

SKB

**TECHNICAL
REPORT**

94-23

PLAN 94

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

Swedish Nuclear Fuel and Waste Management Co.

June 1994

SVENSK KÄRNBRÄNSLEHANTERING AB

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PLAN 94

COSTS FOR MANAGEMENT OF THE RADIOACTIVE WASTE FROM NUCLEAR POWER PRODUCTION

Swedish Nuclear Fuel and Waste Management Co.

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Information on SKB technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01), 1985 (TR 85-20), 1986 (TR 86-31), 1987 (TR 87-33), 1988 (TR 88-32), 1989 (TR 89-40), 1990 (TR 90-46), 1991 (TR 91-64), 1992 (TR 92-46) and 1993 (TR 93-34) is available through SKB.

PLAN 94

Costs for Management of the Radioactive waste from Nuclear Power Production

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June 1994

Keywords: Swedish waste management programme, costs and financing, back-end costs

ABSTRACT

SKB prepares every year, on behalf of the nuclear power utilities, a calculation of the costs for all the measures that are required to manage the spent nuclear fuel from the reactors and the radioactive waste deriving from it and to decommission and dismantle the reactor plants. The cost calculation is submitted to the Nuclear Power Inspectorate (SKI). SKI uses this as a basis for calculating a proposal for the fee for management of the radioactive waste products of nuclear power that is levied on nuclear-generated electricity.

The calculation, which is based on specific scenarios for energy production, waste quantities and required measures, are presented in annually issued reports, the last one PLAN 94, dated June 1994.

PLAN 93 /ref. 7/ was a comprehensive report giving an overview of the Swedish radioactive waste management system. The 1994 status regarding general premises, facilities, systems, RD&D, etc., differs only slightly from 1993, and the present English edition of PLAN 94 has therefore been reduced to include only an updated set of those tables and other significant data that were included in PLAN 93. The reader is kindly advised to consider the present report as an addendum to PLAN 93.

SAMMANFATTNING

SKB upprättar varje år, på uppdrag av kärnkraftföretagen, en beräkning över kostnaderna för samtliga åtgärder som behövs för att omhänderta använt kärnbränsle och radioaktivt avfall från de svenska kärnreaktorerna. Kostnadsberäkningen redovisas till statens kärnkraftsinspektion (SKI) som har att föreslå regeringen den avgift för omhändertagandet av kärnkraftens radioaktiva restprodukter, som skall uttagas på kärnkraftproducerad el.

Kostnadsberäkningen, som är baserad på specifika scenarios för elkraftproduktionen, avfallsmängder och vilka åtgärder som måste vidtagas, presenteras årligen, den senaste rapporten, PLAN 94, är daterad juni 1994.

PLAN 93 /ref. 7/ utgjorde en omfattande beskrivning av det svenska avfallssystemet. Förutsättningarna för PLAN 94 avviker endast marginellt från förutsättningarna i PLAN 93. Av denna anledning har den engelska utgåvan av PLAN 94 begränsats till att innefatta en uppdatering av kostnadstabeller och andra viktiga data vilka är justerade jämfört med PLAN 93. Denna rapport skall enbart betraktas som ett tillägg till PLAN 93.

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ABBREVIATIONS

BWR	Boiling water reactor (ABB-ATOM)
CLAB	Central interim storage facility for spent nuclear fuel
RD&D	Research, development and demonstration
GA	Common facilities
GD	Common parts of a facility
NPP	Nuclear power station
PWR	Pressurized water reactor (Westinghouse)
SFL	Deep repository for long-lived waste
SFL 2	- for spent nuclear fuel
SFL 3	- for long-lived waste from Studsvik and certain operating waste from CLAB (as from 2012) and the encapsulation station
SFL 4	- for decommissioning waste from CLAB and ES
SFL 5	- for core components etc
SFR 1	Final repository for radioactive waste from reactor operation
SFR 3	Final repository for decommissioning waste
SKI	Swedish Nuclear Power Inspectorate
SKB	Swedish Nuclear Fuel and Waste Management Co
SSI	Swedish Radiation Protection Institute

1. ENERGY PRODUCTION AND WASTE QUANTITIES

Energy production in the Swedish nuclear power plants totalled 59 TWh in 1993, which corresponds to an average energy utilization factor of 67%. The average energy utilization factor in 1992 was 71% and in 1991 84%. The relatively low utilization factors for 1992 and 1993 depend on the fact that five reactors were shut down for retrofitting during late 1992 and early 1993. Furthermore, the supply of electricity from hydropower was abundant during 1993.

The electricity production in the nuclear power plants has been estimated to reach a total of 2 000 TWh by the year 2010. The corresponding fuel consumption is approximately 7 810 tonnes of uranium, of which 6 020 from BWR and 1 790 from PWR.

Electricity generation and fuel consumption are summarized in Table 1.1.

Table 1.2 compares electricity generation and fuel consumption for operation until year 2010 (an average operating period of about 30 years) with the cases covering an operation time of 25 or 40 years respectively.

Table 1.1 Electricity production and fuel consumption for the Swedish nuclear power plants.

Reactor and date of commercial operation	Thermal capacity (MW)	Net electrical capacity (MW)	Energy production (TWh)			Uranium consumption (ton U)	
			through 1993	annually from 1994	Total	Discharged through 1993	Total
B1 1975-07-01	1,800	600	70.3	4.1	140	285	600
B2 1977-07-01	1,800	600	65.7	4.1	140	239	560
R1 1976-01-01	2,500	800	78.0	5.5	170	252	700
R2 1975-05-01	2,570	870	79.8	5.6	170	243	620
R3 1981-09-09	2,780	920	67.5	5.9	170	188	590
R4 1983-11-21	2,780	920	64.5	5.9	160	188	580
O1 1972-02-06	1,375	440	56.0	3.0	110	238	500
O2 1974-12-15	1,800	600	72.5	4.1	140	269	590
O3 1985-08-15	3,300	1,160	67.6	7.9	200	181	750
F1 1980-12-10	2,930	970	86.3	6.6	200	280	800
F2 1981-07-07	2,930	970	80.3	6.6	190	252	760
F3 1985-08-22	3,300	1,150	67.5	7.9	200	180	750
BWR total	21,735	7,300	644.1	49.9	1,490	2,176	6,020
PWR total	8,130	2,710	211.9	17.3	510	619	1,790
All	29,865	10,010	855.9	67.3	2,000	2,795	7,810

Energy utilization factor for BWR = 0.78 Burnup for BWR: 38 MWd/kgU
 Energy utilization factor for PWR = 0.73 Burnup for PWR: 41 MWd/kgU

Table 1.2 Electricity production and fuel consumption for the three calculated alternatives.

Calculated case	Total energy production (TWh)	Total uranium consumption (ton U)
I. Operation up to and included 2010	2,000	7,810
II. Operation 25 years of all reactors	1,610	6,510
III. Operation 40 years of all reactors	2,620	9,860

In addition to spent fuel, the Swedish nuclear power programme gives rise to low and intermediate-level operational waste from the nuclear power reactors, CLAB and the encapsulation plant. When the plants are dismantled decommissioning waste arises. Estimated waste quantities are summarized in Table 1.3. Table 1.4 shows how the waste quantities vary for the different calculated cases. The activity content of the different waste types varies widely. The handling and disposal requirements will therefore be dependent on waste type.

Table 1.3 Main types of radioactive waste products to be disposed of

Product	Principle origin	Unit	No. of units	Volume in final repository (m ³)
Spent fuel		canisters	4,500	13,400
α -contaminated waste	Low- and intermediate level from Studsvik	drums and moulds	2,800	1,700
Core components	Reactor internals	moulds	1,400	9,600
Low- and intermediate level waste	Operational waste from NPPs and other nuclear facilities	drums and moulds	56,000	91,000
Decommissioning waste	From decommissioning of NPPs and other nuclear facilities	10-20 m ³ containers	8,500	156,400
Total quantity			73,200	272,100

Table 1.4 Comparison of waste quantities for the calculated alternatives

Product	Operation through 2010 Volume in final repository (m ³)	Operation 25 years Volume in final repository (m ³)	Operation 40 years Volume in final repository (m ³)
Spent fuel	13,400	10,700	17,900
α -contaminated waste	1,700	1,700	1,700
Core components	9,600	9,500	9,600
Low- and inter- mediate level waste	91,000	76,400	116,000
Decommissioning waste	156,400	155,400	157,200
Total quantity	272,100	253,700	302,400

2. FACILITIES AND SYSTEMS

To handle and dispose of the radioactive waste products in Sweden, a number of facilities have to be planned, built and operated. A scenario has been established as a basis for the cost calculations.

Figure 2.1 shows which facilities are included in the system and their operating periods and how the waste products are planned to be handled. Some of the facilities are in operation, e.g. CLAB, SFR1 and the transportation system, which provide a good basis for the cost calculations. In the case of future facilities, the final design has not yet been chosen. However, as a basis for the cost calculations, a possible waste handling scheme has been described in detail and tentative layout drawings have been prepared.

Figure 2.2 illustrates the deep repository, which is one of the major future facilities.

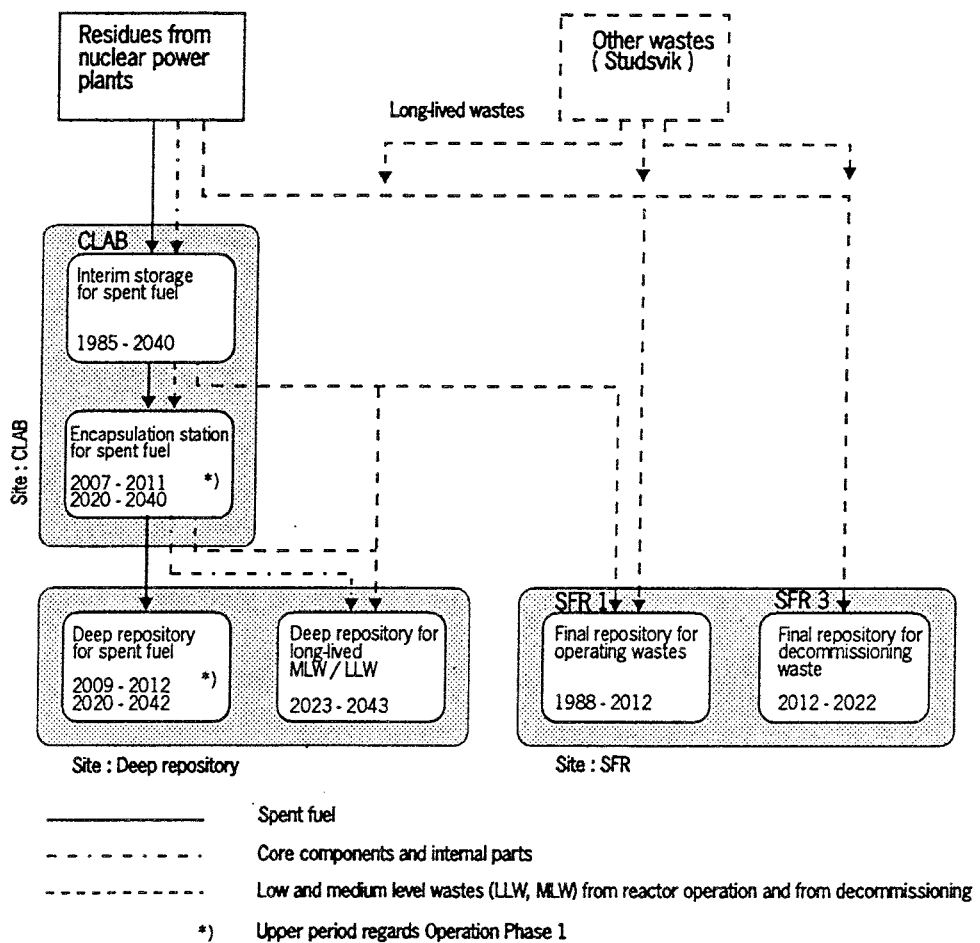


Figure 2.1 Scheme for the handling of radioactive waste products in Sweden

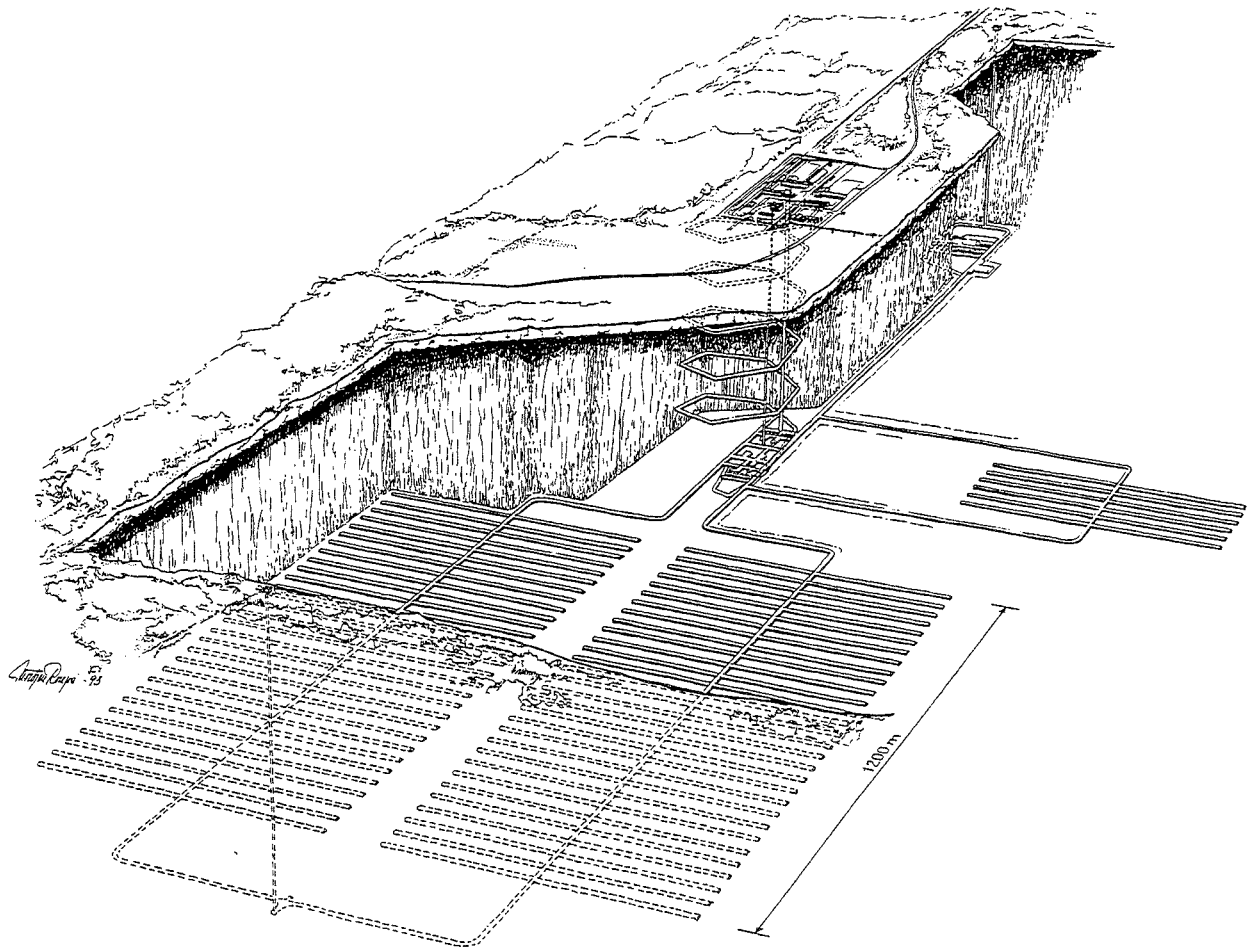


Figure 2.2 Deep repository - an overview

With respect to those facilities or systems which are in operation or under construction, the following key data, compared with PLAN 93, reflect the current development.

Äspö Hard Rock Laboratory	In April 1994 the access tunnel reached the level 430 m (final target level 460 m) under the island of Äspö. The length of the tunnel was then about 3 200 m.
Transportation System	Until the beginning of 1994 about 1 890 tonnes of fuel have been shipped from the nuclear power plants to CLAB and about 13 000 m ³ low and intermediate level waste to SFR.
CLAB	Up to the beginning of 1994, fuel corresponding to 1 890 tonnes of uranium was stored in the facility.
SFR 1	Up to the beginning of 1994, about 13 000 m ³ of waste have been deposited in the facility.

3. **CALCULATION ALTERNATIVES**

To establish a basis for design of the final repositories and the transport system certain assumptions have to be made regarding the operation time of the various nuclear power plants. The main alternative with respect to costs that is accounted for in this report is, as in previous reports, based on the amounts of waste that are produced if all nuclear plants are operated up to and including the year 2010. This results in an average operating time of 30 years. To illustrate the sensitivity with respect to the operating times, calculations are also made and described in this report for the cases of 25 and 40 years of operation of all nuclear power reactors.

4. COSTS

4.1 COST TABLES (Numbering of tables according to PLAN 93 /ref. 7/)

Table 4.1 Future costs (MSEK) from 1995, including contingency allowance for unforeseen items. **Operation of all reactors up to and including the year 2010.** (January 1994 prices).

Object	Cost category	Total future costs	Total future costs per object	Total cost under Financing Act ¹⁾
SKB, Adm, RD&D	-	2,430	2,430	2,430
Transports	Reinvestment	787		
	Operation	938	*) 1,726	1,523
Decommissioning NPP	Shutdown operation	3,015		
	Dismantling	8,808	11,823	11,823
CLAB	Investment	810		
	Reinvestment	757		
	Operation	3,546		
	Decommissioning	368	*) 5,481	5,454
Encapsulation Plant	Investment	2,155		
	Reinvestment	91		
	Operation	5,388		
	Decommissioning	158	*) 7,792	7,753
Deep Repository - External Facilities	Investment	1,733		
	Reinvestment	136		
	Operation	- 466	*) 1,403	1,356
Deep Repository - Industrial Area	Investment	2,892		
	Reinvestment	93		
	Operation	2,391		
	Decommissioning	142	*) 5,519	5,395
Deep Repository - Fuel	Investment	3,491		
	Reinvestment	43		
	Operation	1,479		
	Sealing	3,261		
	Decommissioning	89	*) 8,362	8,321
Deep Repository - Other Waste	Investment	473		
	Operation	111		
	Decom. + sealing	302	*) 886	714
SFR - Common Facilities	Investment	41		
	Decom. + sealing	3	*) 44	1
SFR 1	Investment	303		
	Reinvestment	40		
	Operation	495		
	Decom. + sealing	97	*) 934	28
SFR 3	Investment	446		
	Reinvestment	24		
	Operation	208	*) 736	717
	Decom. + sealing	58		
Reprocessing ²⁾	-	487	487	487
Total			47,623	46,002

* Also includes costs outside the Financing Act. Total over all concerned objects:
Waste from Studsvik, Ågesta etc MSEK 474
Other low- and intermediate- level waste MSEK 1,147

1) Future costs less costs for Studsvik waste etc and other low- and intermediate-level waste

2) Costs of reprocessing including costs at BNFL and for transition of contracts with COGEMA

Table 4.2 Future costs (MSEK) per object under the Financing Act distributed over time. **Operation of all reactors up to and including the year 2010.** (January 1994 prices)

Year	SKB Adm, RD&D	Transp	Decom. NPP	CLAB	EP	Deep reposit- ory	SFR 1 & 3	Reproc.	Total costs	Accumu- lated costs
1995-99	708	71		806	601	634	5	244	3,069	3,069
2000-09	1,062	343		1,557	1,806	5,842	228	243	11,081	14,150
2010-19	440	473	11,510	811	596	1,610	378		15,818	29,968
2020-29	100	356	313	1,283	2,217	3,010	137		7,416	37,384
2030-39	100	187		528	2,225	2,635			5,675	43,059
2040-49	20	93		471	308	2,051			2,943	46,002
Total from 1995	2,430	1,523	11,823	5,456	7,753	15,782	748	487	46,002	

Table 4.3 Future costs (MSEK) per object under the Financing Act distributed over time. **25 years of operation of all reactors.** (January 1994 prices)

Year	SKB Adm, RD&D	Transp	Decom. NPP	CLAB	EP	Deep reposit- ory	SFR 1 & 3	Reproc.	Total costs	Accumu- lated costs
1995-99	708	71	204	792	601	637	334	244	3,591	3,591
2000-09	1,062	342	6,153	1,533	1,805	5,848	288	243	17,274	20,865
2010-19	440	470	4,381	811	596	1,598	184		8,480	29,345
2020-29	100	354		1,185	2,208	3,008	52		6,907	36,252
2030-39	100	186		585	1,529	3,096			5,496	41,748
2040-49	20			123	1	87			231	41,979
Total from 1995	2,430	1,423	10,738	5,029	6,740	14,274	858	487	41,979	

Table 4.4 Future costs (MSEK) from 1995, including contingency allowance for unforeseen items. **25 years of operation of all reactors.** (January 1994 prices).

Object	Cost category	Total future costs	Total future costs per object	Total cost under Financing Act ¹⁾
SKB, Adm, RD&D	-	2,430	2,430	2,430
Transports	Reinvestment	787		
	Operation	845	*) 1,632	1,423
Decommissioning NPP	Shutdown operation	1,929		
	Dismantling	8,808	10,738	10,738
CLAB	Investment	772		
	Reinvestment	660		
	Operation	3,281		
	Decommissioning	340	*) 5,054	5,029
Encapsulation Plant	Investment	2,155		
	Reinvestment	72		
	Operation	4,389		
	Decommissioning	158	*) 6,775	6,740
Deep Repository - External Facilities	Investment	1,733		
	Reinvestment	78		
	Operation	- 403	*) 1,408	1,371
Deep Repository - Industrial Area	Investment	2,892		
	Reinvestment	68		
	Operation	1,925		
	Decommissioning	142	*) 5,027	4,939
Deep Repository - Fuel	Investment	3,096		
	Reinvestment	26		
	Operation	1,217		
	Sealing	2,826		
	Decommissioning	84	*) 7,248	7,211
Deep Repository - Other Waste	Investment	472		
	Operation	88		
	Decom. + sealing	302	*) 862	753
SFR - Common Facilities	Investment	41		
	Decom. + sealing	3	*) 44	1
SFR 1	Investment	155		
	Reinvestment	40		
	Operation	495		
	Decom. + sealing	96	*) 784	23
SFR 3	Investment	446		
	Reinvestment	36		
	Operation	316	*) 856	834
	Decom. + sealing	58		
Reprocessing ²⁾	-	487	487	487
Total			43,345	41,979

* Also includes costs outside the Financing Act. Total over all concerned objects:
Waste from Studsvik, Ågesta etc MSEK 362
Other low- and intermediate- level waste MSEK 1,004

1) Future costs less costs for Studsvik waste etc and other low- and intermediate-level waste

2) Costs of reprocessing including costs at BNFL and for transition of contracts with COGEMA

Table 4.5 Future costs (MSEK) per object under the Financing Act distributed over time. **40 years of operation of all reactors.** (January 1994 prices)

Year	SKB Adm, RD&D	Transp	Decom. NPP	CLAB	EP	Deep reposit- ory	SFR 1 & 3	Reproc.	Total costs	Accum- lated costs
1995-99	708	71		845	601	641	10	244	3,120	3,120
2000-09	1,062	343		1,619	1,805	5,915	19	243	11,006	14,126
2010-19	440	469	3,516	811	596	1,735	514		8,081	22,207
2020-29	100	352	6,493	1,170	2,244	3,173	201		13,733	35,940
2030-39	100	273	729	928	2,225	2,864	118		7,237	43,177
2040-49	20	277		550	1,949	2,318	19		5,133	48,310
2050-59		74		273	55	1,776			2,178	50,488
Total from 1995	2,430	1,859	10,738	6,196	9,475	18,422	881	487	50,488	

Table 4.6 Future costs (MSEK) from 1994, including contingency allowance for unforeseen items. **40 years of operation of all reactors.** (January 1994 prices).

Object	Cost category	Total future costs	Total future costs per object	Total cost under Financing Act ¹⁾
SKB, Adm, RD&D	-	2,430	2,430	2,430
Transports	Reinvestment	877		
	Operation	1,202	*) 2,079	1,859
Decommissioning NPP	Shutdown operation	1,929		
	Dismantling	8,808	10,738	10,738
CLAB	Investment	911		
	Reinvestment	1,049		
	Operation	3,917		
	Decommissioning	349	*) 6,227	6,196
Encapsulation Plant	Investment	2,155		
	Reinvestment	163		
	Operation	7,047		
	Decommissioning	158	*) 9,524	9,475
Deep Repository - External Facilities	Investment	1,733		
	Reinvestment	194		
	Operation	- 567	*) 1,360	1,327
Deep Repository - Industrial Area	Investment	2,907		
	Reinvestment	169		
	Operation	2,842		
	Decommissioning	143	*) 6,062	5,957
Deep Repository - Fuel	Investment	4,217		
	Reinvestment	78		
	Operation	1,847		
	Sealing	4,052		
	Decommissioning	100	*) 10,294	10,242
Deep Repository - Other Waste	Investment	558		
	Operation	156		
	Decom. + sealing	327	*) 1,042	896
SFR - Common Facilities	Investment	41		
	Decom. + sealing	3	*) 44	1
SFR 1	Investment	485		
	Reinvestment	70		
	Operation	898		
	Decom. + sealing	97	*) 1,549	46
SFR 3	Investment	446		
	Reinvestment	36		
	Operation	316	*) 856	834
	Decom. + sealing	58		
Reprocessing ²⁾	-	487	487	487
Total			52,692	50,488

* Also includes costs outside the Financing Act. Total over all concerned objects:
Waste from Studsvik, Ågesta etc MSEK 459
Other low- and intermediate- level waste MSEK 1,745

- 1) Future costs less costs for Studsvik waste etc and other low- and intermediate-level waste
2) Costs of reprocessing including costs at BNFL and for transition of contracts with COGEMA

Table 4.7 Comparison between future costs (MSEK) under the Financing Act for the three calculation alternatives. (January 1994 prices)

	Operation through 2010	25 years of operation	40 years of operation
SKB - Adm, RD&D	2,430	2,430	2,430
Transports	1,523	1,423	1,859
Decommissioning NPP	11,823	10,738	10,738
CLAB	5,454	5,029	6,196
EP	7,753	6,740	9,475
Deep Repository - Above Ground	6,751	6,310	7,284
Deep Repository - Fuel	8,321	7,211	10,242
Deep Repository - Other waste	714	753	896
SFR 1 & 3	746	858	881
Reprocessing	487	487	487
Total costs	46,002	41,979	50,488

Table 4.8 Incurred and estimated costs through 1994. (MSEK current prices)

Object	Cost category	Cost incurred through 1993	Estimated costs 1994
SKB (RD&D, Info, Adm)	-	1,763	227
Transports	Investment	259	-
	Operation	273	21
CLAB	Investment	1,803	-
	Operation	810	115
SFR 1	Investment	743	-
	Operation	157	32
Reprocessing	-	3,276	-
Encapsulation plant	Investment	20	32
Deep Repository	Investment	36	114
Total		9,140	541

Table 4.9 Marginal costs for certain parts of the system.
(January 1994 prices)

Object	Cost (MSEK)	Quantity	Unit (parameter)	Cost/unit (kSEK)	Marg. cost (kSEK/unit)	Remarks
TOTAL FACILITIES ETC. FOR MANAGEMENT OF FUEL						
Facilities for management of fuel incl. core components and RD&D	38,300	7,660	ton fuel	5,000	2,130	
DIFFERENT PARTS OF THE SYSTEM						
						Includes costs for all transports of the waste
Transports						
Total	2,633	16,010	transport unit	165		Ship-transported fuel and waste. The transport unit is a cask or a container
Spent fuel	1,505	7,660	ton fuel	196	54	Incl. core components and LI-waste from CLAB
Operational waste from NPP	261	50,700	m ³ LI-waste	5.1	0.5	By ship from NPP to SFR1
Decommissioning waste from NPP	752	98,000	m ³ LI-waste	7.7	0.6	By ship from NPP to SFR3 and reactor internals from CLAB to deep repository
Studsvik waste	115	19,500	m ³ LI-waste	5.9	0.6	Various wastes
Interim storage facility and encapsulation plant						
CLAB	10,115	7,660	ton fuel	1,320	431	Incl. core components and reactor internals
Encapsulation plant	7,792	7,660	ton fuel	1,017	668	Incl. concreting of core components etc.
Final disposal						
Deep repository - Total	16,170	7,660 4,500	ton fuel canister	2,111 3,593	1,089 1,854	
Deep repository - fuel	14,565	7,660 4,500	ton fuel canister	1,901 3,237	1,001 1,704	Incl. part of Common Facilities
Deep repository - other waste	1,605	15,022	m ³ LI-waste (not decomm.)	107	45	Incl. part of Common facilities
SFR 1	2,361	87,200	m ³ LI-waste	27	9.7	Incl. Common Facilities (SFR)
SFR 3	736	147,800	m ³ decomm. waste	5.0	3.2	

4.2 WASTE MANAGEMENT FEE

In making the proposal, SKI has to consider all relevant factors, such as total costs, expected operation time of the reactors and interest on the money collected in funds. Separate fees are proposed for each reactor owner. For 1994 the fee has been 1.9 öre/kWh (SEK 0.019/kWh) on average.

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N Platts, D J Blackwood, C C Naish

AEA Technology, UK

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Paul Wersin, Kastriot Spahiu, Jordi Bruno

MBT Tecnología Ambiental, Cerdanyola, Spain

February 1994

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Calin Cosma¹, Christopher Juhlin², Olle Olsson³

¹ Vibrometric Oy, Helsinki, Finland

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Jan Cramer (ed.)¹, John Smellie (ed.)²

¹ AECL, Canada

² Conterra AB, Uppsala, Sweden

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Sven Åke Larsson^{1,2}, Eva-Lena Tullborg²

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² Terralogica AB

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Göran Bäckblom (ed.), Christer Svemar (ed.)

Swedish Nuclear Fuel & Waste Management Co,

SKB

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Peter Andersson (ed.)¹, Anders Winberg (ed.)²

¹ GEOSIGMA, Uppsala, Sweden

² Conterra, Göteborg, Sweden

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Olle Olsson¹, Göran Bäckblom²,

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Kjell O Wannäs, Tom Flodén

Institutionen för geologi och geokemi,

Stockholms universitet

June 1994

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Hans Wanner¹, Yngve Albinsson², Erich Wieland¹

¹ MBT Umwelttechnik AG, Zürich, Switzerland

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S M Sharland

AEA Technology, Harwell Laboratory, UK

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A R Hoch, S M Sharland
Chemical Studies Department, Radwaste Disposal
Division, AEA Decommissioning and Radwaste,
Harwell Laboratory, UK
October 1993

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Hans Widén¹, Patrik Sellin²
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Stockholm, Sweden
September 1994

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AEA Technology, Decommissioning & Waste
Management/Reactor Services, Harwell, UK
January 1994

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Ignasi Casas¹, Jordi Bruno¹, Esther Cera¹,
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Antti Öhberg¹, Pauli Saksa², Henry Ahokas²,
Paula Ruotsalainen², Margit Snellman³
¹ Saanio & Riekkola Consulting Engineers,
Helsinki, Finland
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³ Imatran Voima Oy, Helsinki, Finland
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M Gascoyne, G S Lodha, D R Stevenson,
G A Thorne, D Tomsons
AECL Research, Whiteshell Laboratories,
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O Andersson
VBB VIAK AB, Malmö
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Swedish Nuclear Fuel and Waste
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Golder Associates Inc., Seattle, WA, USA
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