Annex 7

COMPARISON OF WASTE DISPOSAL COSTS

1. Introduction

An OECD/NEA Expert Group on Geological Disposal Costs[6] has been studying the costs of disposing encapsulated spent fuel and vitrified high level waste (VHLW) to deep geological repositories. This annex compares disposal cost data from the work of the above-mentioned group with those used by this study. It is shown that the reference costs for this study, which are based on two country-specific examples are representative and close to the average of a range of international views. For sensitivity purposes, this range of views has also been used.

Although the data have been split into reprocessing and direct disposal sets, several countries envisage repositories where the disposal of one type of waste form will predominate but which will nevertheless take a small proportion of the other type. The estimates of disposal costs are very country-specific and are strongly influenced by national regulatory and licensing requirements, the engineering and design approaches and nature of the geology considered for the disposal.

2. Costs for direct disposal of spent fuel

Table 7.1 shows country specific total cost estimates for the direct disposal of fuel as derived by the Expert Group on Geological Disposal Costs. All costs in this table include the cost of encapsulating the spent fuel prior to disposal. Table 7.2 shows the average unit costs calculated from Table 7.1. The results show the effect of scale (based on volume of waste to be disposed) on the unit cost; the overall average is also displayed. The Canadian data are excluded from Table 7.2 because the CANDU reactor system gives rise to a large quantity of low irradiation fuel (average burn-up 8 GWd/tU) with an associated low unit disposal cost. This is not typical of the light water reactor systems (PWR and BWR) that predominate around the world and form the focus of this study.

3. Costs for vitrified high level waste (VHLW) disposal

Table 7.3 shows country-specific total cost estimates for the disposal of VHLW from reprocessing, again taken from the Geological Disposal Costs study. The German data presented in that study classified the fuel as VHLW and are, therefore, not comparable to the German entry to this study which classifies it as spent fuel. To avoid misinterpretation, the German data have been excluded from Table 7.3. Table 7.4 shows the average unit costs as calculated from Table 7.3. In this case, the UK data are excluded from the calculation due to their Magnox fuel content. Magnox fuel (which has an average burn-up of 5.5 GWd/tU) gives rise to relatively small quantities of VHLW per tonne of uranium and higher than average quantities per unit of electricity generated; its inclusion would unfairly distort the costs applicable to LWR fuel.

Table 7.1. **Undiscounted cost estimates for encapsulation and direct disposal of fuel**

Country	Total costs (M $)	Quantity of fuel (tU)	Unit cost ($/kg U)
Finland	760	1 840	413
Spain (salt)	2 300	5 300	430
Spain (granite)	1 900	5 300	358
Sweden	3 214	7 840	410
US	10 000	96 300	104
Canada	8 700	191 000	46

Note: Values taken from the OECD/NEA study on Geological Disposal Costs [(6)]; all the above costs include encapsulation.

Table 7.2. **Total costs of small/large scale operations and the weighted undiscounted average unit cost for encapsulation and direct disposal**

Scale of operation	Sum of costs (M $)	Sum of fuel (ktU)	wt. average unit cost ($/kg U)
Small	6 060	14.94	406
Large	10 000	96.30	104
Total	**16 060**	**111.24**	**144**

Notes:
- Canada is excluded from this table.
- An average value of $396/kg U was taken from Table 7.1 and used as the average cost of waste disposal for Spain.
- US data represent the "large" case.

Table 7.3. **Undiscounted unit cost estimates for disposal of VHLW**

Country	Total costs (M $)	Quantity of fuel (tU)	Unit cost ($/kg U)
France	6 300	100 000	63
Belgium	800	3 530	227
Netherlands	460	2 000	230
Switzerland	1 400	4 000	350
UK	1 700	70 000	24

Note: Values taken from the OECD/NEA study on Geological Disposal Costs[(6)]; all the above costs exclude vitrification.

Table 7.4. **Total costs of small/large scale operations and the weighted undiscounted average unit cost for VHLW disposal**

Scale of operation	**Sum of costs (M $)**	**Sum of fuel (ktU)**	**wt. average unit cost ($/kg U)**
Small	2 660	9.53	279
Large	6 300	100.00	63
Total	**8 960**	**109.53**	**82**

Notes:
- UK data are excluded from this table.
- French data represent the "large" case.

4. Comparison of geological disposal data with data used in this study

The comparison of costs in this annex refers to 1991 money values and although they are related to different months they can be taken to be broadly comparable for the purposes of this annex which are not to look at the fine detail effect on the costs of monthly variations in money values.

Direct disposal

In this study, the reference case (Sweden) gives a total undiscounted disposal cost, including encapsulation, of ECU 2 878 million (SKr 22.1 billion) for 7 800 tU in January 1991 money values. The equivalent value from the Geological Disposal group is ECU 2 885 million (SKr 22.2 billion), again for 7 800 tU. In this study, this quantity of fuel was rounded up to 8 000 tU and the cost was escalated *pro rata* to the fuel quantity to become ECU 2 935 million (SKr 22.5 billion). The exchange rate between the US dollar and the ECU adopted for the purposes of this study assumes parity in the longer term. As a result, the costs in the two Swedish cases are derived from the same base and are equivalent to $360 per kg U.

In the Geological Disposal Costs study, the undiscounted costs of encapsulation and directly disposing fuel (including the Swedish estimate) ranged from $104 to $430 per kg U. It can, therefore, be concluded that the undiscounted cost of this study lies within the range (towards the upper end) shown by the Geological Disposal Costs study.

VHLW

This study requires disposal costs without vitrification since the latter is covered in the reprocessing price. Data in Table 7.4 are, therefore, directly applicable to this study which uses an undiscounted unit cost of ECU 60 per kg U. This cost is at the lower bound of the range shown by the Geological Disposal Costs study and is consistent with the unit cost of the large scale option.

5. Levelised prices

Repository projects all have similar spend profiles since they all have capital, operating and closure costs spread over varying time periods. Individual schemes (design, quantity throughputs, geologies, timings, etc.) can be compared by the calculation of levelised price. The price is calculated by taking net present values of the cost and income streams (based on throughput) to the same point and setting them equal (Annex 1).

Levelised prices are required in this study for two reasons, the first is to allow a comparison to be made between separate options. The second and most important reason is to ensure the price that the plant operator (the disposer) charges for the service is sufficient to enable all future costs and financial targets to be met. A range of discount rates (0 to 15 per cent p.a.) is used to calculate the levelised price to allow the calculation of fuel costs for discount rates (rates of return) other than the reference 5 per cent p.a. rate assumed here. All the costs supplied by the Geological Disposal Expert Group are undiscounted and unlevelised and, hence, cannot be directly compared to the prices of this study at rates greater than zero.

Although the costs resulting from the two studies cannot be compared at rates greater than zero, the undiscounted reference prices used in this study lie within the Geological Disposal Costs study's range. There is no reason to believe that this would change at higher discount rates.

The reference case of this study assumes a 5 per cent rate of return. The levelised unit price for disposal is ECU 90 per kg U and ECU 610 per kg U for the reprocessing and direct disposal options, respectively.

Although the reference VHLW disposal price is at the lower bound of the range, this fuel cycle component makes a very small contribution to the overall, levelised fuel cost and hence any distortion this introduces is negligibly small. A similar comment is applicable to the direct disposal option where the reference disposal price was towards the upper bound of the range.

6. Conclusion

Although country-specific, the reference disposal prices used in this study for VHLW and encapsulated spent fuel lie within the range of costs identified by the NEA Expert Group on Geological Disposal Costs and are, therefore, judged to be appropriate for fuel costing purposes.