RADWASTE STORAGE AND DISPOSAL COST ASSESSMENT IN VARIOUS EUROPEAN COUNTRIES

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ABSTRACT

The aim of the paper is to gather and to compare economic information from several sources on the cost of radioactive waste storage and disposal in various European countries. The comparison is made by using a common cost discounting approach.

Although the accuracy and quantity of data is sometimes limited, specially for geological disposal which in all cases is still very far from operation, tentative conclusions are based on an observed degree of coherence between the unit costs when they are represented in function of the capacity of the storage or disposal facilities.

INTRODUCTION

The purpose of this paper is to analyze the economic data on interim storage and disposal of radwaste in order to assess waste management costs in several European countries.

This paper is based on a report published by the Commission of European Communities (CEC) (1). The data given in this report were updated when possible and completed with most recent data available.

The first part of this paper presents the results of the survey; the second part sets out the data available from another CEC study on the costs of geological disposal (2); the third part gives an outlook of the economic data as they will be published in a OECD report (3).

The last part compares the different overall and unit costs for radwaste management and examines the parameters that are likely to influence storage and disposal costs.

RESULTS OF THE SURVEY ON RADWASTE COSTS

Introduction

The survey was conducted among the following European agencies ENRESA (Spain), ANDRA (France), NUCLECO (Italy), COVRA (Netherlands), NIREX (United Kingdom), PTB (Germany), NAGRA (Switzerland), SBK (Sweden) and ONDRAF/NIRAS (Belgium). The questionnaire sent to each agency concerns technical and economic data on storage and disposal facilities. The proposed classification of the waste consists in the following A, B, C categories : conditioned low and medium level waste belongs to category A or B depending on the absence or presence of quantities of isotopes with a half-life exceeding 30 years; conditioned high- level waste can be either of category C1 (vitrified waste) or C2 (non-vitrified waste).

Spain (ENRESA)

Set up in 1984, ENRESA is in charge of all disposal operations, from collecting, processing/conditioning, to intermediate storage and final disposal of radioactive waste, including used fuel assemblies.

Category A waste is currently stored in the El Cabril facility until later surface disposal. Options for geological disposal of category C waste and used fuel assemblies are being developed in granite, salt an clay formations, geological research on 20 favorable areas is in progress.

France (ANDRA)

ANDRA is in charge of waste disposal. Waste processing, conditioning and storage operations are carried out by the waste producers.

ANDRA is currently operating a disposal facility for category A waste on the La Manche site, which has been in operation since 1969. A new facility in Soulaines has been commissioned in 1991, and will take over from the La Manche site, as this facility reaches saturation around 1994.

Four geological formations are being studied for the disposal of category B and C waste. Until the commissioning of the disposal facility, existing waste is stored on the sites of the waste producers.

ANDRA has initiated in 1987 a research program on the four formations (granite, salt, clay and schist) to select the geological layer that will eventually be chosen. This work is suspended since 1990.

Italy (NUCLECO)

Founded in 1983, NUCLECO operates on behalf of ENEA for the management and disposal of category A and B waste, ENEA being in charge of category C waste disposal. There are however plans to entrust NUCLECO with the realization of the future site for category C waste disposal, once ENEA has concluded its R&D program to select a site. Conditioned category A and B waste is currently stored on the production sites, and NUCLECO is in charge of collecting non-conditioned waste coming from the sector of small producers.

The Netherlands (COVRA)

The Dutch National Agency COVRA, set up in 1983, has a scope of activities covering waste processing/conditioning, storage and disposal operations. COVRA is running a category A and B waste storage facility in Petten. COVRA is considering waste disposal after a storage period of 50 to 100 years. A storage facility which will accommodate all radioactive waste including reprocessing wastes is under construction at the Borssele site. Safety and feasibility studies of geological disposal are being done and will continue at least by the middle of the 1990 's. No site research has yet started.

Federal Republic of Germany (PTB)

PTB, a federal organ, has been in charge of building and operating disposal facilities since 1976. In accordance with *atomic energy* legislation, PTB is authorized to entrust a third person with the execution of this task; DBE, a private company, was thus entrusted with building and operating disposal facilities. All other operations prior to waste management are carried out on the production sites.

The projects include the use of the former Konrad iron mine and the salt formation at Gorleben. The Konrad repository is planned to accept non-heat-emitting waste. Gorleben is designed for all types of waste, including used fuel assemblies.

United Kingdom (NIREX)

Set up in 1982, the objective of NIREX is to design, build and operate a disposal site for conditioned category A, B and C2 waste (low- and medium-level waste). Waste processing/conditioning and storage operations are carried out by the waste producers on their own site. In mid-1987 it was decided to definitely abandon surface disposal of category A waste and to consider its geological disposal together with other categories of waste. At the same time, BNFL is still operating the Drigg site for the disposal of category A waste. In the past years the disposal costs on the Drigg site have increased considerably due to the development of burial techniques made necessary after the imposition of new safety regulations.

BNFL is in charge of the disposal of category C1 waste (vitrified waste). However, as this waste needs to be stored on the surface for a period of 50 years until it has cooled down, there is no urgency as to that matter, and BNFL has storage facilities for reprocessing waste. A wide variety of geology is available in the UK. At present no significant work has been done on site selection for high level waste.

Switzerland (CEDRA/NAGRA)

The National Cooperative Society for the Storage of Radioactive Waste (CEDRA) is in charge of studying, building and operating waste disposal facilities. Disposal concepts are being studied, and a final choice has not yet been made. Two disposal sites are being considered, one for category A and B waste and the other for category C waste. Caves with horizontal access galleries in marl or anhydride formations are being considered for the disposal of category A and B waste. Category C waste is to be disposed of in geological formations at a depth of 1200 m (crystalline subsoil or sedimentary layer).

As the storage of conditioned waste does not fall under the competence of CEDRA, the data relating to the project currently under way have been provided by NOK.

Sweden (SKB)

In Sweden, SKB is in charge of the disposal of both conditioned waste and used fuel assemblies. The SFR facility for the disposal of conditioned category A waste has been operational since 1988. It is built in a granite formation under the level of the Baltic sea near the site of the Forsmark power plant. The disposal of category B and C waste and used fuel assemblies is only planned after a storage period of several decades. The *spent nuclear fuel* is stored in an interim storage facility CLAB near Oskarshamn. The facilities currently studied are called SFL.

It should be noted that, in accordance with Swedish legislation, waste management strategy is defined in a technical and economic report subject to yearly reevaluation. The data of Ref. 3 are from the "Technical Report 90-XX-PLAN 90".

Belgium (ONDRAF/NIRAS)

Set up in 1981, the National Agency for Radioactive Waste and Fissile Materials (ONDRAF/NIRAS) is in charge of the storage, outside the producers' sites, and disposal of radioactive waste. The management strategy set up by ONDRAF/NIRAS runs along the following main lines:

- category A waste is stored on the Dessel nuclear site, in the facilities of its subsidiary Belgoprocess. Four options are currently considered for the disposal of this waste : a surface site in a hydrogeologically favorable area and an underground repository in a clay layer at a depth of 220 m in Mol-Dessel. The commissioning of the surface site is planned for 1998;
- category B and C waste will be stored in the facility currently in the project phase on the Belgoprocess site in Dessel. Disposal is planned around 2035 in the Mol-Dessel clay layer.

The results of the survey indicated that the industrial development of geological disposal has not yet reached a sufficiently advanced stage to make relevant economic assessments.

However some evaluations have been made by international organizations such as the CEC with its study "Costs and Modes of Financing" (2) and the OECD with a recent survey on geological disposal of high level waste (3).

These studies are presented hereafter.

DATA TAKEN FROM THE CEC STUDY ON "COSTS AND MODES OF FINANCING OF GEOLOGICAL DISPOSAL" (1987)

The CEC study conducted jointly by ANDRA, the CEN/SCK and DBE under contract with the CEC was carried out on the basis of technical data available in 1985 and aims at assessing the technical costs of the geological disposal of B and C waste in clay, granite and salt formations.

For the purpose of the analysis, different scenarios have been defined taking into account the following parameters : geological formation, operation time schedule and installed power (see Table I).

The year /0 in the time scale of the scenario is the year in which the first fuel assemblies are unloaded. MLW10 for instance stands for disposal of MLW starting 10 years after unloading; the disposal operations are always spread over a period of 30 years.

The volume of waste produced in each scenario is calculated on the basis of the number of packages produced per GWe-year following the assumptions presented in Table II which sets the correspondence between the present waste classification and the one defined in the CEC study.

The CEC study provides an assessment of investment costs, including site selection and validation, operating costs, costs for backfilling, closing of the site and dismantling of surface facilities. Based on these cost assessments, the unit costs needed for the present study have been calculated by use of the following method:

- objective technical criteria allow to distribute the costs between the heat emitting waste (C1) and the non heat emitting waste (C2 and B);
- discounted costs at the date of commissioning of the facility are calculated by considering the disposal time schedule and a 4% real discount rate.

The detailed cost estimates provided by the CEC study and the derived unit costs assessed following the methodology described above are shown in Table III to V for the three scenarios considered and for the three geological formations, clay, granite and salt dome. (These 1985 data have been inflated by a coefficient of 1.2 to be converted to 1991 data).

DATA TAKEN FROM THE OECD SURVEY ON GEOLOGICAL DISPOSAL

An international review of cost estimates for radioactive waste disposal to geological repositories has been conducted by the OECD/NEA in 1991 (3).

The data have been collected by an international group of experts representing their own national organizations. In the following we consider the data relevant for Europe, adding new information to our own survey described before. The final report is expected to be issued mid 1992.

The objective of the study - as said in the foreword to the report - is to provide better understanding of the wide variations between the cost estimates and to demonstrate the impact of technical and non-technical factors on these variations.

Table VI summarizes the main results of the study for the two options: reprocessing in Belgium, France, Germany, the Netherlands, Switzerland and the United Kingdom; and spent fuel disposal in Spain and Sweden. The United Kingdom and Germany envision the disposal of both spent fuel and B, C waste at the same site.

Due to the difficulty in comparing the various economic and financing considerations in the different countries it was decided at an early stage of the experts work to consider exclusively undiscounted costs. This means that the specific costs per m^3 are greater than the ones actually used for funding. It should be also noted that for the sake of comparison, R&D are excluded from the total expenditures, together with site selection and investigations.

The data as presented in the table are still affected by many technical uncertainties, no country having yet any operating or site selection experience, except for Sweden. No site is expected to become active before 2010, and in some cases - Spain or the Netherlands - several options are still open regarding the geological host formation.

Large uncertainties also exist with regard to the total capacities of the repositories being dependent on the assumed nuclear programs. As an example in the Netherlands, several scenarios are considered for nuclear capacities between 0.5 and 3.5 GWe.

Another source of uncertainties on undiscounted costs are due to non-technical factors related to political or social issues, like difficulty in licensing procedures or public acceptance responsible for cost increases. They are neither completely understood nor described.

All these uncertainties are represented by the means of contingencies added on top of the cost calculations. They vary between 15% an 50% depending on the organization approach.

TABLE I

Description of Scenarios Studies

Formation	Clay			Granite			Salt		
Installed power (GWe)	10	25	60	10	25	60	10	25	60
MLW 10 - VHLW 50	X	X			X			X	
MLW 30 - VHLW 30	X	X	X	X	X			X	X
MLW 50 - VHLW 50		X			X			X	
MLW 10 - VHLW 30						X			X

TABLE II

Volumes of Waste Arisings

CEC Waste Classification	Present Classification	Nature	Number of Packages Per GWe-YEAR	Packages volume (m^3)
VHLW	C1	fission products	20	0.15
MLW/CE	C2	hulls and end fittings	15	1.3
MLW/B	B	sludge	100	0.18
MLW/ABC	B	technological waste	100	0.4

TABLE III

Overall and Unit Costs In Clay Formation

	MLW10-VHLW50	MLW30-VHLW30	MLW50-VHLW50
Overall costs (MECU)			
10 GWe	710	780	590
25 GWe	1,430	1,540	1,130
60 GWe		3,150	
Discounted overall costs (MECU)			
10 GWe	370	290	110
25 GWe	680	500	190
60 GWe		1,000	
Unit costs - VHLW (kECU/m^3)			
10 GWe	2,100	1,070	670
25 GWe	1,460	800	490
60 GWe		670	
Unit costs - MLW (kECU/m^3)			
10 GWe	22.6	24.2	25.9
25 GWe	16.8	16.2	18.6
60 GWe		12.7	

TABLE IV

Overall and Unit Costs In Granite Formation

	MLW10-VHLW50	MLW30-VHLW30	MLW50-VHLW50
Overall costs (MECU)			
10 GWe		1,250	
25 GWe		1,730	1,730
60 GWe	2,670	2,640	
Discounted overall costs (MECU)			
10 GWe		410	
25 GWe		920	250
60 GWe	920	880	
Unit costs - VHLW (kECU/m^3)			
10 GWe		1,340	
25 GWe		820	360
60 GWe	470	600	
Unit costs - MLW (kECU/m^3)			
10 GWe		43.1	
25 GWe		20.2	9
60 GWe	17.4	10.7	

COMPARISON OF COST ASSESSMENTS AND DISCUSSION

Before proceeding to an appropriate comparison, the unit costs are to be determined using the same calculation method as described in the following item. Units cost for interim storage and disposal of category A, B and C waste are given by the survey, a comparison is them made with the CEC study and the OECD data.

Methodology Used For the Results of the Survey

Some answers to the questionnaire provide unit costs per category of waste, others supply general information on the facilities in question.

It was therefore considered useful to integrate the data obtained from a calculation model based on a cost discounting method, which makes it possible to determine the unit costs for each category of waste in terms of ECU per unit of volume. Costs are discounted at the date of the provision of service thus indicating a unit cost for the storage or disposal service independently of the financing mode.

TABLE V

Overall And Unit Costs In Salt Dome

	MLW10-VHLW50	MLW30-VHLW30	MLW50-VHLW50
Overall costs (MECU)			
10 GWe		1,200	
25 GWe	1,790	1,490	1,790
60 GWe		2,000	
Discounted overall costs (MECU)			
10 GWe		520	
25 GWe	1,220	520	260
60 GWe		700	
Unit costs - VHLW (kECU/m3)			
10 GWe		1,930	
25 GWe	3,190	730	840
60 GWe		410	
Unit costs - MLW (kECU/m3)			
10 GWe		45.4	
25 GWe	21.6	19.4	21.7
60 GWe		11.2	

The cost discounting method was based on the following simplifying assumptions:

- when no other indication is provided, investment expenses are supposed to be paid in the year preceding the year of commissioning. As a consequence, this assumption disregards intermediate interest in the investment period, which may sometimes prove to be considerable, for instance in the case of disposal, as the period of time between site selection and commissioning may be as long as a decade;
- operating expenses are supposed to be paid in the center of gravity of the operating period, when no other indication is provided. This assumption does not result in significant distortions of unit costs.

Note that the 1988 data have been inflated by a coefficient of 1.14 to convert them to 1991 economic conditions.

Storage of Conditioned Category A and B Waste

Table VII compares the data from the CEC survey and indicates the characteristics and economic data relating to the storage of category A and B waste.

For some countries like France, the United Kingdom, the FRG and Sweden, no data are indicated for storage, either because a disposal site is in operation, or because storage is provided by the waste producers themselves.

Costs vary between 420 and 1,480 ECU/m^3. The differences result from variable parameters such as storage period, maximum permissible dose rate, building materials, capacity of the facility. In general, category A waste is stored in the same infrastructure as category B waste and according to similar piling concepts.

Storage of Conditioned Category B and C Waste

The comparison of storage costs for conditioned high-level waste proves difficult on account of the diversity of strategies adopted by the different countries.

In countries such as Spain and Sweden, reprocessing is not considered; fuel assemblies are or will be stored on a centralized site. In Belgium and Switzerland projects are under way for the storage of reprocessing waste, whereas in France and in the United Kingdom waste storage is provided on the reprocessing site.

The data gathered for Belgium and Switzerland are shown in Table VIII; unit costs appear to be comparable.

Category A Waste Disposal

Table IX shows the economic data on the disposal of category A waste, as well as the main characteristics of operating or planned facilities. Estimated unit costs were calculated using the discounting method described above.

The analysis of Table IX raises the following comments :

- two tendencies emerge from the projects under way: one group of countries is considering surface or shallow disposal, such as France, Spain and Sweden, another group geological disposal, such as the FRG, the United Kingdom and Switzerland;
- under the influence of the scaling effect, operating and planned sites in France benefit from a comparatively low unit cost as compared to other sites of similar concept;
- the Forsmark SFR3 site is designed to take over the waste resulting from the dismantling of nuclear facilities and will benefit from the existing infrastructure at SFR1, commissioned in 1988; consequently, the unit cost corresponds to a marginal cost in relation to the cost considered for SFR1;
- the low level of the unit cost for the Drigg site is due to the fact that this site has already been in operation for some twenty years; it must be noted that the price applied has already been largely increased following the need to bury the packages in artificial barriers.

TABLE VI

O.E.C.D. Geological Disposal Cost Figures (Draft Version Data)

COUNTRY	BELGIUM	FRANCE	GERMANY	NETHERLANDS	SPAIN	SWEDEN	SWITZERLAND	GREAT BRITAIN
PARTICIPATING ORGANIZATION	ONDRAF	ANDRA	DBE	COVRA	ENRESA	SKB	NAGRA	NE Plc
FORMATION	CLAY	HARD ROCK CLAY SALT	SALT	SALT	GRANITE SALT (CLAY)	CRYSTALLINE ROCK	CRYSTALLINE ROCK	CRYSTALLINE ROCK
COMMISSIONING	2035	2010-2020	2010	SCENARIOS 2010 2050 2080	2026	2020	> 2020	2050
WASTE . C1 (m3) C2 AND B	1,000 20,000	14,000 400,000	4,000 48,000	140,000 ***			1,000 23,000	1,660 -
SPENT FUEL (tU)	-	-	25,000 tU	-	5,300 tU	7,840 tU	-	3,400 CANISTERS
OPERATION PERIOD (YEAR)	40	50	50 - 70	15	25	27	30	50
EXPENDITURES (MECU) *	675	5,400	4,000 **	400	1,880	2,590 **	1,100	1,020
. INVESTMENT	450	1,450	1,290		650	1,200	490	630
. OPERATION	195	3,750	2,710		1,150	950	450	390
. CLOSURE	30	200	-		80	440	160	N/A
CONTINGENCIES (%)	50	30	< 50	15	N/A	(30 + 20)	N/A	AVERAGE 25
UNIT COST (ECU/m3) (UNDISCOUNTED)	195 ECU/kgU 33,000 ECU/m3	50 ECU/kgU 13,100 ECU/m3	110 ECU/kgU	200 ECU/kgU 2,800 ECU/m3	350 ECU/kgU 60,000 ECU/m3	350 ECU/kgU 205,000 ECU/m3	300 ECU/kgU	30 ECU/kgU 700,000 ECU/m3

* OUTSIDE R & D
** INCLUDES CONDITIONING
*** INCLUDES ABOUT 60,000 m3 DECOMMISSIONING WASTE (INFORMATION FROM COVRA)

TABLE VII

Comparaison of the Unit Cost Estimates For Category A and B Waste Storage (in 1991 Currency)

Country	Spain	Italy	Netherlands	U.K.	Switzerland	Belgium
Agency	ENRESA	NUCLECO	COVRA	BNFL	NOK	ONDRAF
Planned Capacity (m^3)	4,000	4,500	5,500	6,000	3,000	12,500
Period (years)	10	20	50	/	10	10
Combined Storage	NO	CAT. B	CAT. B	NO	CAT. B, C1	CAT. B
Expend. (MECU)						
Invest.	2.9		2.2			4.6
Operat.	0.29/y.		0.11/y.			0.14/y.
Unit Cost (ECU/m^3)						
Announced	1,480		930			800
Estimated	1,440	420			570	
Max. Contact Dose Rate (mrem/h)	200	200	200	N/A	N/A	500

TABLE VIII

Comparaison of the Unit Cost Estimates For Category B and C Waste Storage (in 1991 Currency)

Country	Switzerland	Belgium
Agency	NAGRA	ONDRAF
Planned Capacity (m^3)	4,000	1,000
Period (years)	25	45
Unit Cost (ECU/m^3)		
• B	11,400	11,400
• C2	13,700	22,800
• C1	114,000	137,000

The price will probably show an upward tendency in the coming years;

- the NIREX project to be commissioned around the year 2000 has a unit cost estimated to be 5,100-6,800 ECU/m^3 for B and C2 waste (ILW); however, NIREX is planning to use the same site for the disposal of category A waste at a marginal cost estimated at 1,140-2,050 ECU/m^3, which, according to NIREX, can be compared to the cost of a surface disposal site.

The comparison of unit cost estimates in Table IX is illustrated in Fig. 1 which, apart from the influence of the scaling effect already noted, shows that a double evolution appears. A first curve links the points representing deep-burial disposal sites (FRG, Switzerland, United Kingdom); another can be drawn for shallow-burial or surface disposal (Spain, Sweden, Belgium and France).

This evolution seems to indicate that at low capacities (less than 500,000 m^3) unit costs are higher than 6,000 ECU/m^3 for a deep-burial site and around 3,000 ECU/m^3 for a surface or shallow-burial site; for large capacities (more than 500,000 m^3) unit costs are around 2,000 ECU/m3 and 1,000 ECU/m^3 respectively.

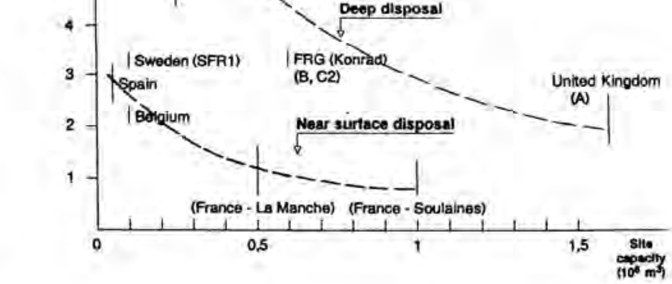
Category B and C Waste Disposal

All countries are considering deep geologic disposal for high-level or long lived waste. The projects are currently in the stage of development; little detailed and industrial economic data is thus available; moreover the projects under way do not plan industrial commissioning before the year 2010.

The estimates provided by the survey (1) as well as the data obtained from the CEC study (2) are presented in Table X.

The unit costs evolutions in function of the site capacity are represented in Fig. 2 for B and C2 waste and in Fig. 3 for C1 waste.

On the other hand the data available from the OECD survey (see Table VI) can be used to derive undiscounted unit costs and compare them to the data from the CEC study gathered in Tables III to V. The resulting plot of these cost



(1) When burial is combined with other waste, the latter are mentioned under the name of the country.

Fig. 1. Disposal of category A waste. Unit cost evolution in function fo site capacity.

TABLE IX

Comparison of the Unit Cost Estimates for Category A Waste Disposal (in 1991 Currency)

COUNTRY	SPAIN	FRANCE		ITALY	NETHERLANDS	GREAT-BRITAIN		WEST GERMANY		SWEDEN		SWITZERLAND	BELGIUM
AGENCY	ENRESA	ANDRA		NUCLECO	COVRA	NIREX		PTB		SKB		NAGRA	ONDRAF
DISPOSAL SITE		LA MANCHE	SOULAINES			DRIGG		KONRAD	GORLEBEN	FORSMARK SFR1	FORSMARK SFR3		
COMMISSIONING	1990/1991	1969	1991		2050	1971	2000	1900		1988	2010	1998	1998
PLANNED CAPACITY (m3)	50,000	485,000	1,000,000			1,000,000	A: 1,500,000 B,C2:600,000	650,000		90,000	113,000	200,000	120,000
PERIOD (YEAR)	13	20	30				50	40		30	15	50	50
COMBINED BURIAL	NO	NO	NO			B	B, C2	B, C2		NO	NO	B	NO
EXPEND. (M.ECU) . INVEST. . OPERAT. . CLOSURE	120 56 50 14		760 140 620					1,520 510 1,010		200 150 40 10	67 45 16 6	930 500 350 80	220 100 110 10
UNIT COST (ECU/m3) . ANNOUNCED . ESTIMATED	 1,030-3,300 2,960	 480 - 1,480	 510 - 1,130	 1,520	 800	 250	 1140 - 2050 *	 3,080		 2,300 3,400	 620 740	 4,500	 2,300

(*) - marginal cost for category A : 1140 - 2050 ECU/m3
- nominal cost for category B and C2 : 5100 - 6800 ECU/m3

TABLE X

Comparison of the Unit Cost Estimates for Category B and C Waste Disposal (in 1991 Currency)

	RESULTS OF THE SURVEY			RESULTS OF THE EEC STUDY								
COUNTRY	SWEDEN	SWITZERLAND	BELGIUM	SCENARIO DMA30-DTHA30 - 10 GWe			SCENARIO DMA30-DTHA30 - 25 GWe			SCENARIO DMA30-DTHA30 - 60 GWe		
AGENCY	SKB	NAGRA	ONDRAF									
DISPOSAL SITE/ FORMATION	SFL2-5		MOL Clay	Clay	Granite	Salt	Clay	Granite	Salt	Clay	Granite	Salt
COMMISSIONING	2020	2020	2035									
PLANNED CAPACITY (m3)	21.300 (1)	B,C2:10.000 C1 : 1.000	B,C2:24.000 C1 : 1.000	B,C2 : 23.500 C1 : 900			B,C2 : 58.135 C1 : 2.250			B,C2 : 139.500 C1 : 5.400		
PERIOD (YEAR)	30	55	50									
EXPEND. (M.ECU) . INVEST. . OPERAT. . CLOSURE	1,630 890 320 420	1,900 820 960 120	760 530 180 50	780 570 180 30	1,250 680 470 100	1,200 850 270 80	1,540 1,150 350 40	1,730 960 610 160	1,490 1,010 380 100	3,150 2,480 620 50	2,640 1,710 710 220	2,000 1,320 550 130
UNIT COST (ECU/m3) . B and C2 . C1	 29,000 (2)	 114,000 1,710,000	 32,000 1,140,000	 24,000 1,070,000	 43,100 1.340,000	 45,400 1,930,000	 16,200 805,000	 20,200 820,000	 19,400 730,000	 12,700 670,000	 10,700 600,000	 11,200 370,000

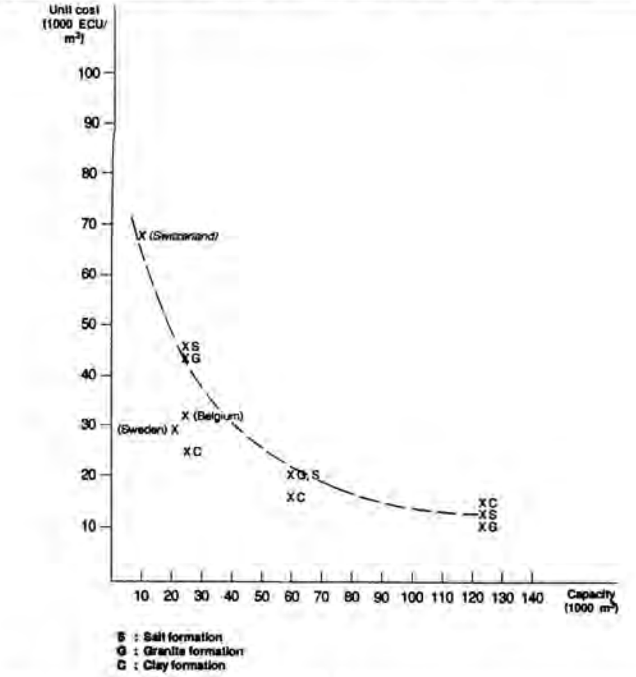


Fig. 2. Disposal of category B & C2 waste. Unit cost evolution in function of site capacity.

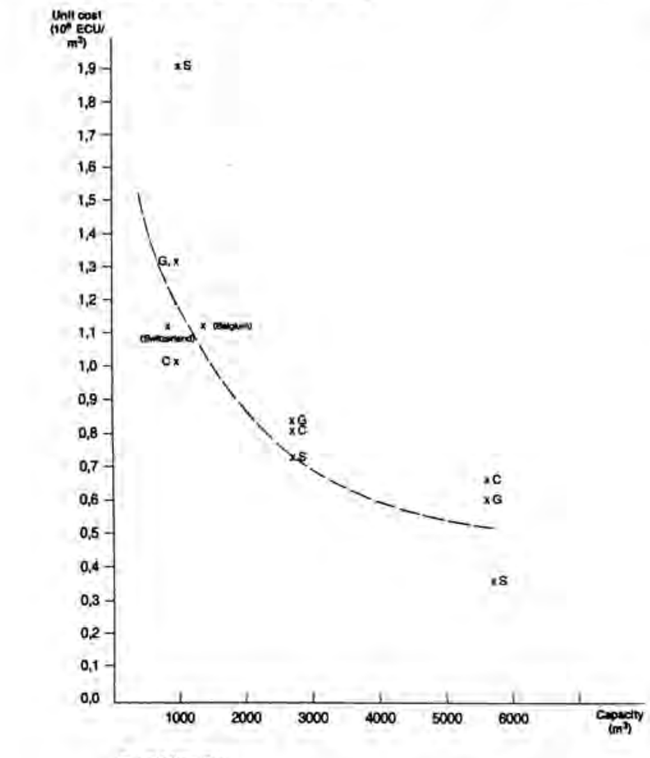


Fig. 3. Disposal of category C1 waste (vitrified waste). Unit cost evolution in function of site capacity.

data against the announced total site capacities is shown in Fig. 4.

Linking curves have been added to the cost data on each of Fig. 2 to 4 to evidence a regular shape in function of size.

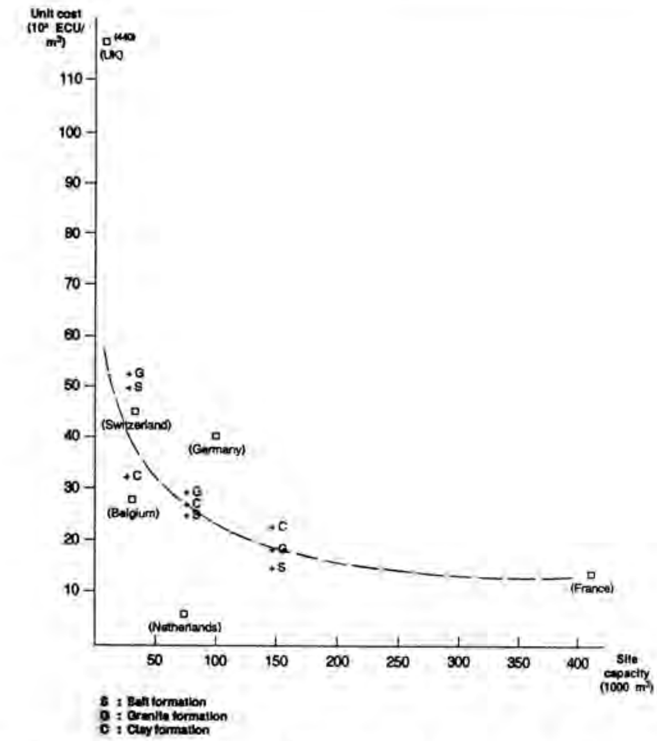


Fig. 4. Geological disposal-OECD study. Unit cost evolution in function of site capacity.

CONCLUSIONS

The present paper gathers the economic data available in 1991 on storage and disposal operations for conditioned low-medium- and high-level waste in several European countries.

Quantitative conclusions should be considered with caution considering the diversity of technical solutions adopted on the national level. The cost discounting approach proposed in the paper permits however relevant economic comparisons in the following terms :

- Most countries are presently storing their low-level waste (category A) under comparable economic conditions in the range between 450 to 1,400 ECU/m^3;
- Few sites for shallow land disposal are in activity or close to start operation. Assessed unit cost, discounted at disposal time are in the range between 1,000 to 3,000 ECU/m^3. Increased elasticity is observed for low capacities - less than 200.000 m^3.
- Deep disposal is still very far from operations in all countries and therefore limited cost data have been provided from the national organizations. Additional data are drawn from a CEC analysis. These data show that despite of the diversity in concept and geological medium, a large part of the variations in costs can be understood in terms of a limited number of key parameters, the most important ones being in decreasing order of importance the size of the disposal site, the time schedules of the project and the choice of the geological medium. Unit costs discounted at disposal time show a range between 11 and 70 kECU/m^3 for B/C2 categories and between 0.4 to 1.2 MECU/m^3 for C1 waste.
- As for category A waste disposal, increased elasticity in function of capacity is observed for low capacities

- less than 20.000 m^3 for B/C2 waste and less than 2.000 m^3 for C1 waste.

The OECD study to be published (3) provides additional global undiscounted cost data for geological disposal for the European countries in question. These data are coherent with the more ancient data, in the sense that undiscounted unit costs show a regular shape when they are plotted in function of the total site capacity.

REFERENCES

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