An informal paper by Ernst and Young on the management and financing of nuclear waste

Some information in this report is confidential and has been redacted.

REDACTED INFORMATION

Description of waste

The categorisation of wastes arising from the nuclear fuel cycle or other nuclear activities are not absolutely consistent around the world, and are still subject to confirmation in the UK by the CoRWM review, which is expected to conclude later in 2006.

The current UK position is as follows:

Category	Definition[1]	Typical description[2]
Very Low level Waste (VLLW)	Wastes that can be disposed of with ordinary refuse, each 0.1 cubic metre containing less than 400kBq of Beta/Gamma activity, or single items containing less than 40kBq.	Generally small volumes of waste from hospitals and universities, disposed to landfill either directly, or after incineration.
Low Level Waste (LLW)	Wastes other than those suitable for disposal with ordinary refuse, but not exceeding 4GBq per tonne of Alpha, or 12GBq per tonne of Beta/Gamma activity	Principal sources will be soil, building rubble, steel items such as ducting, piping and reinforcement, arising from the dismantling and demolition of nuclear reactors or facilities, and the clean-up of nuclear sites. At present, majority of LLW airings are from operation of those facilities, and comprise paper, plastics and scrap metal.
Intermediate level Waste (ILW)	Wastes exceeding the upper boundaries for LLW, but which do not need heat to be taken into account in the design of storage or disposal facilities	Major components are metal items, such as the casings from nuclear fuel assemblies, reactor components, graphite from reactor cores, and sludges from the treatment of radioactive liquid effluents.
High Level	Wastes in which the temperature may rise	Initially comprises nitric acid solutions containing the waste

Waste (HLW)	significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage or disposal facilities	products of the reprocessing of spent nuclear fuels. Accumulated HLW is being vitrified.

Sources: 1 UK Nirex Limited report N/122, November 2005

2 DEFRA/RAS/05.001, UK NIrex Limited Report N/089, Radioactive Wastes in the UK, 2004 inventory

In addition to these categories, there are further types of product which are not currently definitively classified as waste in the UK, but in respect of which the definition may change, and may therefore subsequently require treatment, and disposal of, as waste. The main other groups of product are Plutonium and Highly Enriched Uranium, Uranium, and Spent Fuel.

Plutonium/Highly Enriched Uranium (HEU)

On the assumption that there is no new nuclear programme in the UK, CoRWM anticipate an eventual quantity of Plutonium and HEU of the order of 165t, some in the form of oxide powders.

As with Uranium, these products have until now been considered as national strategic resources, with a potential value and future use, as opposed to a liability, and have not historically been captured and evaluated as waste. They have been held as assets with zero attributed value.

If these products are to be disposed of in a similar way to HLW, CoRWM anticipate a substantial additional cost increment to the cost of a repository, as well as the need for the repository to be open for some 15 years longer than otherwise planned.

Uranium

Similarly, CoRWM anticipate an eventual quantity of Uranium of some 150,000t, equating to 75,000 cubic metres of conditioned waste. This would be expected to be disposed of to an ILW/LLW repository, but would not require extended operation.

Spent Fuel

Nuclear fuel that has been removed after its burn in a reactor has the capability to realise re-usable Plutonium and Uranium, if reprocessed. As reprocessing has historically been the chosen disposal route for Magnox and AGR fuel, such spent fuel has not previously been categorised as a waste.

However, as PWR fuel is not proposed for reprocessing, and AGR reprocessing may end in 2013, these materials potentially should be categorised as wastes, and are likely to be treated as if HLW.

Volumes of legacy waste

The historic and current nuclear activities in the UK (research, power generation, military and other) have resulted in large volumes of wastes (whether already created, or latent, in the form of wastes that will arise, for example from the eventual dismantling of reactors).

Given certain assumptions regarding current and expected operations, the 2004 UK Waste Inventory anticipates that a total of 2.3m^3 of LLW, ILW and HLW has or will arise, and which has not already been disposed of. The components of the wastes are expected to be:

Category	**Volume (m^3)**
LLW	2,100,000
ILW	220,000
HLW	1,300

Source 2004 radioactive waste Inventory

Of these volumes, some 2.2m^3 have already arisen, or are latent, only a little over 100,000m^3 is expected to be newly created from operations beyond 2004.

The underlying assumptions are broadly that:

- all existing power stations close by 2035, with no new build;
- station structures are left on site for some 100 years prior to final site clearance (although this is a different assumption to that now made by the NDA, which is seeking to achieve decommissioning within 25 – 30 years;
- the UK nuclear defence capability remains until 2040, and a nuclear-powered submarine fleet to 2100; and
- fuel reprocessing at THORP ceases by 2013

In addition to these assumed waste arisings, some 1,000,000m^3 of primarily LLW has already been disposed of to Drigg, or at Dounreay.

These volumes remain subject to a number of uncertainties that will potentially only reduce as site clean-up and decommissioning activities proceed:

- it is known that leaks of contaminated liquids have occurred at a number of sites, but the volumes of soil that are affected is unknown, and are not included within the inventory;

- there are substantial volumes of wastes arising from the early 1940's and 1950's programmes that have yet to be extracted from nearly life-expired storage, and their condition and volumes are less well known;
- Substantial uncertainty as to the treatment of wastes that might arise from decommissioning of the Sellafield site, particularly ground contamination, which is notionally estimated in the LLW Review Consultation document as having the potential to increase LLW volumes by 18,000,000m^3.

Volumes of waste from a new build programme

The volumes of waste that may arise from the operation and decommissioning of a new reactor are necessarily tentative. The vendors (Areva, Westinghouse etc) have made statements that the probable designs have sought to minimise operational waste and decommissioning volumes.

A substantial proportion of the higher activity historic wastes arise from legacy decisions, for example to reprocess AGR fuel in THORP, rather than dry-storing and directly disposing of the spent fuel. It is assumed that for any new plant all fuel would be stored prior to direct disposal.

CoRWM's Radioactive Waste and Materials Inventory – July 2005 refers to an Electrowatt-Ekono report number 200520.1, June 2005 that estimated the additional waste volumes that would arise from the operation and decommissioning of a 10GW fleet of AP 1000, EPR or ABWR reactors, with (it is assumed) a 60 year operational life:

Reactor type	**Spent Fuel (tHM)**	**ILW volume (m^3)**	**LLW volume (m^3)**
AP 1000	31,900	9,000	80,000
EPR	21,000	13,000	100,000
ABWR	31,500	187,000	

These volumes broadly equate to an incremental 10% and 5% on top of total existing inventories of HLW/ILW and LLW respectively as disclosed in the UK's 2004 waste inventory, but would represent a much smaller proportion of LLW arisings if substantial additional volumes of LLW arise for the reasons noted in paragraph 28 above.

Waste storage and disposal routes

The UK's current strategy (where defined) for the disposal of wastes is as follows:

<u>LLW</u>

LLW has an existing and operational disposal route. Wastes are conditioned and super-compacted, prior to being placed in ISO containers of various sizes. These containers are then cement filled to immobilise the wastes, and the containers placed into an open, just below ground level, storage facility at Drigg, close to Sellafield.

Drigg has already accommodated 1,000,000m^3 of waste, and has remaining capacity for some 800,000m^3. This capacity is expected to be exhausted by 2050, leaving the excess LLW with no current known disposal route.

Drigg's capacity may be fully utilised much sooner than this however, particularly as the NDA proposes to bring forward the timing of much of its decommissioning activity.

ILW and HLW

Apart from some volumes of ILW disposed to sea prior to the 1980's, all wastes arising are being stored or have been conditioned and packaged ready for (an assumed) disposal to an underground repository.

Whilst no definitive decision had ever been taken by the UK HMG, and different options were being considered, UK Nirex was responsible for identifying a suitable disposal route, and had focused on some form of deep geological disposal. The specification for the treatment and packaging of the wastes is therefore mindful of such a disposal route.

There are several options for disposal, but CoRWM have narrowed the range of options to the following four broad themes:

- Long-term interim surface storage for ILW, for periods of up to 300 years
- Deep geological disposal of ILW/LLW and HLW/SF, either co-located or separately, or deep geological borehole disposal of HLW/SF
- Phased deep geological disposal
- Near surface engineered vaults

Of the identified options, deep geological disposal is considered to be the central case, as it offers permanent, but accessible disposal, and is most in-line with emerging international proposals.

Assuming that a definitive decision is reached by CoRWM on the type of facility that is to be constructed, there are a number of factors that will impact greatly on the actual timing and cost of delivering such a repository:

- identification of site, and satisfaction of all planning and consenting issues;

- period of research, generally via construction of an underground laboratory/research facility, the outcome of which may or may not validate the chosen site; and
- NDA strategy for decommissioning sites and dealing with historic waste arisings, as changes in strategy or timing may materially change the timing and nature of the wastes that arise, and hence operational and design needs for the repository.

Timing of repository construction and operation

UK Nirex Limited has provided illustrative timings (and costings) for the construction, operation and eventual closure of separate ILW/LLW and HLW/SF repositories, as well as for a combined repository. The timings assumed by Nirex target availability of the repository by 2040, although this is later than the date notionally targeted by NDA, of 2025.

Figure 35
ILW/LLW repository programme and costs

	Costs £m	Estimated Dates
Sunk Costs	700	
MRWS	50	2007
Site Characterisation	910	2020
Construction and Underground Research	1940	2040
Operation of Facility (includes further construction)	1830	2090
Care and Maintenance	510	2140
Closure	250	2150
Total	£6.2 billion	Approximate total project duration 150 years

Figure 36
HLW/Spent fuel programme and cost estimate

	Costs £m	Estimated Dates
Site Characterisation	920	2007 2020
Construction and Underground Research	1600	2040
Operation of Facility (includes further construction)	2100	2090
Closure	315	2100
Total	£4.9 billion	Approximate total project duration 100 years

Includes HLW/SF canisters (£670m)

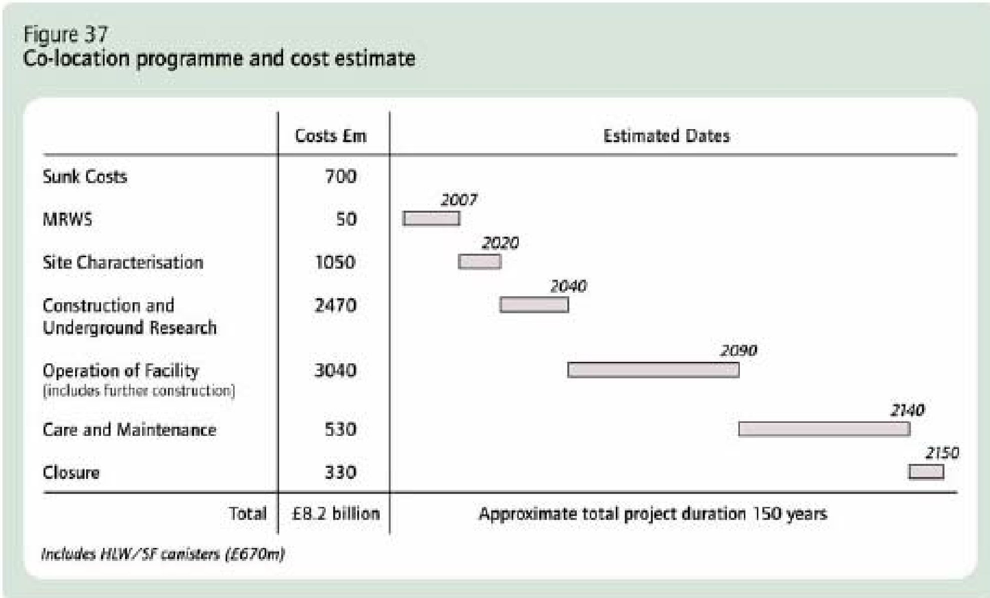

Figure 37
Co-location programme and cost estimate

These timings are necessarily no more than estimates, and embed a number of material uncertainties, however, the intent to start construction of an underground research facility at the chosen site by 2020 will require a clear and directive conclusion from the CoRWM Review.

Much theoretical and practical development work has been performed over many years by Nirex, including site identification, and closer collaboration has been established with other countries' similar research programmes (Sweden and Japan) in order to share learning and proven techniques. These activities may expedite progress, but as noted in Appendix C, no other country has yet commenced construction of an HLW repository, nor a facility for ILW, of the scale necessary in the UK.

Cost estimates for waste disposal options

The primary area of uncertainty relates to the costs of ILW and HLW disposal, on the basis that HMG have yet to determine what the national strategy for their disposal is.

Consequently, only very broad costings have been prepared or submitted to the CoRWM Review, for the range of potential options now being considered, as noted at paragraph 39 above. These are contained in CoRWM's Cost Timelines Paper, document #1448, 28 November 2005, and were expressed in September 2003 money values.

The table below summarises the broad range of other options presented, escalated to March 2006 money values:

Option	**Indicative**	**Comments**

	cost (2006 mv) £m	
Deep geological repository, combined ILW/LLW/HLW	10,050	Presumed to be central case
300 year interim surface storage	4,600	Costs up to and including extraction of waste at end of 300 years, but with no disposal option thereafter
300 year below surface interim storage	4,150	Costs up to and including extraction of waste at end of 300 years, but with no disposal option thereafter
Deep Geological Borehole	4,250	HLW and SF only, with separate ILW/LLW repository needed, assumed to be £5,750m
Phased deep geological repository, combined ILW/LLW/HLW	11,310	Remains open for longer than central scenario, with final closure many decades later
Near-surface engineered vaults	3,232	Encapsulation in heavily engineered tombs

In each case above, the costs provided by CoRWM appear to assume that all Plutonium and Uranium will also be disposed, but do not:

- include any provision for risk contingency
- reflect any new wastes arising from a new programme
- reflect any costs for prior storage, treatment of packaging of the wastes

There is no actual experience against which to benchmark these cost estimates, but it is important to note that there is a major trade-off between the permanence of the solution, and the estimated costs.

A separate cost issue is the likely future costs of disposing of LLW. As noted above, the existing Drigg facility can not accommodate the existing wastes that are known to require disposal, or the potential additional volumes that may arise from uncertainties at Sellafield.

Estimating the costs of disposal of LLW arising from an incremental new build programme will depend on the potential disposal routes that may be recommended by the LLW Review.

Incremental wastes' impact on repository

Information available relating to the potential costs of repositories relate to dealing with the existing body of wastes arising from the historic and current programmes.

The volumes of waste which are estimated to arise from a new build programme's whole lifecycle are not estimated to be material in the context of the then increased aggregate waste volumes, but no detailed studies have been published that assess the impact on the overall estimated costs of the repository options of the additional wastes, on a like-for-like basis.

The CoRWM Cost Timelines Summary Paper identified potential incremental costs for the Deep Geological Repository option as follows:

ILW/LLW or depleted Uranium:	£4,000 per cubic metre
Plutonium/HEU	£10m per tonne

However incremental costs for HLW and Spent Fuel were not disclosed.

A separate BNFL briefing paper (confidential) has estimated a range of Spent Fuel disposal costs based on information from several countries at between £0.5 and £1.5m per tonne.

International experience

No country has yet completed construction of an underground repository for HLW/SF, although some countries have resolved to build such a facility. Further, some relatively shallow, but below ground disposal facilities for ILW have been developed, for example in Finland, where waste is presently being disposed to the Olkiluoto and Loviisa repositories, which have been operational since 1992 and 1998 respectively. These operate at 70 – 100m depths.

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APPENDIX A

CoRWM Cost Timelines Summary Paper, document #1448, November 2005

	Deep Geological Disposal of ILW/LLW			Deep Geological Disposal of HLW/SF			Co-located Deep Geological Disposal of LLW/ILW and HLW/Spent Fuel		
	Years	Cost Sept 2003 mv £m	Escalated Cost March 2006 mv £m	Years	Cost Sept 2003 mv £m	Escalated Cost March 2006 mv £m	Years	Cost Sept 2003 mv £m	Escalated Cost March 2006 mv £m
Site characterisation	13	910	978	13	920	989	13	1,050	1,129
Underground research and construction	20	1,940	2,086	20	1,600	1,720	20	2,470	2,655
Operation of facility and expansion of capacity	50	2,250	2,419	50	2,200	2,365	50	3,600	3,870
Facility closure	10	250	269	10	315	339	10	330	355
Total (excluding risk contingency)	93	5,350	5,751	93	5,035	5,413	93	7,450	8,009
Risk contingency (cost, not time)		1,200	1,290			0			0
U/Pu/HEU disposal							15	1,900	2,043
Total	93	6,550	7,041	93	5,035	5,413	108	9,350	10,051
Volumes assumed (m3 conditioned waste)		275,000	275,000			3,500 tonnes AGR fuel 1,200 tonnes PWR fuel 7,400 canisters HLW			
Cost per cubic metre		0.024	0.026						

Nirex estimates of marginal cost for additional wastes:

Additional ILW/LLW, or depleted Uranium — £4,000 per cubic metre

Additional Plutonium or Highly Enriched Uranium (reflects longer operating life, and additional volume) — £10m per tonne

APPENDIX B

Long-term waste options

NOTE: The most comprehensive relevant information regarding the options, costs and issues for long-term waste disposal or storage is held on the CoRWM website within their document archive. This appendix is a brief synthesis of information from these documents, and contains verbatim extracts.

Background

1 CoRWM have been considering a range of 14 options for the long-term storage or disposal of ILW and HLW, and potentially Uranium, Plutonium and Spent Fuel. The short-listed options being considered are as follows:

Long-term interim storage

1 Above ground, at or close to existing nuclear sites (protected to current standards)
2 Above ground, at a central location (protected to current standards)
3 Above ground, at or close to existing nuclear sites (enhanced protection)
4 Above ground, at a central location (enhanced protection)
5 Underground, at or near existing nuclear sites
6 Underground, at a central location

Geological disposal

7 Geological disposal
8 Deep borehole disposal
9 Phased geological disposal

Non-geological disposal

10 Near-surface vaults, at or close to existing nuclear sites
11 Near surface vaults, at a central location
12 Mounded over reactors
13 Shallow vaults, at a central location
14 Shallow vaults, at or close to existing nuclear sites

(Source: Briefing Paper 3, CoRWM's Short-list of Options, Jan/Feb 06, p1)

2 The non-geological options are only being considered by CoRWM for reactor decommissioning wastes, and are not considered further here.

3 It is expected (but not certain) that the CoRWM Review will favour some form of Deep Geological Disposal, potentially the phased option 9 (ie, retrievable for an extended period before final closure or extraction), but of the alternatives, some form of above ground storage is argued by many

(including the environmental lobby) to be a more favourable option, as it maintains the wastes in a more readily accessible and monitorable form.

4 Further, the UK has spent much of the last 3 decades undertaking detailed investigations into deep repository options under the management of UK Nirex, a HMG owned entity. Their experience, latterly with failed attempts to gain consent for such a facility at Sellafield, suggests that even if CoRWM conclude with a preference for a deep repository, this will not be easily converted into an operational facility.

5 The timescales, risks and costs that attach to delivery of a deep geological option are such that consideration of other options may be pertinent, irrespective of CoRWM's conclusions.

6 It is considered that centralised above ground storage, with enhanced physical security (ie, resistant to terrorist attack with a piloted aircraft), is the most likely viable alternative (option 4 above).

The options being considered

7 CoRWM's Briefing Paper 3, Stakeholder Meetings, Jan – Feb 2006 (document 1495) summarises the characteristics and issues related to each of the options. Broadly, the comments relevant to interim surface storage and deep geological disposal are reported by CoRWM to be as follows:

Long-term interim storage options

8 Waste would be conditioned, packaged and placed in purpose-built stores until another longer-term or permanent option can be implemented. This approach may involve waiting until more information about other options is available, or deciding on a disposal option now but waiting until there is greater confidence that it will work before implementing it. For the purposes of CoRWM's assessment it is assumed that stores are designed with a 300-year lifetime, but would not be permanent.

9 All storage options need continuous institutional control to ensure the safety and security of the wastes. The amount of work involved would depend on the design and location of the stores. All stored materials would be fully retrievable and monitorable.

10 Most countries currently store radioactive wastes until they can be placed into a disposal facility. The Netherlands has selected disposal as its long-term management option, but has postponed going ahead with this for at least 100 years and has built a long-term interim store. France has also selected disposal, but is carrying out research into the long-term storage of High Level Waste and spent nuclear fuel in case it is not possible to be confident in the safety of disposal.

Geological disposal options

11 Waste would be conditioned, packaged and placed in purpose-built structures deep underground. Once the underground structures have been

backfilled and sealed, the intention is that the wastes would not be removed, nor rely on institutional control for safety and security.

12 In principle, all the materials in the CoRWM inventory could be disposed of in this manner however option 8 could only be used for relatively low volume wastes.

13 Geological disposal is the approach favoured by many countries for higher activity wastes, although a repository for these wastes is yet to be built and operated anywhere in the world. A deep disposal facility for long-lived ILW from military activities is in operation in the United States, and other countries have identified candidate sites. Some countries are operating underground research laboratories to study the behaviour of rocks and waste packages.

Deep Geological Phased Repository versus Centralised Surface Storage

14 Focusing on options 4 and 9, the more specific advantages or disadvantages may be summarised as follows:

15 Option 4 – centralised surface storage:

Advantages	**Disadvantages**
One centralised store less expensive than several local or at-station stores	Not a permanent solution – will still require ongoing storage or disposal at end of 300 years, and hence may still require all costs associated with option 9 to be incurred
Site selection and consenting simpler than geological disposal, as geology far less of an issue, and long-term geological considerations not relevant	Requires transport of wastes to the centralised site, necessitating improved infrastructure, and greater unavoidable transient cost
Requires only an operational safety case assessment, rather than long-term post-closure assessment	Wastes may need re-packaging throughout the storage period, but no actuarial experience exists to make this assessment today
Design of structures can be scaled to nature of the wastes (ie, less costly structures for less active wastes, whereas underground repository has high fixed cost for all waste types)	Storage facilities will require permanent monitoring and security, and regulatory standards may change through life, increasing costs, or causing re-evaluation of efficacy of this approach

Wastes readily accessible at low cost	Defers final decision and costs to future generations (though also avoids creating need for high cost recovery of disposed wastes)
Assuming site can be selected promptly, and planning and consenting expedited, first stores could be available before 2020	
Radiological hazard from wastes would decline over time, hence disposal options in 300 years may be less onerous than today	

16 Option 9 – Deep Geological Phased Repository:

Advantages	**Disadvantages**
Permanent solution (in today's terms)	Uncertainty remains as to what, if any, radioactivity may reach the surface over time
Requires no ongoing monitoring and security after repository closure, unless it is desired, or subsequently required, by future generations	Repository unlikely to be available before 2040 – 2050, even if all assumptions met, and first site selected for Rock Characterisation Facility proves suitable
Has a substantially greater body of research and design work already undertaken, and is potentially of more certain cost	Whilst can be designed for retrievability before final closure, and recoverability thereafter, the costs of reversing the disposal would be a substantial one for future generations
Phased nature means that future generations will be given the option whether to finally close the facility, or retrieve the wastes	Delays in repository availability will necessitate additional storage at station or other sites, with associated costs of construction, operation and decommissioning
	Closes off potential for more cost effective or efficacious options developing over next 100 years
	If repository not finally closed after, say, 100 years, the facility may require refurbishment to maintain it in a retrievable state
	No such repository (of the scale required in the UK) yet built anywhere in the world

Cost estimates

17 The CoRWM Costs Note (CoRWM document 1564, 21 February 2006) concludes that although cost is an important criterion in relation to large public expenditures, there are reasons to expect that cost will not play a major role in CoRWM's overall options assessment process.

18 This is mainly because of the large uncertainties associated with cost estimates for different options, which means that costs cannot act as an important discriminator in the fundamental choice between storage and disposal. Cost differentials may, however, play a more significant role in helping CoRWM to think about more detailed choices, for example, between local and centralised stores, current and enhanced security protection, and early and phased deep geological disposal. *(Source: CoRWM e-bulletin No 4, March 2006, p2)*.

19 However, despite these caveats from CoRWM, cost is one of the criteria that it is obliged to consider in evaluating the different options, and hence indicative costs have been identified, drawing upon the work of a series of specialist sub-groups, and with more detailed technical and costing input from Catalyze, Galson Sciences and Enviros.

20 In summary, the range of potential costs over the next 300 years are as follows:

Option Cost range	**(£bn, undiscounted)**		
	Low	**Central**	**High**
Storage			
1 Local above ground – current protection	9	17	27
2 Centralised above ground - current protection	7	9	14
3 Local above ground – protected	12	20	30
4 Centralised above ground – protected	10	12	17
5 Local – below ground	9	17	27
6 Centralised - below ground	7	9	14
Disposal			
7 Geological disposal	10	11	18
8 Boreholes (HLW, SF, Pu, HEU only)	2.9	4.6	18
9 Phased geological disposal	12	13	21

21 Whilst these cost estimates have been based on third-party studies, expert working groups and submissions from Nirex and others, CoRWM note a number of reasons why the cost estimates should be treated with caution:

(a) No commercial long-term waste management facility for higher activity wastes has yet been completed anywhere in the world.

(b) There is no conventional ‘market’ in long-term waste management.

(c) A minimum requirement for costing waste management facilities with any degree of accuracy is a detailed design of the facility. Among the options capable of containing the full CoRWM waste inventory, only some variants of deep geological disposal have been subject to any serious ‘bottom-up’ design and costing in the UK, and in the phased version of deep disposal the long-term costs of monitoring, surveillance etc. are necessarily difficult to determine. For the various long-term storage options no detailed UK design work has been done.

(d) Even where detailed engineering designs exist, the cost of radioactive waste management facilities will be subject to regulatory approval. As the historical trend has been for such standards to become more stringent over time, the risks of significant escalation are high.

22 These very large uncertainties are reflected in the wide range of forecast costs that CoRWM’s specialist cost workshop attached to the costs of the short-listed options.

REDACTED INFORMATION

Table of Sources – Appendix B

Document Title	***Date***	***Source / Author***	***Weblink***
"Note on Costs"	21 Feb 2006	CoRWM (Gordon MacKerron) [CoRWM document 1564]	http://www.corwm.org.uk/pdf/1564%20-%20costs%20corwm.pdf
"CoRWM's short-list of options for managing radioactive wastes in the long-term - Briefing Paper 3, Stakeholder Meetings, Jan-Feb 06"	Jan 2006	CoRWM (author not stated) [CoRWM Document 1495]	http://www.corwm.org.uk/pdf/1495%20-%20short-list%20of%20options%208%20jan%2006.pdf
"CoRWM Information Needs - Cost Timelines Summary Paper"	28 Nov 2005	CoRWM (Tamara Baldwin) [CoRWM Document 1448]	http://www.corwm.org.uk/pdf/1448%20-%202005-12-05%20short%20paper%20v2-2%20-%20final.pdf
"CoRWM Criteria Discussion Paper: Cost"	June 2005	Galson Sciences Ltd (M.B. Crawford and S.M. Wickham)	http://www.corwm.org.uk/pdf/criteria10_cost.pdf
"Summary Descriptions of CoRWM's Short-Listed Options"	Nov 2005	Enviros (Phil Richardson, Gavin Thomson and Bill Miller) [CoRWM Document 1420]	http://www.corwm.org.uk/pdf/1420%20-%20corwm%20options%20report%20v3.3%20final.pdf
"Technical Note - Summary Note for CoRWM on the Viability of Achieving and Maintaining Storage Conditions on the Surface and Underground"	Sep 2005	United Kingdom Nirex Limited (Author not stated)	http://www.nirex.co.uk/foi/corwm/corwm108.pdf
"Long-term issues for indefinite surface storage of intermediate and some low level radioactive waste in the UK"	Sep 2003	United Kingdom Nirex Limited (Samantha King)	http://www.nirex.co.uk/foi/corwm/corwm18.pdf
"Review of CoRWM Document No. 619 -	March 2005	United Kingdom Nirex Limited	http://www.nirex.co.uk/foi/corwm/corwm84.pdf

Risk from Terrorism to Surface Stores"		(Author not stated)	
"Risk from Terrorism to Surface Stores"	Oct 2004	NNC Limited (B J Handy & S Cripps) [CoRWM Document 619]	http://www.corwm.org.uk/pdf/619%20-%20terrorism%20-%20risks%20to%20surface%20stores.pdf
"CoRWM Specialist Workshops – Scoring"	11 Jan 2006	Catalyze Limited (author not stated) [CoRWM Document 1502]	http://www.corwm.org.uk/PDF/1502%20-%20Overall%20Specialist%20scoring%20report%20V1.1.pdf

APPENDIX C

Nuclear waste storage funding and liabilities - international experience

The table overleaf summarises how a number of other countries allocate liabilities and fund the costs of nuclear waste storage and management. Key themes that can be summarised from the international experience reviewed include:

Status of underground repositories:

- All countries envisage deep geological storage repositories as a means of long-term storage for ILW and HLW.
- Whilst France is still consulting on final storage options, all other countries have progressed to research and selection around agreed sites.
- Sweden and Finland are the only countries investigated to have an operational long-term geological store (currently used for ILW disposal, but not HLW).

Funding waste storage:

- All countries investigated require the nuclear operators to fund or contribute to the costs of future waste storage.
- The way in which these costs are collected from operators is expressed (by the sources accessed) as either a levy (e.g. US), charge (e.g. Germany) or a provision (eg, France).
- Where a levy or provision is stated, it is expressed as an amount per kWh - this may however be applied to all electricity generated (from all fuel types e.g. Spain) or just for nuclear generated electricity (e.g. Finland).
- It could not be confirmed whether any countries apply a levy per tonnage of waste produced.

Allocation of storage liabilities:

- There is a difference in approach across the countries examined in the accounting treatment of waste management liabilities – some countries require nuclear operators to record these on the operator's balance sheets (e.g. Germany, Belgium and France), others externalise them through payment to external funds (e.g. Spain, Sweden and Finland)
- For all countries investigated it is agreed or assumed that long-term geological storage for ILW and HLW will be adopted. However, these facilities are not yet in operation (or even constructed) and will not be for some years, even decades. In the interim, most nuclear operators therefore have no choice but to store such waste on reactor sites.

- In most of the countries investigated, an external agency (either owned by the state or by the operators) assumes responsibility for the construction and operation of the underground repositories. Liability for waste storage is therefore assumed (or explicitly stated by the source accessed) to transfer from the operator to this external agency only once the waste is physically transferred to the facility.
- The possible financial risks to operators regarding long-term waste storage are highlighted in the US whereby the Federal Government has agreed to assume ultimate long-term responsibility for waste storage, but in the absence of an underground repository, operators have had to fund temporary on-site storage themselves. Several lawsuits have since followed, at least one having been successful.
- The administration of waste management funds varies by country. At one end of the spectrum some countries allow the operator to manage the fund directly (e.g. in France), whilst in others the Government assumes direct control of the fund (e.g. Spain). Countries such as Finland involve a compromise whereby the fund is administered externally, but the operators may access the funding (eg, as a source of loans).

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
1. US	0.1 US cents / kWh levy is imposed [1] *(further research would be required in order to clarify whether this levy is just imposed on nuclear operators or all electricity operators)* Levy is paid for by consumers but is collected by the operators through customer billing [2]	Final disposal of nuclear waste is the responsibility of Government [1] The fund (Nuclear Waste Fund), into which the levy is paid, has been used to date to make some disbursements to research the site at Yucca mountain [2] Utilities have paid some U$24bn (through the levy) towards final disposal by the Government. The fund is growing by almost U$800m per year [1]	Stated policy is that the Federal Government has responsibility for all nuclear waste [2] Nuclear utilities are currently having to store waste on reactor sites as the Federal Government (Dept of Energy) have yet to construct the planned geological repository at Yucca Mountain (agreed site for final disposal) [1] As the DoE has defaulted on its 1998 deadline to start accepting spent fuel at the planned Yucca Mountain repository, operators are having to cover the costs of additional on-site storage capacity required [1] Some operators (such as Exelon) have recovered some of this unforeseen	US policy forbids reprocessing of spent fuel - it is all treated as HLW [1] The US is relatively advanced (compared to other countries) in progressing towards an underground repository in that there is an agreed policy, a site has been selected and preliminary work has begun on the site [2] The Yucca Mountain repository is planned to store 70,000 tonnes of high-level waste, with current plans to commence operation from 2010 [1] Of the 70,000 tonnes, 63,000 tonnes would be spent reactor fuel, 2,333 tonnes naval and DOE spent fuel and 4,667 tonnes of other high-level wastes [1] As of early 2004, there was

[1] World Nuclear Association Website

[2] Consultation with internal EY experts

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
			cost from the Federal Government and other operators are suing for similar cost recovery [1]	approx 50,000 tonnes of civil spent fuel awaiting disposal, and 8,000 tonnes of Government spent fuel and separated high-level wastes [1] The Exelon agreement covers all its 17 nuclear reactors, and the US $300 million of storage costs recovered from the Federal Government will be funded by Federal Budget, not the Nuclear Waste Fund [1] In addition to the Yucca Mountain facility, Private Fuel Storage LLC (PFS) plans used fuel storage on a site in Utah for up to 40 years pending disposal [1] PFS is a consortium of eight utilities apparently impatient with the DOE regarding the lack of delivery of a long-term storage facility [1] In October 2005 licensing approval was obtained for an additional 40,000 tonne centralised surface dry storage facility, due to open around

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
				2008 [1]
2. France	EdF 'sets aside' 0.14 € cents / kWh on all nuclear generated power [1] *(further research would be required in order to confirm that this amount is passed onto the consumer and whether it is a 'levy' or a 'provision')* EdF is currently responsible for setting the levy amount based on its own assessment of its decommissioning and nuclear waste liabilities and costs [2] [3]	Waste disposal as well as decommissioning and reprocessing costs [1] Storage costs covered by the EdF provision also include the future estimated costs of long-lived, medium and high-level waste, including geological storage [2] As the national policy on final waste disposal has not yet been agreed, EdF has assumed that an underground repository will be the long-term solution [2] EdF's provision for downstream nuclear fuel in France totals €14.8 billion, including €10.3 billion for reprocessing operations and €4.4	The French Government has not agreed final responsibility for waste as yet – they are awaiting the outcome from 2006 consultative process. EdF has responsibility for funding the eventual long-term waste management process, as well as responsibility for waste being generated by current EdF plant. Funding is sourced from dedicated financial assets [2] [3] Operators can however outsource their responsibilities to an authorised third party (e.g. interim storage - CEA, COGEMA and final disposal centre operator - ANDRA) [3] EdF records its nuclear liabilities as a provision on its balance sheet [3]	ANDRA, the waste management agency, is running the consultative process. It expects to report to Government so that parliament can decide in 2006 on the precise course of action [1] EdF has been reprocessing fuel for some time [2] An underground repository is being assumed (by EdF) as the long-term storage solution [2] The national policy is to reprocess spent fuel (before final disposal) so as to recover uranium and plutonium for re-use and to reduce the volume of high-level wastes for disposal (closed fuel cycle) [1]

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		billion for storing waste resulting from nuclear fuel. The provision represents the outstanding liability, being adjusted annually for both new liabilities and amounts spent [2] Provision is maintained by EdF, not Govt [2]		
3. Finland	A charge on nuclear generated electricity is imposed by the Government on the two nuclear operators, TVO and Fortum. This is accumulated into a State Nuclear Waste Management Fund [1] The overall costs of managing	The Government charge (feeding into the State Nuclear Waste Management Fund) on nuclear generated electricity is assessed annually based on the liabilities for long-term waste disposal and decommissioning costs of each company [1] The cost estimate for disposing of 2,600 tonnes of spent fuel	Responsibility for nuclear waste rests with the nuclear operators until the waste is transferred to the planned underground repository (although this is being constructed by a TVO/Fortum joint venture company) [1] TVO and Fortum externalise their liabilities through their payments to the State Nuclear Waste Management Fund [3] Companies report nuclear	The State Nuclear Waste Management Fund exists under the Ministry of Trade & Industry [1] Surface storage pools are in operation at both the Olkiluoto and Loviisa sites [2] The Olkiluoto surface pool storage facility for spent fuel has been in operation since 1987. The € 31 million KPA facility has a capacity of 1,270 tonnes and is designed to hold spent fuel for about 50 years, pending deep geological

[3] Morgan Stanley report "Nuclear: Core of the Matter" – September 2005"

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
	radioactive waste (this includes decommissioning), are currently estimated at 0.23 € cents/kWh (undiscounted) [1] All nuclear waste management and storage costs are included within the price of electricity [2]	from the four existing reactors during 40 years of operation is about € 818 million (this includes construction costs of € 228 million, encapsulation and operating costs of € 538 million). With the fifth reactor (currently being constructed), some 6,500 tonnes of spent fuel will require disposal. By end of 2004, 1380 tU had been accumulated [1] As of mid 2005, € 1.4 billion had been accumulated in the State Nuclear Waste Management Fund from charges on generated electricity. The charges are set in line with assessed liabilities for each company - for 2003 €	provisions (assuming a discount rate) and the corresponding assets (their shares of the waste management fund) [3] Companies are allowed to borrow up to 75% of their respective share of the waste management fund [3]	disposal [1] A joint venture company, Posiva Oy (owned 60% by TVO and 40% by Fortum), was set up in 1995 to be responsible for the final disposal of spent nuclear fuel in Finland. There are advanced plans by Posiva Oy to construct an underground geological site – current plan is to commence operations in 2020 [1] Two underground repositories are already operational for storage of ILW and LLW [1]

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
		732 million for TVO and € 545 million for Fortum [1]		
4. Spain	1% levy on all electricity consumed [1] *Alternative source states that costs for decommissioning and nuclear waste are borne by nuclear generators only* [3] This levy is paid into an external national fund [1]	Funds waste management and decommissioning [1]	ENRESA (Empresa Nacional de Residuos Radiactivos SA) manages the national nuclear fund and is responsible for decommissioning, interim storage and disposal [3] In Spain nuclear companies externalise their liabilities through payments to a national fund [3] Spent fuel is stored at reactor site until a final disposal solution is determined in 2010 [3]	ENRESA was set up in 1984 as a state-owned company to take over radioactive waste management and decommissioning of nuclear plants. It is the only state-owned part of the nuclear fuel cycle in Spain [1] The plan for spent fuel envisages initial storage at each reactor for ten years. Some temporary storage for dry casks is also envisaged at Trillo up to 2010 and establishment of a longer-term centralised facility from then [1] Meanwhile research will progress on deep geological disposal as well as transmutation, with a decision on disposal to be made after 2010 [1] Policy is focused on an open fuel cycle [1]

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
5. Germany	Operators are charged a pre-payment fee for the estimated costs of waste storage at Federal facilities [4] These fees are included within the cost of electricity to consumers and are paid into an external trust fund [1]	The trust fund is designed to cover the costs of waste management, decommissioning nuclear power plants and rehabilitating lignite mines [1] During the period 1999-2000, the fund reached a value of DM 50 billion. However, the Federal Government applied a retrospective tax to the fund, depleting it by 50% [1]	Nuclear operators are responsible for interim storage of spent fuel and decommissioning. They have formed joint companies to build and operate off-site surface facilities (Ahaus and Gorleben). However, current practice is for interim storage at reactor sites [1] Companies manage their own nuclear funds, which they control and to which they have access [3] Companies' provision for plant decommissioning, interim storage and final disposal of nuclear waste on their balance sheets [3] The Federal Government (through the Federal Office for Radiation Protection) is responsible for building and operating final repositories	From 1998 – policy changed to direct geological disposal of spent fuel, and no reprocessing after 2005 [1] A Government agency (Bundesamt für Strahlenschutz) is responsible for the construction and operation of nuclear waste disposal facilities [3] A salt dome at Gorleben is the agreed location for a national centre for disposal of radioactive wastes. It is now being studied as a possible site for geological disposal of high-level wastes [1] These will be about 5% of total wastes with 99% of the radioactivity. The site could be available as a final repository from 2025 [1] Ahaus facility is used for storing intermediate-level wastes, and the Konrad site (a former iron ore mine) was

[4] Website of BFS – German Federal Office for Radiation Protection

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			for high-level waste, but progress has been slow due to opposition from Länder Governments [1]	licensed in 2002 for their disposal with low-level wastes but is not expected to be operational before 2010 due to legal challenges. This will take 95% of the waste volume, with 1% of the radioactivity [1]
6. Hungary	Since 1998, a levy on nuclear generated electricity has been charged [1] Levy revenues are paid into the Central Nuclear Financial Fund [1]	The Central Nuclear Financial Fund is designed to cover the costs of storage and disposal of radioactive wastes, spent fuel, and decommissioning [1]	The Public Agency for Radioactive Waste Management (PURAM) is responsible for all waste management, waste disposal and decommissioning [1] *Further research would be needed to clarify the precise allocation of liability between Government and operators*	Policy based on a closed fuel cycle ie. disposal without reprocessing [1] Spent fuel is stored in ponds at Paks, then transferred to dry storage, also at Paks [1] Following investigation by PURAM, an underground repository site (at Bataapati) for LLW and ILW is planned – now approved by Parliament [1] A low-level waste repository operates at Puspokszilagy for institutional (non-nuclear) radioactive wastes [1]
7. Sweden	Nuclear operators pay a set fee (which has averaged € 2.2 c/kWh) into a state administered fund [1]	The state fund (into which fees are paid) is designed to cover the costs of waste management and decommissioning [1]	The nuclear operators externalise their liabilities through payments to the state fund [3] Nuclear operators are responsible for the costs of	Final underground repository for ILW has been operating near Forsmark since 1988 [1] Some LLW is disposed of at reactor sites. Some waste is incinerated at Studsvik [1]

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
	Fee is set by Government based on advice from the Swedish Nuclear Fuel and Waste Management Company (called SKB) [1 3]	The state fund is administered by the state run Swedish Nuclear Power Inspectorate (called SKI) [1]	managing and disposing of spent fuel. They must provide for those costs as they go [1] SKB was set up by the nuclear operators - it is owned 36% by Vattenfall, 30% Forsmark, 22% OKG and 12% E.ON Sweden. Set up in 1977, its purpose is to develop a comprehensive concept for disposal of spent fuel and other radioactive wastes [1] SKB manages spent fuel [3]	An interim repository (called CLAB) for spent fuel (treated as HLW) operates at Oskarshamn (it commenced operation in 1985). Its capacity is being expanded to 8,000 tonnes (from 5,000) to cater for all the fuel from all the present reactors [1] A final deep (geological) repository is planned and is the subject of current research to identify technical suitability [1] There are currently two short listed sites for this geological repository [1]
8. Belgium	Costs are borne by the power utilities [1] Electrabel determines and makes a provision for nuclear liabilities. These include plant decommissioning, interim nuclear waste storage and final disposal) [3]	The provision covers waste management, storage and decommissioning [1] The provision is paid into a fund which is managed by Synatom (owned by Tractebel and Electrabel) [3]	In Belgium nuclear companies record their nuclear liabilities as provisions on their balance sheet [3] The national agency for radioactive waste and fissile materials management (ONDRAF/NIRAS) is responsible for the safe management of all radioactive materials in the	Synatom was initially formed as a syndicate for the design of large nuclear power plants [1] The main ONDRAF/NIRAS facility is at the Mol-Dessel site, run by its subsidiary Belgoprocess [1] There are proposals for LLW repositories at Mol and Dessel [1] Research on deep geological disposal of ILW and HLW is

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
			country. This includes transport, treatment, conditioning, storage and disposal [1]	underway and focused on the clays at Mol [1] An underground research laboratory (in clay, at Hades) has been constructed to investigate ultimate geological storage [1]
9. Japan	0.2 yen/kWh levy from electricity utilities. Levy cost is passed onto customers [1]	Levy revenues are paid into a fund administered by NUMO (the Nuclear Waste Management Organisation) [1] The NUMO fund will cover the costs of the planned underground repository [1] An independent funds management body, RWMC (Radioactive Waste Management Funding and Research Centre), has since been set up [1] All reserves held by utilities will be transferred to RWMC and companies will be	NUMO was set up by the private sector [1] NUMO is responsible for developing plans for waste disposal and storage. This includes site selection, demonstration of technology, licensing, construction and operation, monitoring and closure [1] *Further research would be needed to clarify the precise allocation of liability between Government and operators*	Legislation (in 2000) mandates deep geological disposal of high-level waste (only vitrified waste from reprocessing spent reactor fuel) [1] NUMO currently runs a site selection process with a view to short-listing by 2007, conducting detailed investigation by 2012 with a final site selected by 2025, and operation commencing in 2035 [1] Estimated cost of the planned underground repository is US$ 28 billion (excludes any financial compensation paid by Government to local communities) [1]

Country	Levy Approach	What does levy cover?	Allocation of waste liability	Other information
		refunded as required for reprocessing [1]		
10. Czech Republic	CEZ, the state owned nuclear plant operator, puts aside US$ 0.2 cent / kWh [1]	Costs of waste disposal, which are lodged with the Czech National Bank [1] The accumulated funds are placed into an "escrow" account and can be used only with the permission of the Radioactive Waste Repository Authority (RAWRA), which administers the fund [3] The funds are however managed by CEZ within an approved framework [3]	CEZ is fully responsible for storage and management of its spent fuel until it is handed over to the state owned, RAWRA[1] RAWRA arranges for the final disposal of waste and spent fuel [3] CEZ reports its provisioning and accumulated funds for decommissioning and interim storage on its balance sheet [3] Waste management (along with licensing, nuclear safety, safeguards, and radiation protection) is regulated by the State Office for Nuclear Safety (SUJB) [1]	Spent fuel storage is undertaken at reactor sites [1] There is also an interim LLW and ILW storage facility (600 tonnes capacity) at Dukovany with further construction underway to add an additional 1,300 tonnes capacity. This facility is operated by RAWRA [1] RAWRA has responsibility for the planned HLW repository. The selection of a site will not commence until 2015 and construction is planned for 2050 [1]