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Strategic Action Plan for Implementation of European Regional Repositories: Stage 2

Work Package 3

Economic Aspects of Regional Repositories

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Contents

1 Introduction 4
  1.1 Objectives of this report 4
  1.2 Boundary conditions and data sources 5
  1.3 Inventory of wastes and the setting of scenarios 7
    1.3.1 The ‘large’ inventory situation 7
    1.3.2 The ‘small’ inventory situation 8
2 Scenarios for storage, transport and disposal 9
  2.1 Repositories and waste encapsulation facilities 9
  2.2 Storage facilities 10
  2.3 Transport routes and distances 10
  2.4 Timing of disposal operations 11
3 Waste Management Costs – Disposal 12
  3.1 Estimated disposal costs: ‘large’ inventory situation 13
    3.1.1 Observations on ‘large’ inventory disposal costs 15
    3.1.2 Comparison with separate repository costs 16
  3.2 Estimated disposal costs: ‘small’ inventory situation 17
  3.3 Conclusions on overall disposal costs 17
4 Waste Management Costs – Transport 19
  4.1 SF and HLW 19
  4.2 ILW 19
  4.3 Costs of transport for the ‘large’ inventory 19
  4.4 Costs of transport for the ‘small’ inventory 20
  4.5 Conclusions on transport costs 20
5 Waste Management Costs – Storage 21
  5.1 Wet storage of SF in pools 21
  5.2 Dry Storage of SF 23
  5.3 Underground Storage of SF 23
  5.4 Capacities of SF storage facilities in Europe 23
  5.5 SF Storage costs 25
  5.6 Reference storage costs assumed for SAPIERR 26
6 Total Costs and Spend Profiles 28
  6.1 Spend Profile: ‘large’ inventory situation 29
    6.1.1 Impact of discounting 31
  6.2 Spend Profile: ‘small’ inventory situation 33
7 Economic benefits of hosting facilities 34
  7.1 Involving communities in the siting process 35
    7.1.1 Community Identification 35
  7.2 Encouraging Participation 36
  7.3 Benefits to a host country 41

    - 7.3.1 Taxes 41
    - 7.3.2 Industrial development....................41
    - 7.3.3 Political leverage....................41
  - 7.4 SWOT Analysis....................42
    - 7.4.1 Cash Incentives for a Community....................42
    - 7.4.2 Social Benefits for a Community....................43
    - 7.4.3 Community Empowerment Measures....................44
    - 7.4.4 National Cash Incentives....................45
    - 7.4.5 National Social Benefits....................46
    - 7.4.6 National Empowerment....................47
  - 7.5 Potential benefit packages offered by an EDO/ERO....................47
    - 7.5.1 National Benefits....................47
    - 7.5.2 Community Benefits 48
- 8 Financing mechanisms for repositories 52
  - 8.1 Surcharge on the price of nuclear electricity....................52
    - 8.1.1 MODEL 1: Future generation surcharge only....................53
    - 8.1.2 MODEL 2: Past and future generation surcharge....................56
    - 8.1.3 MODEL 3: contribution form new NPP programmes 58
  - 8.2 Amalgamation of national nuclear waste managements funds 58
  - 8.3 Generating income with a priced disposal service 59
  - 8.4 Early funding requirements and managing the EDO finances....................59
  - 8.5 The ERO stage: sharing repository costs 60
  - 8.6 Financing Model for the Formative Years....................62
- 9 Differences between national and regional concepts 64
  - 9.1 Positive economic impacts....................64
  - 9.2 Potential negative economic impacts....................65
- 10 Conclusions 66
- 11 References....................70
- A1 Cost Scaling Calculation Examples for Section 3 75
- A2 Types of Benefit and National Examples....................81

1 Introduction

The European Parliament and the EC have both expressed support for concepts that could lead to regional shared radioactive waste management facilities being implemented in the EU. In this context, the EC has funded two projects that can form the first steps of a staged process towards the implementation of shared regional or multinational storage and disposal facilities. In the period 2003 to 2005, the EC funded SAPIERR I, a project devoted to pilot studies on the feasibility of shared regional storage facilities and geological repositories, for use by European countries. The studies indicated that shared regional repositories are feasible and that a first step could be to establish a structured framework for the future work on regional repositories.

This is the goal of SAPIERR II (2006-2008): to develop possible practical implementation strategies and organisational structures. These will enable a formalised, structured European Development Organisation (EDO) to be established after 2008 for working on shared EU radioactive waste storage and disposal activities. The tasks in the SAPIERR II project are listed below. Each task translates into a Work Package (WP), as follows:

1. Preparation of a management study on the **legal and business options** for establishing a European Development Organisation (EDO).
2. A study on the **legal liability issues** of international waste transfer within Europe.
3. A study of the potential **economic implications** of European regional storage facilities and repositories.
4. Outline examination of the **safety and security impacts** of implementing one or two regional stores or repositories relative to a large number of national facilities.
5. A review of **public and political attitudes** in Europe towards the concept of shared regional repositories.
6. Development of a **Strategy and a Project Plan** for the work of the EDO.
7. **Management and dissemination** of information.

1.1 Objectives of this report

This report documents work done in the scope of WP 3 on the economic aspects of a shared, regional waste management solution. The main objectives of the report are to:

- Identify and provide an initial, approximate estimate of, all the costs of implementing and operating a complete regional disposal system;
- Identify those cost items that are most affected by national/regional decisions, i.e. by the number of repositories and by the political/societal decisions;
- Address the question of financing a shared, regional repository project: this relates closely to the questions of organisational forms and liabilities that are treated in WP 1 and WP 2;
- Consider the economic benefits that can result for host organisations, host communities and host countries.

1.2 Boundary conditions and data sources

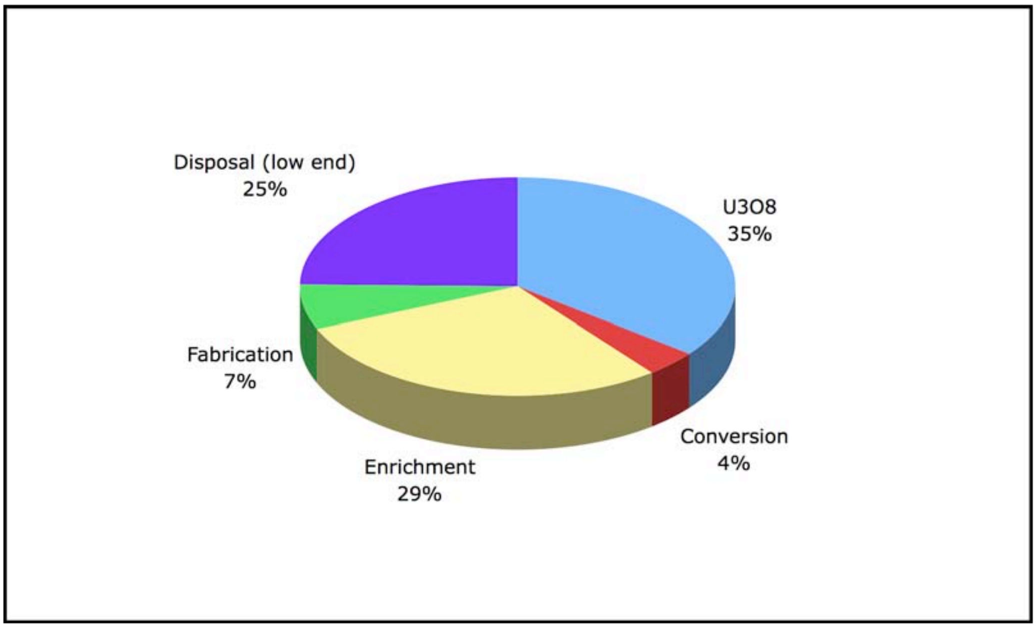
Estimation of the costs of complex, multi-decade, multi-national projects is surrounded with uncertainties. Whilst the nature and types of cost that will arise are rather easy to identify, based on around 40 years of managing wastes in many countries, the scale of costs is dependent on long-term political and social factors as well as local (national) conditions in the countries where the costs arise. Studies of the economics of sharing fuel cycle facilities have a long history. The 1977 IAEA study project on regional nuclear fuel cycle centres included a quite detailed assessment (Meckoni et al., 1977) with a number of financing scenarios. It was among the earliest studies to recognise *"the opportunity for countries with small nuclear power programmes to realise….economies of scale by joining with other countries and jointly utlilizing plants of larger size than could be utilized alone by such countries."*

To facilitate the current analysis, we have set a range of constraints and identified the most appropriate sources of data to use.

- Consider only long-lived wastes that need to be disposed of in a geological repository; spent fuel (SF), high level wastes (HLW), long lived low and intermediate level wastes (LILW-LL) from the fuel cycle and nuclear power facilities, long-lived wastes from outside the nuclear industry.
- Use a range of reference scenarios for the numbers of repositories and storage facilities that might be required and the transport arrangements that might be necessary.
- Use published European data on storage, disposal and transport facilities so far as possible and relevant: the main sources of data were Finland, Sweden, Belgium, Switzerland, Slovenia and the UK. Some data were obtained from US sources (mainly on transport costs).

When judging the costs of disposal of radioactive wastes from nuclear power production, it is useful to set these in a larger framework of the total costs of the nuclear power cycle. Figure 1.1 shows the relative costs of mining and milling uranium, conversion, enrichment, fuel fabrication, and disposal (for which high and low values from the literature are given).

It is noticeable that, despite the recent rises in uranium prices, the back-end costs of the nuclear fuel cycle remain significant, whichever estimate of disposal costs is considered. A further observation is that all of the activities on the chart are carried out by a limited number of countries throughout the world as services for other nuclear power users – with the exception of waste disposal. Although, there are examples of specific foreign wastes being accepted under commercial arrangements or else to enhance security, there are as yet no multinational repositories implemented or even agreed upon. This is the reason for initiating the SAPIERR studies – to make the potential for such cooperation in a regional European framework more concrete.



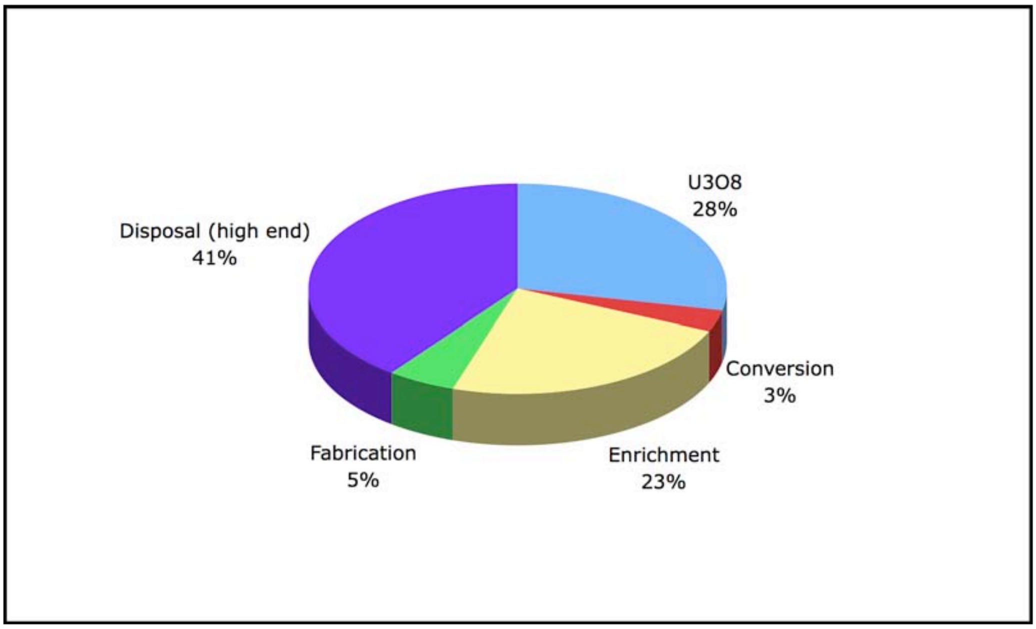


Figure 1.1. Cost distributions across the nuclear fuel cycle. Upper figure assumes a low-end cost for SF/HLW disposal of 500 USD/kg. Lower figure assumes a high-end cost for disposal of 1000 USD/kg. As discussed later in this report, projected prices for a commercial spent fuel disposal service in Russia are about 1500 USD/kgHM. The values above assume 90 USD/kg price for U_3O_8.

Information source: World Nuclear Association.

A further important boundary condition comes from the conclusions of Work Package 1, on the potential form of a shared repository organisation. The proposed WP1 model, whereby an initial European Development Organisation (EDO) transforms into or establishes a European Repository Organisation (ERO), is important from the viewpoint of financing mechanisms and spend profiles. The definitions of EDO and ERO are as follows:

- **EDO (European Development Organisation):** the initiating, non-profit organisation for a shared geological disposal facilities project. Its objective is to establish the systems, structures and agreements and carry out all the work necessary for putting in place a shared waste management solution and geological repository (or repositories). This work would continue through the investigation of potential sites and up to the point of license application to begin the construction of a repository. It is assumed that this takes about 10+ years. At this point the EDO may decide to transform into or separately establish the ERO.
- **ERO (European Repository Organisation):** the implementing organisation for waste disposal. The ERO would be the license holder for the repository and responsible for all subsequent operational activities in a host country that has agreed to dispose of wastes from other European countries. The form for the ERO will be chosen at a future date by the members of the EDO, assuming that they come to the conclusion that the EDO organisation needs to be altered. The choice will also be strongly influenced by the preferences of the country or countries that have been identified as repository hosts. The ERO could be either non-profit or commercial in structure.

1.3 Inventory of wastes and the setting of scenarios

Although a particular waste inventory is not central to the viability of a shared European repository, some assumptions are needed as a basis for exploring the sharing concept. In this study we have looked at a ‘large’ European inventory and a ‘small’ European inventory and developed scenarios for each.

1.3.1 The ‘large’ inventory situation

In SAPIERR I, the waste inventory used as a reference was the total waste arisings from the fourteen countries from which organisations participated in the project. This was not meant to indicate that any or all of these countries had chosen a final disposal strategy, but rather to give a set of quantitative working assumptions. For ease of comparison with the earlier work in SAPIERR I, the same inventory is used as the reference case in the current study, again emphasising that the inclusion of a national inventory within the SAPIERR reference inventory does not imply that the country concerned would choose to participate in a shared European solution.

The reference inventory in SAPIERR I at 2040 was derived as:

- 25,637 t of spent fuel (SF)
- 355 m^3 of vitrified high level wastes (HLW)
- 31,000 m^3 of long-lived intermediate level wastes (LILW-LL)

SAPIERR I proposed that the HLW/SF could be packaged in about 13,500 containers, but this we discuss this in more detail in Section 3. For the ‘large’ inventory, SAPIERR II uses the numbers above (or rounded versions of them) but we again emphasise their arbitrary nature –

an eventual European regional repository could hold much more or much less waste than considered here. We have used the ‘large’ inventory as the basis for most of the economic analyses in the current study.

1.3.2 The ‘small’ inventory situation

To look at the economics of a situation where only two or three countries decide to share disposal solutions, we have also looked at a ‘small’ inventory. This is not assessed in as much detail as the ‘large’ inventory and we have made some additional approximations in estimating the costs and other aspects of the ‘small’ inventory.

The ‘small’ inventory is derived from an evaluation of the individual national inventories of the fourteen SAPIERR I countries and comprises approximately 25% of the ‘large’ (SAPIERR I) inventory:

- 6280 t of spent fuel (as discussed later, we make an approximation which assumes that this equates to about 3500 containers for disposal);
- 6800 m^3 of long-lived intermediate level wastes (LILW-LL).

To arrive at these figures, we looked at a range of hypothetical, 2 and 3-country sharing situations that gave total amounts of spent fuel of between about 4700-7600 t SF and of LILW-LL of between 6200-9000 m^3, with the numbers actually selected for the ‘small’ inventory model being averages of the various situations considered.

Inventories in these ranges could be derived if, for example: Belgium and the Netherlands were to share a disposal solution; Bulgaria and Romania were to share a solution; Slovakia, Slovenia and the Czech Republic were to share a solution. Note, of course, that these hypothetical partnerships do not reflect in any way on the intentions or policies of these countries but are only provided as illustrations of scale for the ‘small’ inventory situation.

2 Scenarios for storage, transport and disposal

A set of reference scenarios for implementation of regional repositories in the EU has been defined for the purposes of the analysis. Clearly, other variants are possible, but the group selected covers the main aspects of the options that are considered most realistic. Each of these scenarios can then be compared against a base case, in which all countries are constrained to have a national geological disposal facility.

2.1 Repositories and waste encapsulation facilities

As there is clearly no idea at present as to the geological environment in which a regional repository might be located, we continue to use the generic models from SAPIERR I, whereby repositories are either in 'hard rocks' or 'sediments'. This allows us to assign cost data from relevant programmes. The scenarios that have been used here, and the sources of the data used to derive costs, are as follows:

> **Scenario I(H):** Single repository for all wastes in hard rock. Using two separate cost models: (a) the Swedish (SKB, 2003) cost study (covering all the wastes) and (b) the Finnish (Posiva, 2005) cost study for SF combined with the SKB data for ILW.
>
> **Scenario I(S):** Single repository for all wastes in sediments (clays). Using a combined model: the Swiss (Nagra, 2001) HLW/SF cost study and the Swiss Wellenberg (NEA, 1999) cost study for ILW.
>
> **Scenario II(H):** Separate repositories for HLW/SF and for ILW in hard rock. Using two separate cost models: (a) the Swedish (SKB, 2003) cost study and (b) the Finnish (Posiva, 2005) cost study for the HLW/SF repository plus the SKB data for ILW.
>
> **Scenario II(S):** Separate repositories for HLW/SF and for ILW in sediments (clays). Using the Swiss (Nagra, 2001) HLW/SF cost study and the Swiss Wellenberg (NEA, 1999) cost study for ILW.
>
> **Scenario IIIa:** Two separate repositories, each with half the SAPIERR waste inventory, one in hard rock and one in sediment, assuming each has its own encapsulation plant: by scaling the costs of Scenarios I(H) and I(S). The Swiss model from Scenario I(S), scaled to 50% of the waste, is combined with both the Swedish and Finnish Scenario I(H) models, also scaled for 50% of the waste.
>
> **Scenario IIIb:** the same as Scenario IIIa, but with only one encapsulation plant, located at the hard rock repository site. For this estimate, it was only possible to deconvolute the SKB data sufficiently to make an encapsulation estimate, so the results are presented as a Swiss/Swedish model only.

There are various reasons why a 'two repository' scenario might be favoured. These include geographical efficiency with respect to transport, ensuring security of supply of disposal services and catering for possible widely differing times of waste arising in different regions. The 'large' inventory situation, upon which most of the economic assessment in this study is based, looks at all of the scenarios listed above. For the 'small' inventory situation, which is evaluated in less detail, Scenario I(H)a is the only model considered. The scenarios are shown schematically in Figure 2.1.

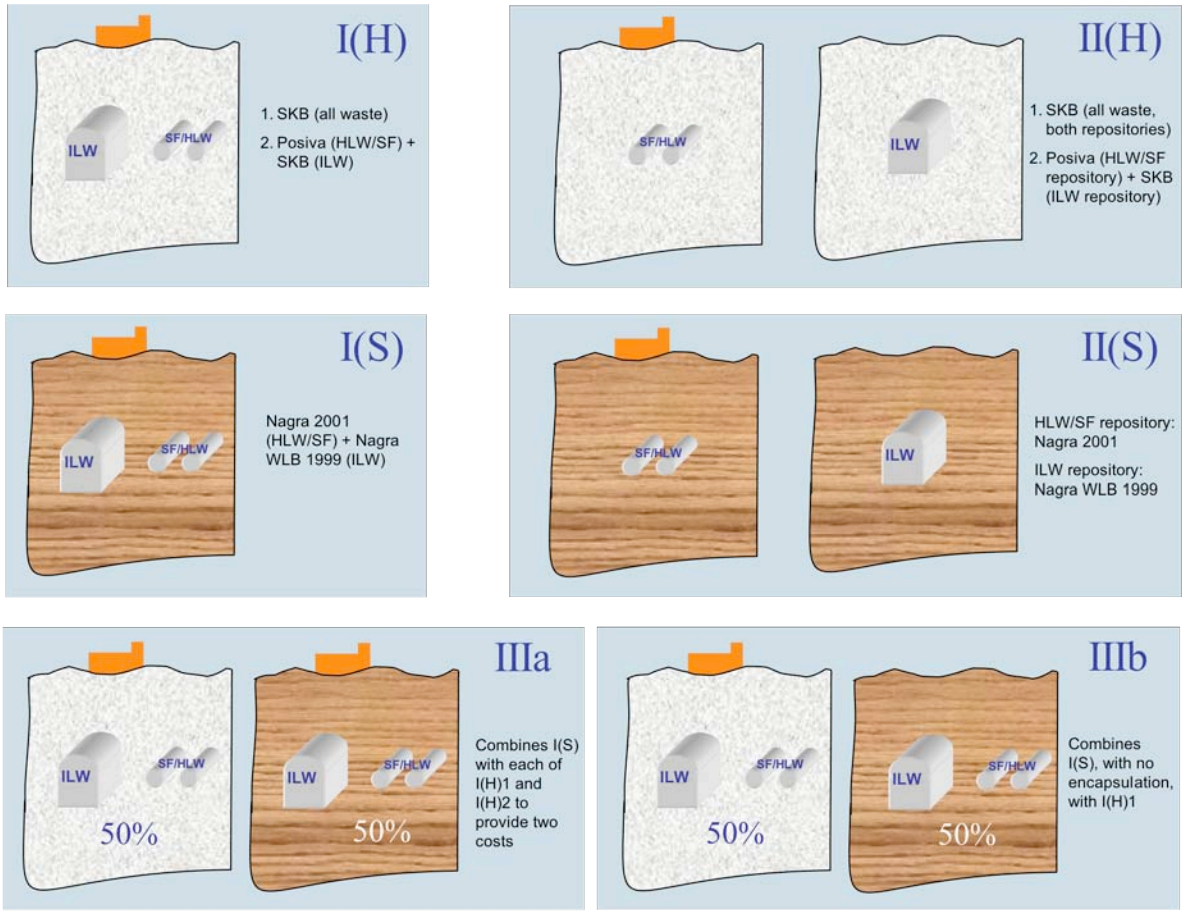


Figure 2.1: Schematic illustration of the Scenarios costed and the data sources for each

2.2 Storage facilities

SAPIERR I considered the issue of shared storage facilities and came to the conclusion that, provided disposal facilities were available in a timely fashion with respect to the rate of waste arising and becoming ready for disposal, then there was little advantage in centralised shared stores. Adequate storage is available at the source of the wastes and, with modular dry cask storage, there is no large economy of scale impact. However, some buffer storage capacity would be needed at the location of the repository and encapsulation plant.

2.3 Transport routes and distances

Clearly, these cannot be definitively laid down prior to considering siting options. Transport routes are not considered to be a decisive legal or technical factor, since radioactive wastes in the EU, like any other goods, must be able to be freely shipped across Europe. In practice, of course, it could be a societal problem if wastes had to cross countries that were not involved in the regional repository and were anti-nuclear. The distances that wastes have to be transported in national or multinational scenarios, along with the transport modes, are important when comparing safety, security and environmental aspects. In the absence of a site or sites for the facilities, the following arbitrary, but plausible assumptions are made.

For security reasons, and practicality of moving heavy loads, rail transport might be preferred wherever existing infrastructure allowed. Dedicated railhead facilities might be constructed at encapsulation and disposal facilities. Road transport could be used where needed to fill 'gaps' between waste sources and national rail networks.

As very approximate surrogates for the average distance to be transported, we can look at the area of countries and use the radius of the equivalent circles. The average area of all countries in Europe is ~156,400 km^2, giving an average radius of 220 km. To take into account the fact that countries interested in a multinational facility may be more likely to be the smaller countries and to avoid an overestimate of national transport distances that would lead to a bias in favour of multinational options, this number is rounded down to a reference value of 100 km. If the whole area of Europe were joined, the radius would be 1240 km. If divided into two equal area regions, the radius for each is 880 km. Rounding the numbers, we get the following:

	Transport distance (km)
National repository scenario	100
Multinational scenario I	1200
Multinational scenario II	1200
Multinational scenario III	900

These figures assume that encapsulation is in all cases at the repository site(s). In practice, if disposal were national but encapsulation offered internationally as a service, the transport distances in the national scenario would increase significantly.

As will be shown later, these illustrative figures do not have any large effect on safety or on costs – but they may be significant in a discussion on the societal issues associated with radioactive waste transports. Of course, in a multinational scenario, the transport distance would be one of the factors in a multi-attribute analysis leading to a choice of sites.

2.4 Timing of disposal operations

SAPIERR I sketched out a timetable leading to disposal operations between 2035 and 2095. This is retained here as a reference case. This assumption impacts upon the storage requirements until these dates (as discussed above) and thus on issues such as security at existing and future stores. It also constrains the time available for siting work and associated R&D, which both have significant impacts on estimated costs.

3 Waste Management Costs – Disposal

Disposal costs (repository costs plus HLW/SF encapsulation costs) have been calculated by scaling the number of SF+HLW waste packages in the SAPIERR inventory to those of other national programmes, using similar repository design assumptions (the KBS-3V concept for hard rock and the Nagra concept of axial emplacement along the centreline of disposal tunnels in sediments: as in SAPIERR I). A more detailed evaluation has been made since the SAPIERR I estimates, which is based partly on the approach used by Chapman and McCombie (2006) for estimation of UK New Build spent fuel disposal costs.

All costs have been updated to end-2006 values, using standard national inflation indicator statistics. The details (inflation rates and data sources) are shown in the Tables in Appendix 1.

In carrying out the cost scaling, some key assumptions have been made on waste packaging for emplacement in the repository:

1. For the ‘large’ inventory situation, the number of spent fuel and HLW packages is as described in the SAPIERR I project: 13,246 SF of assorted lengths and 2021 HLW containers. For the ‘small’ inventory, we have assumed an arbitrary number of 3500 SF packages (see Section 1.3.2 for derivation).

2. For disposal in vertical deposition holes in hard rock (KBS-3V concept), a single deposition hole would be required for any of the three SAPIERR spent fuel package types (5.0, 4.3 and 3.7 metre lengths). This results in 13,246 spent fuel containers and deposition holes for the ‘large’ inventory.

3. For HLW disposal in vertical deposition holes in hard rock, a package about 5 m long containing three 150 litre HLW glass casting containers is assumed (equivalent to a package three times as long as the Nagra HLW container). This results in 2021 HLW containers and 674 deposition holes for the ‘large’ inventory.

4. The total number of HLW and SF deposition holes for the ‘large’ inventory, hard rock scenarios is thus 13,920.

5. For horizontal disposal is sediments (axially along the centreline of disposal tunnels) no distinction is made between SAPIERR package sizes and scaling to the Nagra sediment study costs is done simply on the total number of packages (13,920 – using the same packaging assumptions as for hard rock).

6. For ILW disposal, costs have been scaled on waste volume, using the SKB SFL3-5 data for hard rock and the Nagra Wellenberg data for sediments. For co-disposal, the cavern construction, operation and closure costs of the ILW part of a combined repository are simply added to those for the SF-HLW repository (which include access works). Co-disposal is the only scenario considered for the ‘small’ inventory situation.

7. For separate ILW repositories, the cavern construction, operation and closure costs of the ILW are added to the siting and administrative costs of a SF-HLW repository.

8. Different elements of the costs contain different ratios of fixed to variable costs. For example, a repository will need the same number of access ramps or shafts, regardless of the amount of waste emplaced in it (unless it becomes very large, when additional

access or ventilation may be needed). Thus, this element of cost is treated as fixed. Encapsulation costs include a large element of operational costs, which depend predominantly on the number of waste containers being produced. This is an example of a variable cost. For some costs, the ratio is dependent on the model used: for example, repository closure costs sometimes include mainly costs of backfilling and sealing disposal tunnels, while in other models they only include the costs of access closure. In allocating fixed to variable cost ratios to each broad cost subhead, we have made generalised assumptions that would no doubt vary upon more detailed scrutiny, but these are considered adequate for the present level of analysis. The assumptions made for fixed to variable (F/V) ratios are shown in Table 3.1 below.

Table 3.1: Fixed to variable cost ratios assumed for the databases on which the analysis is based.

SKB data		Posiva data		Nagra data	
Cost Item	**F/V ratio**	**Cost Item**	**F/V ratio**	**Cost Item**	**F/V ratio**
Siting	100:0	Above ground* facilities	100:0	Siting	100:0
Construction	30:70	Above ground* operations	20:80	Construction	50:50
Operation	20:80	Above ground* decommissioning	100:0	Operation	40:60
Closure	0:100	Repository facilities	30:70	Closure	0:100
R&D and Admin	100:0	Repository operations	20:80	R&D and Admin	100:0
Encapsulation	10:90	Repository closure	90:10	Encapsulation	30:70

*the above ground facilities and operations are dominated by encapsulation

3.1 Estimated disposal costs: 'large' inventory situation

Section 2.2 gave details of the various repository scenarios considered for the 'large' inventory situation. Summarised, these are:

- **Scenario I(H):** Single repository for all wastes in hard rock. Using two separate models: (a) Swedish and (b) Finnish.
- **Scenario I(S):** Single repository for all wastes in sediments (clays) – Swiss model.
- **Scenario II(H):** Separate repositories for HLW/SF and for ILW in hard rock. Using two separate models: (a) Swedish and (b) the Finnish for the HLW/SF repository plus Swedish for ILW.
- **Scenario II(S):** Separate repositories for HLW/SF and for ILW in sediments (clays) – Swiss model.
- **Scenario IIIa:** Two separate repositories, each with half the SAPIERR waste inventory, one in hard rock and one in sediment, assuming each has its own encapsulation plant: by scaling the costs of Scenarios I(H) and I(S).

- **Scenario IIIb:** the same as Scenario IIIa, but with only one encapsulation plant, located at the hard rock repository site.

The component costs (i.e. for each separate repository for which costs were estimated) that were combined to establish the total Scenario costs are shown in Table 3.2 below (this information is abstracted from the detailed Tables in Appendix 1).

Table 3.2: Cost estimates for individual repository components of the Scenarios.

Cost component and data used to scale costs	**Total Cost MEUR** **Dec 2006 values** repository plus encapsulation plant
Swedish data: single HLW and SF repository in hard rock for 13920 containers	**8076** (5442 plus 2633)
Swedish data: single HLW and SF repository in hard rock for 6960 containers	**4910** (3547 plus 1362)
Finnish data: single HLW and SF repository in hard rock for 13920 containers. Encapsulation costs are difficult to deconvolute: an approximate estimate is that encapsulation (including all surface facilities at the repository site operating for >70 years, plus decommissioning) comprises >60% of the total.	**9597**
Finnish data: single HLW and SF repository in hard rock for 6960 containers.	**5177**
Swedish data: single repository for 31,000 m^3 ILW in hard rock	**1418** (of which, vault construction, operation and closure = 95)
Swiss data: single HLW and SF repository in sediments for 13920 containers	**7964** (5531 plus 2433)
Swiss data: single HLW and SF repository in sediments for 6960 containers	**4747** (3435 plus 1312)
Swiss data: single repository in sediments for 31,000 m^3 ILW	**627** (of which, vault construction, operation and closure = 361)

The data above have been combined to produce estimated total costs for the Scenarios described previously. Again, the details of the cost calculations can be found in tabular form in Appendix 1. The Scenario costs for the large inventory are shown below in Table 3.3.

Note that the costs calculated based on Finnish data, although the highest, do not include costs for siting and R&D work (other than in ONKALO), although they do include some contingency costs. An amount to cover these costs is added for the discussion in Section 6 on spend profile with time.

Table 3.3: Estimated disposal costs for the Scenarios.

Costs in MEUR (Dec 2006 values)		
Scenario I(H) single hard rock repository	Swedish Model	Finnish Model
	8170	**9690**
Scenario I(S) single sediment repository	Swiss Model	
	8330	
Scenario II(H) separate hard rock repositories for HLW/SF and ILW	Swedish Model	Finnish Model
	9490	**11,010**
Scenario II(S) separate sediment repositories for HLW/SF and ILW	Swiss Model	
	8590	
Scenario IIIa separate hard rock and sediment repositories, each for 50% of inventory with encapsulation plant at each	Swiss/Swedish Model	Swiss/Finnish Model
	9890	**10,150**
Scenario IIIb separate hard rock and sediment repositories, each for 50% of inventory with a single encapsulation plant (at hard rock repository)	Swiss/Swedish Model	
	9840	

3.1.1 Observations on 'large' inventory disposal costs

The first point to emerge from examination of Table 3.3 is that, overall, there is not a major difference between the Scenarios considered. The difference between the least and the most costly is about 2800 MEUR (about 26% of the most costly). If uncertainty and contingency were to be taken into account, the differences may be further blurred (e.g. some of the Finnish costs incorporate a 20% contingency). Nevertheless, some options are clearly more economic than others:

1. The Swedish and Swiss models for Scenario I are almost identical in cost, suggesting no significant difference between disposal in sediments and hard rock (although the Finnish model gives ~15% higher cost for hard rock).

2. Separate hard rock repositories for SF/HLW and for ILW – Scenario II(H) – add about 12-14% (over one billion Euros) to the price of a single repository (Finnish and Swedish models, respectively) – but see comment (3) below.

3. Separate sediment repositories for SF/HLW and for ILW – Scenario II(S) – add only about 3% to the price of a single repository. The difference compared to the hard rock Scenario II(H) is because the latter includes undifferentiated R&D costs for SF geological disposal which have escalated the calculated cost for that scenario. A reasonable increment for both Scenarios II(H) and II(S) may thus be closer to 5-10%.

4. Splitting the total waste inventory equally between two repositories (one in hard rock and one in sediment – Scenario IIIa), each with an encapsulation facility of its own, adds up to ~ 20% to the cost of a separate repository (depending on which model is chosen).

5. Scenario IIIb, with only one encapsulation plant, is almost identical cost to the equivalent Scenario IIIa (with two encapsulation plants) illustrating that most of the costs associated with encapsulation are materials and operational costs rather than capital (closely scaled to the amount of SF/HLW), so the choice of whether to have one or two plants has little impact on total programme costs, although it could affect transport costs.

3.1.2 Comparison with separate repository costs

If each of the fourteen countries[1] whose data were used in the SAPIERR I analysis had to build its own repository, the cost increase is dramatic. Some countries (Austria and Latvia) only have ILW to dispose of, but would still need a geological repository. We have used the cost scaling method described above to make one simple calculation to illustrate the economies of scale that are to be gained from sharing.

In this scenario, it is assumed that each of the 14 countries constructs a repository in hard rock, with the consequent costs scaled according to the Swedish dataset used throughout. Individual national costs range from 1330 to 3650 MEUR. The total cost is a staggering 37,670 MEUR. Even with the most expensive of the shared option scenarios, the savings are well over 25,000 MEUR.

It is important to note that more than half of this saving (~15 BEUR) comes from pooled R&D and administration, with a substantial portion of this amount (perhaps more than half) being from the shared R&D element – or from not having to carry out some R&D at all. The Swedish cost basis data include all the R&D work for their SF repository programme (and, in our calculations, the historic costs over the last 30 years have not been inflated to present day values – if a programme had to start with a similar R&D programme today it would inevitably cost much more than the values used here).

It is acknowledged that the large apparent R&D saving might be greatly overestimated. New or recently developed national programmes would not each emulate the long-term R&D work that has supported the Swedish programme for several decades. Not only would this be inappropriate for small (e.g. ILW only) inventories, but also unnecessary, since there is now a considerable scientific and technical pool of knowledge internationally upon which to base any new programme. Indeed, the EU has recently run a parallel project to SAPIERR (called CATT) that has investigated the possibilities for sharing knowledge and experience.

Moreover, several of the SAPIERR I nations (e.g. Belgium, Switzerland) have already sunk large amounts into their own R&D, also over several decades, and the historic R&D costs of

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[1] Note the caveat in Section 2.1: the inclusion of a national inventory within the SAPIERR reference inventory does not imply that the country concerned would choose to participate in a shared European solution.

all the SAPIERR countries should, in any case, be deducted from the apparent saving defined above (a rough estimate could be around 4 BEUR). Nevertheless, sharing future R&D between the partners and using published data and other routes will comprise a significant proportion of future economy of scale.

If, nevertheless, one makes the highly unrealistic assumption that no further R&D would be necessary in national programmes, the economy of scale savings of sharing a disposal solution are still around 15 BEUR.

3.2 Estimated disposal costs: 'small' inventory situation

The analysis performed for the situation where only two or three countries are sharing a single repository (see Section 1.3.2 for details of waste amounts and hypothetical sharing models) is based upon the methodology and information sources described above for the 'large' inventory situation. In this situation, we are looking at only approximately 25% of the total SAPIERR I inventory.

The single scenario chosen here is co-disposal of SF and LILW-LL in a single, hard rock repository with its own encapsulation plant: Scenario I(H), using the Swedish data for both waste types.

The total disposal cost derived for this scenario is 3980 MEUR[2]. Using the same assumptions as discussed in Section 3.1.2, the saving on having two or three separate national repositories is about 3300 MEUR. As for the 'large' inventory case, much of this saving is in R&D and siting costs. Even accounting for 'sunk costs, as discussed in Section 3.1.2, the implication is that each country involved in a small sharing partnership might be expected to save in the order of 500 – 1000 MEUR.

3.3 Conclusions on overall disposal costs

The cost calculations used are relatively simplistic and could be carried out in considerably more detail, but this is not considered appropriate at this stage of an assessment of this kind. The scenarios analysed point to some relatively simple conclusions on the economics of disposal itself:

1. Total disposal costs for the full SAPIERR I ('large') inventory are around 10 BEUR.
2. Implementing two shared repositories with half the total inventory in each rather than a single regional facility (for geographical, political or other reasons) may add up to about 20% to overall costs.
3. There is only a modest overall cost advantage in having a single encapsulation plant. Encapsulation costs are predominantly operational (e.g. staff and materials), rather than investment costs.
4. Separate repositories for HLW/SF and for ILW may add only ~5-10% to overall costs for single repositories for the 'large' inventory.
5. The overall impact of opting for a shared rather than numerous solo solutions in the SAPIERR I nations amounts to a saving to the EU of at least 15 BEUR.

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[2] This compares with an estimated cost for the smaller Finnish spent fuel repository of about 2540 MEUR for about 2900 containers (compared to the ~3500 containers, plus ILW, in our 'small' inventory).

6. Even if only two or three countries were to share the costs of a repository (the ‘small’ inventory situation) the savings continue to be substantial: possibly between 500-1000 MEUR for each country.

4 Waste Management Costs – Transport

4.1 SF and HLW

Most cost studies for SF transport use a single estimated figure based on mass, which does not consider distance – the implication being that the main elements of transport costs are the capital costs of transport casks and vehicles, preparing the material for movement, and waste reception. In other words, once waste is on the move, the cost is not highly sensitive to the distance moved. This is exemplified by the explicit cost numbers given by Nirex in the UK for rail and road transports of HLW (Nirex 2003d).

For SF transport within the European area, the NEA (1994) has quoted a range of unit prices from 20-80,000 USD/t with a reference value of 50,000 USD/t. This is in broad agreement with USA estimates of 50- 55,000 USD/t (Bunn et al., 2001). Parks and Wagner (2004) quote industry estimates of the cost of individual shipments of SF to Yucca Mountain, including freight charges and operational costs, to be between 200,000 and 500,000 USD. A 2002 study on the costs of SF storage in the Republic of Korea (Kang, 2002) give transport costs of 61,000 USD /t for PWR fuel and 57,900 USD /t for MOX fuel.

Fairlie (2000) quotes the following figures from three different German studies:

- Spent Fuel Transport: Germany to France: 117,000 and 125,000 USD/t.
- Transport to German Conditioning Plant: 30,000 USD/t.

Transport costs estimated by Hensing (1996) are 50,000 DM/t for internal transport.

Very much lower costs have also been reported. The Posiva programme costs study gives a SF transport cost of 240,000 EUR for 41 containers of SF (one year's production) – equivalent to about 6000 EUR per container (each containing an average of 1.95 tU). This gives a cost of about 3000 EUR/t. The costs of road transport of SF from the Loviisa NPP to the encapsulation and disposal site at Olkiluoto are 6.9 MEUR for 698 containers (1018 tU) – about 6800 EUR/t. These values are close to Japanese figures for transport to a centralised SF store of 7000 EUR/t. Bunn et al. (2001) speculated that this low value results from the fact that the transport infrastructure was already available, possibly as with the Finnish data.

In order not to underemphasise transport costs that may arise in a regional repository scenario, we will neglect the low Finnish and Japanese values and assume that international transports are more expensive than national transports. Accordingly, in the present report the assumed unit costs for SF transport are 40,000 EUR/t for the international transports that a European regional repository would require.

4.2 ILW

Little published information is available here. Brusa et al (2002) estimated the costs of transporting decommissioning wastes from the Trino NPP in Italy to a final repository to be 5165 EUR per 10 tonne load. This value is used in our estimations.

4.3 Costs of transport for the 'large' inventory

The reference SAPIERR-I SF and HLW inventory in 2040 consists of 25,637 t of spent fuel and 355 m^3 of HLW. Converting the HLW to mass (at a density of 2.7) and treating it as SF gives a total mass of 26,632 t. There is also 31,000 m^3 of LILW-LL (for which we assume an average ILW density of 2 t/m^3, giving a total mass of 62,000 t).

All of these materials must be transported at least once, whether in a national repository scenario or in a regional framework. The costs of a single transport for all materials based on the values selected above would be:

- SF and HLW: ~1065 MEUR
- LILW-LL: ~32 MEUR

4.4 Costs of transport for the 'small' inventory

Using the same assumptions as above, the costs of a single transport for the 'small' inventory of SF and LILW-LL would be:

- SF and HLW: ~250 MEUR
- LILW-LL: ~7 MEUR.

4.5 Conclusions on transport costs

It can be seen that the costs of even a single transport are significant when compared with the estimated disposal costs of around 10 BEUR (i.e. about 11%) for the large inventory and around 4 BEUR (i.e. around 6.5%) for the 'small' inventory (which has SF and LILW-LL only).

The total costs of transporting the wastes will depend on the numbers of transports, which depends in turn on the scenarios assumed for the locations of stores, encapsulation plants and repositories. The conclusions to be drawn are that:

- the costs of transport are a significant fraction of back-end costs;
- moving spent fuel to a regional repository does not cost significantly more than transports to national facilities;
- in both cases, significant savings are achieved by co-locating the encapsulation plant and the repository.

Since not all European countries are likely to have a national encapsulation plant, using a foreign service-provider that must return the encapsulated fuel entails significant extra transport costs.

5 Waste Management Costs – Storage

In this section, we look principally at the storage costs for spent fuel, as these dominate overall storage costs for the SAPIERR waste inventory.

All water-cooled reactors store the spent nuclear fuel, when it is unloaded from the reactor, under water in a pool at the reactor site. The water provides both radiation shielding and cooling for the highly radioactive, heat generating fuel elements. Originally it was planned that spent fuel would be shipped off site after a few years of cooling; the fuel would then go for reprocessing or for longer term storage to allow further cooling before direct disposal. In practice, reprocessing is currently carried out in only a few programmes and the need for storage has thus increased. This can be at the reactor site or centralised (away from reactor – AFR). However, centralized storage facilities have proven difficult to site. Accordingly the capacity of storage pools has been increased at many reactors and at some sites dry storage facilities have been implemented.

The cooling time before spent fuel can easily be disposed of in a geological repository is some 30-50 years. Even if this delay were not necessary for technical reasons, there are other arguments for delaying disposal. For small nuclear programmes, many years of operation would be required to accumulate an inventory of spent fuel that justified embarking on an expensive deep repository project. Furthermore, by extending surface storage times for decades, the large expenditures needed for implementing such a solution can be postponed. By normal accounting procedures, which assume a rate of interest on invested funds that is higher than the monetary inflation rate, this is a sound economic strategy. As discussed later, however, this approach does not go unchallenged.

It has also been argued in some countries that extended storage of spent fuel is an alternative to the commonly favoured long-term strategy of geological disposal. In particular in Europe, the UK public consultation exercise run by the Government-initiated CoRWM Committee treated storage as a long-term option, with the facilities being renewed at the necessary intervals of several decades. Ultimately, however, CoRWM recommended to the government that disposal should be the objective, although this can be accomplished in a staged manner, which still requires many years of storage. In fact, most national programmes now view storage as an interim measure that can last even up to some hundreds of years – but it must be followed by a disposal programme. For example, the Netherlands have decided that extending storage up to a period of ~100 years or more is a sensible strategy – provided that mechanisms are introduced to ensure that the funding needed for final disposal will be accumulated during the years of reactor operation and SF storage.

The objectives of this Section are to review storage requirements in Europe, estimate the associated costs and consider whether shared storage facilities could bring an economic benefit to EU countries. We begin by looking at the technical options for storage.

5.1 Wet storage of SF in pools

All operating light water reactors have a fuel storage pool. This requires maintenance, since the water must be treated to remove the small quantities of radioactive materials that can escape from damaged or contaminated fuel elements. During the period when the reactor is in operation, this is a small supplementary activity. If the pool is maintained for a period after shutdown, then dedicated operations are necessary. Pool storage has also been implemented at centralised, away-from-reactor (AFR) facilities in some European countries. For example, the

CLAB facility in Sweden accepts spent fuel from all Swedish reactors. Table 5.1 gives a summary of away-from-reactor (AFR) wet storage facilities in Europe. It should be noted that AFR does not indicate a separate site; only that there is additional storage outside the reactor pool itself. There are some specific disadvantages of pool storage. One is that a large facility must be constructed at the outset to allow for future accumulation of spent fuel, so that much of the storage space remains unused for a long period. Another is that maintenance can become expensive if final disposal lies far into the future. Recently, pool storage has also been criticised as being particularly susceptible to terrorist attacks (Alvarez et al., 2003), although such vulnerability has also been refuted by regulatory bodies (USNRC, 2003; NRC, 2005). The result is that spent fuel is increasingly stored in dry storage facilities, which have lower operational costs and which can be implemented in a modular fashion.

Table 5.1: Away-from Reactor (AFR) wet storage of NPP spent fuel in Europe

Facility Name	Status	Scale	Country
Eurochemic (Belgoprocess Site) Storage Pools	Decommissioning	Commercial	Belgium
Tihange NPP Site	In operation	Commercial	Belgium
Kozloduy NPP Site	In operation	Commercial	Bulgaria
Loviisa NPP Site (Spent Fuel Storage 1)	In operation	Commercial	Finland
Loviisa NPP Site (Spent Fuel Storage 2)	In operation	Commercial	Finland
Olkiluoto NPP Site, TVO KPA	In operation	Commercial	Finland
La Hague - C	In operation	Commercial	France
La Hague - D	In operation	Commercial	France
La Hague - E	In operation	Commercial	France
La Hague - HAO	In operation	Commercial	France
La Hague - NPH	In operation	Commercial	France
Greifswald NPP Site, ZAB - Zwischenlager	In operation	Commercial	Germany
Karlsruhe	Shutdown	Pilot plant	Germany
Bohunice NPP Site SFSF	In operation	Commercial	Slovakia
CLAB ISF	In operation	Commercial	Sweden
BNFL Sellafield B29 Pond	Decommissioning	Commercial	UK
BNFL Sellafield B30 Pond	Decommissioning	Commercial	UK
BNFL Sellafield B27 Pond	In operation	Commercial	UK
BNFL Sellafield Fuel Handling Plant	In operation	Commercial	UK
BNFL Sellafield Pond 4	In operation	Commercial	UK
BNFL Thorp RT and ST-1,2	In operation	Commercial	UK

5.2 Dry Storage of SF

If smaller quantities of spent fuel are stored, or if the incremental rate of SF arising is modest, then the preferred dry storage option is in concrete or metal casks, each of which can hold 5 to 17 t of fuel. The casks can be purchased as required; they do not require a strengthened or strongly shielded building and can even be placed on pads on the open air. The cladding of SF in casks can rise to higher temperatures (~350°C). Concrete casks are often ventilated but metal casks are cooled primarily by radiation and natural convection and can have higher external temperatures.

If large quantities of spent fuel (above about 600 t) are ready for extended storage at one time, then the most economical approach can be dry storage in a gas-cooled vault. This system was already being employed in 1970, for example, at the Wylfa plant in the UK. Vault stores can handle large quantities of spent fuel, with high thermal output, whilst maintaining relatively low fuel cladding temperatures (~200-250°C).

Table 5.2 lists existing dry storage facilities in Europe. The large number of stores in Germany results from a governmental policy decision to construct individual stores at individual NPP sites rather than transport the spent fuel to one of the existing centralised storage sites at Gorleben and Ahaus.

5.3 Underground Storage of SF

Most storage facilities are built above ground, although there are exceptions such as the Swedish CLAB spent fuel pool, situated in a rock cavern some tens of metres below surface, with a similar (dry storage) solution currently being proposed in Canada, but at greater depth. The security and terrorist concerns mentioned above have heightened interest in the potential advantages of building storage facilities underground. This approach has recently been considered in the UK CoRWM work – where such stores are referred to as “hardened” facilities. The possibility of hardening the storage facility by constructing missile resistant casks has also been proposed in the USA. A more far-reaching alternative would be to have spent fuel storage facilities at repository depths (hundreds of metres) with the possibility of later converting these stores into final disposal facilities. This was suggested some years ago for the Yucca Mountain facility in the USA (Eriksson 1991) and has recently been developed further in the Japanese disposal programme (Masuda et al 2004).

5.4 Capacities of SF storage facilities in Europe

As illustrated above, there are currently a number of SF storage facilities operating in Europe and more are in construction or planned. Table 5.3, also based on IAEA data, gives an overview of the present situation. Nuclear power generating countries not appearing in the list rely on storage at the reactor, in some cases made possible only by extensive re-racking in the reactor pools.

The trend is clearly towards dry storage. The large wet stores in France and the UK are because the fuel is stored for subsequent reprocessing. As noted above, the large extension of dry storage in Germany is a result of government policy, which favours building new stores at reactor sites.

Table 5.2: Dry storage of NPP spent fuel in Europe

Facility Name	Status	Scale	Country
Metzamor NPP Site	In operation	Commercial	Armenia
Doel NPP Site	In Operation	Commercial	Belgium
ISFSF Dukovany	In operation	Commercial	Czech Republic
SFSF Dukovany	Commissioning	Commercial	Czech Republic
SFSF Temelin	Under study	Commercial	Czech Republic
Ahaus Central Interim Storage	In operation	Commercial	Germany
Biblis NPP Site, Brennelement-Zwischenlager	Under construction	Commercial	Germany
Biblis NPP Site, Interim Storage (Temporary)	In operation	Commercial	Germany
Brokdorf On-Site Storage Facility	Under construction	Commercial	Germany
Brunsbuettel NPP Site Interim Storage (Temporary)	Awaiting license	Commercial	Germany
Brunsbuettel On-site Storage Facility	Under construction	Commercial	Germany
Gorleben Central Interim Storage	In operation	Commercial	Germany
Grafenrheinfeld On-site Storage Facility (KKG BELLA)	Under construction	Commercial	Germany
Greifswald NPP Site ZLN Dry Storage	In operation	Commercial	Germany
Grohnde On-site Storage Facility	Under construction	Commercial	Germany
Gundremmingen On-site Storage Facility	Under construction	Commercial	Germany
Isar On-site Storage Facility (KKI BELLA)	Under construction	Commercial	Germany
Juelich Research Center, AVR Storage	In operation	Commercial	Germany
Kruemmel NPP Site Interim Storage (Temporary)	Under construction	Commercial	Germany
Kruemmel On-site Storage Facility	Under construction	Commercial	Germany
Lingen On-site Storage Facility	In operation	Commercial	Germany
Neckarwestheim NPP Site (GKN)	Under construction	Commercial	Germany
Philippsburg NPP Site ISFSF	Under construction	Commercial	Germany
Pilot Conditioning Gorleben (PKA)	Stand by	Pilot plant	Germany
Paks NPP Site ISFSF	In operation	Commercial	Hungary
Existing Dry Spent Fuel Storage Facility - Ignalina	In operation	Commercial	Lithuania
New Dry Spent Fuel Storage Facility - Ignalina	Planned	Commercial	Lithuania
Cernavoda NPP Site SFS	In operation	Commercial	Romania
Mochovce NPP Site SFSF	Under study	Commercial	Slovakia
Trillo NPP Site SFSF	In operation	Commercial	Spain
ZWIBEZ	Under construction	Commercial	Switzerland
ZWILAG	In operation	Commercial	Switzerland
Wylfa NPP Site	In operation	Commercial	UK

Table 5.3: Summary of Away-from Reactor (AFR) SF storage capacity (tHM) in Europe (data from the IAEA Nuclear Fuel Cycle Information Service)

	DRY	WET
Belgium	2100	2130
Bulgaria		600
Czech Republic	3310	
Finland		1694
France		18000
Germany	440	
Germany	19,103*	615
Hungary	580	
Lithuania	280	
Romania	6600	
Slovakia	780	1690
Spain	1680	
Sweden		8000
Switzerland	3100	
United Kingdom	700	11800
Total	38,088	44529

*9883 currently in operation

5.5 SF Storage costs

For wet storage the most accessible cost data are those from the Swedish CLAB facility. The total estimated costs for 40 years are 9079 MSEK (SKB, 2003). Since annual operating costs are 83 MSEK (NEA, 1994), this implies a capital investment of 5759 MSEK including refurbishment and decommissioning. This is for a total of 8000 tonnes of SF. These operating costs are in line with the annual maintenance costs for a SF pool at a shut down reactor, which have been estimated at 10.6 MUSD (Fairlie, 2000: quoting 1994 data). This covers continued maintenance of the required facilities. Costs should be similar for a centralised facility and be relatively independent of the capacity of the store.

At current exchange rates, the above costs for 40 years of wet storage in CLAB are ~980 MEUR. This gives a figure of 122,000 EUR/t.

For dry storage in a specially constructed vault, the costs include capital costs and running costs for maintenance and security. Relatively recent figures for dry vault storage are available from the Netherlands, where the HABOG facility cost 125 MEUR to construct and will cost 2.3 MEUR per year to maintain. A recent IAEA review of dry storage (IAEA, 2007) recognises that, taking into consideration the 20-50 years, or even longer, required for storage, naturally cooled dry storage options are an attractive alternative to pools. A number of cask systems (some licensed for dual-purpose function: both storage and off-site transportation) are commercially available. Spent fuel storage technologies, especially dry storage concepts, continue to evolve rapidly in response to changing market circumstances and other requirements, such as underground storage to meet demands of increased security.

However, there are very few recent data on the costs of existing systems. Figures given by Bunn et al. (2001 and 2003) are 60-90,000 USD/t (or 44-66,000 EUR/t), which includes both purchasing and loading costs (labour and equipment). Another independent estimate of cask costs alone was made by Hensing (1996), with a figure of 2.5 MDM per Castor cask containing 10 t of fuel; this high figure (equivalent to around 125,000 EUR/t) reflects the high costs of the Castor container. The running costs for a dry cask store are quoted as 2.6 MUSD per year (Bowser et al., 1994). Other running cost estimates from the USA are 3-4 MUSD per year (Bunn et al., 2001). In the USA, the costs for implementing a new dry storage facility (without the casks) have been estimated at 9-18 MUSD by Alvarez et al. (2003), 8-12 MUSD by Bunn et al. (2001) or 12.4 MUSD by Bowser et al. (1994). Bunn et al. (2001) quote an undiscounted cost for 40 years of cask storage of 1000 t SF at a closed reactor site as 250 MUSD and point out that a 5% real interest rate would reduce the net present cost to 160 MUSD.

Some more recent data (January 2005) were published when GNS-NUKEM was awarded the contract for the design and construction of an interim spent fuel storage facility for approximately 18,000 fuel assemblies from the two reactor units at the Ignalina NPP in Lithuania. The contract value was 92.7 MEUR for Phase 1 (delivery of the whole infrastructure and 39 CONSTOR casks) and 64.6 MEUR (price basis 2004) for Phase 2 (delivery of 163 CONSTOR casks). The Phase 2 costs imply a cost of 396,000 EUR per cask. Each cask can hold 182 fuel bundles, which is equivalent to a heavy metal mass of about 11.5 t, thus giving a unit incremental cost of 34,500 EUR/t. The cask costs are broadly compatible with the Bunn estimate of 55,000 EUR/t, but initial infrastructure costs of over 77 MEUR seem high.

As pointed out by Shropshire et al. (2007) the extra cost of dry storage would be reduced significantly if the casks could be used for both transport and ultimate disposal. For multipurpose canisters with stationary concrete overpacks, the extra cost would then be associated primarily with the overpack (about 20% of the total cost) and with the need to buy the canisters earlier than if the spent fuel stayed in dense-packed pools until it was transported to the geological repository. These authors also emphasise that use of high burn-up and mixed oxide fuels could necessitate some development of more expensive containers unless allowed to cool longer in a pool. The reference costs that they select are 120,000 USD/tHM, with a range of 100,000-300,000 USD/tHM.

In the scope of the present study on the potential for shared AFR stores in Europe, it could be necessary to assume that some kind of enhanced security measures would be taken – the facility would be ‘hardened’ against terrorist activities. The costs of such hardening measures have been looked at by various groups in recent times. High storage costs of 210,000 USD/t (150,000 EUR/t) are given by Alvarez et al. 2003 for missile hardened casks. This is about double the reference value. In the UK CoRWM work (Crawford and Wickham, 2005), the costs of a protected centralised store storage building are estimated to be around twice the cost of an unprotected store.

The actual cost of storage will depend upon the choice of technology and vendor, as well as the timescales for implementing the chosen technology, assuming future costs are discounted. The figures chosen for this report as guides to storage costs are summarized with other basic backend cost data.

5.6 Reference storage costs assumed for SAPIERR

Clearly, from the above discussion, wet storage costs are significantly more than dry storage costs. Consequently, dry storage will be assumed here to be the preferred technology for potential shared stores in Europe. For reference purposes, the following approximate, undiscounted figures for dry cask storage of 10,000 tonnes of SF for 40 years can be used:

Pad construction: 15 MUSD

Casks: 750 MUSD (mean figure from Bunn et al)

Maintenance: 140 MUSD (mean figure from Bunn et al)

TOTAL: 905 MUSD or 660 MEUR

This equates to a unit cost of 66,000 EUR per tonne, with incremental costs of 75,000 USD or 55,000 EUR per tonne.

The above figures illustrate that for the preferred option of dry storage in casks, there are few economies of scale. This is understandable since most of the costs are in the flask purchase itself. Moreover, the unit costs of storage are significantly less that those of encapsulation and disposal as detailed in Section 5 and are comparable with the costs of transport that are estimated in Section 4. Accordingly, there are currently no compelling economic arguments in Europe for implementing large multinational storage facilities.

There are also very few European countries with pressing demands for additional storage capacity. Most of the small nuclear countries have realised that disposal is a far off option since they will accumulate spent fuel only slowly. They have therefore arranged to make adequate storage capacity available. In fact, even worldwide, shortage of storage capacity tends to be more of a problem in those large nuclear programmes that have progressed towards disposal more slowly than was hoped (e.g. the USA, Japan, UK, Germany and South Korea).

There may, nevertheless, be sound arguments in favour of shared interim stores in the future. If shared multinational repositories or conditioning plants are eventually implemented, then logistics may be easier if there are also shared stores at the same locations. A further important justification for consolidating European spent fuel at fewer shared storage sites may be that the physical security of these sites can be enhanced beyond that feasible at multiple distributed stores.

6 Total Costs and Spend Profiles

In this section, we estimate the total programme costs for the various scenarios advanced in Section 2, using the data on disposal, transport and storage from the previous discussions. Note that these totals do not include any benefits payments made to local communities, which are addressed separately, in Section 7.

The **disposal** costs (MEUR) for each scenario, from Section 3 are as follows:

'Large' Inventory Situation	
Scenario I(H): Single hard rock repository	**8170 - 9690**
Scenario I(S): Single sediment repository	**8330**
Scenario II(H): Separate hard rock repositories for HLW/SF and ILW	**9490 - 11,010**
Scenario II(S): Separate sediment repositories for HLW/SF and ILW	**8590**
Scenario IIIa: Separate hard rock and sediment repositories, with encapsulation plant at each	**9890 - 10,150**
Scenario IIIb: Separate hard rock and sediment repositories, with a single encapsulation plant	**9840**
'Small' inventory situation	
Scenario I(H): Single hard rock repository	**3980**

The costs of **storing** spent fuel or HLW in a national repository scenario or with a regional European repository that would begin operation in 2035 are dependent on the existing storage capacities and on the need for further storage. The table below compares the current storage capacities of the ten SAPIERR I countries that have spent fuel (as given in section 5.3) with the projected arisings up to 2040, as given in the SAPIERR I report.

Country	2040 Spent fuel inventory (tHM)	Current storage capacity (tHM)
Belgium	4300	4230
Bulgaria	2039	600
Czech Republic	3496	3310
Hungary	1314	580
Italy	NA[1]	299[1]
Lithuania	2504	280
Romania	5570	6600
Slovakia	2375	2470
Slovenia	620	620[2]
Switzerland	3120	3100
Total	**25,637**	**22,089**

1: All fuel from decommissioned reactors; all will have been sent for reprocessing by 2040 and 300 containers of HLW will be in storage

2: All in pool storage at the single reactor

It is clear that most countries have organised storage capacity for SF that will last until 2040, at which time a regional repository could be in operation. The exceptions are Hungary (which has a modular expandable dry vault store at Paks) and Bulgaria and Lithuania (where a German consortium is implementing dry cask storage systems at Kozloduy and Ignalina respectively). The conclusion to be drawn is that, since all spent fuel in the SAPIERR inventory will be capable of being stored in the producing nations until 2035, there will be no economic incentives to implement new regional stores. Also for new nuclear plants that may be constructed in Europe in the coming decades, the lack of certainty about centralised or national repositories may compel the operators to make enough interim storage available to ensure capacity until after the assumed SAPIERR repository implementation date of 2035.

For these reasons, the costs of interim storage can be neglected in a comparison of strategies that consider the time-span out to 2040 with national or regional European repositories. The availability of a regional repository at the proposed time would, on the other hand, have a significant impact on the costs of fuel storage after that date. The existing stores could be re-used, possibly after refurbishing, with a direct impact on future fuel cycle costs. The undiscounted costs of having to arrange for the dry fuel storage of the lifetime inventory of a 1000 MWe NPP that runs for 50 years are around 70 MEUR.

For illustrative purposes and comparison with the disposal costs, it is interesting to obtain a ‘ball-park’ figure for lifetime storage costs associated with the ‘large’ SAPIERR inventory of 25,637 t of spent fuel. If an inventory of this size were in dry cask storage for 40 years with unit costs of 66,000 EUR/t, the undiscounted total cost would be 1692 MEUR. In practice, the storage costs will be less because some fuel will remain in reactor pools until moving to an encapsulation plant and some fuel will be in existing dry vault storage.

For the **transport** costs, we note that these are dominated by the spent fuel transports and that the total cost of a single transport (from NPP to encapsulation plant located at the repository) for all the HLW and SF is about 1065 MEUR for the ‘large’ inventory and 250 MEUR for the ‘small’ inventory. These costs are about 11% and 6.5% respectively of the estimated total costs of repository siting, construction, operation and closure. The estimated 32 or 7 MEUR transport costs for LILW-LL for the two situations are an almost insignificant part of total programme costs.

In Scenario IIIa, with two regional repositories, each with an encapsulation plant, only one transport is needed. If there are two repositories, but only one encapsulation plant (Scenario IIIb), then two transports are needed for half the fuel (which has to be taken to the encapsulation plant first, then onwards to the other repository site), giving costs of about 1600 MEUR. If a third party country were to provide encapsulation services, then all fuel would have to be transported at least twice.

6.1 Spend Profile: ‘large’ inventory situation

To estimate a spend profile for a SAPIERR repository, we have principally used the Finnish economic analysis data, which is the most complete. The profile is thus estimated ***only*** for Scenario I(H): a single repository for all wastes in hard rock. It should be noted that, although the Finnish data provide a valuable and consistent baseline for these calculations, they are unlikely to be wholly representative for other locations in Europe (obviously, geologically, but also in terms of management structures and labour costs). While the spend profile calculated here is regarded as being usefully indicative in its structure and form, the absolute values for each component will thus be more variable when transferred to other situations.

In addition, we have made the following simplifying (and largely conservative) assumptions:

1. We have added to the Finnish programme costs an estimated 300 MEUR for repository siting (a rough average of Swedish and Swiss costs) and 200 MEUR for R&D (a lower value than either Swedish or Swiss costs, reflecting the fact that R&D information can now largely be taken from the results of decades of mature international programmes). A further addition of 1097 MEUR is made for transport costs to the repository. This gives a total cost of ~11,300 MEUR.
2. Repository siting costs and all R&D costs are incurred over a period of 10 years from programme start (Years 1 to 10).
3. All above ground facilities at the repository site are constructed in Years 10-15 of the programme.
4. All underground facilities in the repository are constructed consecutively and without significant breaks, in Years 10-20.
5. The encapsulation facility begins operation in Year 15.
6. The rate of encapsulation and disposal is the same each operational year.
7. Waste transport to the encapsulation plant begins in Year 15 and continues at an equal rate over 60 years (equivalent to about 440 tonnes of SF or HLW per year).
8. The repository begins receiving waste in Year 20 and operates for 60 years: this is an average disposal rate of 232 SF/HLW packages per year – about one per working day.
9. The disposal facilities cease operation after 60 years of operation in Year 74 (encapsulation plant) and Year 79 (repository).
10. Decommissioning of the encapsulation plant takes 3 years (Years 75-77) and closure of the repository takes 3 years (Years 80-82).

The resulting cost profile is shown in Figure 6.1. The relatively higher investment costs in Years 10-20 of the programme are evident. Afterwards, the spend profile is dominated by operating costs for the encapsulation facility, with operation costs of the repository being a considerably smaller proportion of the total and roughly equivalent to transport costs for moving the waste to the site.

Other aspects of the spend profile to note are the ~50 MEUR pa requirement for siting and R&D during the first decade of the programme and the relatively constant spend of ~150 MEUR pa during the operational life of the disposal facilities.

There are, of course, many ways in which the spend profile developed above could be varied to suit economic considerations. Examples of project variables that would have significant impact on the time of cost arisings include:

- the rate of encapsulation – this could be managed in campaigns (e.g. every five years), with facilities kept on stand-by and maintenance in the interim;
- the time at which sections of the repository are constructed (here we assume this is all done early: it would be possible to delay constructing a large part of the repository for several decades;
- delay the start of disposal and use higher emplacement rates in order to shorten operating periods.

The cost impacts of such changes will be highly dependent on discounting assumptions, as discussed in Section 6.1.1.

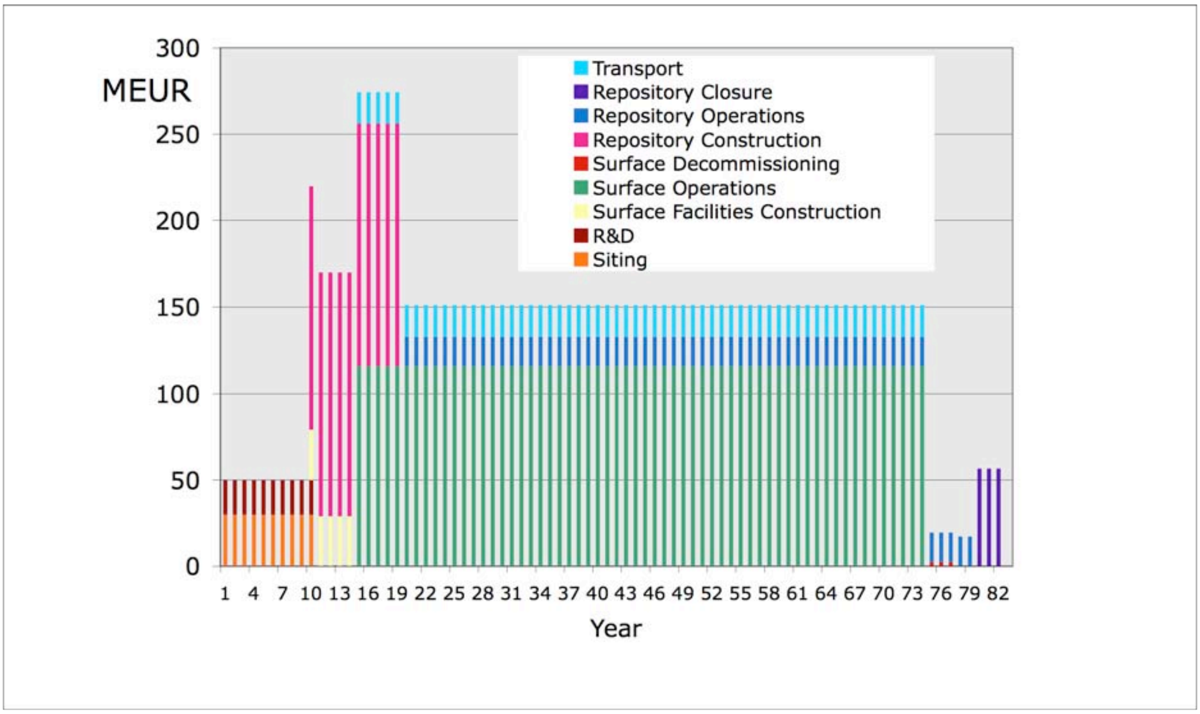

Figure 6.1: Spend profile for a SAPIERR shared repository for the 'large' inventory situation (siting, R&D, encapsulation facility, repository and closure/decommissioning). See text for explanation.

6.1.1 Impact of discounting

Long-term projects require investment far into the future. Standard economic practice is to discount future costs on the basis that currently available money is of more value that money in the future. The rate at which this reduction in value is estimated is called the 'discount rate' and varies considerably between different authorities, countries and types of project. Many authorities refer to the 'UK Green Book' (UK Treasury, 2003) in selecting discount rate values. The Green Book describes the principle of discounting as follows:

> *"It is ... based on the principle that, generally, people prefer to receive goods and services now rather than later. This is known as 'time preference'. For individuals, time preference can be measured by the real interest rate on money lent or borrowed. Amongst other investments, people invest at fixed, low risk rates, hoping to receive more in the future (net of tax) to compensate for the deferral of consumption now. These real rates of return give some indication of their individual pure time preference rate. Society as a whole also prefers to receive goods and services sooner rather than later, and to defer costs to future generations. This is known as 'social time preference'; the 'social time preference rate' (STPR) is the rate at which society values the present compared to the future."*

The Green Book goes on to describe the concept of 'present value' and to provide recommended discount rates:

> *"The discount rate is used to convert all costs and benefits to 'present values', so that they can be compared. The recommended discount rate is 3.5%. Calculating the present value of the differences between the streams of costs and benefits provides the net present value (NPV) of an option. The NPV is the primary criterion for deciding whether government action can be justified."*

The 3.5% rate is recommended for a period of 30 years.

Rose (2006) reports on a survey carried out by Weitzman (2001), who reported a survey of the professionally considered ‘gut-feeling’ of economists in response to the question: *“Taking all relevant considerations into account, what real interest rate do you think should be used to discount over time the (expected) benefits and (expected) costs of projects being proposed to mitigate the possible effects of global climate change.”* For over 2,100 replies from economists in 48 countries the mean value was 3.96 percent, with a standard deviation of 2.94 percent. This is close to the value recommended in the UK Green Book and, in addition, addresses a question that appears relevant in the SAPIERR context.

The UK Green Book (UK Treasury, 2003) also provides longer-term discount rates:

Period of years	0–30	31–75	76–125	126–200	201–300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

These values are used in our own study.

The present value (PV) at the middle of year 0, of an annual investment amount (AI) made at the middle of year n is given by:

$$PV = AI/(1+r)^n$$

where r is the discount rate (e.g. 0.035).

The discounted spend profile from Figure 6.1 is shown in Figure 6.2.

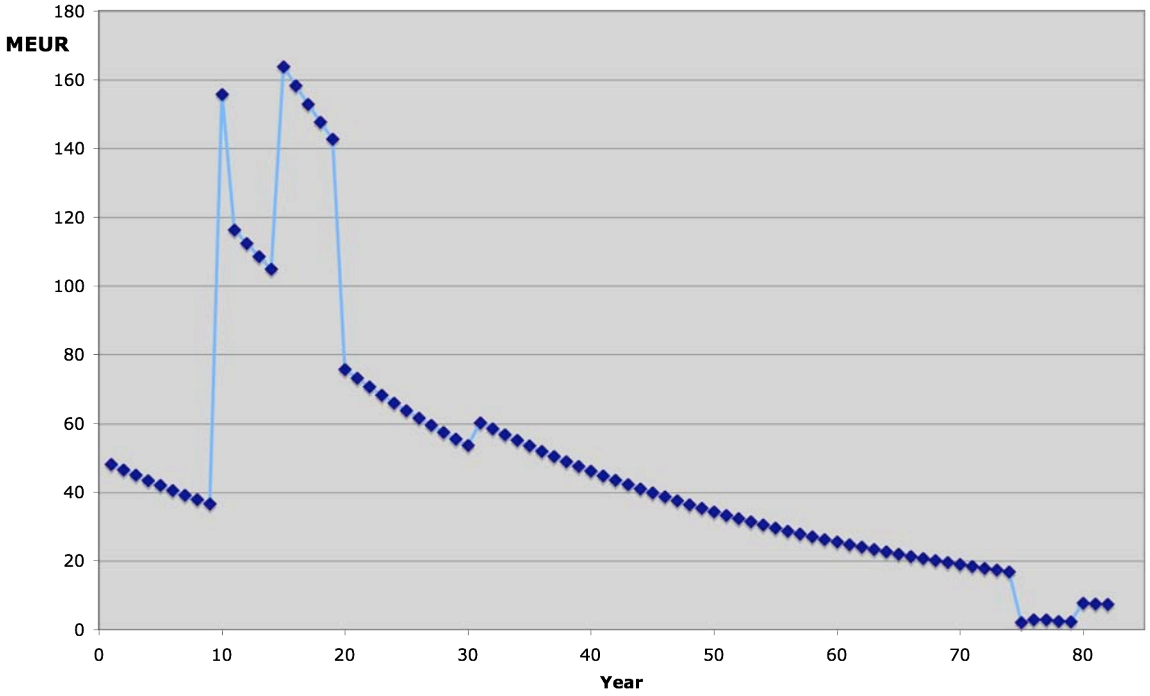

Figure 6.2: Discounted spend profile for the costs shown in Figure 6.1. UK Treasury discount rates are used (see text). The steps at Years 31 and 76 indicate changes in discount rate.

As can be seen, the PV of the annual investment has been approximately halved by the time at which encapsulation and disposal begin. The peak investment costs from Years 15 to 19 are reduced in PV by around 100 MEUR pa. The total, discounted PV of the project is reduced from ~11,300 MEUR to ~4000 MEUR (approximately the same as the undiscounted cost of a single national repository).

6.2 Spend Profile: 'small' inventory situation

The calculations described above for the 'large' inventory were repeated for the 'small' inventory situation, using exactly the same assumptions and approaches discussed in Section 6.1. The resultant spend profile for this smaller repository system is shown in Figure 6.3.

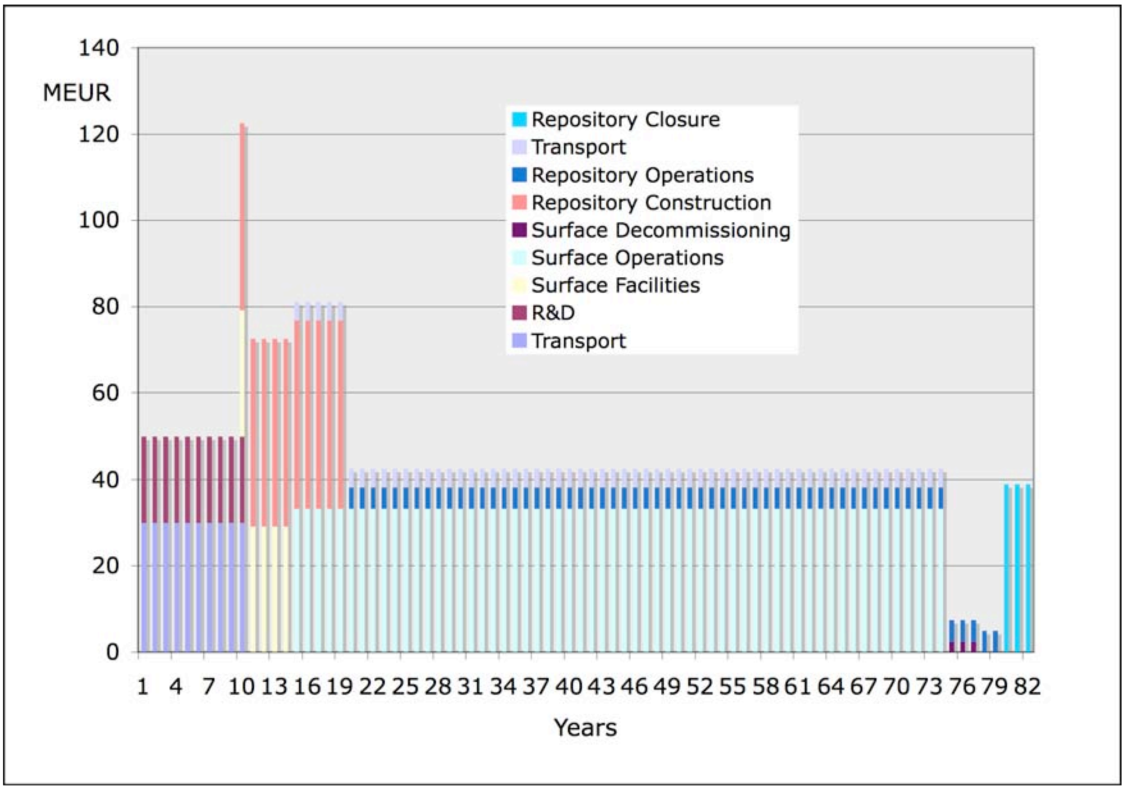

Figure 6.3: Spend profile for a SAPIERR shared repository for the 'small' inventory situation (siting, R&D, encapsulation facility, repository and closure/decommissioning). See text for explanation.

It can be seen that, apart from the period of about ten years when the repository and surface facilities are under construction, the spend profile (based on the waste arising rates assumed) lies at around the 40-50 MEUR per annum level for almost the whole period of the programme. The discounted net present value of this case is only about 1500 MEUR.

The same comments made for the 'large' inventory situation on flexible project variables (time of encapsulation; strategy towards construction timetable, etc) and discounting are also equally valid in this case.

7 Economic benefits of hosting facilities

Multinational sharing of storage or disposal facilities necessitates that some country or countries must be prepared to accept spent fuel or wastes from foreign countries. Although transfers of other hazardous materials are part of normal regulated international trade, sensitivities are much higher in the nuclear field. Hence, it is important to establish principles which ensure that multinational nuclear facilities are implemented in a sound and transparent ethical framework.

It is generally recognised that a number of ethical principles underlie any effort to encourage community participation in a siting process using some form of compensation and impact mitigation. In simple terms these can be summarised as:

- the development of a state of the art, safe and secure facility is a condition, *sine qua non,* in any negotiation;
- no nation or community should be compelled to accept a facility against its will;
- nations and communities that host facilities that provide services to others are entitled to receive compensation for this service;
- compensation is for performing a community service and is not any form of risk premium;
- financial and other potential benefits should not be used as leverage to encourage participation by poor communities or countries that are not in a position to offer a state of the art facility;
- it is essential to involve the community directly from the beginning of any site selection process.

It is also important to recognise the impacts that a radioactive waste repository could potentially have on future generations, given the timescales involved for siting, construction and operation. Add to that the time over which the wastes will remain radioactive, and a whole area of ethical debate is opened up, including the conflicting concerns about the duty of care of the present generation and the need not to make decisions on behalf of others that cannot be reversed. This introduces the issue of when to close a facility and whether to incorporate retrievability into the design. This is not an issue that is explored further here, but one which must be acknowledged to exist.

Some proposed community benefit packages incorporate provision of so-called ‘Perpetual Care Funds’, designed to provide funding in the event of a need for future work should this be necessary. This assumes that, in the long periods after facility closure, an operator may not continue to exist.

The process of providing justified benefits for hosts of multinational facilities is sensitive also because national practices in this area vary significantly. In various countries in Europe, however, successful approaches have been developed for designing fair benefits schemes. These national approaches consider the types of benefits, the level of any direct payments, the distribution of the benefits and also how to involve local populations in negotiations on these topics. The lessons learned in these national siting approaches, e.g. in Belgium, France, Hungary, Slovenia, Sweden, Switzerland, etc., can provide guidance for identifying feasible multinational approaches.

7.1 Involving communities in the siting process

Experience with providing benefits to increase acceptance of a ‘locally unwanted land use’ (LULU) has been gained almost exclusively at the national level. This section reviews the experience gained through the processes established by national governments or project implementers in providing benefits to local communities. Section 7.2 postulates further benefits that could be obtained at the national level, if a country chooses to host a facility that provides a disposal service to a number of other European countries.

All around the world an important safeguard generally offered to potential host communities is that the community should not find itself worse off than before the process began. This has in turn led to the development of a number of so-called ‘impact mitigation’ measures. Not least amongst these has been the offering of specific benefits packages to the community, by way of compensation, not for bearing an increased risk, but rather for being willing to provide a service to a wider group of users. It is now generally the case that such benefits comprise a mixture of direct financial contributions and other measures designed to assist the community to take part and ensure enhanced well-being, over and beyond the lifetime of the facility in question.

Other benefits can be social and institutional. In some cases cash benefits are offered solely as an incentive to encourage participation in the process in the first place, and can either be paid right at the beginning (with or without controls on how they are spent) or they can be offered as a guaranteed future payment, only available if a facility is eventually sited. For example, the raft of community benefits negotiated with the Kincardine and adjacent communities in Ontario, Canada, incorporating community funds, guaranteed property values etc, only become available following the granting of a construction and operation licence for the ILW repository proposed by OPG.

7.1.1 Community Identification

Community identity, in terms of who may host a facility and who might be able to volunteer and receive benefits is clearly important in any discussion of community benefits, given the need to focus these on particular locations and individuals. The natural spatial definitions of community, based upon proximity and common-sense understandings of shared space, would generally be insufficient in understanding the dynamics of possible NIMBY (‘not in my backyard’) opposition. The definitions of ‘local’ in terms of an affected area or of ‘community’ overall therefore underlie the entire issue of involvement and participation in a siting process.

The identification of the relevant and applicable community is fraught with potential difficulties – but also with opportunities for engaging the most appropriate persons and groupings. Placing strong boundaries around municipalities for purposes of public participation may be considered to violate two key conditions of a democratic siting policy, namely maximising social inclusiveness and ensuring a large unit of review. This must be balanced against the need to identify a legitimate decision maker capable of representing the aspirations of those likely to be affected by a development.

This reflects directly the current thinking within most national siting programmes, in that within any area, the ‘community’ is likely to be made up of many different interest groups, which will come together for a whole variety of reasons. Community groups may focus on ‘place’, the area where they live and work, or may focus on interests, principles, issues, values or religion.

A related issue to be taken into account in any model development is the realisation that perceived impacts from any existing or proposed facility do not necessarily conform to convenient boundaries and that communities, in the psychological sense, have no geographical boundaries and a community can likely be conceptualised as a grouping of people who will, or perceive that they might be, affected by any new development. In other words, those communities surrounding volunteers must also be consulted and their views taken into account if overall acceptance and support is to be forthcoming.

There are numerous ways of approaching this. For example, the EU COWAM 2 Project considered that communities could be referred to in terms of:

- scale (government or administrative region);
- history (in terms of local knowledge of the nuclear industry);
- geography/geology (with regard to a potential siting region or area).

A community can be defined simply as a joining together of individuals to take (or regain) control of their future. How such a group comes together varies from place to place and situation to situation. The stimulus can be from a perceived threat or opportunity or be in response to an approach for development of a new facility. The important point is that no definition of community is necessarily the right one; any self-defining grouping can theoretically call itself ‘local’. A structured local process, based on democratic principles, can assist a sustainable dialogue on a wide range of risk-related issues and develop a sense of ownership of any local development.

It can also be helpful to distinguish between a ‘**community of locality**’ and a ‘**community of interest**’. Any benefits relating to the value of ‘local’ content in manufacturing, for example, may be defined as ‘local’ on a county or regional basis. A fund to improve local community facilities may only be considered as ‘local’ if it is restricted to the villages or towns immediately adjacent to a facility.

7.2 Encouraging Participation

Work carried out to examine the use of community benefits in association with radioactive waste repository siting (Richardson, 1998; UK Nirex, 2005) recognises a broad tripartite division: ‘Cash Incentives’, ‘Social Benefit’ measures and ‘Community Empowerment’ measures, although it should be noted that it is normal to offer packages containing payments and benefits of several different types, depending on when in the project development the particular process is. It is also important to appreciate that not all types of benefit or payment are included in every process (Richardson, 1998).

Benefits can be identified in undertakings beyond repository siting, both within and outside the nuclear arena. Appendix 2 provides descriptions that concentrate on their use in repository siting, with other (non-nuclear) examples also being provided where appropriate. Appendix 2 provides details of both the way in which the various forms of benefit can be defined and examples of the incentives offered to communities (including the amounts of payments that have been, or will be paid), under the following headings:

- Cash Incentives
    - lump sums
    - annual payments
    - expert support packages
    - tax revenue
    - trust fund for future generations

    - profit sharing
- Social Benefit Measures
    - employment
    - infrastructure improvements
    - property value protection
    - integrated development projects and miscellaneous facilities
    - relocation of developer
    - discounts and services
- Community Empowerment Measures
    - local involvement in decision-making
    - capacity building
    - local partnership to oversee the project
    - involvement support packages

Whilst all these categories of benefits have direct relevance to the economics of shared facilities, cash incentives are often those that are most talked about and receive the widest media attention.

Table 7.1 illustrates some of the cash benefits available or proposed in various countries, associated with the siting of various types of radioactive waste repository.

Table 7.1: Some of the cash benefits available or proposed in various countries, associated with the siting of various types of radioactive waste repository (for notes, see end of table).

Country	Facility Name	Affected Community	Date of Operation	Waste stream	Facility Capacity	Lump Sum Payments (as EUR)	Annual Fee (as EUR)	Annual taxes received (as EUR)	Comments
Australia	Repository and National Store	Muckaty Station Traditional Owners	TBD	L/ILW	<10,000 m^3	7 million	No	No	Fund to be used for educational grants etc.
Canada	Port Hope	Clarington Port Hope	Future	Historic LLW (from uranium milling)	1 million m^3	6.7 million (1)	No	Yes	Payment of ‘diminished taxes’ guaranteed (1)
	Kincardine	Kincardine et al	2017	L/ILW	89,000 m^3	1.5 million plus 1.05 million (2) to Kincardine only	0.7 million	No	Plus Property Valuation Protection. Lump sums subject to milestones and payable to several communities
Finland	VLJ Olkiluoto (3)	Olkiluoto	1992	All LLW	8,800 m^3	No	No	Yes	Local property tax is 2.2% higher than national average
	Loviisa (3)	Loviisa	1998	Operational LLW	5,500 m^3	No	No	No	
France	Centre de l'Aube		1992	All LLW	1 million m^3	5.2 million in a Support Fund for local projects	No	6.2 million on average	Municipal land tax payable (common for all industry)
	Morviliers		2003	VLLW	750,000 m^3	3 million for development	No	0.6 million on average	20% of projects must come from local community
France (contd)	Bure-Saudron URL	Bure	2025	HLW	6,000m^3	10 million as ‘economic support measure’ to affected Departments	750,000 during exploration; CLIS also funded	Yes	Benefits were specified in 1991 Waste Law. In 2006 a new Planning Act was passed, detailing payments of €20 million due from taxes on the repository, with a similar 20% contribution required as above
Hungary	TBD	Üveghuta	2008	All L/ILW	40,000 m^3	No	Yes	No	Annual fee is calculated as a % of the project exploration budget and paid to adjacent communities

Country	Facility Name	Affected Community	Date of Operation	Waste stream	Facility Capacity	Lump Sum Payments (as EUR)	Annual Fee (as EUR)	Annual taxes received (as EUR)	Comments
Japan	Rokkasho (4)	Rokkasho	1992	All LLW	600,000 m^3	No	No	Yes	Calculated as sub-set of the Nuclear Fuel Handling Tax, which is reassessed every 5 years. €163/m^3 disposed
	HLW Repository	TBD	Future	HLW	40,000 packages	5.6 million	Yes	No	Initial lump sum payment during preliminary desk studies; €11.9 million available as annual fees if construction application is made
S Korea	TBD	Gyeongju	Future	All LLW	800,000 drums	228 million (5)	7.5 million average	TBD	Site selected February 2006. Annual fee expected to depend on volume of waste emplaced
Slovenia	TBD	Posavje (Krško)	2013	LILW-SL	20,000 m^3	No	0.22 million (during site investigations) then 2.23 million	No	Community can receive annual payments in advance, to initiate major projects
Spain	El Cabril		1992	All LLW	200,000 m^3	No	1.5 million average (6)	No	Calculation laid down in 1998 Government Order
Sweden	TBD	Östhammar Oskarshamn	2025	SNF	40,000 MtU	No	No	No	Review Groups and NGO's funded from the National Waste Fund
Taiwan	TBD	TBD	Future	All LLW	>100,000 drums	112 million	No	No	No site selected to date; 4 potential locations identified, one to be selected by end-2008 (7)
United Kingdom	National LLWR	Drigg village and Copeland Borough	2008 (facility began operation in 1950s)	LLW	c.1.75 million m^3 but depends on future designs	14 million to a trust fund (via Copeland Borough Council and Cumbria County Council)	2.1 million (via Copeland Borough Council and Cumbria County Council): c. 90,000 pa of which to Drigg community	No	Although the repository has been in operation since the 1950s, this new (2007) agreement only comes into force as the basis for extension of disposal capacity from 2008

Country	Facility Name	Affected Community	Date of Operation	Waste stream	Facility Capacity	Lump Sum Payments (as EUR)	Annual Fee (as EUR)	Annual taxes received (as EUR)	Comments
United States	Barnwell (8)		1971	Non-DoE LLW	850,000 m^3	No	1.5 million (9)	187,000	A proportion of disposal fees are used for local projects by the State (includes €9 million for higher education and school building in 2005 and €600,000 from the Barnwell Economic Development Fund (set up by Compact with €9 million)
	Clive (8)		1988	Institutional Wastes	1.5 million m^3	No	Perpetual care fee of 303,000 p/a to State	3 million p/a on average to County	State fee charged at €0.11 per ft^3 and €0.7 per curie, plus annual 5-12% tax on revenues; Tooele County also levies a surcharge of 5% of annual fees, around; €3 million
United States (cont'd)	Hanford		1961	Non-DoE LLW	990,000 m^3	No		59,000 to Benton County plus 133,000 to Hanford Area Economic Fund [in 2005]	Benton County Surcharge: €1.40 per ft^3 of waste disposed. Hanford Area Economic Investment Fund Surcharge: €3.42 per ft^3 of waste
	WIPP		1999	Defence TRU	175,600 m^3	No	14 million p/a from 1997 for 15 years to State for economic impact support		The annual fee is specifically targeted on road improvements associated with waste transport. There was also a one-off grant of €2.7 million in 2003/4 for infrastructure-related projects (10)

Notes:

1. Specified in the Port Hope Agreement
2. Specified in the Kincardine Agreement (2004)
3. Facility situated adjacent to NPP
4. Adjacent to reprocessing facility and HLW interim store
5. Specified in "The Act for Promoting the Radioactive Waste Management Project and Financial Support for the Local Community" 2000, amended by 2005 Waste Bill
6. Specified in Government Order of 1998
7. Act on Site Selection for a Low-level Radioactive Waste Final Disposal Facility 2006
8. Both facilities now operated by EnergySolutions Inc.
9. Specified in South Carolina State law
10. Public Law 102-579, 102nd Congress, October 30, 1992 Amended by 104th Congress, Waste Isolation Pilot Plant Land Withdrawal Act.

7.3 Benefits to a host country

In the case of a regional facility serving the waste management needs of more than one country, there are also benefits that may accrue to the host country beyond those that might be made available to the specific host community. In general terms the country could be seen as making a contribution to solving a regional or wider-scale problem, and such benefits should therefore be seen as a natural feature of such an action. Indeed, they might be seen by some countries as an incentive to become involved in such a proposal (whilst of course taking into account the ethical issues raised previously).

7.3.1 Taxes

Irrespective of the funding mechanism selected, it is certain that the construction and operation of a repository will give rise to increased tax revenues for the host country, due to the need for increased jobs, purchasing of materials and provision of services. For example, the ITER facility in France is expected to generate 1400 jobs during construction and up to 2400 jobs during operation[3].

7.3.2 Industrial development

The development of a regional repository will require a wide range of support industries able to provide the necessary services. It is likely that additional facilities such as encapsulation and packaging could be located close to the facility, and the national economy would therefore derive a double benefit from the repository, by supplying additional services to client countries.

Other spin-offs would also likely be developed, including specialist transport services, research centres of excellence etc.

7.3.3 Political leverage

In addition to the economic benefits that would accrue to a host country from the industrial developments associated with a facility, there are also the intangible benefits associated with the political credibility that would follow. If a country is prepared to shoulder a regional responsibility and help to solve a major problem, its influence would likely be increased in other spheres, as it would be recognised as a supporter of responsibility and compromise. This aspect may become more important in the future because of the current proposals by the USA and the Russian government to promote international nuclear fuel cycle services. The proposed schemes, GNEP and GNPI, both suggest that the global nuclear community should be divided into countries that supply services and countries that only use nuclear power, without having indigenous fuel cycle facilities. Emphasis to date has been on enrichment and reprocessing services, but the importance of the back end, including disposal, will grow. A country offering a disposal service could gain considerable leverage in negotiations with service providers and recipients.

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[3] 'Les Enjeux du Projet', supplied during the 2006 Public Debate on ITER

7.4 SWOT Analysis

In order to assess the usefulness of the various benefits and mitigation measures described above in Section 7.2, a SWOT (**S**trengths, **W**eaknesses, **O**pportunities and **T**hreats) analysis has been performed.

This has been done separately, first from a local community perspective and then from a national perspective, to draw out any issues of significance. The results are shown in tabular form below. It is important to note that this is both generic (in that it has no particular country or national culture in mind) and intentionally only illustrative. Opinions on the entries in the tables below are likely to vary depending on the composition of the group that carries out the SWOT analysis.

7.4.1 Cash Incentives for a Community

Strengths	Weaknesses	Opportunities	Threats
Lump Sums			
Encourages participation from many communities. Allows easy recognition of benefits from involvement. Brings immediate benefits	Can appear as if poorer communities are being targeted. Opens the process to accusations of bribery. Can open questions of safety, as in 'why do you have to offer this if it's really so safe?'. Does not on its own demonstrate a long-term commitment to the community. Sets national and industry precedent Difficult to transparently justify the level of funding.	Enables initial discussions to be initiated; this can lead to a greater understanding and increased willingness to participate. Can tailor amounts to suit local requirements. Can limit uses to which money is put.	Some communities are never satisfied with the available resources and demand more for continued involvement, especially if volunteers are few. May allow community to 'take the money and run', if no controls are placed on use. Doughnut effect may come into play without equitable distribution proposals. Funds may dry up with time.
Annual Payments			
Allows community to calculate benefit of participation. Demonstrates a long term commitment by the developer. Allows developer to calculate costs.	Community may become dependent on these and suffer if site is eventually proved to be unsuitable. Difficult to transparently justify level of funding. Can make the community economy dependent on facility. Sets national and industry precedent	Develops bond between the community and the facility; local people may become champions for the development, especially if payments linked to project and licensing milestones.	Delays in the process could cause excessive cost overruns due to continuing payments, unless linked. Doughnut effect may come into play without equitable distribution proposals. Changes in government policy can stop these.
Expert Support Packages			
Allows community to seek advice from outside experts not associated with the project. Allows participation of small or remote communities with little local competence Demonstrates independence from developer.	Could encourage multiple communities, especially those with poor economies, to volunteer simply in order to receive funding, unless tight conditions imposed.	Encourages local involvement and demonstrates impartiality. If the case for facility development is strong, independent review can benefit local perceptions.	Opens up the debate to opposition bodies with a wider agenda.
Tax Revenue			

Provides a regular income for the community. More transparent if determined by existing regulations.	Can make the community economy dependent on the facility.	Special conditions to assist siting in particular areas could be included in legislation, so as to encourage involvement. Can allow a local authority to reduce other local taxes.	Changes in legislation could remove income from community after operation begins. Local authority may 'swallow up' the revenue unless they are specifically allocated.
Trust Fund for Future Generations			
Demonstrates a long-term commitment to the community. Counters accusations that locals are accepting benefits at the cost of future generations Allows smooth transition when repository income stops	Does not provide a tangible benefit to the current generation who will make the decision on siting.	If community is involved in setting this up, choices can be made to benefit particular groups or projects.	Future fund managers could misappropriate money and thereby sully the projects image.
Profit Sharing			
Lays the ground for a smooth transition to other economic activities in the future.	Requires careful identification of where funds will go, or local rivalries may develop	Generates funds that can be used by the community in any way it sees fit.	Future waste arisings may decline and result in lower revenues than anticipated. Could allow individuals to gain personal benefit; requires close monitoring.

7.4.2 Social Benefits for a Community

Strengths	Weaknesses	Opportunities	Threats
Employment			
Offers support to community development. Allows young people to remain. Encourages other companies to relocate into area.	Can make the host community dependent on the facility. Can disrupt existing employment profile and salary levels. May not be a significant factor if area already has good employment. Repository work force not likely to be huge.	Operator can guarantee local hiring where practical; employees develop pride in facility and become champions. Local skills base enhanced. Community well-being increased.	Can set up divisions in the community between those employed at facility and those not. Influx of outsiders can destroy community spirit. Can isolate the community from environs if there is local opposition.
Infrastructure Improvements			
Supports developments that would otherwise not take place. Highly visible to local population	Local opposition can result due to negative impacts on local environment.	Improved communications can lower transport costs to the facility.	Opposition to new roads, rail lines etc can increase opposition to facility in surrounding communities that do not benefit.
Property Value Protection			
Generates confidence in local population that no financial losses will be incurred due to facility development.	Difficult to assess impact; difficult to define potentially affected area.	Assuming low number of claims. Can be used to demonstrate low real impact of a facility over time.	Causes division amongst community unless all houses are included. May need to introduce similar schemes for corridor communities.
Integrated Development (or related) Projects			
Allows community to become involved in its own future.	May be in conflict with existing local, regional and national economic	Encourages community to enter into discussions with developer.	Opposition can arise from other communities if they are not included in the

Demonstrates a long-term commitment on the part of the developer.	development planning.	Allows mutual trust and confidence to be established.	planning. Plans may conflict with other local, regional and national visions.
Relocation of Developer			
Provides additional benefits to the community in terms of jobs, tax revenue, skills base etc. Demonstrates long-term commitment by developer. Demonstrates confidence of the developer in safety and environmental areas	Identifies the community with the project in the mind of opposition groups and other communities who may not be in favour.	Community or region can be developed as a 'centre of excellence' and attract support industries and high-tech development. Personal contacts between developer staff and local strengthened.	Increased development may alter the social fabric of the community and lead to resentment. Jealousy over property deals if these made with individuals rather than the community. May lead to loss of implementer staff who do not wish to relocate
Discounts and Services			
Allows community to see a tangible benefit from its actions and a recognition of performing a national service.	Community becomes reliant and suffers when facility is closed. Sets precedent.	Can be associated with other benefits and be used to attract other developments into the community.	Must continue in perpetuity unless an end-date agreed at the beginning. Otherwise the developer would have an open-ended liability.

7.4.3 Community Empowerment Measures

Strengths	Weaknesses	Opportunities	Threats
Local Involvement in Decision-Making			
Encourages a sense of involvement and allows a community to feel some control of the development.	Difficult to decide who makes the decisions. Can be open to manipulation by opposition.	Development of local expertise allows input of developer's viewpoint in a reasoned fashion. Local knowledge may result in specific improvements in the project.	Subject to continued political support. Division in community could prevent any decisions being made. Opposition may take over the process in some cases.
Capacity Building			
Develops local expertise, allowing community to understand issues and to discuss them in a reasonable way.	Can open the process to manipulation by pro or anti groups. Can cause delays in progress – can only move at the pace of the community.	Allows development of relationships between actors; allows opportunities for reasoned discussions. Allows people to visit operating facilities and gain confidence in the technology.	May take a considerable time to reach decisions, which in turn causes stakeholder fatigue. Those involved become associated with the project and seen as too close to the implementer side.
Local Partnership to Oversee Project			
Allows a sense of local involvement and control. Provides a sense of confidence that project will progress.	Placing control in the hands of non experts could slow the progress of the project..	Allows mutual trust and confidence to be established. Project can be tailored to address local fears and aspirations.	Could allow the development of a 'clique', which may be perceived as unrepresentative of local opinion.
Involvement Support Packages			
Allows the community to take a full part in initial deliberations, exploring the issues and increasing	LA may be perceived by constituents as being in support of project by	Allows implementer to develop a legitimate presence in the community without sense of a surprise	Provision of support can be divisive if not allocated to surrounding communities, with resulting

understanding, without excessive cost in terms of time or money.	accepting payments. Provision of support could be seen as ‘buying agreement’ May need control or oversight mechanism to avoid misuse.	by the public.	doughnut effect. Management of the funding could cause concerns that LA actions are actually being unduly limited. Policy changes may remove funding support before siting decision made, thereby ‘stranding’ the community.

7.4.4 National Cash Incentives

Strengths	Weaknesses	Opportunities	Threats
Lump Sums			
Encourages national governments to enter into dialogue with potential communities, as they could be seen as bringers of riches. Can offset or remove costs of a national repository	Can appear as if poorer countries are being targeted. Opens the process to accusations of bribery. Can open questions of safety, as in ‘why do you have to offer this if it’s really so safe?’ Does not demonstrate a long-term commitment to the facility. Sets international and industry precedent. Difficult to transparently justify the level of funding. Funding mechanisms may be complex depending on entities involved	Enables exploratory discussions to be initiated; this can lead to a greater understanding and increased willingness to participate. Can tailor amounts to blend in with national strategic planning.	Countries may demand more for continued involvement, especially if volunteers are few. Neighbouring countries may impose transport bans. Funds may dry up with time. Could lead to dispute between host country and community on allocation of benefits
Annual Payments			
Allows country to calculate potential benefit of participation. Demonstrates a long term commitment by the developer. Allows developer to calculate costs. Can offset or remove costs of a national repository	Poorer countries may become dependent on these and suffer if site chosen is eventually proved to be unsuitable. Difficult to transparently justify the level of funding. Can make the national economy over-dependent on one particular activity. Funding mechanisms may be complex depending on entities involved	Helps to maintain momentum in national regulatory organisations if payments are linked to project and licensing milestones.	Delays in the process could cause excessive cost overruns for the developer due to continuing payments, unless linked. Neighbouring countries may impose transport bans. Changes in government policy could change situation. Could lead to dispute between host country and community on allocation of benefits
Expert Support Packages			
Enables national agencies, which may not be sufficiently expert in these fields, to draw upon Europe-wide expertise. Demonstrates independence from developer.	Could cause concern amongst national experts if they feel that their views are not valued.	If the case for facility development is strong, independent international review can benefit national and local perceptions.	Opens up the debate to opposition bodies across Europe with a wider agenda.

Tax Revenue			
Provides additional national income.	Can allow national authorities to divert normal regional development funds, thereby causing local resentment around the facility.	Can allow improvements in relevant national infrastructure and local services, thereby enhancing national prestige.	National authorities may 'swallow up' the revenue unless they are specifically allocated.
Profit Sharing			
Lays the ground for a smooth transition to other economic activities in the future.	Requires careful identification of where funds will go, or regional and national rivalries may develop.	Generates funds that can be used by the country in any way it sees fit.	Future waste arisings may decline and result in lower revenues than anticipated. Could allow individuals or companies to gain personal benefit; requires close monitoring

7.4.5 National Social Benefits

Strengths	Weaknesses	Opportunities	Threats
Employment			
Offers support to regional development within the country. Allows young people to remain in chosen community. Allows development of expert capabilities, helping country to become a leader in nuclear technologies etc.	Can disrupt existing employment profile and salary levels. May not be a significant factor if area already has good levels of employment. Repository work force not likely to be huge.	Increases national skill levels and can encourage other companies and industries to relocate into the country.	Influx of outside experts could demoralise nationals. Can isolate the country if there is regional opposition amongst neighbouring countries.
Infrastructure Improvements			
Supports developments that would otherwise not take place due to lack of funds.	Perceived negative impacts on environment could cause resentment and national opposition, especially if country is largely rural.	Improved communications can lower transport costs to the facility and therefore attract more business. Similarly, other industries can be attracted to relocate.	Regions of the country not affected could feel excluded from benefits.
Integrated Development (or related) Projects			
Allows plans to be developed with long-term benefits both locally and nationally. Provides national leverage with regard to other proposed regional developments. Moves country into supplier status in nuclear business and enhances national credibility in energy-related negotiations.	May be in conflict with existing regional, national and international economic development planning.	Encourages national authorities to enter into discussions with developer; allows mutual trust and confidence to be established. Could support national efforts to win development of other major scientific research projects.	Other countries may pass non-transit laws etc. which could affect development plans. Internal political change in the future might remove project support. Projects may be challenged by EU.
Relocation of Developer			
Provides additional benefits to the country in terms of jobs, tax revenue, skills base etc.	Identifies the country with the project in the mind of opposition groups and other countries that may	Country can be developed as a 'centre of excellence' and attract support industries and high-tech	If beneficial conditions are offered to individuals relocating from other countries, national

Demonstrates long-term commitment by developer.	not be in favour.	development.	resentment could result.

7.4.6 National Empowerment Measures

Strengths	Weaknesses	Opportunities	Threats
Involvement in Decision-Making			
Encourages a sense of involvement and allows a country to have control over the development.	Difficult to decide who makes the decisions if developer is not located in the host country.	Local knowledge may result in specific improvements in the project.	Subject to continued political support. Sufficient opposition could prevent any decisions being made.
Capacity Building			
Develops national expertise where this may have been lacking. This in turn can help communication in the siting process.	Can open the process to manipulation by pro or anti groups. Can cause delays in progress – can only move at the pace of the community.	Allows development of relationships between actors; allows opportunities for reasoned discussions. Allows people to visit operating facilities and gain confidence in the technology	May take a considerable time to reach decisions which in turn causes stakeholder fatigue.

7.5 Potential benefit packages offered by an EDO/ERO

Given the many uncertainties that exist as regards country identity, community location, national economic and social situations etc, it is not practicable here to suggest specific monetary amounts relative to each particular benefit described. In fact, it would be counterproductive to be too prescriptive at the present stage. Sufficient flexibility must be left open to allow meaningful negotiations with the host country and community. ***Nevertheless, consideration of the scale of benefits that have been offered in national programmes suggests that, over the lifetime of the project, they could amount to between <1 and a few percent of overall programme costs (with 1% being about 100 MEUR).***

The SWOT analyses can be used to help develop suggestions as to what form a benefits package might take for a country and community offering to host an EDO.

7.5.1 National Benefits

Cash Benefits

1. Lump Sum and Annual Payments: Such benefits may be better directed to affected communities, rather than countries.

2. Expert Support: This is a benefit to be stressed, allowing national agencies to gain from interaction with other sister organisations. Less well-developed agencies must not be made to feel inferior.

3. Tax revenue: This can be a strong issue in favour, and may allow government to carry out projects hitherto seen as too expensive. However, the funds MUST be ring-fenced.

4. Profit sharing: This requires careful negotiation and agreement.

Social Benefits

1. Employment: This could be powerful incentive – care should be taken to give realistic estimates, including all knock-on effects. It is essential that agreements are reached to ensure majority local hiring of industrial staff and recruitment of experts from within the country wherever possible.

2. Infrastructure improvements: Another potentially important benefit, allowing projects to be carried out that were previously impossible due to cost. Funding should however be limited to projects associated with the development. It is important to share the improvements with a number of communities (host, transport corridor etc).

3. Integrated Development Projects etc.: This could allow a country to become a regional or international leader in this technology, but will require careful discussions with neighbours.

4. Relocation of Developer: It will be essential for the ERO to be based in the country selected for a repository, guaranteeing other benefits, such as tax revenue and other income for the national government concerned. Control of the project should also be the responsibility of an implementing body domiciled in the host country.

Empowerment

1. National involvement in decision-making: This will be essential in developing a sense of project ownership.

2. Capacity building: This can be seen as a major incentive to countries with small programmes, in that it will raise their profile internationally and help them attract other prestigious projects, if they so wish.

Summary

To summarise, the following national benefits may be appropriate:

- Tax revenue from waste disposal activities (ring-fenced for relevant use) and a profit sharing agreement

- Support for relevant infrastructure projects related to repository development and operation

- Support for integrated development projects and full involvement in all relevant decision making concerning facility design and operation

- Guaranteed local hiring and use of national experts wherever possible

- Location of ERO headquarters in host country

7.5.2 Community Benefits

It is to be expected that local community benefits will be the subject of negotiations between the community, the host state and the repository developer. Potential components are as follows:

Cash Benefits

1. Lump sum: Community payments should be clearly specified in advance, and efforts made to demonstrate that these are for ‘community service’ and not to mitigate risk. The huge figures seen in some past cases should be avoided. Payment should be linked to project milestones. There should be no sharp geographical cut-off in the community receiving benefits.

2. Annual payments: It is important not to make these so large as to cause community dependence. Whatever sums were agreed, they must be linked to project milestones. There should be no sharp geographical cut-off in the communities receiving benefits.

3. Expert Support: This is a benefit to be stressed, allowing communities to gain access to a wide range of opinions. Controls on how funds are spent, while essential, must not be seen to exclude counter arguments.

4. Tax revenue: This can be a strong issue in favour, but must ensure that national government does not seek to gain total revenue. However the split is arranged, the funds must be ring-fenced. Again, it is important not to make community dependent on these for general expenditure.

5. Trust Fund for future generations: This may be one of the most important components of any benefit package. Initial payment must be sufficiently large to demonstrate commitment to long term value. Care must be taken in arranging trustees etc.

6. Profit sharing: This requires careful negotiation and agreement. Whilst it can instil a sense of local ownership, the community ought not to become dependent upon it.

Social Benefits

1. Employment: It is essential that agreements are reached to ensure the maximum possible local hiring of industrial staff, with efforts made to ensure recruitment of young people for training, as they will become the experts of tomorrow.

2. Infrastructure improvements: Another potentially important benefit, allowing projects to be carried out that were previously impossible due to cost. Funding should however be limited to projects associated with the development. It is important to share the improvements with a number of communities (host, transport corridor etc), although impacts on local and regional quality of life must be considered.

3. Property Value Protection: This is crucial to gaining local support. Agreed baseline values should be open to scrutiny by an independent body to avoid disputes

4. Integrated Development Projects etc.: Any benefit package must allow local people to contribute to development of ideas and plans for such projects, in order to gain community support. All views should be canvassed and decisions made transparently. Care must be taken not to alienate regional interests and to dovetail with other development planning.

5. Relocation of Developer: It will be essential for the ERO to be based in the community selected for a repository, guaranteeing other benefits, such as tax revenue and other income, in negotiation with the national government concerned. Support should be given for the area to become a ‘centre of excellence’ if so desired, thereby attracting other specialist industries.

6. Discounts: Subject to national practices, some recognition of ‘community service’ being performed, in terms of reduced utility bills etc. should be considered. This can then be used as an incentive for location of other developments. Careful negotiation of ramping down of benefit should be undertaken, to avoid community impact when the facility closes.

Empowerment

1. Local involvement in decision-making: This will be essential in developing a sense of project ownership. Care should be taken to balance the roles of elected and non-elected individuals. Final decisions should be taken by most relevant level of local government, depending on national cultural and legal setting.

2. Capacity building: An essential part of any benefit package. Local support can be lost overnight if the project does not move at a pace dictated by local concerns.

3. Development of a local partnership: This is becoming a feature of many ongoing successful siting processes, allowing development of mutual trust and confidence in the project and those involved. Negotiated contractual agreements should be introduced, with guarantees of ring-fenced funding agreed to by national government and placed outside the impact of normal spending rounds.

4. Involvement Support Packages: These are essential to gaining reasoned local involvement. Community participation must not be impeded by lack of capabilities or funds. Careful design of these packages must ensure that other communities beyond the immediate area can become involved if they wish, including those along transport corridors.

Summary

To summarise, the following community benefits may be appropriate:

- Lump sums, clearly specified in advance for ‘community service’; avoid disproportionately large sums.
- Like lump sums, annual payments should linked to project milestones (site selection; licensing; operation); limit capability for community dependence.
- Communities must be allowed support to access alternative views and independent experts.
- Tax revenue from waste disposal activities (ring-fenced for relevant use) and a profit sharing agreement, with local/national balance carefully negotiated.
- Trust Funds could be established to support the community in the long-term and demonstrate commitment to future generations.
- Local employment should be a priority.

- Support for relevant infrastructure projects related to repository development and operation, with care taken over local and regional sensitivities.
- An open and transparent property value protection scheme should be developed.
- Support for integrated development projects and full involvement in all relevant decision making concerning facility design and operation.
- Location of ERO offices in the host community.
- Clearly defined roles for local bodies in the decision-making process.
- Support for local capacity building.
- All of the above benefits may be best collected within an overall contractual agreement with a formal local partnership, involving elected and non-elected parties. Partnerships should be backed by ring-fenced funding.
- Benefit packages should be tailored to meet local needs, and include support to transport and to neighbouring communities.

8 Financing mechanisms for repositories

The costs of a shared repository are substantial and mechanisms for financing these must be developed. However, for our reference model, the implementation date is some way into the future (around 2035 was suggested as appropriate) and, as outlined in Section 6, many of the costs lie many decades further into the future. Accordingly, there is a long period in which the necessary funds can be accumulated.

Nevertheless, it is necessary to initiate the process at an early stage – in particular at a time when the nuclear power plants giving rise to wastes are still operating and hence could set aside funding from the revenues earned on sale of electricity, if this is to be the chosen financing mechanism. In multinational, as in national disposal programmes, the following key questions need to be answered when considering financing models:

- what mechanisms are used to accumulate funding at the necessary rate and guarantee that the accumulated funds will be segregated for the intended purpose?
- how should the costs be divided between the ultimate users of the repository?
- who is liable for unplanned costs that could arise because a potential site is lost or because remedial action becomes necessary at a site?

In this Section these questions are explored and suggestions made as to how the scenarios described earlier might be financed. Various models appear to be feasible for gathering the funds required and managing the early life of the EDO:

- Financing from a surcharge on the price of nuclear electricity in the eventual user countries.
- Amalgamation of some or part of existing national nuclear waste management funds (or government allocations) to establish the EDO.
- Providing pooled funding only for the period up to start of repository operations, then generating income based on a price per tonne of waste disposed.

Of course, a combination of these models is also possible. We discuss them separately below and give examples of how a financing scheme might work, using the ‘large’ inventory situation as our base case. The mechanisms proposed may appear complex and the task of implementing them challenging. It is worth noting, however, that the difficult decisions to be faced are not specific to multinational programmes. All of the points raised are also valid for the financing of national programmes – most particularly in countries where nuclear power plants have been operated by competing private utilities.

8.1 Surcharge on the price of nuclear electricity

A possible route to accumulating funds is to include a waste management charge within the price of electricity sold from nuclear power plants. Some countries already have such a mechanism in place to provide a waste management fund. Three possible ways of evaluating such a surcharge were considered here:

1. **MODEL 1:** The surcharge would come only from the existing nuclear power plants that will produce wastes between now and their time of closure – and only for the remaining lives of these plants. SAPIERR I identified the NPPs and their currently expected lifetimes in the 14 countries used as the basis for our inventory and cost calculations[4]. In

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[4] See footnote 1.

2007, the range of lifetimes of the operational NPPs was between 1 and 42 years – a progressive decline in NPP usage that assumes no new-build or further plant-life extension. There is a total of about 382 GWe.years of generation capacity remaining in the SAPIERR I countries (see Appendix A 1.4).

2. **MODEL 2:** Considering all of the electricity that has been and will be generated by the NPPs that have already produced waste and will continue to do so until they are closed. This is an intrinsically fairer approach. While it is not, of course, possible to go back in time and place a surcharge on past generation, several countries already have waste management funds in place that have grown from such historical surcharges and which may thus contribute to the funds required for a shared repository.
3. **MODEL 3:** Including with (2) above the possibility that there will be new NPPs in many European countries, so a rolling surcharge could be applied to all future power generation, which will not only pay for its own disposal costs but could also contribute (perhaps significantly) to those of past power generation. There are clearly major commercial issues at stake here, depending on how past and future NPPs were and will be financed in different countries, and on the way that contributions to a waste fund are decided. The requirement to find solutions for wastes from new NPPs that have to be managed alongside historic wastes must be a realistic scenario in many countries, given the impetus to build new NPPs in the EU to cope with carbon emissions and security of electricity supply. Because this increases the size of the resource pool and the time over which funds can be generated, it seems both inevitable and economically sensible that the new funds re combined with the old in disposal facilities that share access, R&D, encapsulation etc (whether this sharing is national or regional) .

In the following sections we look at the surcharge implications of these three Models, using the ‘large’ inventory as the basis for the calculations.

8.1.1 MODEL 1: Future generation surcharge only

A reasonable figure needs to be established for the price increment that could be charged for the waste management fund for future generation from the existing NPPs. The Eurostat database shows the 2006 price of electricity in EURcents/kWh to be rather variable across the EU, as shown in Table 8.1. The average price is 10.78 EURcents/kWh

Table 8.1: Price of electricity in the 14 SAPIERR countries in 2006 (EURcents/kWh: source Eurostat)

Belgium	11.23	Netherlands	12.07
Czech Republic	8.29	Austria	8.94
Italy	15.48	Slovenia	8.74
Latvia	7.02	Slovakia	12.16
Lithuania	6.09	Bulgaria	5.52
Hungary	8.96	Romania	8.59

For the purposes of Model 1, we began by examining an arbitrary surcharge of 2.5% of the approximate average price of electricity – equivalent to 0.25 EURcents/kWh. Assuming an 80% load factor on the NPPs evaluated, the amount of funding that could be generated by this mechanism is shown in Figure 8.1 (see Appendix A 1.4 for details of the calculations).

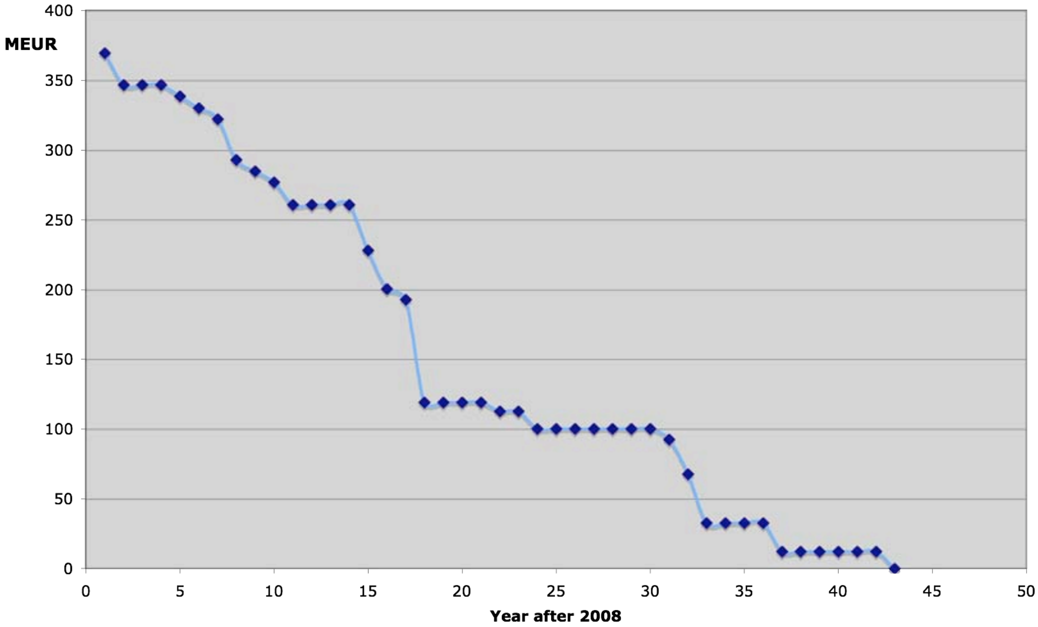

Figure 8.1: Annual generation of funds from a 0.25 EURcents/kWh levy on the price of nuclear electricity in the 14 SAPIERR countries (MODEL 1).

It can be seen that, owing to the ageing reactor fleet, there is a rapid decline in the generation of funds over a period of less than 20 years. Nevertheless, a total of some 6.7 BEUR could be generated by this level of surcharge on nuclear electricity pricing.

Of course, a key factor is the rate of accumulation of funds compared to the rate at which funds will be required for the repository development programme. Section 6.1 showed an estimate of the spend profile for a reasonable repository development programme scenario and Figure 8.2 shows this plotted against the income profile from the nuclear levy, for the period over which the funds would continue to accrue.

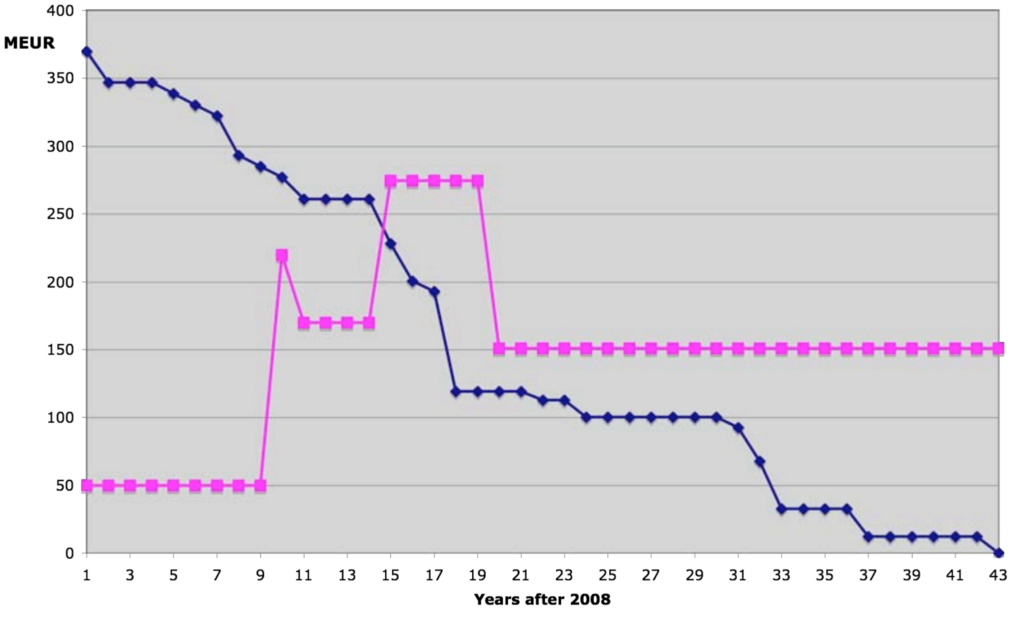

Figure 8.2: Accumulated nuclear waste fund compared to spend profile for the ‘large’ inventory situation discussed in Section 6.1.

This information has to be looked at in terms of the cumulative spend and income and, for the latter, some assumption can be made about the rate of interest that could accrue to money held in the fund. A figure of 3% p.a. is assumed a reasonably conservative interest rate here. Figure 8.3 shows the cumulative figures for spend and fund growth, as well as the amount of the fund remaining each year after costs have been deducted. It can be seen that, after about 20 years, the value of the fund only grows slowly, although adequately covering the costs.

Figure 8.4 looks further into the future, when the only source of income is interest on previously generated revenue. Even at the end of the disposal programme, the fund has not been drawn down and retains about 6 BEUR to cover any post-closure costs that might be foreseen.

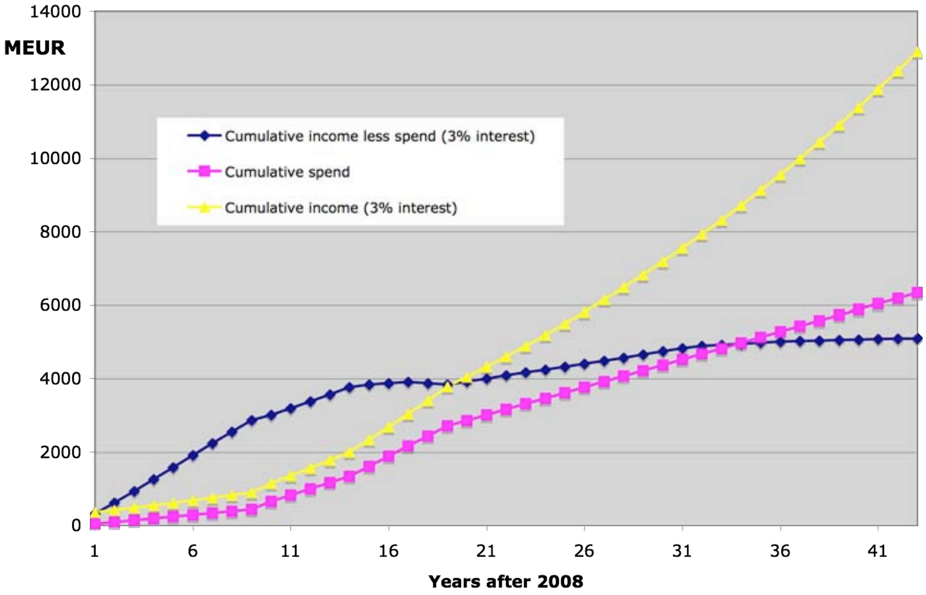

Figure 8.3: Cumulative growth of the fund at 3% interest compared to cumulative spend on the repository programme and the consequent balance of the fund for the period during which revenue is being generated by the NPPs.

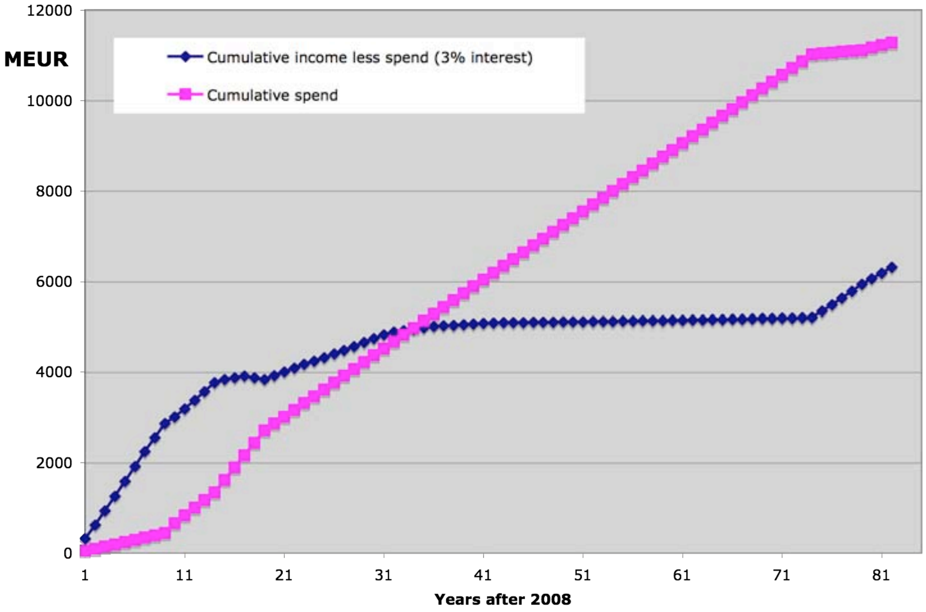

Figure 8.4: Longer-term balance of the fund out to the end of the disposal programme.

Clearly the arbitrary 0.25 EURcent/kWh surcharge we began with generates too much capital if the interest rate is sustained over the long period evaluated. In fact, the calculations are exceptionally sensitive to both the surcharge rate and the assumed rate of interest. Figure 8.5 shows the effect of assuming a small decrease in the surcharge rate to 0.22 EURcent/kWh. It can be seen that with this reduction of only 12%, the fund is drawn down and completely exhausted by the end of disposal operations.

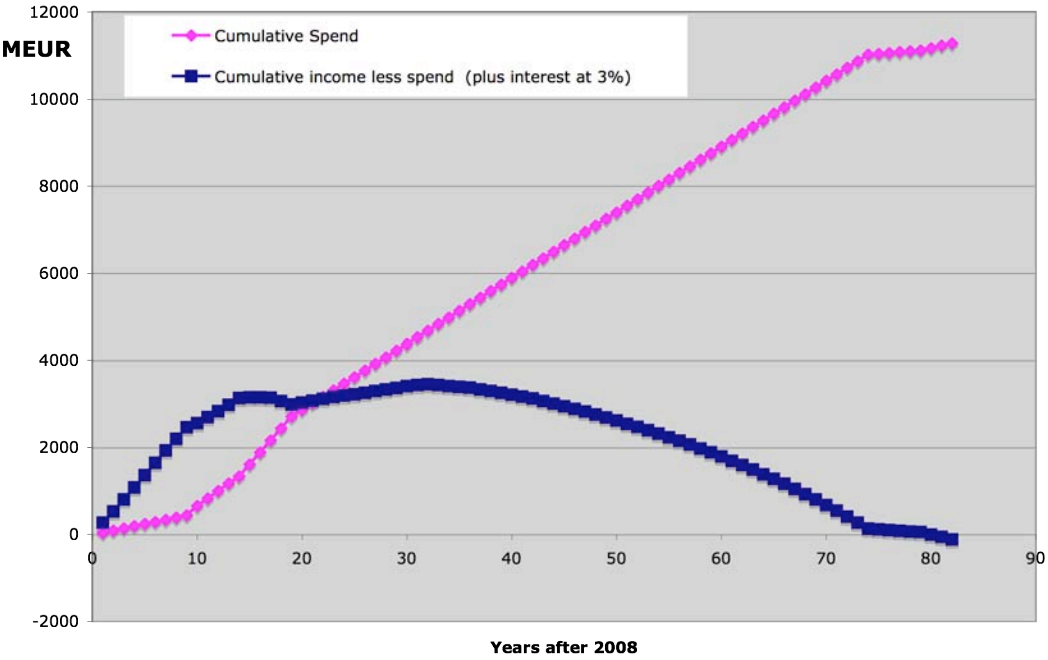

Figure 8.5: Longer-term balance of the fund out to the end of the disposal programme, assuming a reduced levy on the price of nuclear electricity of 0.22 EURcent/kWh.

8.1.2 MODEL 2: Past and future generation surcharge

As noted above, it is not, of course, possible to go back in time and place a surcharge on past generation. However, several countries do have waste management funds in place that have grown from such historical surcharges and which may thus contribute to the funds required for a shared repository.

For the purposes of this Model we made a ‘what if’ assumption that:

- a small proportion of the cost of electricity generated between the time that the NPPs in all 14 SAPIERR I countries (i.e. continuing to use the ‘large’ inventory situation) became operational and today had been set aside in a fund and;
- that a slightly greater surcharge would continue be made on all future generation (as in Model 1, but at a lower surcharge rate).

The objective of this Model is to see how large these two contributions would need to be to cover the costs of disposal. It also gives an indication of how much funding one might expect to be seeing today, on aggregate, in national waste funds in the countries modelled.

Some boundary assumptions or estimates were made concerning the time from which to begin the calculations in the countries modelled. The main point is that the start date for calculations for those countries that used to return spent fuel to the former Soviet Union is the time at which such exports are believed to have either stopped or been significantly reduced. The reason for making this approximation is that exported SF clearly does not contribute to the 'large' inventory whose disposal costs the surcharges are intended to cover. Our treatment is certainly an approximation. It is based upon the national programme information in SAPIERR I, which is not uniformly specific about the amounts of waste returned and remaining at each NPP.

The values selected for the historic contribution and the future surcharge are 0.05 and 0.1 EURcent/kWh, respectively. The resultant fund, balanced again the disposal costs (equivalent to Figure 8.5) is shown in Figure 8.6.

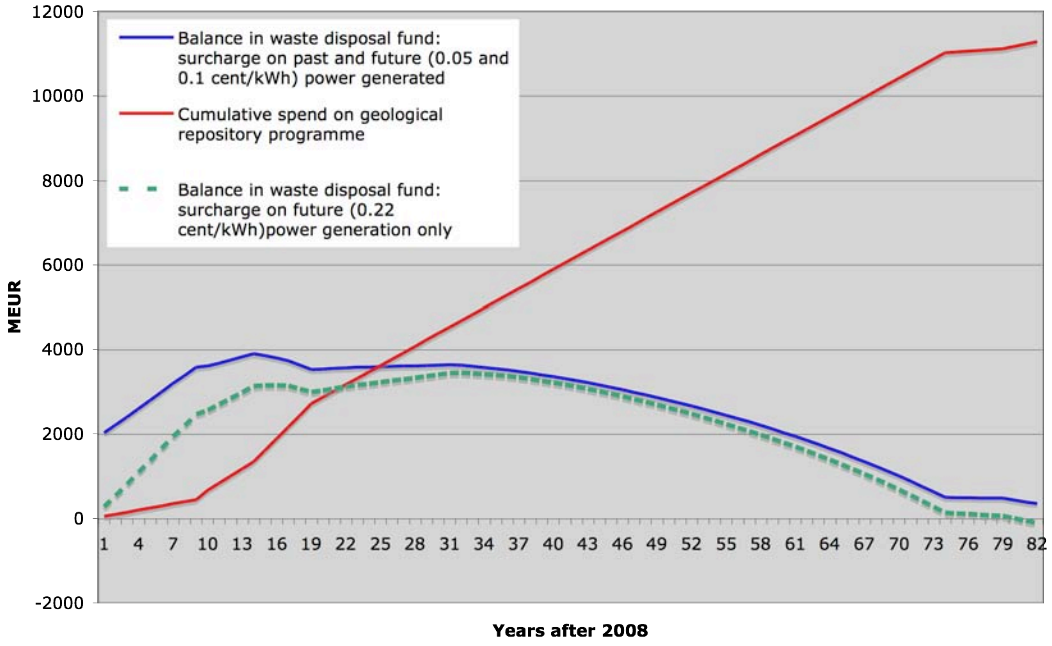

Figure 8.6: Model 2: historic contribution and future surcharge: balance of the fund out to the end of the disposal programme.

It can be seen from Figure 8.6 that the values selected for this Model result in a very similar long-term balance profile to those for the 0.22 EURcent/kWh surcharge scenario of Model 1, but for a considerably lower future surcharge (0.1 EURcent/kWh). At the end of the period there is still some 350 MEUR in the fund to cover further costs (e.g. post-closure monitoring).

The small value selected for historic contribution (0.05 EURcent/kWh) would have led to an accumulated fund today, *without* any interest being applied, of about 1900 MEUR, certainly sufficient to begin a disposal programme. The actual amount of capital held in national disposal funds across the 14 SAPIERR I countries is not known. However, as indicators, Switzerland held 2092 MCHF in its waste fund at the end of 2004 (~1350 MEUR at current exchange rates) and the Czech Republic had received payments into its spent fuel storage fund of ~260 MEUR[5]. The important implication of the Model 2 analysis is that, with forethought and early provision, it is fiscally relatively painless for electricity users (and producers) to pay for the costs of disposal.

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[5] Information from national reports to IAEA Joint Convention, May 2006.

Clearly, these figures, and those of Model 1, should only be taken as indicative of how a nuclear electricity surcharge could contribute towards financing a shared disposal programme. The size of the fund that could be raised would be highly dependent upon which countries were to participate, the number and capacity of the NPPs that they operate and their planned lifetimes. Some countries (e.g. Italy) have no means of contributing to such a fund and some (e.g. Lithuania and the Netherlands) have such small remaining generating capacity that they would be able to contribute very little. Attaining equity in fund contributions will be a challenging task and, for some groupings of countries, this mechanism of fund generation may be unable to generate sufficient money to finance a repository programme. Also, as we have seen, the price of electricity and the consequent magnitude of the levy that would be found tolerable will vary from country to country.

8.1.3 MODEL 3: contribution form new NPP programmes

The concept of a waste surcharge on the electricity from new-build NPPs also needs to be considered. It is a potentially powerful means of paying for even historic waste arisings, using only modest levels of surcharge.

In an evaluation of new-build spent fuel didposal costs in the UK, for example, Chapman and McCombie (2006) calculated that a ~10 GWe UK new-build programme could pay for its own spent fuel disposal after ~30 years and for all the UK 'geological disposal inventory' after ~50 years (with a surcharge of ~0.17 EURcent/kWh and an interest rate of 2.5%).

If future nuclear power generation levels in the EU countries in SAPIERR I were maintained so as to be similar to today's level, then the modest Model 2 surcharge of 0.1 EURcent/kWh would contribute about 185 MEUR a year to total waste managements systems. This is more than an adequate sum to pay for the disposal of existing wastes with the spend profile shown in Figure 8.2 and likely for the wastes from the continued nuclear power programme too (as illustrated by the Chapman and McCombie study cited above). If, on the other hand, the scale of nuclear power use expands over the next decades, then the income to a waste fund will also increase and, owing to the economies of scale, the cost of disposing of the additional waste will not increase at the same rate. Up to a certain point, the models used here can be adapted to explore this situation but, at some scale, additional repositories (or other facilities) will likely be required and the whole economic strategy would need to evolve.

The overall implication for SAPIERR is that, although establishing a surcharge system for future generation from existing NPPs may be difficult, the added dimension of having to manage new-build NPP wastes will be an incentive to setting both national and European mechanisms in place and formulating transparent waste funding policies – especially where they may not yet exist.

8.2 Amalgamation of national nuclear waste managements funds

Several countries have funds already set aside for the management of waste from nuclear power generation. Some of these funds are already being used to finance national waste management organisations (WMOs). When an EDO is established, or when it transitions to an ERO, participating countries could decide to allocate part of their nuclear waste funds towards the new organisation. Clearly, adequate funding would have to remain with the national organisation, which may have to manage planned or existing LLW facilities and other waste management activities. In addition, as the shared repository project run by the EDO might be only one strand of a country's dual track approach (shared multinational plus purely national disposal, until a feasible solution emerges from one track), it could be necessary to continue the WMO's own geological disposal project. The decision on whether to use additional, new money from the national fund for the EDO or to incorporate its requirements within the existing budget of the WMO could be a difficult matter to resolve.

The same model could apply to using government or industry funding for waste management that was not sourced from a national nuclear fund, but directly from the nuclear industry or government.

As noted at the beginning of Section 8, an ERO could be financed by a mixture of both levy funding and national contributions, with different countries using different approaches.

8.3 Generating income with a priced disposal service

In this approach, the partner countries in an EDO would cover the development costs of a repository up to the point of it being operational. The past and future costs would then be recouped by a charge on users on a per-tonne of waste disposed basis.

In the ‘large’ inventory case, the initial costs up to the point of operation (Year 20), based on the data used to produce the spend profile in Section 8.1.1, are about 2000 MEUR (excluding transport and encapsulation costs of the ‘early’ waste arrivals intended to ensure waste is ready for disposal immediately the repository is ready). The remaining cost of about 9300 MEUR arises from encapsulation, disposal and closure activities.

As discussed in Section 8.1.2, an amount of 2000 MEUR is what could have been generated by the very modest ‘historical’ surcharge of 0.05 EURcent/kWh envisaged in Model 3, and would provide enough pump-priming funds to get the repository operational.

A simple calculation as an example shows that, on a non-profit basis, the 25,637 tonnes of SF in the ‘large’ inventory could cover all transport and disposal costs (including the ILW inventory) if a price of about 0.44 MEUR/tonne was charged (440 EUR/kgHM).

8.4 Early funding requirements and managing the EDO finances

The critical early period of the EDO requires relatively modest level of funding. The major spending begins to arise when site characterisation studies begin. The spend profiles discussed previously all begin at the point when siting studies commence and consider an annual requirement of the order of 50 MEUR for siting and associated R&D for about 10 years.

Prior to site characterisation work beginning there would be a period during which the EDO is establishing itself, staffing-up and tackling the initial political, legal and financial negotiations with member and potential member countries, as well as establishing and implementing its approach to potential site identification (i.e. before any site investigation work begins). This may take two to three years. The funding requirements in this period are relatively modest. We envisage that this formative work could be undertaken by a small group of staff with an annual budget of a few million EUR. An additional source of funding in this period might be from industrial shares in the EDO (seed money), from organisations with an interest in eventually providing services to the subsequent ERO (e.g. in transport and construction). Clearly, any organisation investing seed money into the EDO would need some guarantee of future involvement, but without prejudicing the ability of the ERO to enter flexible commercial tendering arrangements.

It is clear that, once this initial period of two to three years is complete, the requirement to ramp up the spending and consequent input from member countries means that a high level of confidence must have been achieved in identifying both a host country and an eventual site. Nevertheless, final site choice may still be some years into the future, especially if a number of alternatives are being assessed. These aspects are discussed more quantitatively in Section 8.5.

8.5 The ERO stage: sharing repository costs

Work Package 1 of SAPIERR II noted that the main concern of the present project is to consider the critical next step – that of establishing the EDO – and it was acknowledged that it is too early to look in detail at the organisational form of the subsequent ERO. While the same is true of the economic aspects of how an ERO would operate, we have already noted that it could function as either a non-profit organisation or a commercial enterprise and the cost and spend profile data presented in Section 6 have looked out to the period in which the ERO will operate. In this Section we look briefly at some of the issues affecting cost sharing or the pricing of a commercial service.

If a non-profit, cost based service for the ERO is to be developed by a consortium of repository users, then equitable financial burdens should be placed on the partners. In a partnership type of organisation, such as is often the case in national programmes, an important consideration is the fair distribution of costs amongst partners, given that these partners will deliver different volumes of different waste types on differing timescales. It is likely that a partner in a regional repository project or a customer in the commercial case will wish to feel assured that costs are being distributed on a fair basis. Accordingly this approach of equitable distribution of cost amongst the partners/customers should also be examined.

For a commercial model, the issues involved will, to a large extent, be independent of whether the operator is a private company, a government owned entity or a consortium. It is reasonable to assume that there will be a wish to construct and operate the facilities in a manner that ensures that the users have acceptable prices and the operator a reasonable profit. In a commercial undertaking, there are clearly market forces that influence or even dominate the pricing strategy for a commodity. However, the cost of production is always a key marker for pricing – if only to ensure that the minimum economic price can be established. Thus, the total cost of developing and operating a regional storage and disposal system is a key parameter. The total income of the repository operator must cover all costs and also give profit margins appropriate for the risk levels involved (taking into consideration also the time distribution of costs and income).

An indication of the potential revenues and prices (at least, for spent fuel storage and disposal) can be obtained from current developments in Russia. For economic reasons, Russia would be prepared to import spent fuel from countries to which it has supplied fresh fuel and also from other countries, if the required international consensus could be reached and if local misgivings could be addressed. According to Bunn (2007) the MINATOM concept for an international spent fuel service would offer two different services: temporary storage with later return of the spent fuel, or reprocessing without return of plutonium or wastes (for most customers however this is not currently possible in Russian law). Importing 20,000 tons of spent fuel over 10 years would generate USD 21 billion, using an estimated temporary storage price of USD 300-600/kgHM, and an estimated price for reprocessing without return of wastes and plutonium of USD 1200-2000/kgHM. The cost of providing the services is estimated to be about USD 10.5 billion, with a further USD 3.3 billion going to national and regional taxes and other payments to governments. This would leave about USD 7.2 billion available for addressing socio-economic and ecological issues.

Bunn notes that the Non-Proliferation Trust (NPT) has proposed a much different approach, in which a commercial dry cask storage facility would be established in Russia to take 10,000 tons of spent fuel from other countries. The projected price of USD 1500/kgHM would generate USD 15 billion in revenue, with estimated total costs (transport, storage and eventual

SF disposal) of about USD 4 billion (USD 400/kgHM). This would leave about USD 11 billion in excess revenue, which NPT suggests routing almost entirely to disarmament, non-proliferation and cleanup initiatives in Russia.

It is interesting to apply these values to the SAPIERR I inventory of 25,637 tonnes of spent fuel. The NPT price for transport, storage and disposal of USD 1500/kgHM (~1000 EUR/kgHM) would generate a total revenue of over 25 BEUR. This can be compared with the estimated transport and disposal costs presented in Section 6 for the total SAPIERR waste inventory of about 10-12 BEUR, indicating a potential for 10 – 15 BEUR profit if a commercial model was to be adopted. Using the NPT cost of USD 400/kgHM (~275 EUR/kgHM) also provides a useful crosscheck on the estimates made earlier in this report. It produces a cost for SAPIERR spent fuel transport, storage and disposal of ~7 BEUR, which is a reasonable match for the 10-12 BEUR estimate for management of the full SAPIERR waste inventory.

In both the non-profit and the commercial Models for the ERO, there will be need to establish relative ‘contributions’ (non-profit model) or prices (commercial model) for using the repository to take different waste streams. This must be done in such a way that users/customers would regard the final distribution of their contribution to total income/revenue as ‘fair’ in an objective sense. As discussed in Section 3, the costs that have to be covered include both fixed and variable components (see Table 3.1) with the fixed components of specific cost categories indicating where economies of scale should be achievable for large facilities.

It is ultimately a matter of judgement how much each user/customer should provide towards covering the fixed and variable costs of disposal (together with an appropriate profit margin, in the case of the commercial model). There are, however, some technical characteristics of waste packages that potentially influence the disposal costs. These factors, which are not all independent of one another, are tabulated below.

Table 8.1: Waste package characteristics potentially affecting disposal cost/price

1. Mass and dimensions of package	Affects handling requirements; type and size of vehicles,; shaft or ramp access
2. Engineered barrier system required	Determines disposal volume required and excavation and materials costs involved
3. Heat output	Determines near-field and far-field temperatures which affect package spacing and consequent size of repository and amounts of excavation and backfilling materials
4. Radiation levels at delivery	If adequately shielded by standard procedures may not affect disposal operations
5. Toxicity at delivery	Does not affect operations; may affect risks (which are small, however)
6. Radiation or toxicity at long times	At times beyond about 1000 years is determined mainly by transuranics and long-lived fission products
7. Burn-up in original fuel	This affects activity and toxicity; it also is related to energy produced and hence to revenue earned earlier by the user/customer
8. Handling requirements	Repository can be equipped for ‘standard’ packages; special handling would invoke a surcharge

Using this kind of information to discriminate, for example, between spent fuel and HLW from different sources indicates that lower burn-up spent fuel or older (longer stored) spent fuel or HLW would be less costly (lower price) to dispose of, MOX fuel would be more expensive and unirradiated fuel would be considerably cheaper to dispose of.

Clearly, establishing a transparent pricing or contribution algorithm for different types of waste with different characteristics would be an important task that would initially be tackled by the EDO, to provide input for establishing the ERO.

8.6 Financing Model for the Formative Years

The first decade of existence of the regional repository organisation is clearly uppermost in present considerations of practicality. In this period it is expected that the EDO will be set up, will establish the legal and management structure under which eventual sharing (and any external, third-party) services will be developed and offered, will commence and proceed through siting negotiations and will carry out investigations at one or more potential repository locations.

A ten-year programme is an ambitious target for the EDO. It requires that countries enter the project with a commitment to move forward at a reasonable pace and to put sufficient resources, support and experience into its activities. It may be found that the EDO has to continue work for several more years. At the end of this period of ten or more years, before the major commitment to begin underground construction is made, the EDO is expected to transition to, or hand over to, the ERO, which will be responsible for managing actual disposal activities (see Section 1.2). Based on the information in previous Sections, it is possible to look in a little more detail at the economic aspects of this critical period and suggest a model of how it may be managed.

In the proposed model we have used the nominal ten year lifetime for the EDO discussed above, but recognise that even moving into the formative first years is going to take a period of groundwork. Consequently, we include a ‘Year 0’ in which this work can take place. The activities in Year 0 will include further discussions with potential member countries, meetings with nominated organisations from the initial ‘core group’ of countries and administrative work leading to the establishment of the EDO office in Year 1. The objective is to enter Year 1 with a basic administrative infrastructure agreed or even in place, so that the business of the EDO can commence.

The activities that are expected to take place in this period and the main cost elements are shown in Table 8.2. The rising profile of financial requirements to cover the work in Table 8.2 is shown in Figure 8.6.

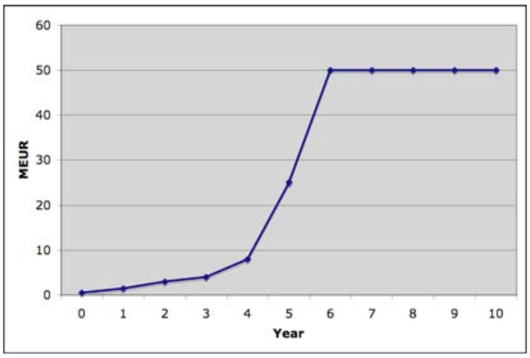

Figure 8.6: Annual funding requirement (MEUR) for the EDO prior to establishment of the ERO

It can be seen that the initial three years after Year 0 require relatively modest funding, with requirements rising steeply once site-specific work begins. The way that these costs are distributed among the partners in setting up the EDO would clearly be an important matter for discussion. The discussion may, for example, revolve around appropriate levels of funding from countries with different amounts of waste and different sizes of nuclear power programme. Beyond this time, the commitment increases, but the prospects of achieving a common solution are progressively stronger and, by Year 8, it is expected that legal arrangements for whichever site is to be selected (and it may be that only one has been evaluated) are binding on both the host country and the partner organisations.

Table 8.2: Activities and Costs for the EDO

Year	Infrastructure	Main Activities	Funding (MEUR)
0	No infrastructure in this period: work managed from initial partners offices	Further discussions with potential member countries. Meetings with nominated organisations from the initial 'core group' of countries. Administrative work leading to the establishment of the EDO office	0.5
1	Establish small office with ~5 staff (two technical, one legal/financial. one administrative, one secretarial), possibly seconded from partner organisations. Management board set in place.	Scoping the legal and financial aspects of shared facilities. Establishing strong lines of contact with partner countries, potential users, the EU and the IAEA. Refine legal, cost and repository studies. Some of this work will be contracted out	1.5
2	Three additional staff (total 8), including one or two public communications	Establish approach to site identification and commence negotiations with potential host countries	3
3		Identify one or more potential host countries, establish national siting task forces and establish contacts with potential local communities Finalise legal and commercial basis for host countries to offer access	4
4	Two additional staff (total 10)		8
5	Five additional staff: mainly technical (total 15)	Begin initial site evaluation studies, design options work and safety studies	25
6	Establish local technical office(s) at site(s) being investigated (assume 2-3): recruit local staff to manage site investigations (total 20)	PHASE 1 Site Investigations Parallel design, engineering and safety studies Continued evaluation and negotiation on legal and financial basis of ERO Detailed liaison with local regulatory authorities on site-specific matters Finalise legal basis for all aspects of host country provision of a site and other facilities: arrangements should be binding by this stage	50
7			50
8	Additional staff from host country or countries (total now ~25 staff).		50
9		PHASE 2 Site Investigations (completion of surface based work leading to selection of preferred site) Completion of preliminary design and safety studies and submission of first licence application to host regulators Completion of legal work and agreements to establish the ERO	50
10	Prepare for movement of all facilities to the host country and site. Recruitment of local staff to establish the ERO.		50

9 Differences between national and regional concepts

The discussion in the previous Sections has identified a number of important economic differences between a shared, regional approach and entirely national concepts. These are reiterated briefly in this section, with the focus being largely on EU level and national level benefits.

9.1 Positive economic impacts

The most important economic impact is the cost saving made through the economy of scale of a shared repository. Other, perhaps less obvious, advantages are also mentioned briefly below:

1. Repository fixed costs include activities or facilities (research, siting, shafts, head works, work force etc) that do not have to be repeated or duplicated in each country. This amounts to a huge saving at a European scale – possibly about 15 BEUR is estimated in the current study for the 'large' inventory of the 14 SAPIERR I countries[6], even without accounting for much of the potential shared R&D savings.
2. The national economic benefits to a host country could be extremely large. These include associated infrastructure projects, direct and spin-off employment and demand for services and materials and, if a commercial approach was taken, taxes and royalties on profits. As an example, it was estimated in 1999 that the proposed Pangea project to build an international repository for 75,000 tU in Australia, would have generated as many as 70,000 jobs (1500 directly associated with the facilities) and increased the national GDP by 1%. More recent Japanese estimates (NUMO) are that 2200 persons would be employed throughout the 60 years of repository operation.
3. The host country could be offered substantial 'user benefits' for disposing of its wastes. These could be in the form of reduced costs of disposal or not having to pay any of the front-end costs of constructing the repository – these being paid for by the other partners, with the host paying only a reduced disposal fee much later in the programme. The host community could offer the site but the investigation costs and construction costs could be borne by the other participant countries.
4. If the ERO were to have a commercial operating basis and provide services on a for-profit basis, then it is estimated that it could generate surplus revenues of around 10 – 15 BEUR for the host country and partners, with a significant portion of this being transferred as tax or royalties to the host government.
5. The availability of a broader range of siting environments in the potential host countries could mean that a more economic design solution is available than in a national programme with possibly more restricted choice.
6. The availability of a regional disposal option could make fuel-leasing services that may be offered as an alternative by larger programmes such as Russia and, possibly, the USA, less attractive. Such schemes would have to become more competitive, so a regional EU solution could force down prices internationally.

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[6] See footnote 1.

9.2 Potential negative economic impacts

Potential negative impacts are also recognisable, although at a different and much smaller scale to the positive impacts mentioned above.

1. More complex licensing and legal arrangements would be required and would entail additional costs over and above a purely national programme. This will increasingly tend to be offset anyway by the developing requirements to manage large environmentally sensitive projects within a European legal dimension.
2. The peripheral benefits of hosting a large project (see item 2 in the previous section) would be enjoyed only by the country that hosts the repository. This need not be totally one-sided, however, and some means of sharing of benefits such as engineering and construction could be developed to ensure that the major participating countries were involved.
3. The most appropriate financing scheme to accumulate funds may be more complex that a national scheme. In addition, it is likely that an EDO would require extra funding over and above necessary national programme funding – and this would occur in the next few years. This would be rapidly offset by sharing the costs of the site characterisation work, which is also an inevitable feature of any national programme.

- There will be some pressure within a shared project to expedite the process so as to reduce programme uncertainties. This could mean earlier emplacement than envisaged within a national programme, thus reducing the potential fiscal planning benefit of cost discounting involving a long-term storage option.
- There is a potential risk, unless clearly specified in the EDO agreement, that late withdrawal by the host country (a change of mind/policy) would return the burden back to the national programmes, which may by then have made internal financial decisions that may be difficult to reverse.

10 Conclusions

A shared, regional disposal solution developed by, and providing services for, several European countries is an economically attractive proposition at all scales – the European Union, the national level and the community level. This is true for all partners involved in the enterprise. In the foregoing discussions we have looked at the economics of both the EDO stage (approximately the next 10 years) and the subsequent, operational ERO phase. We have also looked at sharing on a 'large' scale, with multiple partner countries involved, or on a 'small' scale, with just two or three. We draw the following principal conclusions:

1. We have made cost estimates at a relatively simplistic level throughout, but these are considered to be appropriate for the present study, which is meant to provide a robust indication of economics to potential partner countries. Although more detailed costing would be possible, it would contribute largely only to the precision of some component costs, rather than the accuracy of the overall costs, which we consider to be correct to within a factor of about 0.5, at the time of writing (i.e. a contingency of about 50% could be added to the present figures).

2. The total disposal costs (waste encapsulation and disposal) for the full SAPIERR I 'large' inventory are around 10 BEUR. These are dominated by the costs of disposing of spent fuel. SAPIERR uses a large inventory of wastes and it is unlikely that a shared EU project would commence with an inventory of such magnitude. However, if the project is successful and gains momentum, then an equivalent inventory is easily conceivable. This view is reinforced by the fact that we have looked only at wastes arising from current NPPs, all of which will have been phased out in the next ~40 years, and it is most likely that several potential partner countries will be operating new NPPs within the period out to almost the end of the century that is considered in this study.

3. Nevertheless, we have also looked at the implications of only two or three countries sharing is a disposal solution (our 'small' inventory situation, with only around 25% of the 'large' inventory of wastes). The total disposal cost derived for this scenario is about 4 BEUR. Using the same assumptions as for the 'large' inventory case, the saving on having two or three separate national repositories is about 3 BEUR and again, much of this saving is in R&D and siting costs. Even accounting for 'sunk costs already spent by national programmes, the implication is that each country involved in a small sharing partnership might be expected to save in the order of 500 – 1000 MEUR.

4. A single repository for all the wastes is the most economical solution (and was the only model assessed for the 'small' inventory case). In the 'large' inventory case, a cost increase of up to 20% results from having two repositories rather than one (with the total inventory split equally between them). Thus, if there are strong political reasons within the partner organisations of the EDO for having more than one repository, the increased cost may be acceptable. Two separate repositories designed (one for HLW-SF and one for ILW) to keep waste streams segregated, to reduce transport distances or to maintain a diversity of disposal service providers, are more economical than the 50:50 total inventory split model, adding only about 5 – 10% to overall costs.

5. Conversely, there is little overall cost advantage in having a single encapsulation plant when dealing with a large inventory. Encapsulation costs are predominantly operational (e.g. staff and materials), rather than investment costs. Consequently, encapsulation could be carried out at a number of locations, rather than only at the repository site itself. In the present analysis, however, we have assumed the latter case (as it is marginally the most economic). Of course, encapsulation could also be carried out as a service by a third party country. Encapsulation other than at the waste production site or at the repository does add a transport step.

6. Considering the 'large' inventory case, with the 14 countries in the SAPIERR I project[7], the overall impact of opting for a shared rather than numerous national solutions is possibly around 15 BEUR of savings to the EU, clearly illustrating the potential for economy-of-scale savings. This is without including all of the saving that could be made from the pooling of R&D costs, which could amount to several more BEUR.

7. The minimum transport cost of wastes to the repository is estimated to be between 6.5 to 11% of the disposal costs, depending on the size of the inventory. For the 'large' inventory situation, the transport cost is around 1 BEUR assuming (albeit unrealistically) that all waste was only transported once (about 260 MEUR for the 'small' inventory). These figures could be significantly higher depending on the eventual number of shipments that prove necessary which, in turn, depends on the number of encapsulation plants, stores and repositories. It is thus one of the largest uncertainties in the present analysis. However, it should be noted that moving wastes to a shared regional repository does not cost more than moving it to a national facility. In this sense, transport costs could arguably be removed from this comparison exercise.

8. Storage costs for spent fuel dominate overall storage costs for the SAPIERR inventory. We calculate that the overall cost of dry cask storage of the SAPIERR spent fuel 'large' inventory for 40 years would be about 1.7 BEUR. However, as already observed in SAPIERR I, since all spent fuel will be capable of being stored in the producing nations until 2035, there will be no economic incentives to implement new regional stores. Also for new nuclear plants that may be constructed in Europe in the coming decades, the lack of certainty about centralised or national repositories may compel the operators to make enough interim storage available to ensure capacity until after the assumed SAPIERR repository implementation date of 2035. Consequently, the costs of interim storage can be neglected in a comparison of strategies out to 2040 with national or regional European repositories. The availability of a regional repository at the proposed time would, on the other hand, have a significant impact on the costs of fuel storage after that date.

9. The EDO should make provision for a substantial benefits package for affected communities at and around the repository location. We make no quantitative suggestion as to the overall increment of this package on the overall programme cost but observe that it could amount to something between <1 and a few percent over the lifetime of the project (with 1% being about 100 MEUR). A wide range of possible benefits has been identified, including lump sums, annual payments, trust funds,

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[7] See footnote 1.

provision of local employment, local infrastructure projects and integrated development projects.

10. The national government of a repository host country can expect to receive a steady income from tax and royalty payments, as well as numerous other spin-off benefits of employment and infrastructure projects. If the ERO were to have a commercial operating basis and provide services on a for-profit basis, then it is estimated that, for the 'large' inventory case, it could generate surplus revenues of around 10 – 15 BEUR for the host country and partners, with a significant portion of this being transferred as tax or royalties to the host government.

11. Spend profiles for the total programme cost of disposal plus transport, with no storage cost included (~11.3 and 4.2 BEUR for the 'large' and 'small' inventory cases) show a significant increase in annual spending once a site is selected and construction begins (Year 10 in the 82 year model timeframe used here). The highest investment costs are in Years 10-20, after which the spend profile is dominated by operating costs for the encapsulation facility, with operation costs of the repository being a considerably smaller proportion of the total and roughly equivalent to transport costs for moving the waste to the site. There is a relatively constant spend (~150 MEUR pa and ~40 MEUR pa for the 'large' and 'small' inventory cases) during the operational life of the disposal facilities.

12. If discounting at a rate of 3.5% up to thirty years, 3% up to 75 years and 2.5% thereafter is taken into account, the present value of the overall 'large' inventory project cost is reduced from ~11.3 BEUR to ~4 BEUR (which is approximately the same as the undiscounted cost of a single national repository). The corresponding present value for the 'small' inventory case is about 1.5 BEUR.

13. Of the various ways that an ERO might secure the funding for the project, perhaps the most transparent would be to assign a surcharge on the price of future nuclear electricity generation for the NPPs from which waste has come and will arise. The funds generated could be combined with funds (possibly already existing in national programmes) derived from surcharges on or allocations for past generation of nuclear electricity. We used the 'large' inventory situation and looked at three models for the time period over which such surcharges might be considered, taking account of both past and future power generation. For a 'future only' nuclear power generation model, we estimate that a surcharge of 0.22 EURcent/kWh on the remaining electricity to be generated by the current NPPs in the SAPIERR I countries would be sufficient to cover all the programme costs, assuming a modest rate of interest of 3% pa. For a model that looked at all the power generated from the same NPPs since they began operation, a past surcharge of only 0.05 EURcent/kWh and a future surcharge of 0.1 EURcent/kWh would provide adequate funds.

14. We used the last value of 0.1 EURcent/kWh in our third model to look at continued nuclear power production at current levels (that is, assuming that older NPPs are replaced to keep the current nuclear electricity production level). This would generate around 185 MEUR per year, more than enough to deal with past and, likely, future waste arisings. Clearly, there are commercial balances to be found here, depending on how past and future power production has been and will be financed in the countries concerned.

15. The upcoming decade will be the most critical for the success of a shared solution and the foundation of an economic basis for the EDO, which would operate over approximately that period, is thus a major concern for interested parties. In this period it is expected that the EDO will be set up, will establish the legal and management structure under which eventual sharing (and any external, third-party) services will be developed and offered, will commence and proceed through siting negotiations and will carry out investigations at one or more potential repository locations. We propose a Year 0 period, during which administrative arrangements can be started and the necessary meetings and discussions with initially interested partner countries take place. The approximate budget requirement for this period is ~0.5 MEUR. The following three years require relatively modest funding, with requirements rising steeply once site-specific work begins. For Years 1 to 3, a group of (for example) five countries would need, on average, to allocate between 400,000 and 1 MEUR each to get the EDO off the ground.

16. An analysis of the potential positive and negative impacts of a shared regional solution indicates that the positive economic advantages far outweigh in magnitude any likely negative impacts. The positive impacts will be felt at all levels, from the local community up to the European Union as a whole. Such important economic benefits will confer considerable political influence on those countries involved, especially the host country.

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Appendices

A1 Cost Scaling Calculation Examples for Section 3

A3.1 Disposal of SF & HLW for the 'large' inventory situation: Swedish and Swiss basis

SF/HLW cost scaling based on SKB Plan 2003 costs

SKB (2003). Plan 2003. Costs for management of the radioactive waste products from nuclear power stations. Technical Report TR-03-11

Item	SKB estimated costs (MSEK) based on 4500 SF packages: Future	To end 2003	Total	Fixed to Variable Assumption	Fixed Cost MSEK	Variable Cost MSEK	Scaled costs on ratio of package numbers: in MEUR at 1 SEK = 0.108 EUR: Single SF/HLW Repository 13920 containers	Single SF/HLW repository 6960 containers
Repository siting	1040	1018	2058	100:0	2058	0	222	222
Repository construction	6700		6700	30:70	2010	4690	1784	1000
Repository operation	4610		4610	20:80	922	3688	1332	716
Repository closure	2510		2510	0:100	0	2510	839	419
Repository-related R&D & admin	4860	4832	9692	100:0	9692	0	1047	1047
Spent fuel and HLW interim storage	4610	4469	9079	0:100 (b)	0	9079		
Encapsulation facility	7920	193	8113	10:90	811	7302	2527	1307
TOTAL	**32250**	**10512**	**42762**					
			4618	**MEUR**				

		Single SF/HLW Repository 13920 containers	Single SF/HLW repository 6960 containers
A	**Repository (only) Total**	**5223**	**3404**
B	**Repository and Encapsulation**	**7750**	**4712**
A	**Inflated to Dec 2006 costs**	**5442**	**3547**
B	**Inflated to Dec 2006 costs**	**8076**	**4910**
	Encapsulation component	**2633**	**1362**

Using 4.2% inflation: Swedish Central Office of Statistcis
From January 2003 to December 2006
www.scb.se

Assumptions

Siting and R&D/Admin do not need to be scaled (shown as grey boxes)

Spent fuel and HLW interim storage costs (CLAB, in Sweden) have NOT been included in the scaled cost estimates

(a) increment calculated as function of variable costs only

(b) the F/V for interim storage will depend on the technology used (wet/dry; vault/

SF/HLW cost scaling based on Nagra (2001) costs

Zuidema, P & Issler, H. (2001). Kosten der Endlagerung radioaktiver Abfälle. SVA Tagungssreferate: Die Kernenergie im offenen Strommarkt.

Item	Nagra estimated costs (MCHF) based on 2065 SF packages and 720 HLW packages (2785 total)	Fixed to Variable Assumption	Fixed Cost MCHF	Variable Cost MCHF	Scaled costs on ratio of package numbers: in MEUR at 1 CHF = 0.610 EUR: Single SF/HLW Repository 13920 containers	Single SF/HLW repository 6960 containers
Repository siting	800	100:0	800	0	488	488
Repository construction	1100	50:50	550	550	2012	1174
Repository operation	600	40:60	240	360	1244	695
Repository closure	400	0:100	0	400	1220	610
Repository-related R&D & admin	500	100:0	500	0	305	305
Spent fuel and HLW interim storage*	1000	0:100 (b)	0	1000		
Encapsulation facility*	1000	30:70	300	700	2317	1250
TOTAL	**5400**					

*from Nagra estimate

		Single SF/HLW Repository 13920 containers	Single SF/HLW repository 6960 containers
A	**Repository (only) Total**	**5269**	**3272**
B	**Repository and Encapsulation**	**7586**	**4522**
A	**Inflated to Dec 2006 costs**	**5531**	**3435**
B	**Inflated to Dec 2006 costs**	**7964**	**4747**
	Encapsulation component	**2433**	**1312**

Using 4.98% inflation: Swiss Federal Office of Statistics
From January 2001 to Dec 2006
www.bfs.admin.ch

Assumptions

Siting and R&D do not need to be scaled (shown as grey boxes)

R&D/Admin includes 500M compensation

Spent fuel and HLW interim storage costs (ZWILAG in Switzerland) have NOT been included in the scaled cost estimates

(a) increment calculated as function of variable costs only

(b) the F/V for interim storage will depend on the technology used (wet/dry; vault/

A3.2 Co-disposal of ILW with SF and HLW for the 'large' inventory situation: Swedish and Swiss basis

Co-disposal scaled costs based on SKB total deep repository (SF and ILW) costs

					SKB basis: MEUR at 1 SEK = 0.108 EUR		
					Separate ILW repository	**Scenario I(H) Co-disposal**	**Repository for** 6960 HLW/SF containers and 50% of ILW
Item	**Single SF/HLW Repository** 13920 containers **MEUR**	**Single SF/HLW repository** 6960 containers	SKB estimated costs (**MSEK**) for 21,200 m3 ILW		**31,000 m3 ILW**	**Single Repository All Wastes**	
Repository siting	222	222			222	222	222
Repository construction	1784	1000	360		57	1841	1029
Repository operation	1332	716	120		19	1351	725
Repository closure	839	419	100		16	854	427
Repository-related R&D & admin	1047	1047			1047	1047	1047
Encapsulation of HLW and SF	2527	1307				2527	1307
				Repository (only) Total	**1361**	**7842**	**4757**
				Inflated to Dec 2006 costs	**1418**	**8171**	**4957**

Using 4.2% inflation: Swedish Central Office of Statistics
From January 2003 to December 2006
www.scb.se

SAPIERR inventory to SKB ILW inventory scaling factor = 31/21.2 = 1.462

Assumptions
Siting and R&D/Admin do not need to be scaled (shown as grey boxes)
Only repository construction, operation and closure costs scale for ILW

Scenario II(H): separate SF/HLW & ILW repositories (Swedish)	**9493**
Scenario II(H): separate SF/HLW & ILW repositories (Finnish)	**11015**

Co-disposal scaled costs based on Nagra (2001) SF/HLW and Wellenberg (NEA, 1999) data

					Nagra basis: MEUR at 1 CHF = 0.610 EUR		
					Separate ILW repository	**Scenario I(S) Co-disposal**	**Repository for** 6960 HLW/SF containers and 50% of ILW
Item	**Single SF/HLW Repository** 13920 containers **MEUR**	**Single SF/HLW repository** 6960 containers	Nagra estimated costs (**1995 MCHF**) for 200,000 m3 ILW	Fixed to Variable Rate for ILW	**31,000 m3 ILW**	**Single Repository All Wastes**	
Repository siting	488	488	400	100:0	266	488	488
Repository construction	2012	1174	820	30:70	223	2235	1285
Repository operation	1244	695	610	20:80	131	1375	761
Repository closure	1220	610	70	0:100	7	1227	613
Repository-related R&D & admin	305	305	**Note 1**	NA		305	305
Encapsulation of HLW and SF	2317	1250		NA		2317	1250
				Repository (only) Total	**627**	**7947**	**4703**
				Inflated to Dec 2006 costs	**627**	**8325**	**4928**

Note 1: Project work, compensation, and regulatory work included in construction and operation subheads: siting sub-head includes all other preparatory work

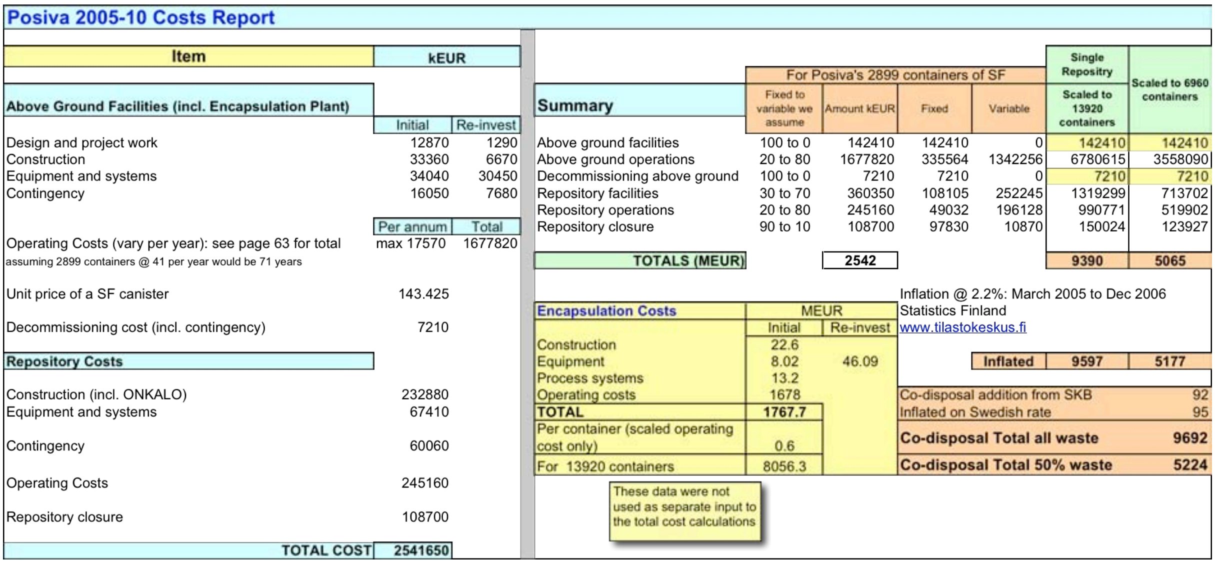
Using 8.9% inflation for ILW costs: Swiss Federal Office of Statistics
From end 1995 to end 2006
www.bfs.admin.ch

SAPIERR inventory to Nagra ILW inventory scaling factor = 31/200 = 0.155

Assumptions
Siting and R&D/Admin do not need to be scaled (shown as grey boxes)
Only repository construction, operation and closure costs scale for ILW

Scenario II(S): separate SF/HLW & ILW repositories	**8591**

A3.3 Disposal of SF and HLW: Finnish basis



Posiva 2005-10 Costs Report

Item	**kEUR**	
Above Ground Facilities (incl. Encapsulation Plant)	Initial	Re-invest
Design and project work	12870	1290
Construction	33360	6670
Equipment and systems	34040	30450
Contingency	16050	7680
	Per annum	Total
Operating Costs (vary per year): see page 63 for total assuming 2899 containers @ 41 per year would be 71 years	max 17570	1677820
Unit price of a SF canister	143.425	
Decommissioning cost (incl. contingency)	7210	
Repository Costs		
Construction (incl. ONKALO)	232880	
Equipment and systems	67410	
Contingency	60060	
Operating Costs	245160	
Repository closure	108700	
TOTAL COST	**2541650**	

	For Posiva's 2899 containers of SF				Single Repositry	
Summary	Fixed to variable we assume	Amount kEUR	Fixed	Variable	Scaled to 13920 containers	Scaled to 6960 containers
Above ground facilities	100 to 0	142410	142410	0	142410	142410
Above ground operations	20 to 80	1677820	335564	1342256	6780615	3558090
Decommissioning above ground	100 to 0	7210	7210	0	7210	7210
Repository facilities	30 to 70	360350	108105	252245	1319299	713702
Repository operations	20 to 80	245160	49032	196128	990771	519902
Repository closure	90 to 10	108700	97830	10870	150024	123927
TOTALS (MEUR)		**2542**			**9390**	**5065**
				Inflated	**9597**	**5177**

Inflation @ 2.2%: March 2005 to Dec 2006
Statistics Finland
www.tilastokeskus.fi

Encapsulation Costs	MEUR	
	Initial	Re-invest
Construction	22.6	
Equipment	8.02	46.09
Process systems	13.2	
Operating costs	1678	
TOTAL	**1767.7**	
Per container (scaled operating cost only)	0.6	
For 13920 containers	8056.3	

These data were not used as separate input to the total cost calculations

Co-disposal addition from SKB	92
Inflated on Swedish rate	95
Co-disposal Total all waste	**9692**
Co-disposal Total 50% waste	**5224**

A3.4 Disposal surcharge from remaining generating capacity (MODEL 1 in Section 8.1.1)

The table on the following page shows the amount of generating capacity remaining in the existing nuclear power plants in the ten countries that participated in the SAPIERR I project and which have operational NPPs. This is based on current or recent assumptions on the plant lifetimes.

The number of future MWa and kWh of generation are shown, assuming an 80% load factor. These figures are used to generate a total possible income generation assuming a surcharge or levy of 0.25 EURcent/kWh.

These data were used to produce the future annual generation of fund graph for 42 years from 2007, shown in Figure 8.1.

The second table shows the effect of including the accrual of interest at an annual rate of 3% and drawing down the fund for development and operation of the repository, extending the estimates out to 82 years. Also shown are data assuming a smaller surcharge (0.22 EURcent/kWh).

See section 8.1.1 for discussion of this information. Similar tables were produced for the ‘past and future’ generation capacity calculation (Model 2: Section 8.1.2).

Mwe	until	Years	MWyears	MWa @ 80%	kWh 80%	EUR raised at 0.25 cent/kWh levy	EUR per operational year
				Hours in year	8760		
Belgium							
392	2015	7	2744	2195.2	19229952000	48074880	6867840
392	2015	7	2744	2195.2	19229952000	48074880	6867840
970	2022	14	13580	10864	95168640000	237921600	16994400
1001	2025	17	17017	13613.6	1.19255E+11	298137840	17537520
870	2015	7	6090	4872	42678720000	106696800	15242400
900	2022	14	12600	10080	88300800000	220752000	15768000
1000	2025	17	17000	13600	1.19136E+11	297840000	17520000
Bulgaria							
910	2018	10	9100	7280	63772800000	159432000	15943200
910	2023	15	13650	10920	95659200000	239148000	15943200
Czech							
440	2025	17	7480	5984	52419840000	131049600	7708800
440	2025	17	7480	5984	52419840000	131049600	7708800
440	2025	17	7480	5984	52419840000	131049600	7708800
440	2025	17	7480	5984	52419840000	131049600	7708800
1000	2040	32	32000	25600	2.24256E+11	560640000	17520000
1000	2040	32	32000	25600	2.24256E+11	560640000	17520000
Hungary							
465	2012	4	1860	1488	13034880000	32587200	8146800
465	2014	6	2790	2232	19552320000	48880800	8146800
465	2016	8	3720	2976	26069760000	65174400	8146800
465	2017	9	4185	3348	29328480000	73321200	8146800
Lithuania							
1300	2009	1	1300	1040	9110400000	22776000	22776000
Netherlands							
475	2013	5	2375	1900	16644000000	41610000	8322000
Romania							
707	2050	42	29694	23755.2	2.08096E+11	520238880	12386640
Slovakia/Croatia							
440	2024	16	7040	5632	49336320000	123340800	7708800
440	2025	17	7480	5984	52419840000	131049600	7708800
440	2038	30	13200	10560	92505600000	231264000	7708800
440	2039	31	13640	10912	95589120000	238972800	7708800
Slovenia							
676	2023	15	10140	8112	71061120000	177652800	11843520
Switzerland							
365	2029	21	7665	6132	53716320000	134290800	6394800
365	2031	23	8395	6716	58832160000	147080400	6394800
355	2031	23	8165	6532	57220320000	143050800	6219600
970	2039	31	30070	24056	2.10731E+11	526826400	16994400
1165	2044	36	41940	33552	2.93916E+11	734788800	20410800

YEAR	EUR Levy per year	MEUR Levy per year	Disposal Needs	Cum Pool @ 3% interest	Cum Spend	Cum Pool @ 3% interest if unspent	EUR raised at 0.22 cent/kWh levy	EUR per operational year	EUR Levy per year	MEUR Levy per year	Cum Pool @ 3% interest
1	369724560	370	50	320	50	370	42305894.4	6043699.2	325357613	325	275
2	346948560	347	50	626	100	431	42305894.4	6043699.2	305314733	305	539
3	346948560	347	50	942	150	494	209371008	14955072	305314733	305	810
4	346948560	347	50	1267	200	559	262361299.2	15433017.6	305314733	305	1090
5	338801760	339	50	1594	250	625	93893184	13413312	298145549	298	1371
6	330479760	330	50	1922	300	694	194261760	13875840	290822189	291	1653
7	322332960	322	50	2252	350	765	262099200	15417600	283653005	284	1936
8	293354880	293	50	2563	400	838			258152294	258	2202
9	285208080	285	50	2875	450	913	140300160	14030016	250983110	251	2469
10	277061280	277	220	3019	670	1160	210450240	14030016	243813926	244	2567
11	261118080	261	170	3201	840	1365			229783910	230	2704
12	261118080	261	170	3388	1010	1576	115323648	6783744	229783910	230	2845
13	261118080	261	170	3581	1179	1793	115323648	6783744	229783910	230	2991
14	261118080	261	170	3779	1349	2016	115323648	6783744	229783910	230	3140
15	228355680	228	275	3847	1624	2352	115323648	6783744	200952998	201	3161
16	200568960	201	275	3888	1898	2697	493363200	15417600	176500685	177	3158
17	192860160	193	275	3923	2173	3052	493363200	15417600	169716941	170	3148
18	119258640	119	275	3886	2447	3418			104947603	105	3072
19	119258640	119	275	3847	2722	3795	28676736	7169184	104947603	105	2995
20	119258640	119	151	3930	2873	4060	43015104	7169184	104947603	105	3039
21	119258640	119	151	4017	3024	4333	57353472	7169184	104947603	105	3084
22	112863840	113	151	4099	3175	4614	64522656	7169184	99320179.2	99	3125
23	112863840	113	151	4184	3326	4903			99320179.2	99	3167
24	100249440	100	151	4259	3477	5201	20042880	20042880	88219507.2	88	3199
25	100249440	100	151	4336	3628	5508			88219507.2	88	3232
26	100249440	100	151	4415	3779	5825	36616800	7323360	88219507.2	88	3267
27	100249440	100	151	4497	3930	6150			88219507.2	88	3302
28	100249440	100	151	4581	4081	6486	457810214.4	10900243.2	88219507.2	88	3338
29	100249440	100	151	4668	4232	6831			88219507.2	88	3376
30	100249440	100	151	4757	4383	7187	108539904	6783744	88219507.2	88	3414
31	92540640	93	151	4841	4534	7554	115323648	6783744	81435763.2	81	3447
32	67837440	68	151	4903	4685	7931	203512320	6783744	59696947.2	60	3459
33	32797440	33	151	4932	4836	8320	210296064	6783744	28861747.2	29	3441
34	32797440	33	151	4962	4987	8721			28861747.2	29	3422
35	32797440	33	151	4993	5138	9134	156334464	10422297.6	28861747.2	29	3402
36	32797440	33	151	5024	5289	9559			28861747.2	29	3382
37	12386640	12	151	5036	5440	9996	118175904	5627424	10900243.2	11	3344
38	12386640	12	151	5049	5591	10447	129430752	5627424	10900243.2	11	3304
39	12386640	12	151	5062	5742	10912	125884704	5473248	10900243.2	11	3263
40	12386640	12	151	5075	5893	11390	463607232	14955072	10900243.2	11	3221
41	12386640	12	151	5089	6044	11883	646614144	17961504	10900243.2	11	3177
42	12386640	12	151	5103	6195	12390			10900243.2	11	3132
43	0	0	151	5105	6346	12913					3075
44		0	151	5107	6497	13451					3017
45		0	151	5109	6648	14006					2956
46		0	151	5111	6799	14577					2894
47		0	151	5114	6950	15165					2830
48		0	151	5116	7101	15771					2764
49		0	151	5119	7252	16395					2696
50		0	151	5121	7403	17038					2625
51		0	151	5124	7554	17700					2553
52		0	151	5127	7705	18382					2479
53		0	151	5129	7855	19085					2402
54		0	151	5132	8006	19808					2323
55		0	151	5135	8157	20553					2242
56		0	151	5138	8308	21321					2158
57		0	151	5142	8459	22111					2072
58		0	151	5145	8610	22926					1983
59		0	151	5148	8761	23765					1892
60		0	151	5152	8912	24629					1798
61		0	151	5155	9063	25518					1700
62		0	151	5159	9214	26435					1600
63		0	151	5163	9365	27379					1498
64		0	151	5167	9516	28351					1391
65		0	151	5171	9667	29353					1282
66		0	151	5175	9818	30384					1170
67		0	151	5179	9969	31447					1054
68		0	151	5183	10120	32541					934
69		0	151	5188	10271	33668					811
70		0	151	5193	10422	34830					685
71		0	151	5197	10573	36025					554
72		0	151	5202	10724	37257					420
73		0	151	5207	10875	38526					282
74		0	151	5213	11026	39833					139
75		0	20	5349	11046	41047					124
76		0	20	5490	11065	42298					108
77		0	20	5635	11085	43587					91
78		0	17	5787	11102	44912					77
79		0	17	5943	11120	46276					62
80		0	57	6065	11176	47721					7
81		0	57	6190	11233	49209					-49
82		0	57	6320	11289	50742					-107

A2 Types of Benefit and National Examples

A2.1 Cash Incentives

These tend to be exactly what the word implies; they are an incentive to a community to either become involved in a process, or to allow a development to continue, or both. Some examples of this type are fixed and not subject to negotiation, having been laid down within some pre-existing legal instrument (Slovenia, Spain), whilst others are often open to negotiation after the initial expression of interest has been registered, as a way of strengthening community involvement.

Details of some payments may be given up-front, before any work has been carried out, and in very rare cases can be payable even if no further investigations take place. Others may only become available once a facility becomes operational. In some cases payments are offered to potentially suitable communities only following an initial ‘Technical Screening’ stage, using pre-established site filtering criteria. They are designed to encourage targeted communities to participate, and to assuage local opposition. Some countries have followed an approach which also allows for additional volunteers to come forward after the screening stage.

Cash benefits are seen across the spectrum of contentious facilities, and everywhere are open to the same charges by opposition forces of ‘bribery’. It is in the design of the allocation of payments and the breadth of their use where these charges are best refuted.

A.2.1.1 Lump sums

These are payments made directly to the affected community (however that may be defined, see above) in order to encourage participation. In many cases there are few controls on what the money may be used for, in others, conditions are attached. It is not uncommon for the payments to be made in instalments, dependent upon achievement of project milestones (e.g. site exploration permits; construction and operation licences).

Nuclear
A range of examples exists (see Table 7.1) illustrating the huge range in amounts available:

- Australia L/ILW; €7.5 million, subject to repository site approval, for educational support
- Canada ‘historic’ LLW; €7 million
- Canada ILW; €1.5 million, subject to local and regulatory approval
- France LLW; €5.5 million (at 1992 prices)
- France HLW; €20 million
- Japan HLW; €6 million for initial desk study, followed by more when exploration begins
- South Korea LLW; €241 million
- Taiwan LLW; €114 million

Non nuclear

- Wind farms[8]: generally not paid, but some examples do exist
    - Germany; €210-8000/Mw per turbine
    - Spain; € 30,000 for a construction licence, payable to local community authority

A2.1.2 Annual Payments

In many cases agreements or incentive packages contain details of regular payments that are available, enabling local communities to estimate the benefit they could receive. The level of payments can vary depending on certain factors, such as the volume or activity of the waste emplaced, and whether regulatory approvals are forthcoming. In some instances the amounts are specified within legal instruments.

Nuclear

Examples (see table 7.1):

- Canada ILW; €0.7 million to Kincardine, subject to project milestones
- Japan HLW; €12.2 million (only if construction application is submitted)
- Slovenia LILW-SL; € 2.3 million during operation -once a site has been agreed, these can be claimed in advance to allow long-term economic planning
- Slovenia HLW; €2.8 million
- South Korea LLW; €7.5 million (dependent on volume of wastes emplaced)
- Spain LLW; €1.6 million average (dependent on volume of wastes emplaced)
- Switzerland LLW; €2.0 million proposed for Wellenberg –site abandoned
- US WIPP; €20 million for 20 years
- Japan NPP siting; € 985,000/yr during initial studies, followed by € 6.2 million/yr during an EIA process.
- Spain Interim Spent Fuel Store; Approx € 11.5 million (dependent on volume stored)[9]
- Switzerland NPP operation; up to € 720,000/yr to host community (e.g. Gösgen NPP)
- Switzerland interim storage facility; a total of € 850,000 to the surrounding communities, with 58% to the immediate site host.

Non nuclear

- Wind farms[10]: again, not common, but examples do exist
    - Germany; €360-5600 per turbine

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[8] Centre for Sustainable Energy 2005; 'Community benefits from Windpower'; a report to the Renewables Advisory Board and DTI

[9] Ministerio de Industria, Turismo Y Comercio, Salamanca 10/08/06; 'Industria Resuelve las Primeras Peticiones de Información Acerca del Almacén Temporal Centralizado'

[10] Centre for Sustainable Energy 2005; 'Community benefits from Windpower'; a report to the Renewables Advisory Board and DTI

A.2.1.3 Expert Support Packages

In some programmes, support packages are offered that are intended to assist communities to commission reviews by independent experts. This is seen as an important way of demonstrating transparency in the way in which information is supplied to the community during a project. In many cases these funds are paid as part of the support provided as 'Community Empowerment', described in more detail in Part C below.

Examples (these figures include social empowerment measures):

- Canada ILW; Consultants, reviewers and experts can be hired as part of € 23 million of available support over the next 35 years.
- France HLW; € 300,000/yr for Bure CLIS (the local review group receives financial support to carry out independent studies.)
- Sweden HLW; € 217,000/yr. Local community review groups receive funding from the National Waste Fund, managed by the County Board

A.2.1.4 Tax Revenue

In some cases, special taxes are payable to the local community as an additional incentive for involvement. Sometimes these are only available if a definite impact on local economic development can be demonstrated.

Nuclear
Examples:

- Canada LLW; Guaranteed payment if local property tax revenue is affected (up to a max of €35,000)
- Finland L/ILW; Local Property Tax set >2.2% above national average
- France HLW; to fund the 2 Public Interest Groups (GIP's) for Meuse and Haute-Marne Departements, € 10 million /yr 1999-2006, for each, corresponding to the tax due for 2 NPPs. 2006 law introduced the Economic Development Tax and Technology Diffusion Tax, worth €20 million /yr each from 2007 until the repository site is confirmed. Split between local and regional activities.
- Japan LLW; Amount calculated as part of fuel storage tax (€166 per m^3)
- Japan NPP operation; €450-750,000/yr to prefecture per NPP[11]

Non nuclear

- Wind farms[12]: Normally in the form of local business rates
    - Ireland; €5000/Mw/yr
    - Spain; €29,000/yr

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[11] Hideki Kawamura, Pers. Comms; various 2007

[12] Centre for Sustainable Energy 2005; 'Community benefits from Windpower'; a report to the Renewables Advisory Board and DTI

A.2.1.5 Trust Fund for Future Generations

Examples exist of agreements whereby funds are established which are intended to support the community in the long-term, or to help the community initiate other development projects and reduce any dependency that may exist during the lifetime of the facility Funds can also be established to provide capability to carry out any necessary potential remediation in the future in situations where the original site operator is no longer in existence. In the nuclear field there are so far few examples of these funds, but they are starting to feature in local negotiations. More examples occur outside the nuclear arena, in specific instances.

Nuclear
Examples:

- UK LLW; Agreement reached in December 2007 between Nuclear Decommissioning Authority and local authorities for establishment of a £10 million (€13.4 million) fund, with annual payments of £1.5 million (€2 million), for extension of existing facility at Drigg
- US LLW; EnviroCare (now EnergySolutions), Clive, Utah €22 million Bond and Perpetual Care Fund with €310,000 pa
- Switzerland LLW; €14.5 million proposed at Wellenberg
- Belgium LLW; –not quantified to date, but were part of conditions laid down by the selected host community, and will be subject to future negotiation

Non nuclear

- Sullom Voe Oil Terminal (Shetland Islands)[13]; The Sullom Voe Agreement, formalising arrangements between the then Zetland County Council and the companies wishing to pipe oil ashore from the North Sea in the 1970's is a prime example of local control over the progress of a project. This was unique at the time in the UK and required a special Act of Parliament so as to allow decisions to be controlled locally.
  - The Harbour Authority Reserve Fund: €11m/yr plus €4m/yr 'disturbance fund'. Total value €120m.
  - The Repairs and Renewals Fund: Current value €125m.
  - The Capital Fund: built up from associated business rates, with a current value of €145m.

A2.1.6 Profit Sharing

It has been proposed in some instances to allow the host community to benefit from facility operation by some form of profit-sharing scheme. In the United States, a proportion of the income from the operation of the LLW sites at Barnwell and Clive is paid as a levy to the local County government. Examples include:

- US LLW, Barnwell, South Carolina; €9 million levy on annual fees in 2006
- US LLW, Clive, Utah: €3 million as levy on annual fees

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[13] McMorrow F 2005; The Shetland Islands Precedent: Summary Report of a Visit to Shetlands Islands Council/Sullom Voe Oil Terminal, November 05

A2.2 'Social Benefit' measures

These are any compensatory measures, financial or otherwise, which are intended to offset any stigma, perceived or actual, regarding either the community's participation in any stage of the siting process, or associated with the actual location, development and operation of the facility within the community or area.

Included within this group are measures such as guaranteed property prices and guarantees of majority local hiring. Improvement to infrastructure such as roads and other services can also come under this heading, although there is sometimes a blurred distinction about where such developments become pure incentives designed to attract a community in which such things may be absent or poorly developed, rather than offset a perceived or actual impact. In many cases some details of benefits and payments are available from the start because they are laid down within legal instruments, and these include things such as emergency preparedness training, and payments-equal-to-taxes (PETT). As before, some only become available after disposal operations actually begin.

A2.2.1 Employment

In many cases the enhanced employment opportunities that will result from a repository development are advanced as potential benefits designed to encourage communities to become involved. Clearly the wages associated with any new jobs created will boost the local economy. The significance of the impact will depend, *inter alia*, on the workforce catchment area, the degree of employment of 'local' people, or the requirement for skills influx, the balance of job creation against job retention and the value of the jobs created. This has to be carefully balanced so as not to appear as if a proposal is targeting an area only because of its high unemployment. It can also be perceived as a major disruption to an established employment profile. If suitably qualified workers are not available in the community, an influx of outsiders can often be seen as a major detriment. For both nuclear and non nuclear facilities, the construction period is seen as the time of highest employment, with often only small numbers required for operation and long-term surveillance.

Nuclear
Examples:

- Canada ILW; 300 jobs are expected during repository construction
- France HLW; 350 jobs have been created at the Bure URL, as well as more from the associated economic development programmes
- Finland Spent Fuel; Posiva predict creation of up to 150 jobs during operation of a repository at Olkiluoto
- According to a study for CoRWM in the UK, maximum employment figures for the various development stages would be as follows:
    - Site investigation; 200
    - Construction and underground research; 370
    - Waste emplacement; 500
    - Backfilling and closure; 120
- US WIPP; 1,000 jobs directly created, with a third of the local workforce directly or indirectly employed

- Spain Spent Fuel Interim Storage; 300 construction jobs and 90 operational jobs estimated[14]

Research facilities:

- ITER[15] (France); 1400 jobs during construction, and up to 2400 jobs during operation. ITER and its personnel are expected to spend around €100 million/yr during the 10-year construction period and up to €135 million/yr during the two decades of operation.

Non nuclear

- Wind farms[16];
  - it is estimated that over 20,000 people were employed in the industry in Denmark in 2003
  - up to 50,000 jobs created in support industries in Germany in 2005

A2.2.2 Infrastructure Improvements

It is generally recognised that development of a nuclear waste repository will have a number of impacts upon a local community, especially one where no nuclear facilities have previously existed. In many cases these impacts are perceived, rather than actual, especially at the beginning of a siting process. It is because of this that a number of benefit packages over recent years have offered to offset these perceived impacts by agreeing to ensure that the local infrastructure (roads, schools, hospitals) is not adversely affected. Given that a new facility in a non-industrial area will necessitate increased transport during both construction and operation, these benefits often include road improvements and assistance in expanding local schools and healthcare provision. There is sometimes a blurred distinction about where such developments become pure incentives designed to attract a community in which such things may be absent or poorly developed, rather than offset a perceived or actual impact.

Other major developments can also have major impacts on the local infrastructure, and this can be offset by contributions to necessary improvements. In some cases, such as ITER, the community/region offerered to upgrade the infrastructure in order to (successfully) attract the development.

Nuclear

Example:

- US (WIPP): €14 million/a from 1998-2-12 to improve local roads and support infrastructure developments[17]

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[14] Ministerio de Industria, Turismo Y Comercio, Salamanca 10/08/06; 'Industria Resuelve las Primeras Peticiones de Información Acerca del Almacén Temporal Centralizado'

[15] 'Les Enjeux du Projet' supplied during the 2006 Public Debate on ITER

[16] Centre for Sustainable Energy 2005; 'Community benefits from Windpower'; a report to the Renewables Advisory Board and DTI

- ITER (France); the regional government agreed to build up to 3000 homes over 15 years, and develop necessary additional schools etc. The French government also paid €105 million to improve access for construction equipment.

Non nuclear

- Wind farms; in the United Kingdom, all developments must demonstrate habitat enhancement; one in Wales cost €350,000 as compensation for loss of forestry and intensive agriculture[18].

A2.2.3 Property Value Protection

There is sometimes a perception in some sections of the public that the presence of a nuclear waste facility can reduce house prices, encourage an influx of lower income families to the immediate vicinity and reduce the overall economic profile of a region. It is therefore not uncommon for benefit packages to include some form of property price protection, whereby funds are put aside to compensate claimants for demonstrable decreases in value. It is significant to note, however, that there are few examples of where large payments have been necessary. Indeed, in some situations, evidence suggests that property values around operating facilities have actually risen, because of improvements in the local economy. Examples include:

- Canada LLW; The Port Hope Agreement contains a scheme whereby property owners who can demonstrate that financial loss or mortgage renewal difficulties occurred between October 2000 and the termination of the program, expected in 2012, are eligible to claim compensation. To date there have been approx. 12 claims, mostly with regard to properties along transport routes or immediately adjacent to contaminated sites[19].
- Canada ILW; a similar scheme to that at Port Hope has been developed in discussion with the communities around the proposed ILW repository at Kincardine.

A2.2.4 Integrated Development Projects and Miscellaneous Facilities

It is fast becoming the norm for community benefit packages to comprise integrated projects designed to benefit the community not only during the immediate siting process and subsequent facility operation, but long into the future. The development of structured development plans, comprising support industries, specialist services and linked research facilities can be seen in numerous programmes. Again, whilst the actual monetary value of these projects can not always be clearly quantified, the associated benefits in terms of jobs, taxes, improvement in local services and standard of living are expected to be appreciable. It is normal that such benefits only become available following local agreement to host a facility and the granting of the necessary construction permits and regulatory authorisations.

Examples (all proposed):

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[17] PUBLIC LAW 102-579 THE WASTE ISOLATION PILOT PLANT LAND WITHDRAWAL ACT as amended by Public Law 104-201 (H.R. 3230, 104th Congress)

[18] Centre for Sustainable Energy 2005; ‘Community benefits from Windpower’; a report to the Renewables Advisory Board and DTI

[19] Sue Stickley, LLRWMO, Canada. Pers. Comm. 02/04/07

- Belgium LLW; as part of the integrated projects developed by the local community required for accepting a repository, Dessel called for a Community Digital Network and a Radioactivity Science Park and Communication Centre. In addition, they called for a Sustainability Fund, financed by the federal government, to support or implement projects that will contribute to improving the quality of the living, housing and working conditions of the Dessel population. The projects can cover various areas: social, economic, cultural, environment-oriented, health and welfare. The value of this Fund is currently the subject of negotiation.
- Canada ILW; as part of the Kincardine Agreement between the local community and the facility proponent, OPG, a Centre of Energy Excellence will be developed. It is not possible to quantify the cost of this at present, as it is dependent on repository construction.
- France HLW; Money from EDF, AREVA and CEA for an economic support programme for Meuse and Haute-Marne Districts, with 4 thematic areas[20]:
    - Development of regional excellence in electricity generation using biomass (investment of more than €20 million)
    - Make the region a pilot for new energy conservation measures (€18 million between 2006-2010)
    - Improvements in local industrial development, especially in metallurgy
    - Support for local groups and establishment of new businesses, including a €15 million archiving operation by EDF.
- Spain Interim Spent Fuel Store (ATC); it is proposed to locate a Technological Research Centre adjacent to the facility, together with an Enterprise Park, with an overall total of some € 700 million[21], of which around € 50 million is envisaged beyond the cost of the ATC[22].

A2.2.5 Relocation of Developer

As part of the benefits offered to local communities for agreeing to host a repository, it is becoming increasingly common for the facility operator to offer to relocate its main operational headquarters to the locality. Whilst this can be seen as a potential benefit in terms of increased local taxes, improved employment opportunities and similar, the commitment is often seen as a vote of confidence in the safety of the facility itself. If the community is rural, or poorly developed, however, there can be some opposition to the plan from within the organisation itself. Examples include:

- South Korea LLW; As part of the siting agreement with the Gyeongju community, the facility implementer, Korea Hydro and Nuclear Power Co. will move to the area. In addition, a physics research facility may also be located near by.
- Finland Spent Fuel; Although few other major benefits (cash, infrastructure, community support) are being offered to the local area, the main offices of Posiva

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[20] EDF 2006 ; 'Accompagnement Economique de Meuse et Haute-Marne, Laboratoire de Bure-Saudron'

[21] Ministerio de Industria, Turismo Y Comercio, Salamanca 10/08/06; 'Industria Resuelve las Primeras Peticiones de Información Acerca del Almacén Temporal Centralizado'

[22] Dossier de Prensa 2007 ; ENRESA (July 2007)

Oy, the developer of the proposed repository and ONKALO URL, have been moved to the area.

A2.2.6 Discounts and services

In some countries it is recognised that when a community fulfils a role considered to be in the national interest, there should be some tangible compensation, often in terms of reduced utility fees etc. In addition, schemes to incorporate regular monitoring of community health and environmental well-being are becoming more common. This is relatively common in some countries with regard to siting and operation of NPP's, a feature which is now being adopted in other areas. Examples include:

- Lithuania LLW; Very recently (November 2007) it has been agreed that communities in Visaginas Municipality, surrounding the proposed repository site near the Ignalina NPP, will benefit from reduced prices for electricity from the plant.
- Switzerland LLW; It was proposed to offer cheap electricity to the communities around the now-abandoned LLW repository at Wellenberg, This would have been equivalent to 0.25% of the electrical output of all Swiss nuclear power plants, or a minimum of 25,000 MWh/yr, free of charge to the cantonal distribution utility. This would have been payable for a 40-year facility lifetime, and was estimated to be equivalent to € 2.1-2.5 million/yr. It was also proposed to introduce regular health monitoring at a similar cost.

A2.3 'Community Empowerment' Measures

These types of measures can also be regarded as a form of incentive, designed as they are to allow a community to feel a sense of control over the siting, development and even operation of the facility. They usually include such things as establishment of local monitoring or review groups, especially where the community is a volunteer participant, but vary as to the extent of real power that is actually available.

In many cases the funding of these measures is non-negotiable and is often laid down in Law, although examples do occur of additional payments being made as the process develops. Control over expenditure is normally in the hands of an external group, either an elected governmental body or a non-political agency. These payments are sometimes subject to acceptance by the community, in contractual form, of an agreed level of investigation, only after which are further decisions made.

Also included within this group of measures are the payments made to enable local people, elected representatives, national and local journalists etc., to visit existing waste management facilities either nationally or internationally, usually as part of a proponent's 'information and education' programme.

Examples now exist of siting processes where these various payments and support structures are developed in partnership with the prospective host community. Both local representatives and proponent join together in formal or semi-formal partnerships which examine the potential of the community to site a facility, and develop integrated socio-economic projects designed to benefit the community in the long-term. A good example of this can be seen in Belgium, where a proposed site for a LLW repository was agreed in Dessel following deliberations in 3 potential communities.

Such partnership arrangements have also been proposed for use in the United Kingdom, where previous efforts to site a deep repository have failed due to public opposition. Intensive public discussion resulted in a series of implementation proposals which were the subject of a public consultation, prior to the anticipated launch of a new process in 2008.

A2.3.1 Local Involvement in Decision Making

It is now becoming common for community partnerships to be established, involving local elected bodies, interest groups, citizen groups etc. which are given the opportunity to influence the details of the project, sometimes (rarely) including technical design, but more frequently regarding associated integrated economic development projects.

In many cases the local community possesses a right of withdrawal from a process, or a veto at certain defined points in the decision making process. This can sometimes involve referenda or other forms of plebiscite.

The local community partnership often receives financial support to allow it to oversee the project and ensure that local views and concerns are taken into account throughout. Examples include:

- Belgium LLW; The local partnerships established in 3 communities were provided with various forms of support:
    - €247,000 p/yr to run a local office
    - €74,000/yr to carry out socio-economic studies
    - €74,000/yr to ‘visualise the project’ (assist in design consideration)
- France HLW; The local CLIS (review group) has an annual budget of €300,000

A2.3.2 Capacity Building

This is somewhat similar to the above, but includes measures designed to allow the oversight group or partnership to become more knowledgeable about the issues involved. This can include organisation of meetings, discussions with independent experts, and visits to operating facilities. It can also assist a community to develop the capability to cope with additional demands on health and other services that may be required. It can also include support for other groups to allow them to be involved. Examples include:

- Canada ILW; In order to allow NGO’s and other groups to take part in the EIA process associated with the proposed Kincardine repository, up to € 34,000 was made available, to be followed by further funds to allow participation in hearings.
- Sweden HLW; the Review Groups established in the 2 potential host communities are funded directly from the National Waste Fund. The amounts varied as the process advanced.
    - €214,000/yr during feasibility studies
    - €430,000/yr during site investigation

  In addition, since 2004, Swedish NGO’s have been able to receive support to enable them to take part in the siting process. A lump sum of € 320,000/yr is available for all eligible groups to share, depending on their membership.

- Japan NPP operation; €5/Kw output/yr for associated activities[23].

A2.2.3 Development of a Local Partnership to Oversee Project

As mentioned elsewhere, it is becoming common for community partnerships to be established in a repository siting process, in order to allow a sense of ownership and control to be developed locally. They are usually based on a contractual agreement between the local community and either government or the implementer. The contractual agreements normally specify the amount of resources available to allow participation (see various above and below).

A2.2.4 Involvement Support Packages

The various payments and funding arrangements described above are sometimes amalgamated into a single agreement, designed to allow local communities to take part in a siting process without being financially impacted. These packages can therefore include items discussed already, such as secretarial support, use of experts, management costs for partnerships etc. Examples include:

- Belgium LLW
    - €250,000/yr was available to support the partnership during the initial feasibility work, followed by €125,000/yr following agreement to site a facility (subject to current review)
- Canada LLW
    - All costs incurred by taking part in the process are covered by the federal waste management office
- Canada ILW
    - Consultants, reviewers and experts can be hired as part of €23 million of available support over the next 35 years.

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[23] Hideki Kawamura Personal Communications; various 2007