

Annex 4

DIRECT DISPOSAL OPTION COST ESTIMATES AND FUTURE TRENDS: SWEDEN (REFERENCE)

1. Introduction

The Swedish Nuclear Fuel and Waste Management Co., (SKB), a body which is responsible for carrying out nuclear waste management in Sweden, has provided cost information on its country's option. This study's reference direct disposal option replicates these costs on timescales which coincide with the needs of the hypothetical PWR.

A major change has occurred since the 1985 NEA study in that the Swedish Intermediate Storage Facility (CLAB) has now been in operation for 7 years. Experience gained from the construction and operation of this facility has been taken into consideration in deriving the basic cost estimates. Research efforts for the final disposal of spent fuel continue and, at present, the Äspö laboratory for rock research is being built. Yearly reports containing future cost calculations are being prepared and sent to the Swedish authorities.

2. Outline of the programme

Figure 4.1 shows the general programme and time schedule for construction, operation and decommissioning of the facilities for interim storage, encapsulation and final disposal of spent fuel, based on the SKB's achieved and planned timings.

It has been assumed, for the purpose of this study, that the spent fuel is stored at the reactor site for five years (or at least four years in the case of the final core) before being transported to the interim storage facility (CLAB). This is an underground water pond storage facility which also caters for the interim storage of some active core components and other reactor parts.

Prior to encapsulation and disposal, spent fuel will be stored for approximately 40 years, including the time at the reactor site. During this time period, both the radiation and the heat flux will have reduced by about 90 per cent.

The spent fuel will finally be disposed of in a 500 meter deep repository in granitic rock with an isolation based on a multiple barrier system. The first barrier is the spent fuel itself, which has very low solubility in ground water. The second barrier is a copper canister around the spent fuel which will be intact for 100 000 years as copper does not corrode in ground water which does not contain dissolved oxygen. The third barrier is compacted bentonite clay around the canister and the fourth barrier is the granitic rock. Ground water flow in the rock will be very slow as large cracks are avoided when choosing the site, and the flow of radioactive substances is even slower.

There are certain costs associated with the site for final disposal; such costs are calculated separately from the costs for the actual disposal.

3. Plant cost estimates

The cost estimates are based on a nuclear programme with a capacity of 10 GWe, producing 67 TWh per year, which produces a total fuel quantity of 8 000 tonnes over the plants' operating lives.

The cost estimates for the transport, storage, encapsulation and disposal of the spent fuel are summarised in Table 4.1. The experience and assumptions on which they are based are described below.

Table 4.1. **Summary of basic data used by SKB for calculating the cost of PWR spent fuel management**
(million SKr, 1991 money values)

Plant	Size	Capital M SKr	Operating M SKr p.a.	Refurbish- ment M SKr	Decommis- sioning M SKr
Transport of spent fuel to interim storage	(a)	423	21	516	-
Interim store (CLAB)	8 000 tU ^(b)	3 978	83 ^(c)	868	358
Encapsulation (ES)	270 tU/y	2 824	161	123	254
Repository site services ^(d)		3 393	50	208	231
Spent fuel disposal facility	270 tU/y	4 736	31	3 160 ^(e)	193
Assumed exchange rate: SKr 7.45 = ECU 1 (long-term rate) SKr 7.70 = ECU 1 (January 1991)					

- a. One ship, 10 transportation casks, 5 land vehicles (SKr 400 000 each).
- b. Initial 3 000 tU, 5 000 tU achieved by compact racks, further caverns needed to give 8 000 tU.
- c. Includes small cost for the handling and disposal of LLW and ILW.
- d. Improvement to harbour, 50 km rail, preparation and handling.
- e. Includes sealing of the repository.

Transport

Transport of the spent fuel from the nuclear power plants to the interim store and then to the final disposal takes place by special ship and railway. In order not to underestimate the cost shown in Table 4.1, a sea transport of 750 km and a railway transport of 200 km have been postulated.

Interim storage

The cost estimates for this plant draw on the experience gained from the construction of an interim storage facility (CLAB) and its operation for seven years. At present, CLAB has a 5 000 tU capacity. To enable CLAB to take the full amount of spent fuel from the Swedish system, further caverns have also been costed and these costs are reflected in the reinvestment cost shown in Table 4.1.

Waste streams from interim storage

A small amount of radioactive waste will occur on receipt of the spent fuel to the interim store from the cleaning water in the pools and from maintenance operations.

Practical experience from the last four years shows that there will be 30 m³ of treated and packed intermediate level waste (ILW) and 10 m³ of treated and packed low level waste (LLW) per year. The average cost for the final disposal of these wastes in the "Final Repository for Radioactive Operational Waste (SFR)" is ECU 2 600 per m³. Thus, the total cost for disposal of these wastes is ECU 0.1 million p.a. These small costs are included in the operating cost for the interim store, see Table 4.1.

Encapsulation

The costs shown in Table 4.1 are based on encapsulation of the spent fuel into 100 mm thick copper canisters. It assumes a throughput of 270 tU p.a. Currently, no waste streams are foreseen from this process apart from those from the decommissioning shown in Table 4.1.

Decommissioning

The decommissioning wastes from CLAB and the encapsulation facility (ES) come to a total of 7 320 m³ in packed form. These wastes will be disposed finally in the tunnel system remaining after the disposal of the spent fuel has been completed. On completion of this operation the tunnels will be backfilled.

Final disposal

The system costed assumes final disposal of the spent fuel into a repository situated in a granitic rock substructure. The bentonite cost is included in the cost for refurbishment of the repository (Table 4.1).

Contingencies and costs excluded

In order not to underestimate this fee, the cost calculations are deliberately made in a very conservative way, for example, assumptions concerning locations and availability of infrastructure. The cost estimates include a contingency of 27 per cent to reflect the greater uncertainty associated with design and construction of the encapsulation plant.

The following costs are not included in the calculations:

- research;
- costs for reprocessing contracts;
- decommissioning of nuclear power plants;
- disposal of low and intermediate active waste from nuclear power plants.

4. Levelised price derivation

The capital, operating and decommissioning cost estimates used to calculate the levelised prices can be seen in Table 4.1. A simplified cash flow profile for the complete SKB plan is shown in Table 4.2 and diagrammatically in Figure 4.2.

Costs have been discounted to obtain levelised prices at the point of delivery to the respective sites (i.e. storage or disposal) in accordance with the methodology described in Annex 1. These are shown in Table 4.3 for various discount rates.

In Sweden, delivery to the interim storage facility (CLAB) commenced in 1985 and it is planned that the delivery to the encapsulation and disposal facility will commence in 2020. The reference 5 per cent levelised prices for these operations are ECU 230 per kg U and ECU 610 per kg U, respectively. As these prices are levelised, they can be applied to the timings assumed in the direct disposal reference case of this study.

Table 4.2. **Undiscounted cash flows for direct disposal option**
(million ECU, 1991 money values)

Time period	Transport	Interim storage	Final disposal	Total
1980-1989	107	490	0	597
1990-1999	21	230	2	253
2000-2009	39	145	24	208
2010-2019	34	116	1 117	1 267
2020-2029	57	150	626	833
2030-2039	25	123	611	759
2040-2049	22	106	555	683
Total	305	1 360	2 935	4 600

5. Potential improvements

Continued research and development may improve the present technology for direct disposal of spent fuel. This might lower the total cost by 15 per cent. It should be noted that the aim is not to lower costs but to develop a safer method for disposal.

However, a new composite canister with a self-supporting steel body covered by a protective layer of copper, currently being developed in a common Finnish-Swedish project, may be both safer and have a lower cost of production compared to the reference canister of pure copper.

Improved knowledge of thermal behaviour and more accurate engineering may allow more fuel elements in each copper canister; this will lower the total cost.

In the SKB *Project Alternative System Studies, PASS*, the alternative VLH (Very Long Holes) with a composite canister with hemispherical ends should give a lower cost than the reference alternatives. However, the safety of these alternatives must be proved before they could be selected for use.

6. Sensitivity range

As shown in Table 4.3, the undiscounted total cost is ECU 570 per kg U which has been deliberately calculated in a very conservative way, with a contingency of 27 per cent, in order to reflect the uncertainty associated with the design and construction of the encapsulation and disposal facilities.

There is a potential for further improvement in costs based on the alternatives mentioned above. If these could be developed, costs may be reduced by 15 per cent to ECU 485 per kg U.

Table 4.3. **Back-end levelised unit prices (ECU/kg U) for the direct disposal option at various discount rates**

Discount rate	0%	2%	5%	8%	10%	12%	15%
Transport/ Storage	210	200	230	280	340	400	500
Encapsulation/ Disposal	360	430	610	870	1 100	1 390	1 920

Note: The transport/storage costs are levelised to the point of delivery to the storage facility, i.e. commencing in 1985, whilst the encapsulation/disposal costs are levelised to the point of delivery to the disposal site, i.e. commencing in 2020, using the method indicated in Annex 1. These levelised prices are not additive.

Figure 4.1 Facilities for the management of spent fuel

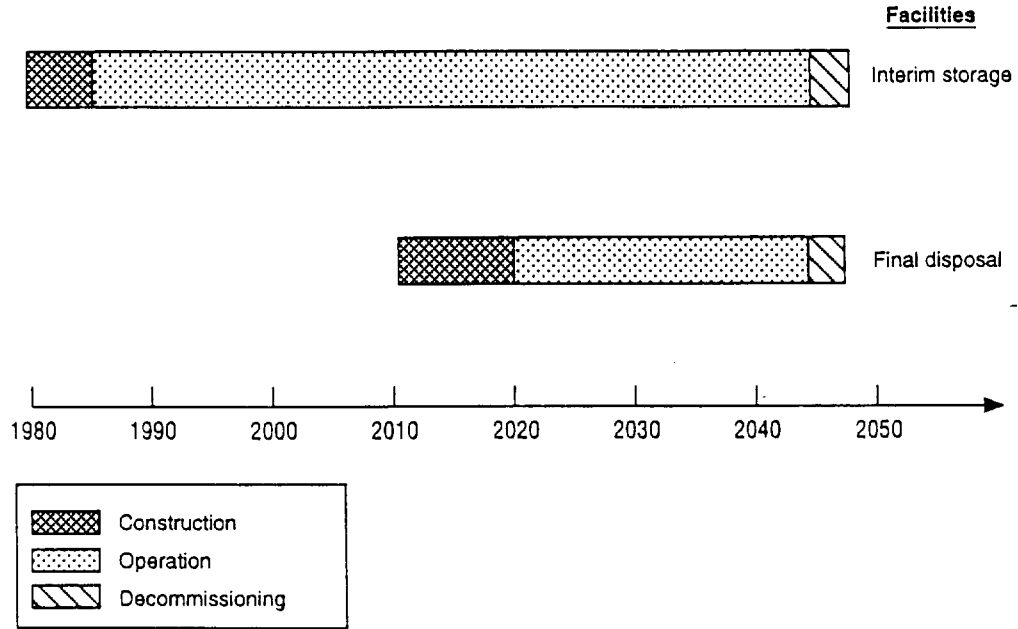


Figure 4.2 Annual future costs for spent fuel in M ECU (1991 money value)

