Deep Repositories for Spent Fuel – Burying the Truth

In the last four years the Nuclear Decommissioning Agency has been established with a remit to manage the radioactive waste from the nuclear legacy. The Committee on Radioactive Waste Management (CoRWM) has considered long term options for the disposition of these legacy wastes.

Both organisations have been able to build a degree of public trust on the basis that they were addressing a finite problem that concerns all of us.

The Government's push for new nuclear power stations is putting all that hard work in jeopardy by forcing these organisations to include the huge additional amounts of highly radioactive spent fuel from a new nuclear programme.

CoRWM considered that "should a new build programme be introduced… it would require a quite separate process to test and validate proposals for the management of wastes arising." These warnings have gone unheeded.

The Government intends that spent fuel from new nuclear power stations would be packaged, stored and disposed of with no reprocessing. The May 2007 consultation document on the role of nuclear power states that: [1]

> "The Government believes that new waste could technically be disposed of in a geological repository and that this would be the best solution for managing waste from any new nuclear power stations."

In order to reduce costs for energy companies considering investing in new nuclear stations the Government would like to dispose of both new and legacy waste in the same repository facilities.

Although it may be technically possible to do this, there are doubts as to whether it would be wise. There is no disposal site operating anywhere in the world for high level radioactive waste (HLW). As well as being less radioactive low level waste (LLW) and most intermediate level wastes (ILW) emit no heat. This means that they can be packaged and disposed of (or stored) in a densely packed vault.

Spent fuel and HLW resulting from reprocessing are both heat-emitting wastes and require a disposal facility which spreads the packaged waste over a much larger area in order to avoid a heat build-up which might accelerate the deterioration of the waste, its packaging, the engineered zone around it and the geological environment.

Clearly, if the public are to make an informed decision about whether or not to accept a new nuclear power programme or 'volunteer' their community for a radioactive waste disposal facility, the size of the repository proposed for all possible waste arising is of considerable interest. This is acknowledged in the Defra June 2007 consultation document "A framework for implementing geological disposal":[2]

> Communities will want a clear understanding of what could be disposed of, and where the uncertainties might be, before they agree to the project going ahead.

Although the subject of the 'footprint' of a facility for legacy waste was raised, no estimate was given for the size of the additional repository required for new build spent fuel [3]:

> "....the underground area of host rock required (i.e. the 'footprint') for an ILW/LLW disposal facility would be of the order of 1km², and for a HLW and spent fuel disposal facility (assuming that the latter were treated as a waste) would be of the order of 3km².

From that statement alone, the reader might infer that if a disposal facility for legacy HLW and spent fuel would be of the order of 3Sq Km (for 9,440 m^3 of packaged waste) [2], it follows that spent fuel from a new build programme (with an estimated volume of packaged waste of 31,900 m^3) [4] would (if it was packaged and disposed of at the same density as legacy spent fuel) require a disposal facility with a footprint of over 10 square kilometres**.**

Far from giving the public a clear understanding of the implications of disposing of the spent fuel from new nuclear reactors the 'other' consultation document sought to play down the impact using an analysis by Nirex that:[5]

- A stand-alone ILW repository for legacy waste would need to be around 3% bigger to accommodate waste from new power stations.
- A stand-alone HLW/Spent Fuel repository would need to be approximately 89% bigger to accommodate waste from new power stations.
- The additional quantities of ILW and HLW/Spent Fuel would increase the overall footprint of a co-located repository by approximately 50%.

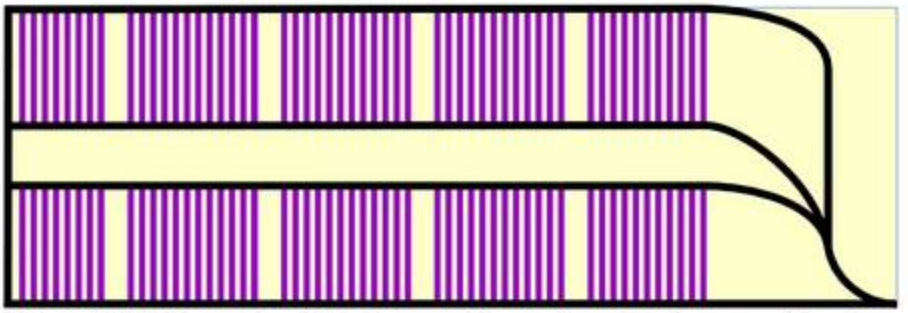
This last statement has lead people to believe that only an extra two Sq Km would be needed to add to the legacy repository of 4 Sq Km. Others might conclude that a 3 Sq Km repository for legacy spent fuel and HLW would require to be 89% bigger to accommodate spent fuel from new build (2.7 Sq Km extra).

Information on the subject of spent fuel from new nuclear power plants, all published in May and June 2007 specifically to 'help' the public, has thus resulted in confusion. This paper is an attempt to clarify the situation in order to help people make an informed decision on both issues. To understand what is going on it is necessary to look at the background assumptions.

A further Nirex paper explains that [6]

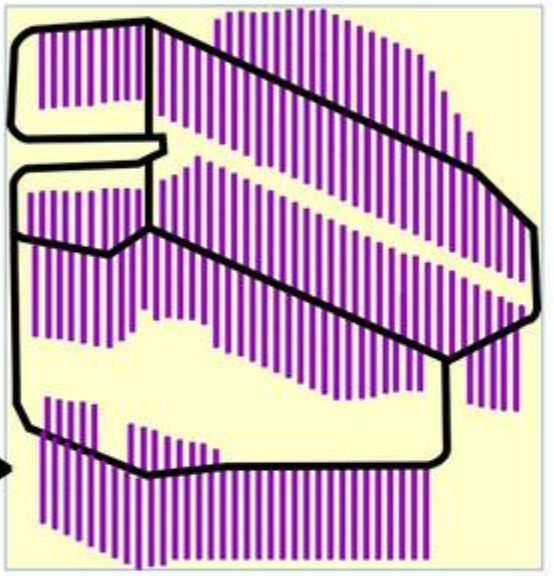
> "For the UK Reference HLW/SF Repository Concept the impact that new build waste would have on the repository footprint is dependent on the number of disposal canisters required and the heat output associated with the SF."

Fig 1. Spent Fuel Repository Footprints Scale 1:2500



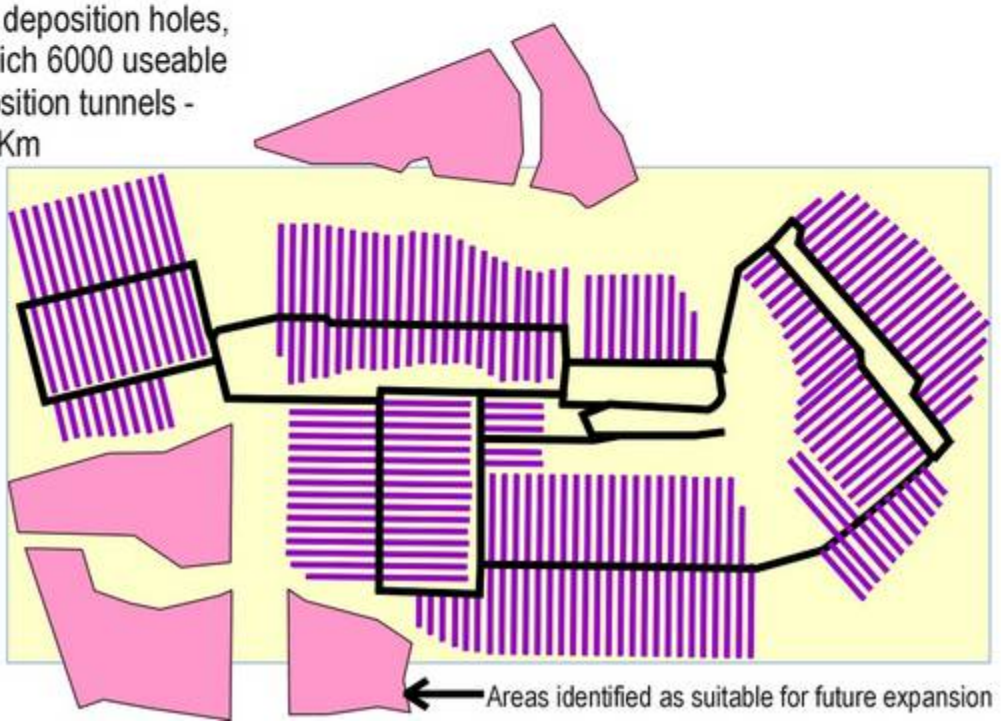
Nirex HLW/Spent Fuel Reference Repository for Legacy Waste
3.0 Sq Km Deposition tunnels @ 38m ctrs, total length 41.8 Km

Forsmark - 3.4 Sq Km
6660 deposition holes,
of which 6000 useable
Deposition tunnels - 49.4 Km



Footprint

Laxemar - 5.5 Sq Km
7500 deposition holes,
of which 6000 useable
Deposition tunnels -
63.0 Km



Areas identified as suitable for future expansion

The UK Reference HLW/SF Repository Concept is in turn based on work undertaken at two possible sites for spent fuel disposal in Sweden: Laxemar and Forsmark. All three designs are illustrated in Figure 1. A series of deposition tunnels is excavated at a depth of about 500 metres and eight metre deep holes are drilled each having a diameter of 1.75 metres. These holes are spaced at six metres (from centre to centre). In Sweden where geological conditions at actual sites informed the calculations between 11% and 20% of the holes drilled were estimated as likely to be unusable. [7]
Into these holes a standardized copper canister (called the KBS-3) is placed containing spent fuel. A buffer zone of Bentonite clay is formed between the rock and the canister. In the Swedish concept the deposition tunnels are spaced at 40 metre centers to allow the heat from the spent fuel to dissipate.

Figure 1 illustrates the layout of tunnels in the three concepts to the same scale 1:2500. The Nirex repository, for existing spent fuel and HLW legacy waste is clearly a 'desk exercise' based on a simple rectangular grid measuring 1 Km by 3 Km. Spaced at 38 metre centres this grid contains almost 42 Km of deposition tunnels. Clearly the conditions found at real sites will require a more flexible layout, as Laxemar and Forsmark illustrate.

Table 1 Increase in Repository Footprint for New Build Spent Fuel
Source: The Gate Process Table 13

Waste type	Number of disposal canisters for legacy waste	Number of disposal canisters for waste from 10 AP1000s	Combined total	Increase in disposal canisters(%)
HLW *	4,480	0	4,480	
AGR SF	3,400	0	3,400	
PWR SF	650	7,588	8,238	
Total	8,530	7,588	16,118	89
* based on the 2004 radioactive waste inventory				
Total SF cans	4,050	7,588	11638	187

The figure used by Government to inform the public of the impact of radioactive waste from new build, that a stand-alone HLW/Spent Fuel repository would need to be approximately 89% bigger, is misleading because it is based on the number of containers. Only one PWR spent fuel container can be put in each deposition hole compared with four HLW containers and two AGR containers. The impact of direct disposal of spent fuel from new nuclear reactors will be considerably larger than '89% bigger'.

It is unhelpful to compare the Swedish ideas for spent fuel disposal with the Nirex reference repository without examining in more detail the vitrified HLW and two different types of spent fuel that comprise our legacy waste.

A recent 'concept' paper prepared by the Nuclear Decommissioning Authority illustrated HLW containers placed on the floor of the deposition tunnels which are then back-filled with bentonite clay [8]. As this Japanese 'vault' idea requires active ventilation to provide cooling for three hundred years, it is inconsistent with the Swedish concepts for spent fuel which require no cooling. [9]

Only detailed examination of background documents reveals that the Nirex reference repository consists of an area where two HLW containers of vitrified waste are placed inside a KBS disposal canister, and that two of these canisters are placed in each deposition hole (see Fig 2)[10]. If the deposition tunnels and holes are spaced at the same intervals as those for spent fuel, approximately 418 HLW containers can be assumed for each kilometre of tunnel. A further area has two KBS disposal canisters with AGR spent fuel in each deposition hole, and the remainder of the repository has one PWR spent fuel canister in each deposition hole.

Table 2 Repository Footprints for HLW and Spent Fuel

Type of waste	Volume of packaged waste m3	Height of container m	Diam of container m	Volume m3	No. of containers	No. of containers per Km	Length of deposition tunnel km	Footprint of repository Sq km
Legacy PWR Spent Fuel	2740	4.5	0.9	2.86	957	107	9	
Legacy AGR Spent Fuel	5410	2.5	0.9	1.59	3402	214	16	3.0
Legacy HLW *	1290	1.3	0.43	0.19	6833	418	16	
* No. of canisters in 2040 resulting from reprocessing UK fuel								
Average Swedish SF repository					6000	107	56	4.9
Spent fuel from new UK reactors								
AP1000 PWR in KBS 3	31900	4.8	1.1	4.56	6993	107	65	5.7
in 'optimised canisters'					6673	107	62	5.4

Table 2 indicates the different sizes of the waste packages for AGR fuel, PWR fuel from Sizewell B and HLW; as identified by AMEC NNC for CoRWM [11]. This enables a calculation to be made of the number of containers of each sort, and the spacing of the spent fuel containers in the Swedish repository designs gives an indication of the length of deposition tunnels and the footprint of a repository capable of accommodating Britain's legacy waste. Because the containers for AGR spent fuel are half the height of the Swedish KBS canisters, and AGR fuel is cooler than PWR fuel having a lower burn-up (24000 MWd/tU), one is emplaced above another as shown in Figure 2 below.

With its 42 km of tunnels the Nirex reference repository consists of 16 km for the legacy HLW a further 16 km for the AGR spent fuel and 9 km for the spent PWR fuel from Sizewell B.

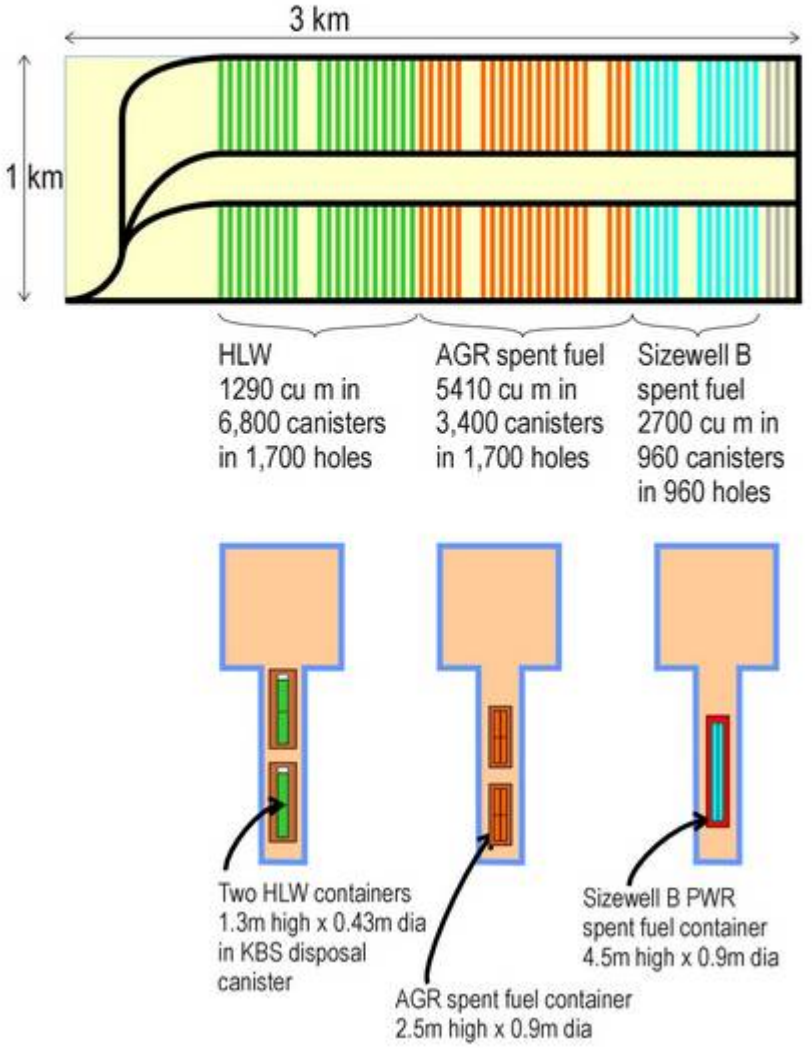
If the Swedish model is adopted for the provision of a repository for spent fuel from new nuclear reactors in Britain and the disposition of spent fuel canisters at Laxemar and Forsmark is used as a guide, each deposition hole will accommodate a single KBS spent fuel canister, so a repository covering 5.7 Sq Km would be required for a 'stand alone' repository for new build.

Nirex has suggested the use of 'optimised' canisters but as the number of fuel assemblies to be disposed of remains the same, each canister holds four PWR assemblies, and the spacing of containers is determined by the heat output of the spent fuel, it is unclear how a slight reduction in the number of canisters has been achieved. If the high burnup spent fuel being proposed for the PWR reactors is pursued, (60,000MWdays/tonne of Uranium) then even fifty years after removal from the reactor the heat output of four fuel

assemblies is likely to exceed the temperature limits of the KBS canister. If only three fuel assemblies per canister were allowed, a 'stand alone' repository for new build repository would cover 7.6 Sq km.

Fig 2 The 'Reference' Repository

Nirex HLW/Spent Fuel Reference Repository for Legacy Waste
3.0 Sq Km Deposition tunnels @ 38m ctrs, total length 42 Km



Conclusions

The Government's stated desire 'to reduce costs for energy companies considering investing in new nuclear' has created a strong motivation to put new build waste in the same repository as legacy waste.

The Nuclear Decommissioning Authority advised the Government that: [12]

> "The data concerning the impact of new nuclear build on waste volumes can be presented in a variety of ways, depending on one's point of view. It is certain that new nuclear build will increase total waste volumes to a small degree."

However, in order to make an informed decision about the feasibility of a single deep underground repository to take all the legacy and new build waste from nuclear power the public needs to be told the truth:

- The footprint of a 'legacy only' repository for HLW and spent fuel would need to be 3 Sq Km to allow for the conditions at a real site, and legacy waste of all types would thus require a repository of 4 sq Km
- Spent fuel alone from new build would require another 5.7 sq Km.
- A single deep underground repository to take all the waste could require at least 10 sq km.
- If, in order to accommodate high burnup spent fuel, greater spacing of tunnels, or fewer fuel assemblies per canister are required the single repository might require up to 12 sq km.

It is this 10 to 12 sq Km footprint that will settle the feasibility of finding a single location for the construction of a deep underground repository for all of Britain's radioactive waste. According to the Royal Society if a new nuclear power programme is established the need for a separate disposal site for newer HLW would remain.[13] Defra accepts that this might be necessary if the geology at potential sites were not suitable for a single geological disposal facility. It will be considerably more difficult to find a geological environment of 10 sq kilometres which has the necessary consistency and integrity, than one of 4 sq kilometres.

If the government continues in its questionable policy of deep geological disposal, there would be some benefit in restricting such a publicly funded repository to accommodate only the legacy waste. The 'host community' would then know (if it felt that government could be trusted) that the repository is finite, and would be operated and closed in a known and fixed timetable.

An entirely separate repository for new-build waste would help the Government to try to convince the public that there is no hidden waste-disposal subsidy to support the energy companies. It would also help the nuclear industry to show its resolution to fulfill its responsibilities for radioactive waste management, and as new power stations are decommissioned later than existing plants the new-build facility could stay open longer, without threatening the integrity of the legacy waste facility.

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[4] "Potential Waste Volumes Arising from New Build" Statement Prepared by: Dr Paul Gilchrist, Strategy Manager, Spent Fuel, Nuclear Materials and HLW. Nuclear Decommissioning Authority. 17th October 2006.

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[8] Annex 1 to Study into the Concepts for Geological Disposal of High-Level Waste and Spent Fuel briefing paper Drafted for Nuclear Decommissioning Authority in advance of NSG Meeting November 2007 Ref NSG29a, Concept 8

[9] (eventually published as: Geological Disposal Options for High-Level Waste and Spent Fuel; Report for the UK Nuclear Decommissioning Authority. Tamara Baldwin, Neil Chapman & Fiona Neall. January 2008 page 45)

[10] see for instance: Cost Estimates for Disposal of Spent Fuel from New Build Reactors in the UK. Neil Chapman Charles McCombie January 2006 Para 4.8 page 25

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