❖ Local inspectors at the plants ❖ Attitudes around authorities ❖ Rationalisation ❖ The repetition effect/effect of large-scale work ❖ The organisation and management of SKI	• Organisation and management as during the period 1996-1999	• Development of new principles of management • Outsourcing • An efficient organisation • Experience/Repetition effect • An efficient information policy	• External expertise may be uncertain • Organisational problems • Low rationalisation and repetition effect due to unique task and organisations • Conflict between confidentiality and openness • High demand for information e.g. re permanent storage
A3 ORGANISATION/ MANAGEMENT, SSI ❖ The organisation and management of SSI ❖ See A2 for other matters	• Organisation and management as during the period 1996-1999	• Outsourcing • An efficient organisation • Experience/Repetition effect • An efficient information policy	• External expertise may be uncertain • Organisational problems • Low rationalisation and repetition effect due to unique task and organisations • Conflict between confidentiality and openness • High demand for information e.g. re permanent storage
A4 WORK SHARING SKI/SSI/SKB ❖ Delegation and sharing of responsibility ❖ Conflicts of interest SKI / SKB ❖ Cooperation SKI / SSI ❖ Principles of control and supervision	• The previous year's share of responsibility is assumed	• Merging SKI and SSI is a two-way uncertainty • The philosophy of supervision is a two-way uncertainty	• Merging SKI and SSI is a two-way uncertainty • The philosophy of control and supervision is a two-way uncertainty

Groups/keywords	Base case reference	Opportunities	Potential risks
B TECHNOLOGY ❖ Delayed SKB programme ❖ The degree of re-establishment ❖ Re-use of power plants ❖ Competition from other types of energy ❖ The quality of the SKB programme ❖ New technology/Technical advances ❖ Principles of decommissioning	• Level of technology during 1996-99 • Decommissioning is assumed to start 8 years after end of operation. Some of these years are a mothballing period • Decommissioning not before 2010 • A 'brown field' clean-up is assumed • SKB plans accepted • No external effects included	• New technology may reduce costs • Technology from other types of energy is a two-way uncertainty • Timing uncertainty in the SKB programme is a two-way uncertainty	• Technological problems • Technology from other types of energy is a two-way uncertainty • Timing uncertainty in the SKB programme is a two-way uncertainty
C PERMANENT STORAGE ❖ Number and locations of storage stations ❖ Technical rock issues/Geology/Hydrology ❖ Rules for acceptance ❖ Permanent depositing of pure material ❖ Delayed acceptance of permanent locations ❖ Municipal versus governmental interests ❖ Schedule/Methods/Solutions ❖ The final choice of location	• Present plans (from 1996-1999) • The localisation problem will, it is assumed, be solved in due time	• Timing and methods are two-way uncertainties • The same applies to rules for acceptance	• The problem of an accepted location • Timing and methods are two-way uncertainties • Rules for acceptance
D INTERNAT. & ECONOMY D1 INTERNATIONALISATION ❖ Business globalisation ❖ Contributions from the EU as well as EU integration ❖ More international cooperation ❖ Effects of other nuclear plants in neighbouring countries	• No particular effects or synergies included	• Cooperation synergy • Use of experience	• Handicapped by other sets of rules • EU may complicate matters • More travel costs due to intensified international cooperation
D2 ECONOMY ❖ Conversion of the fund from SEK to EURO ❖ World economy and political developments	• No consideration of conversion to EURO • The previous year's world economy and political situation will not change significantly	• Economic development is a two-way uncertainty • The same applies to conversion of Swedish currency	• Economic development is a two-way uncertainty • The same applies to conversion of Swedish currency

Groups/keywords	Base case reference	Opportunities	Potential risks
E COSTS OF OFFICE FACILITIES ❖ A more efficient utilisation of office facilities ❖ More home working ❖ Local levels of rent ❖ New working conditions ❖ Relocating SKI outside the city centre	• Cost of office facilities assumed to be 70,000 SEK per person per annum on average • Present location and working conditions assumed • Costs of travel, IT, etc. assumed to be 100,000 SEK per person per annum on average	• New working practices may reduce the demand for office facilities • New locations may reduce the costs • The same applies to increase home working	• The general level of rent rates may increase. It may even have been underestimated
F ENVIRONMENTAL ISSUES ❖ Attitude toward environmental issues ❖ Environmental and other NGO groups ❖ Global warming/The sea level	• Environmental legislation during the period 1996-1999 is assumed to be in force • No particular consideration of changed laws or attitudes	• The energy issue may dominate increasingly in future compared to environmental issues	• More focus on environmental issues may increase costs • Heavier workload due to augmented duties • Possible ‘green field’ demands
G THE REAL INTEREST RATE ❖ Inflation ❖ Investment policy	• The real interest rate indicated by KAFS, 4% per annum until 2020, and 2.5% per annum thereafter	• The real interest rate may vary from 2.5% to 4.5%	• The average real interest rate may vary both ways.
H ANALYSIS-SPECIFIC UNCERTAINTIES H1 UNCERTAINTY IN EVALUATIONS	• Neutrality assumed	• Uncertainty in the evaluations is a two-way uncertainty	• Uncertainty in the evaluations is a two-way uncertainty
H2 THE QUALITY OF THE BASIC FIGURES ❖ Precautionary principles and errors ❖ Overlap/omissions, misunderstandings	• Best estimate without special attention to uncertainties, in other words aimed at realism or neutrality, but clearly related to the planning scenario called ‘25+5’ • The situation in 1999 • No errors assumed	• Bias in the basic figures is a two-way uncertainty	• Bias in the basic figures is a two-way uncertainty
H3 THE SYSTEMATIC EFFECT OF LARGE MAXIMUM VALUES	• No effect included	• A typical upward bias may cause a reduction	
H4 REMAINING STATISTICAL DEPENDENCY	• No effect included	• A minor symmetrical uncertainty is most likely	• A minor symmetrical uncertainty is most likely

Groups/keywords	Base case reference	Opportunities	Potential risks
J TIMING OF THE DECOMMISSIONING The length of the operating period The length of the mothballing period	• Scenario 25 + 5 years and SKB's plan	• Scenario representing the earliest possible, the most likely and the latest possible timing • Most likely a longer operating period • Possibly a longer mothballing period	
K UPDATING THE BASIC FIGURES K1 PRICE INDEX AND INFLATION	• 1999-01-01 price index and the official inflation index included in the discount factor	• A higher productivity may be achieved • Inflation may fall	• 2.5% annual inflation included up to 2002-01-01 • Additional inflation in relevant sectors may occur
K2 REDEFINING DEMAND FOR WORKFORCE	• The net demand for human resources		• Gross demand allowing for all sorts of absence
K3 REDEFINING THE WAGE LEVEL	• The current wage level		• The future wage level may be higher • A working week of 35 hours may increase costs • Wage levels in the EU, which may be higher than in Sweden, may drive the Swedish wage levels considerably upwards
K4 UNKNOWN ACTIVIES AND UNPLANNED EVENTS Activities unknown today Unplanned events	• Only activities known today are included • No unplanned events are included		• Some unknown activities and unplanned events are foreseen

Chapter 4 Quantification

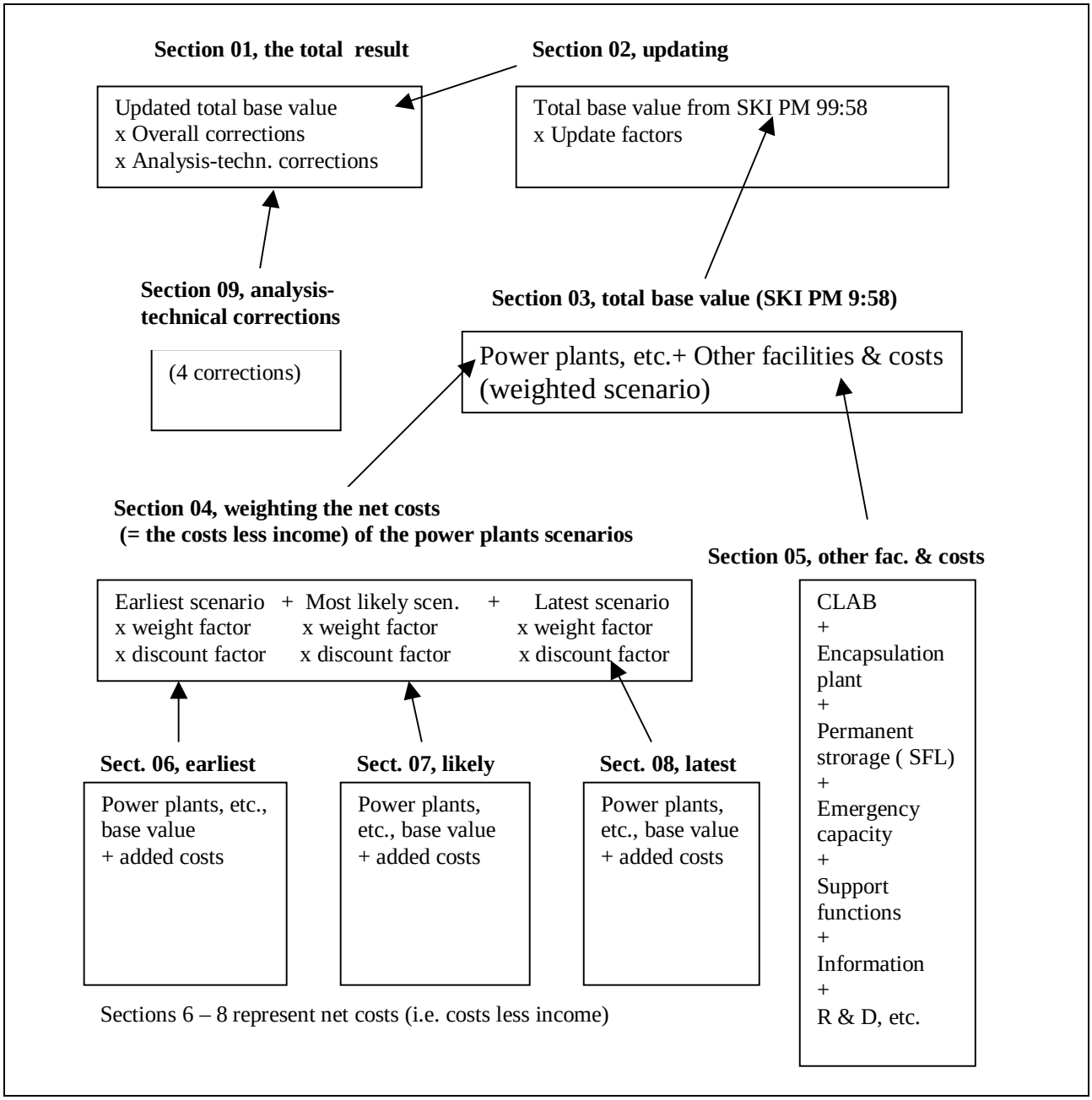
General comments

This chapter deals with the calculation structure, the analysis group's relevant quantitative evaluations, and the statistical calculations of the result.

The result is a Net Present Value. That requires discounting of the various cost and income items, which generally covers several years. Instead of the classical discounting of every ear´s cost or income, we operate with the total cost or income, which is discounted from the Economical Point of Gravity, EPG, of the cash flow. This leads to the same mean value as the classical method and it allows a more correct handling of the uncertainty.

The calculation structure

The calculation structure is hierarchical. The complete system for analysing the programme is presented in the diagram below.



The top section, 01, yields the total resulting Net Present Value or NPV. Each section consists of one or more items to be added together. Each item may either be evaluated directly or be a product of two or more factors: typically ‘cost’ x ‘a discount factor’ or ‘base value’ x ‘a correction factor’ expressed as a percentage.

Every item or factor may be specified in an underlying calculation section with sub-items and related factors. The sum of items in a section is finally transferred up to the related higher level section, where it replaces the former figure of the original item or factor. This transfer is continued up to the very top section.

The calculation sections are numbered 01, 02, etc., while items are numbered 10, 20, 30, etc. (if necessary 5, 10, 15, etc.). Factors are indicated with an ‘*’. Letters A, B, C, etc. are used to indicate overall correction factors. They generally correspond to the groups A, B, C in chapter 3.

Sections 01 – 05 all represent NPV figures, while the calculation sections 06 – 08 represent non-discounted costs. The latter are transferred to and discounted in section 04.

The structure seeks to allow independent items and factors to be established, as this is a prerequisite for a correct yet simple statistical calculation. Further, it is structured so as to allow correction factors of overall uncertainty to be allocated appropriately.

The structure in greater detail

Section 01 The total NPV
The result is calculated from the updated base value (transferred from section 02) multiplied by a set of percentage corrections for the future real interest rate and the other previously defined overall factors, A,, B, C, etc. The uncertainty from the overall timing is recorded as an item here.

Section 02 Updating from SKI PM 99:58 (NPV)
This result is calculated as the total basic NPV from section 03 inflated from 1999 to 2002 and multiplied by other relevant updating factors concerning workforce, wage levels, etc. See the preconditions of this analysis in Chapter 2.

Section 03 The total base value (NPV)
This section adds together the NPV from the power plants and other facilities and costs directly linked to power plants (transferred from section 04) with the NPV from other facilities (transferred from section 05). The reason to separate the plants from other facilities is the timing uncertainty related to the plants.

Section 04 Weighting of the various power plant scenarios
The existing timing uncertainty is accounted for here. The triple estimate theory is used to calculate a sufficiently correct mean value. It is based on the theoretical weighting factors 20%, 60%, and 20% for the extreme earliest, the most likely, the extreme latest scenarios respectively. The total costs of these three specific scenarios are transferred from sections 06, 07 and 08. The group evaluated for each of these three scenarios the ‘average point of time’ for these costs. From this, a discount factor is derived. In this section the correct mean scenario is derived. However, the related contribution to the total uncertainty has to be derived separately in section 01.

In conclusion, the sum = 0.20 x NPV for the ‘earliest scenario’ + 0.60 x NPV for the ‘most likely scenario’ + 0.20 x NPV for the latest scenario.

Section 05 NPV from all other facilities, and costs (except SFR which belongs to Section 04)
This section adds together the costs of CLAB, encapsulation plant, permanent storage, SFL, emergency capacity, support functions, information, fund administration, other functions and finally related R & D. Every item is discounted according to its specific cash flow.

Overall uncertainties
The set of grouped overall uncertainties has been established during the first session. See chapter 3. The majority of these have been evaluated as a group triple estimate. The figures are percentages of the total values, in some cases as a percentage of the relevant share of the total, e.g. the wage costs. However a few of these sources of uncertainty have been derived in another manner. This is further developed below.

The uncertainty arising from the discount factor
The two extreme values of the discount factor (see chapter 2) have been used to discount all items in the following manner: two alternative copies of the total calculation are produced, one with the evaluated minimum discount factor, and the other using the maximum discount factor. Together with the 'normal' result (which is considered to be most likely here) the three results are recorded in section 01 as corrections to the total net cost (i.e. the costs less the income) expressed in percentage terms.

The uncertainty arising from the timing of the programme
This source is based on the differences in MSEK between the discounted costs of the earliest and the latest scenario in section 04.

Evaluations
Several steps have been taken in order to minimise bias. The analysis group is composed with this consideration among others in mind. In addition, every evaluation is made as a wholly personal matter, without the risk of outside influence. The collection and handling of the evaluated figures also rely on sub-routines in order to avoid bias and to provide the basis for neutral and 'healthy' results. Finally, all evaluations are made as conditional triple estimates under 'all other matters equal'. This will further safeguard against statistical dependencies.

Calculations
Uncertain values are evaluated here while using the so-called 'group triple estimate technique', which is a further development of the classic triple estimate method. Each member of the analysis group evaluates both the extreme highest and the lowest values of the uncertain value followed by an evaluation of the most likely value. The most extreme values in the group and an average of the most likely values provide the basis for the final triple estimate.

The mean value is then derived from this final triple estimate as a weighted sum of the three figures. The weightings are 20%, 60% and 20%. These weightings are based on scientific studies of the relevance of the various known statistical distribution functions (the normal distribution, the Beta distribution, the triangular distribution, etc.). These studies have shown the Erlang function to be the most relevant for calculation tasks like this.[3]

The mean values are then used as normal deterministic values. The conditional standard deviation of each local uncertainty is calculated. The related conditional effect on the total result is then calculated. The total sum of variances of these last-mentioned figures equals, with a good approximation, the uncertainty of the result. For further information on the calculation rules, see the literature on the Successive Principle.

[3] The classic use of the Erlang function is to measure the capacity of a telephone cable.

The estimates

Section 01, Total NPV (MSEK): Mean value and std. dev.: 2912+/- 981

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Total costs before MSEK-corrections**			**2911**	
	* Updated base value				
	(See section 02)	**MSEK**	**2,266**		
	* A Politics, org., share of activities, etc.				
	0.85 / 1.1 / 1.6	%	1.151		17%
	* B Technological advances				
	0.85 / 1.02 / 1.2	%	1.022		5%
	* C Permanent storage				
	0.92 / 1.1 / 1.3	%	1.104		5%
	* D Internationalisation, economy				
	0.8 / 1.04 / 1.22	%	1.028		7%
	* E Costs of office facilities				
	0.95 / 1.02 / 1.15	%	1.032		2%
	* F Environment				
	0.95 / 1.05 / 1.2	%	1.060		2%
	* G Future real interest rate				
	0.87 / 1 / 1.3	%	1.035		7%
	* H Analysis-specific uncertainty				
	(See section 09)	**%**	**0.850**		
20	**J uncertainty about the timing of plant decommissioning**			**0**	
	-27 / 0 / 27	MSEK	0,000		0%

Comments:

01/10A Politics, etc.
The figures x/y/z here and below refer to section 3, Overall uncertainties. They indicate the effect on the result, which potential deviations from the base case preconditions may have. For example, 0.85 means not more than a 15% reduction, while 1.6 means not more than 60% higher.

01/20 Uncertainty about the timing of plant decommissioning
The total range of difference between the earliest and the latest scenario is derived at 54 MSEK (measured as a NPV). It is inserted here as +/- 27 MSEK. This result is drawn from the difference between 1009 MSEK x 0.435 = 439 MSEK in item 05/30 as the maximum value, and 601 MSEK x 0. 64 = 385 MSEK in item 05/10 as the minimum value. Both figures refer to the NPV of the two extreme scenarios.

Section 02, Updated base value (NPV) (MSEK): Mean value and std. Dev.: 2266+/- 639

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Base value updated**			**2,266**	
	* Base value from SKI-PM 99:58				
	(See section 03)	**MSEK**	**1,219**		
	* K1 Price level update 1999 to 2002				
	1.03 / 1.075 / 1.12	%	1.075		0%
	* K2 Re-def. net to gross workforce				
	1.1 / 1.14 / 1.23	%	1.150		1%
	* K3 Re-def. to future wage level				
	0.92 / 1.4 / 2.3	%	1.486		35%
	* K4 Unknown act. & unplanned events				
	0.8 / 1.02 / 1.2	%	1.012		6%

Comments:

02/10 Base value updated

See the preconditions in chapter 2.

02/20 Re-definition of net to gross workforce

The base case preconditions operate with an available workforce. This is transformed here into workforce on the payroll, allowing for all sorts of absence. Only an approximate figure for total workforce costs is required because the dominating uncertainty is the degree of absence. The analysis group evaluated this at 15%, 19% and 30% of the net workforce needed. As the wage costs are only a 75% share, the figures are reduced accordingly, as shown above.

Section 03, Base value (NPV) from SKI-PM 99:58 (MSEK):
Mean value and std. dev.: 1219+/- 38

Item	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Power plants + SFR (See section 04)**	MSEK		396	
20	**Other facilities and costs (See section 05)**	MSEK		824	

Comments:
This section of the estimate adds together the two different groups of activities. The first, see item 10, consists of all activities, which definitively depend on the length of the remaining operating period and the length of the mothballing period. They are therefore dependent on the considerable uncertainty in the timing. The other item (item 20) covers all activities, which are more or less unaffected by this uncertainty relating to timing.

The figure in item 10 represents the weighted scenario; see the notes on section 04.

Section 04, weighted scenario of power plants, etc. (NPV), (MSEK):
Mean value and std. dev.: 396+/- 25

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Power plants, etc., shortest scenario**			**77**	
	* Total costs, powerpl. etc., shortest scenario				
	(See section 06)	**MSEK**	**601,500**		
	* Weighting factor				
	/ 0.2 /	%	0.200		0%
	* Discount factor				
	0.62 / 0.64 / 0.66	%	0.640		0%
20	**Power plants, etc., likely scenario**			**231**	
	* Total costs, powerpl., etc., likely scenario				
	(See section 07)	**MSEK**	**836,340**		
	* Weighting factor				
	/ 0.6 /	%	0.600		0%
	* Discount factor				
	0.43 / 0.46 / 0.49	%	0.460		0%
30	**Power plants, etc., longest scenario**			**88**	
	* Powerpl., etc., longest scenario				
	(See section 08)	**MSEK**	**1,009,300**		
	* Weighting factor				
	/ 0.2 /	%	0.200		0%
	* Discount factor				
	0.42 / 0.435 / 0.45	%	0.435		0%

Comments:
In this section the expected scenario is derived through a weighting between the NPV of the extreme earliest scenario, the most likely, and the extreme latest. Note that in this analysis, as a precondition, the extreme longest operating period is defined as 40 years.

The weighting factors 20, 60 and 20% respectively for the above three scenarios, according to the Bayesian statistical theory, are the factors which produce the mean value or the expected value.

See also 01/20 for the related uncertainty.

The input values in this section represent the costs. Here, they are transferred into NPVs, using the discount factor for the ‘Economical Point of Gravity’, EPG. This is evaluated on the basis of corresponding existing cash flows.

Section 05, other facil. & costs (NPV) (MSEK): Mean value and std. dev.: 824+/- 29

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**CLAB**			**56**	
	* Total costs / 120 /	MSEK	120,000		0%
	* Discount factor				
	0.44 / 0.46 / 0.5	%	0.464		0%
20	**Encapsulation plant**			**83**	
	* Total costs / 179 /	MSEK	179,000		0%
	* Discount factor				
	0.43 / 0.46 / 0.5	%	0.462		0%
30	**Permanent storage, SFL**			**132**	
	* Total costs				
	/ 307 /	MSEK	307,000		0%
	* Discount factor				
	0.4 / 0.43 / 0.46	%	0.430		0%
40	**Related emergency capacity**			**46**	
	* Total costs				
	/ 81 /	MSEK	81,000		0%
	* Discount factor				
	0.45 / 0.57 / 0.69	MSEK	0,570		0%
50	**Support functions**			**125**	
	* Total costs				
	/ 269 /	MSEK	269,000		0%
	* Discount factor				
	0.43 / 0.46 / 0.52	%	0.466		0%
60	**Information**			**62**	
	* Total costs				
	/ 137 /	MSEK	137,000		0%
	* Discount factor				
	0.42 / 0.45 / 0.48	%	0.450		0%
70	**Fund administration**			**99**	
	* Annual costs				
	/ 5 /	MSEK/yr	5,000		0%
	* No. of years				
	45 / 50 / 60	Yr	51,020		0%
	* Discount factor				
	0.37 / 0.39 / 0.41	%	0.390		0%
80	**R & D related to the programme**			**220**	
	* Total costs				
	/ 424 /	MSEK	424,000		0%
	* Discount factor				
	0,49 / 0,52 / 0,55	%	0.520		0%

Comments:

This section collects the costs of the various activities and related costs, which are more or less independent of the previously indicated timing for the plants. Each cost item is discounted here, and the existing cash flow is used in evaluating the 'Economical Point of Gravity', EPG, of each activity.

Section 06, total costs, power plants, etc., earliest scenario (MSEK):
Mean value and std. dev.: 602+/- 1.5

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Base costs, 25+5 scenario**	MSEK		**487**	
30	**Added costs relative to 7.3 yr mothballing period**			**35**	
	* Annual costs				
	10 / 15 / 20	MSEK/yr	15,000		0%
	* No. of additional years				
	/ 2.3 /	yr	2,300		0%
40	**Miscellaneous costs**			**80**	
	* Annual costs				
	/ 10 /	MSEK	10,000		0%
	* Period 2003 - 10				
	/ 8 /	yr	8,000		0%

Comments:
This section adds together the costs related to this specific scenario.

06/10 Base costs, the 25+5 scenario
This item represents the cost of the existing basic scenario, called ‘25+5’ (25 years of operation and a 5 year-mothballing period). It is the sum of 417 MSEK, related to the plants, and 70 MSEK related to SFR-3.

06/30 Added costs relative to 7.3 years mothballing period
This item derives the mean value of the additional cost for the additional 2-3 year-mothballing period, which the analysis group evaluated as a mean value.

06/40 Miscellaneous costs
This item covers miscellaneous costs of approx. 10 MSEK/year, which are deemed necessary until the last plant finishes its operating period. The cost of fund administration is deducted at a rate of 5 MSEK/year and allocated to 05/70.

Section 07, Total costs, power plants, etc., likely scenario (MSEK):
Mean value and std. dev.: 836+/- 17.1

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Base costs, 25+5 scenario**	MSEK		**487**	
20	**Extra costs arising from additional waste (37+9.5 scenario)**			**72**	
	* More waste due to 12,3 yr longer period				
	0 / 80 / 120	MSEK/yr	71,837		0%
30	**Add costs due to 4.5 yr longer mothballing period**			**68**	
	* Annual costs				
	10 / 15 / 20	MSEK/yr	15,000		0%
	* No. of added years				
	/ 4.5 /	yr	4,500		0%
40	**Miscellaneous & other costs**			**210**	
	* Annual costs				
	/ 10 /	MSEK/yr	10,000		0%
	* Period 2003 - 23				
	/ 21 /	yr	21,000		0%

Comments:
This section adds together the costs related to this specific scenario. It is analogue to section 06, except for item 20; see the following item.

07/20 Extra costs arising from additional waste
An operating period of 12 years longer than in the “earliest scenario” generates correspondingly more waste. The resulting additional processing costs have been evaluated directly as shown.

Section 08, total costs, power plants, etc, latest scenario (MSEK):
Mean value and std. dev.: 1,009+/- 8,7

Item/factor	Min/Most Likely/Max	Unit	Factor Mean	Item Mean	Prio%
10	**Base costs, 25+5 scenario**	MSEK		**487**	
20	**Extra costs arising from additional waste (40+18.5 scenario)**			**90**	
	* More waste due to 13.5 years longer operation period				
	0 / 100 / 150	MSEK	89,796		0%
30	**Additional costs due to longer mothballing period**			**203**	
	* Annual costs				
	10 / 15 / 20	MSEK/yr	15,000		0%
	* No. of years				
	/ 13.5 /	yr	13,500		0%
40	**Miscellaneous & other costs**			**230**	
	* Annual costs				
	/ 10 /	MSEK/yr	10,000		0%
	* Period 2003 - 25				
	/ 23 /	yr	23,000		0%

Comments:
This section adds together the costs related to this specific scenario. It is analogue to section 07.

Section 09, H Analysis-specific uncertainty in %: Mean value and std. dev.: 0.85+/- 239

Min/Most Likely/Max Factor	Unit	Factor Mean	Item Mean	Prio%
Aggregated value			**0,85**	
* H1 Evaluation uncertainty				
0.9 / 1 / 1.1	%	1.000		2%
* H2 Uncert. in PM 99:58 fig.				
0.9 / 1 / 1.1	%	1.000		2%
* H3 Effect of max values				
0.75 / 0.85 / 0.95	%	0.850		2%
* H4 Remaining dependencies				
0.95 / 1 / 1.05	%	1.000		0%

Comments:
This final section adds together the uncertainties related to the analysis procedure itself.

The first factor takes into account any possible remaining general optimism or pessimism in the group as a whole.

The second factor deals with the aggregated effect of any minor errors, misunderstandings, double counting or omissions, etc.

The third factor makes a correction for the many maximum values, which at this early stage of the programme are extraordinarily high. These maximum values have a definite effect on the mean value, which therefore needs to be reduced in order to cover the part related to the present extra orderly lack of information.

Let factor 01/10A be an example. A symmetrical version would be 0.85/1.10/1.35. However, it is skewed upwards as the maximum value is 1.60, or 0.25 greater than 1.35. This skewness raises the mean value by a factor of 20% or 0.20 x 25% = 5%. Part of the maximum value is a normal, natural uncertainty, but a part is attributable to a significant lack of information at this early stage of the programme. Other factors are also more or less skewed upwards, partly for the same reason: not least e.g.1/10C and G, as well as 02/10B, but also some more minor skew items. This adds up to a systematic error in the form of too high a mean value. Together it is calculated that the mean value needs a reduction of the order of 15%. This is introduced into the estimate as factor H3, a correction for the effect of excessively high maximum values, as 0.75/0.85/0.95.

The fourth and last factor reflects a marginal effect of remaining dependencies. Basically, the procedure as a whole results in a large degree of independence. However, items and factors cannot be completely without a certain level of mutual dependency. Again, this can be transferred to a symmetrical uncertainty as the H4 factor demonstrates.

Chapter 5 Results and conclusions

Summary:

The total Net Present Value is calculated as

Mean Value(M):	2912	MSEK
Standard Deviation (S):	980	MSEK

Uncertainty Profile:

The main sources of uncertainty are the following:

No	Name	Priority	
1	K3 Adjustment for future wage level	35%	*of overall uncertainty*
2	A Politics, org., share of activities, etc.	17%	
3	D Internationalisation, economy	7%	
4	G Future real interest rate	7%	
5	K4 Unknown act. & unplanned events	6%	
6	B Technological advances	5%	
7	C Permanent storage (SFL)	5%	
8	E Costs of office facilities	2%	
9	F Environmental & nature	2%	
10	H1 Evaluation uncertainty	2%	

Final conclusions

In the light of many years of practical experience this result can be seen as a neutral, realistic prognosis within the conditions outlined in section 2.

The level of uncertainty is for natural reasons rather high. It is natural to attempt to reduce this uncertainty. The ‘top-ten list’ shown overleaf indicates the issues on which such efforts should focus.

The test applied to the level of the authorities’ future costs gives an estimate of 2.9 billion SEK in the price level of January 1 2002. There is still a considerable uncertainty, which is expressed by the standard deviation of nearly 1 billion SEK.

Continued examination of the results identifies two items as the cause of more than half of the uncertainty. Uncertainty as to the scale of future rises in wage levels necessitates more in-depth research into future wage levels in Europe.

The difference between a 50% and a 90% level of confidence is 1265 million SEK. It is essential to define this amount since it may be seen as equivalent to the uncertainty for unplanned events. The reserve in respect of safety should therefore be increased by around 1.2 billion.

Future research
Studies of the future cost of skilled workforce in Europe need to be carried out in order to better understand the future government costs.

It would also be advisable to find better ways of predicting changes in interest rates.

Some concluding remarks
It has been demonstrated that the Successive Principle offers a way of calculating the future government agencies' costs. The model seems to be robust and objective and therefore appropriate for very complex capital budgeting issues.

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List of Abbreviations.

AUB - (in Swedish, Avgiftsunderlagsbeloppet)
A value that gives the total estimated expense for the Swedish programme for managing all nuclear waste and dismantling nuclear power plants. This value shall include all measures that have to be undertaken after that the reactors has served their economic life span of 25 years. According to the law this cost ought to be calculated based upon the most probable future scenario, i.e. the base case that describes all measures that needs to be undertaken for the final solution of the waste and the decommissioning of the nuclear power plants.

CLAB - Central Interim Storage Facility for Spent Nuclear Fuel
The spent fuel elements are transported, by ship, in specially designed containers. These containers are stored at CLAB in fuel pools for approximately 40 years. During this time-span the radioactivity diminishes and less heat is released.

EPG - Economical Point of Gravity
A technical term used in capital budgeting to express an estimate of the shape of the payment streams. The EPG is an estimate for the middle point of all disbursements and incomes scattered over time.

FMK - (in Swedish, Försvarets Materielverk), Swedish Defence Materiel Administration

Fortifikationsförvaltningen, The Swedish administration of Military Installations

GB - (in Swedish, Grundbeloppet)
An estimated amount of all future costs that will prevail if, and only if, the Swedish nuclear power programme was curtained. This amount is only applicable for the actual date when the calculation was made, e.g. this amount describes the total cost for a decision to stop the program instantaneously.

KAFS - (in Swedish, Kärnavfallsfondens styrelse) – The Board of the Swedish Nuclear Waste Fund
Since 1996, the Board of the Swedish Nuclear Waste Fund has been responsible for the administration of the accumulated funds.

NPV - Net Present Value (in Swedish, nuvärde)
NPV is a technical term that is used in capital budgeting to describe total discounted value of all income and disbursements that an investment or activity gives. In other words, net present value is a measure of how much value is created or added today by undertaking an investment.

KTH – (in Swedish, Kungliga Tekniska Högskolen) The Royal Technical University, Stockholm

PLAN process
The concept PLAN process is used to describe the yearly activity to analyse and calculate the future cost for the final solution of the waste and the decommissioning of the nuclear power plants for the Swedish nuclear power programme. The aim of this process is to find an optimal level of the fees for the Board of the Swedish Nuclear Waste Fund.

SEK - Swedish Crowns - (in Swedish, Svenska Kronor)
Crowns is an ancient currency still in use as a local currency in some remote regions of Europe (please also compare Danish Crowns (DKK), Norwegian Crowns (NOK). At present the value of one SEK is equal to 0.1 EURO (10 European cents).

SFL - or more correct SFL 3 – 5
A planned facility for permanent storage of lows and intermediates level waste.

SKB - Swedish Nuclear Fuel and Waste Management Company (in Swedish, Svensk Kärnbränslehantering AB)
Common abbreviation for Svensk Kärnbränslehantering AB that is a commercial company under the Swedish Company Act that is jointly owned by the Swedish nuclear industry. The reactor owner owns all the shares and it is a non-public company.

SKI - (in Swedish, Statens Kärnkraftinspektion), Swedish Nuclear Power Inspectorate

SSI - (in Swedish, Statens Strålskyddsinstitut), Swedish Radiation Protection Institute

Successive Principle
An analysis methodology, which is specially designed to calculate and describe complex projects. The method may best be described as a non-deterministic approach that is based upon the use of Baysian statistical analysis. The aim of the method may be summarised as to derive a neutral, or objective, quantitative result in spite of uncertain input figures.

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