LLW Repository Ltd

ED26

LLW Repository, Holmrook, Cumbria:

Site Optimisation and Closure Works

Need for Disposal Capacity at the LLWR

RP/340737/PROJ/00033 Version 2

January 2015

This page is left blank intentionally.

Objective

The objective of this document is to present projected fill dates for existing and potential future vaults at the Low Level Waste Repository (LLWR), based on the latest available information, and discuss the uncertainties in the projected dates. The paper has been produced to provide information to Cumbria County Council planning officers relating to the need for future vaults at the LLWR. Following discussions with Council planning officers based on Version 1 of this paper, a new section has been added providing fill dates based on adjusted vault volumes (some other minor additions and revisions have also been made).

Background

The LLWR submitted to the Environment Agency a new Environmental Safety Case for the LLWR in May 2011 (the '2011 ESC').

The 2011 ESC assessed two different sized repositories with different numbers of vaults, covering a Reference Disposal Area (RDA) and an Extended Disposal Area (EDA).

The RDA repository comprised the trenches used for disposal up to 1995 and seven vaults, Vaults 8 to 14, of which the first two have already been constructed. The trenches and these vaults cover what was formerly known as the 'Consented Area', with future vaults constructed south of the existing vaults down to approximately the end of the trenches. The EDA repository included six more vaults than the RDA repository. The EDA repository comprises Trenches 1 to 7 and Vaults 8 to 20.

A repository covering the RDA would have the physical capacity to take all the UK's Low Level Waste (LLW) arising up to about 2080, depending on a number of future decisions about LLW management, including the extent to which waste segregation and treatments are applied. The assessment for a repository covering the EDA was undertaken to investigate whether all the LLW in the United Kingdom's Radioactive Waste Inventory (UKRWI) requiring vault disposal could be safely disposed at the site, excluding very low activity waste and wastes where an alternative route is available or is planned to be available. The UKRWI has arisings up to about 2130 and taking all waste requiring vault disposal at the LLWR would extend the lifetime of the repository out to the same date. Much of the capacity in the additional vaults for the EDA repository would be required for the 'final stage' decommissioning wastes from the UK's gas-cooled reactors.

The 2011 ESC also assessed the impacts from four different inventories of waste to explore the implications of uncertainties in future inventories of disposed wastes. The four inventories were referred to as Cases A to D in the 2011 ESC. Case A was treated as the reference case. In order to calculate the distribution of waste materials including radionuclides between different vaults, an inventory model called PIER (Projected Inventory Evaluation Routine) [2] was created using Excel. Assumptions were made about the extent of waste diversion and treatment and packing fractions in waste containers and in the vaults in order to calculate the physical volumes occupied by the disposed wastes in the vaults. The PIER model was also used to calculate the fill dates of the vaults under the assumptions of the different inventory cases.

The UKRWI is revised and published every three years. The 2011 ESC was based on the 2007 UKRWI (the 2010 version was not available before ‘data freeze’ in 2010 for the ESC).

Soon after the submission of the 2011 ESC, an associated planning application for the works necessary to develop and close the LLWR was submitted to Cumbria County Council. This application was based on the RDA repository and the reference Case A inventory.

The PIER calculations for the 2011 ESC have been updated for this document, based on the latest 2013 UKRWI and experience of the effects of waste diversion and treatment gained since the 2011 ESC.

PIER Model

The PIER model and its application in the 2011 ESC are described in references [1] and [2]. This section summarises this information.

PIER provides, as output: the volumes of primary and secondary wastes disposed to LLWR each year, taking account of waste processing, diversion and treatment, and quantities of radionuclides disposed of to LLWR annually. In addition, PIER determines the inventories and fill dates of individual vaults based on information on the available capacity of vaults and packing fractions. The information about the radiological and materials inventories of each vault is then used as input to impact assessment models.

The analysis undertaken by the PIER model uses information from the UKRWI. The UKRWI is the best available source of data on future waste arisings in the UK. Each waste producer is required by the Government to provide detailed information on the nature and volumes of future waste arisings. The UKRWI identifies the nature of the waste materials, for example, of what type of metal they are comprised, as well as radiological content.

The inventory used in the 2011 ESC was based on the 2007 UKRWI and assumptions about waste diversion and treatment made at the time of development of the ESC. It includes all the material identified as LLW unless it has an alternative identified in the UKRWI, e.g. the new Dounreay facility, CLESA at Sellafield, and Clifton Marsh. It assumes no LLW will be diverted to a possible deep geological repository and will be disposed at LLWR. In addition, it assumes all Very Low Level Waste (VLLW) and similar low-activity LLW streams will be diverted to alternative landfill facilities. For the remaining waste streams, PIER makes assumptions about the reductions in physical volume of the wastes resulting from supercompaction, such as that provided by the Waste Monitoring and Compaction (WAMAC) facility at Sellafield, or incineration of organic wastes in various different facilities in the UK or abroad, and metal treatment such as provided by the Studsvik Lillyhall facility in Cumbria or metal melting facilities, all currently abroad. PIER processes the waste based on the following steps:

- Segregation of the waste stream into its component material types;
- Assignment of each material type to a processing route;
- Processing each material type to generate secondary wastes;
- Disposal of secondary wastes and any unprocessed primary wastes.

The volumetric changes to the raw waste before disposal due to processing, diversion and treatment are calculated by application of a number of multiplicative factors. Finally, factors are applied to take account of the packing fractions of wastes in ISO containers and ISO containers in the vaults. The factors used are listed in Table 1.

The values of the factors used for the 2011 ESC are given in column two of Table 1. These factors were based on:

- a judgment about the extent of waste segregation that would be achieved over time;
- assumptions about routing of different types of materials;
- evidence from existing treatment facilities in the case of volume reductions resulting from treatment;
- judgments about the packing fractions of wastes in containers and containers in vaults, partly based on engineering design information.

Table 1 Waste processing factors

Factor	2011 ESC Value	New Value	Reason for change
Percentage of treatable waste segregated	75%	75%	There are no new data that would cause a change to this factor
Assumed routing for: Graphite	100% untreated	100% untreated	There are no new data that would cause a change in the assumption that graphite waste would not be treated
Assumed routing for: Metals	100% smelting	100% smelting	There are no new data that would cause a change in the assumption that metallic waste is all processed via this route
Assumed routing for: Oil	100% incineration	100% incineration	There are no new data that would cause a change in the assumption that oils are all processed via this route
Assumed routing for: 'Other'	100% untreated	100% untreated	The cautious assumption that all 'other' wastes are untreated is still valid
Assumed routing for: Plastic/rubber	50% compaction and 50% incineration	5% compaction and 95% incineration	Understanding based on utilisation of the treatments routes suggests the main treatment route will soon be incineration

Factor	2011 ESC Value	New Value	Reason for change
Assumed routing for: Soft organics	50% compaction and 50% incineration	5% compaction and 95% incineration	Understanding based on utilisation of the treatments routes suggests the main treatment route will soon be incineration
Assumed routing for: Soil/rubble	100% untreated	100% untreated	There are no new data that would cause a change in the assumption that soils and rubbles would not be treated
Assumed routing for: Wood	50% compaction and 50% incineration	5% compaction and 95% incineration	Understanding based on utilisation of the treatments routes suggests the main treatment route will soon be incineration
Assumed routing for: Unknown material	100% untreated	100% untreated	The cautious assumption that all 'unknown' wastes are untreated is still valid
Volume of secondary waste: Compacted puck	20%	20%	There are no new data that would cause a change to this parameter
Volume of secondary waste: Incinerator ash	1.5%	1.5%	There are no new data that would cause a change to this parameter
Volume of secondary waste: Incinerator filter	1.5%	1.5%	There are no new data that would cause a change to this parameter
Volume of secondary waste: Smelting slag	2.5%	2.5%	There are no new data that would cause a change to this parameter
Volume of secondary waste: Smelting filter	2.5%	2.5%	There are no new data that would cause a change to this parameter
Radionuclide distribution to: Puck	100%	100%	There are no new data that would cause a change to this parameter
Radionuclide distribution to: Incinerator ash	80% (assumed 20% to filter)	80% (assumed 20% to filter)	There are no new data that would cause a change to this parameter
Radionuclide distribution to: Smelting slag	90% (assumed 10% to filter)	90% (assumed 10% to filter)	There are no new data that would cause a change to this parameter

Factor	2011 ESC Value	New Value	Reason for change
Compaction first utilised in	2005	2005	There is no change to this parameter as this route is already fully utilised
Incineration first utilised in	2010	2008	This parameter has been changed to reflect the expected reduction in the use of the compaction route in favour of incineration
Smelting first utilised in	2009	2011	This parameter has been changed to reflect the rapid increase in use of smelting
Compaction fully utilised by	2006	2006	There is no change to this parameter as this route is already fully utilised
Incineration fully utilised by	2015	2020	This parameter has been changed to reflect the expected reduction in the use of the compaction route in favour of incineration
Smelting fully utilised by	2015	2012	This parameter has been changed to reflect the rapid increase in use of smelting
Max fraction treated: Compaction	100%	100%	There are no new data that would cause a change to this parameter
Max fraction treated: Incineration	80%	95%	Understanding based on utilisation of the treatments routes suggests maximum fraction of waste treated will be greater
Max fraction treated: Smelting	60%	70%	Understanding based on utilisation of the treatments routes suggests maximum fraction of waste treated will be greater
Packing fraction into a vault	0.855	0.855	There are no new data that would cause a change to this parameter

Factor	2011 ESC Value	New Value	Reason for change
Packing fraction into a container	0.600	0.472	Analysis of data for disposals indicates the packing fraction is less than assumed in the 2011 ESC
Remaining capacity in Vault 8	121596 (m^3)	12000 (m^3)	It is expected that the extent of higher stacking undertaken in Vault 8 will be less than assumed in the 2011 ESC and hence leads to a reduced available space for disposals

Volumes of the secondary wastes given in Table 1 are the percentages of the volumes of wastes before treatment, for example, a disposed compacted puck is assumed to have 20% of the volume of the uncompacted puck. The PIER model makes assumptions about the ramp up in use of treatment services to reflect their start and increasing use, hence parameters are required to be set on the dates of first use and full utilisation of each type of service. Although it may be possible to segregate wastes, it may not be possible because of the acceptance criteria of the treatment services to treat all the segregated wastes, hence there are 'Max fraction' parameters giving the fraction of segregated wastes assumed to be treated. Wastes will not completely fill the internal volume of a waste container and hence a 'Packing fraction into a container' needs to be set in the model. Also, the difference between the internal and external volumes of a container and the efficiency with which containers can be placed to fill the envelope volume of a vault need to be taken into account. These factors are accounted for using a single parameter, 'Packing fraction into a container'.

The calculation of the waste volume that can be emplaced in an individual vault takes account of the packing efficiency of waste into containers and of containers into the vault. The actual 'air space' volumes of each vault for the receipt of waste is taken from the design assumed in the 2011 ESC and planning application, see Table 2. The volume of Vault 8 given in Table 2 is the total volume available (assuming maximum higher stacking); the remaining available volume assumed is given in Table 1.

Table 2 2011 ESC vault disposal capacities

Vault	Volume (m^3)[1]
Vault 8	308,000
Vault 9	247,000
Vault 9A	23,000
Vault 10	171,000
Vault 11	120,000
Vault 12	125,000
Vault 13	141,000

Vault 14	162,000
Vault 15	*153,000**
Vault 16	*98,000**
Vault 17	*122,000**
Vault 18	*72,000**
Vault 19	*67,000**
Vault 20	*61,000**

1 Air space volumes to the nearest 1000 m^3
* The EDA vaults would be higher stacked to accommodate the increased waste relating to Case B (see below)

Four high-level inventory cases were considered in the 2011 ESC to give an insight into uncertainties over future waste arisings:

In summary Case A is based on:

- Inclusion of all materials identified in the UKRWI as LLW unless it can be confidently assumed that they will be routed elsewhere.
- Exclusion of all waste streams comprising of very low active wastes on the basis that these will be more appropriately disposed of to a facility other than LLWR.
- Inclusion of all waste streams in the UKRWI arising from the management of contaminated land (with the exception of waste from Dounreay and a small amount from Sellafield assumed to be disposed locally).
- Inclusion of LLW identified as routed to the deep Geological Disposal Facility.
- Inclusion of 'orphan' wastes (i.e. those with no routing information).
- Exclusion of new build wastes.

Case A was taken as the 'Reference Case', and was intended as a representation of a reasonable bounding case for wastes in the UKRWI. Case B considers the effects of a new nuclear build programme on the inventory of LLWR. Case C addresses the effects of uncertainties in the disposed volume to illustrate the effects of VLLW diversion, and Case D considers the effects of alternative routing for some waste streams associated with the management of contaminated land. Case B assumed a fleet of eight new reactors. Case C assumed an arbitrary 25% reduction in physical volume (but not radioactivity).

The vault fill dates calculated using the PIER model for the four cases are given in Table 3.

Table 3 2011 ESC fill dates for vaults

Vault	Fill date (†)			
	Case A	Case B	Case C	Case D
8	2011	2011	2013	2012
9*	2022	2022	2026	2022
10	2027	2027	2031	2028
11	2030	2030	2047	2039

12	2034	2034	2076	2057
13	2053	2052	2087	2077
14	2077	2076	2101	2089
15	2086	2087	-	-
16	2092	2094	-	-
17	2100	2101	-	-
18	2106	2107	-	-
19	2111	2112	-	-
20	2126$	2127	-	-

† Dates rounded to last year in which disposals occur
* Includes Vault 9A
\- Only Cases A and B were included in the EDA assessment
$ PIER calculates that approximately 10 m^3 of waste will not fit in Vault 20, in effect the fill date is 2127

Revised Results for Vault-fill Dates

The vault-fill dates have been recalculated using the latest available inventory data, from the 2013 UKRWI. The multiplicative factors have also been revised based on experience thus far in application of waste diversion to landfill, incineration and metal treatment (supercompaction has been in use since the mid-1990s), and packing efficiency in containers. Information on waste diversion, treatment and disposal in the period April 2012 to September 2014 has been used. The revised factors are given in the third column of Table 1, with an explanation given in the fourth column.

The revised results for vault-fill dates are given in Table 3. Only results for inventory Cases B and C are given. It now seems much more likely that there will be a fleet of new reactors and hence it is reasonable to now use Case B as the reference case (although the difference in fill dates between Cases A and B is small, less than a year for early vaults when only small amounts of operational wastes are being created – see Table 2). Case C, illustrative of large amounts of VLLW diversion from LLW streams not labelled as very low activity streams, has now been adjusted to include the fleet of new reactors.

Case B suggests that Vaults 10, 11 and 12 will be required to be constructed before 2050 although it is possible that some segregation of VLLW out of LLW streams will be achieved although not necessarily to the extent assumed for Case C. Segregation of LLW out of Intermediate Level Waste (ILW) streams would counter this effect – see below.

Table 3 Revised fill dates for vaults

Vault	Fill Date	
	Case B	Case C
8	2013	2013
9	2023	2028
10	2035	2051

11	2048	2076
12	2073	2081
13	2077	2090
14	2086	2095
15	2090	2100
16	2092	2103
17	2095	2113
18	2097	2129
19	2098	-
20	2099	-
21	2129	-

A profile of volumes of waste requiring disposal at the LLWR is given in Figure 1. The volumes shown are those of the wastes after diversion and treatment but do not include associated packaging volumes, i.e. the volumes are those of the wastes and not the containers of wastes. The initial spike arises because the PIER model assumes all ‘stock’ wastes arrive straightaway. The total volume of wastes has increased in the 2013 UKRWI from the 2007 UKRWI but the waste arisings in earlier decades have reduced.

Figure 2 gives the percentage breakdown by material type for the wastes before any diversion and treatment other than diversion to other disposal facilities. The diversion to other facilities includes that of the low-activity wastes to landfill. The information is for wastes arising out to the 2129 end date of the 2013 UKRWI. The total volume of the waste is 1,160,018 m^3. Figure 3 gives the same information but for wastes arising up to 2050, the total volume of waste in this case being 402,632 m^3.

Figures 4 and 5 give the sources of these wastes by organisation.

Figure 1 Profile of waste arisings

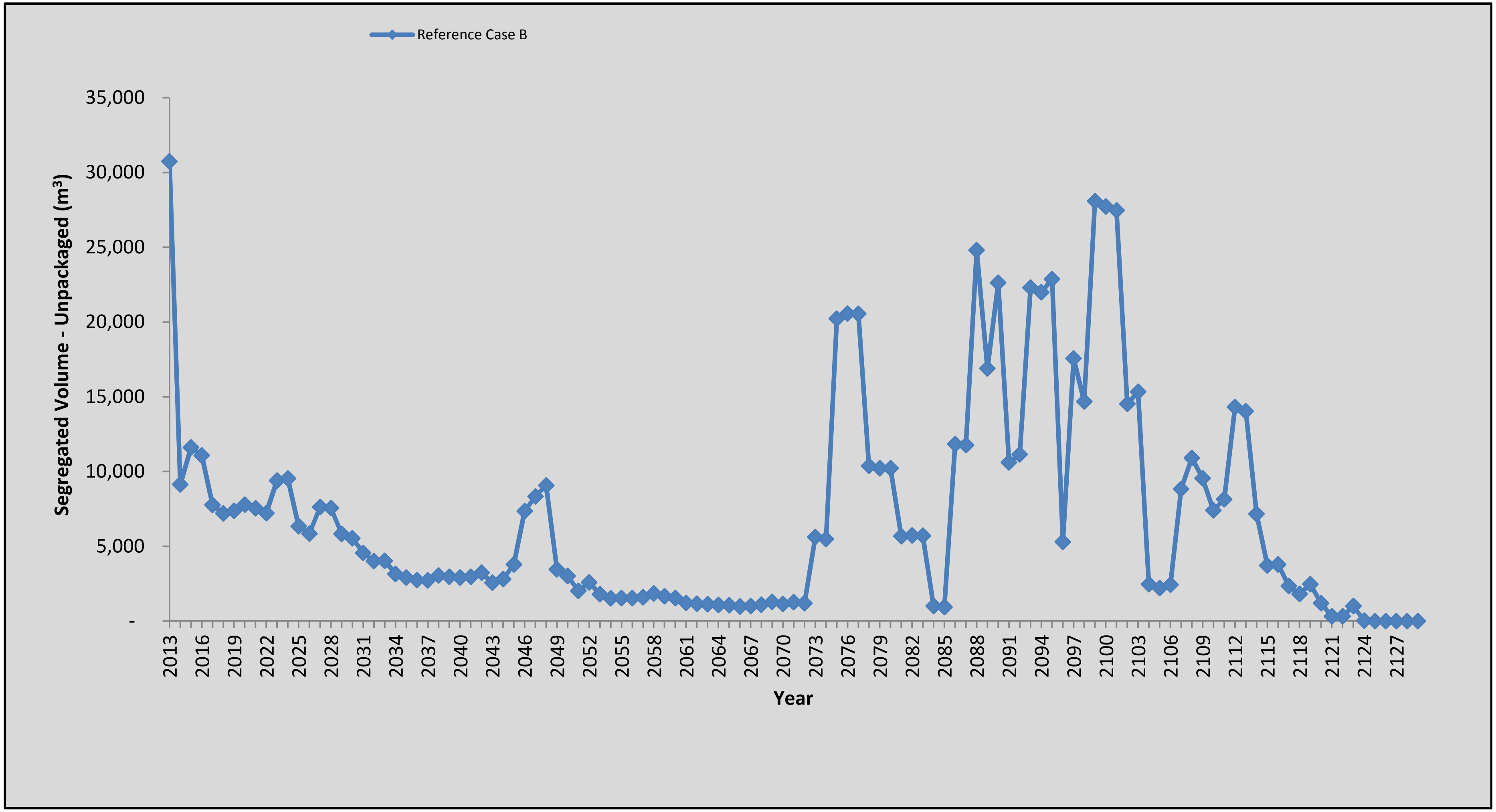


Figure 2 Waste composition – inventory to 2129

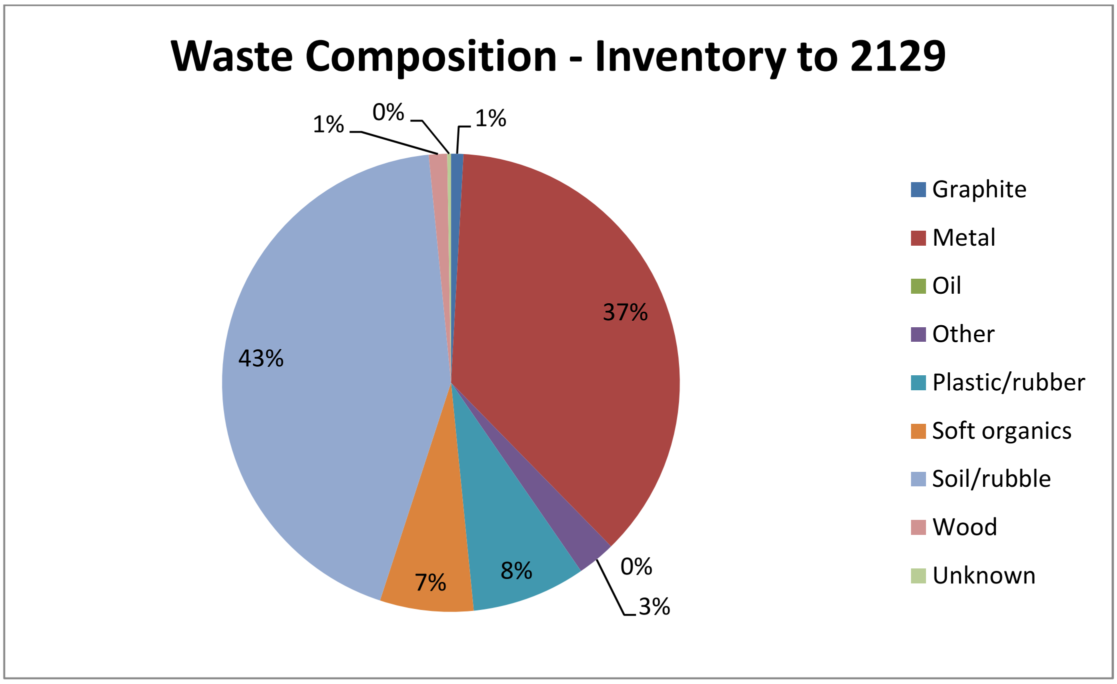


Figure 3 Waste composition – inventory to 2050

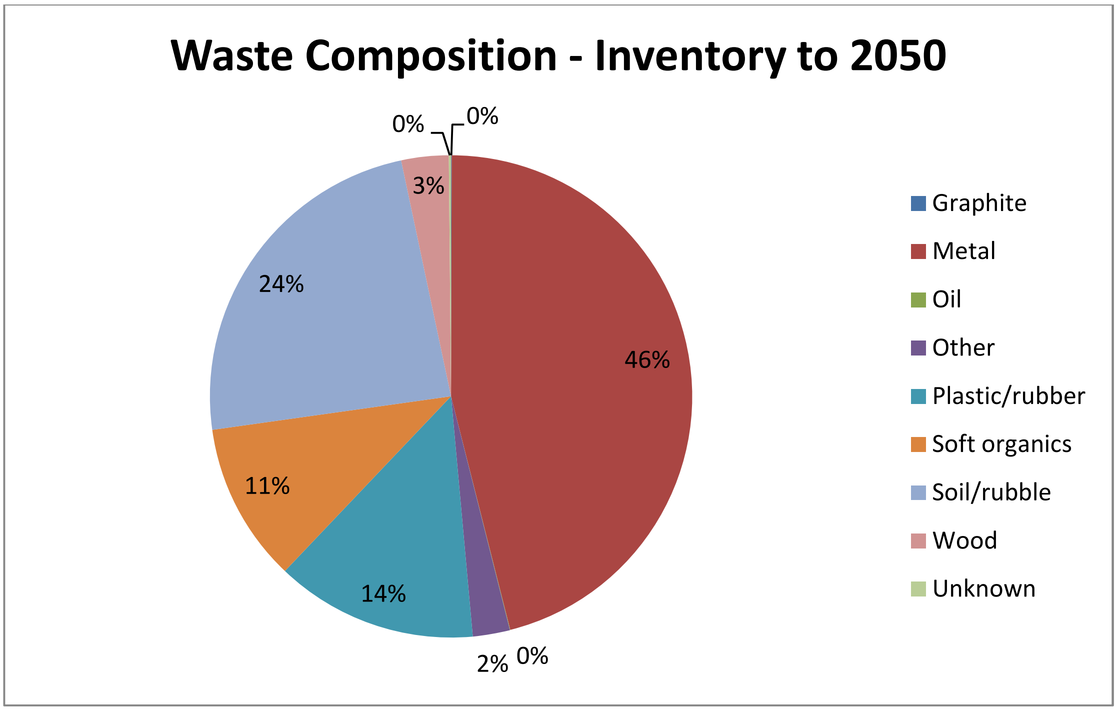


Figure 4 Waste consignors – inventory to 2129

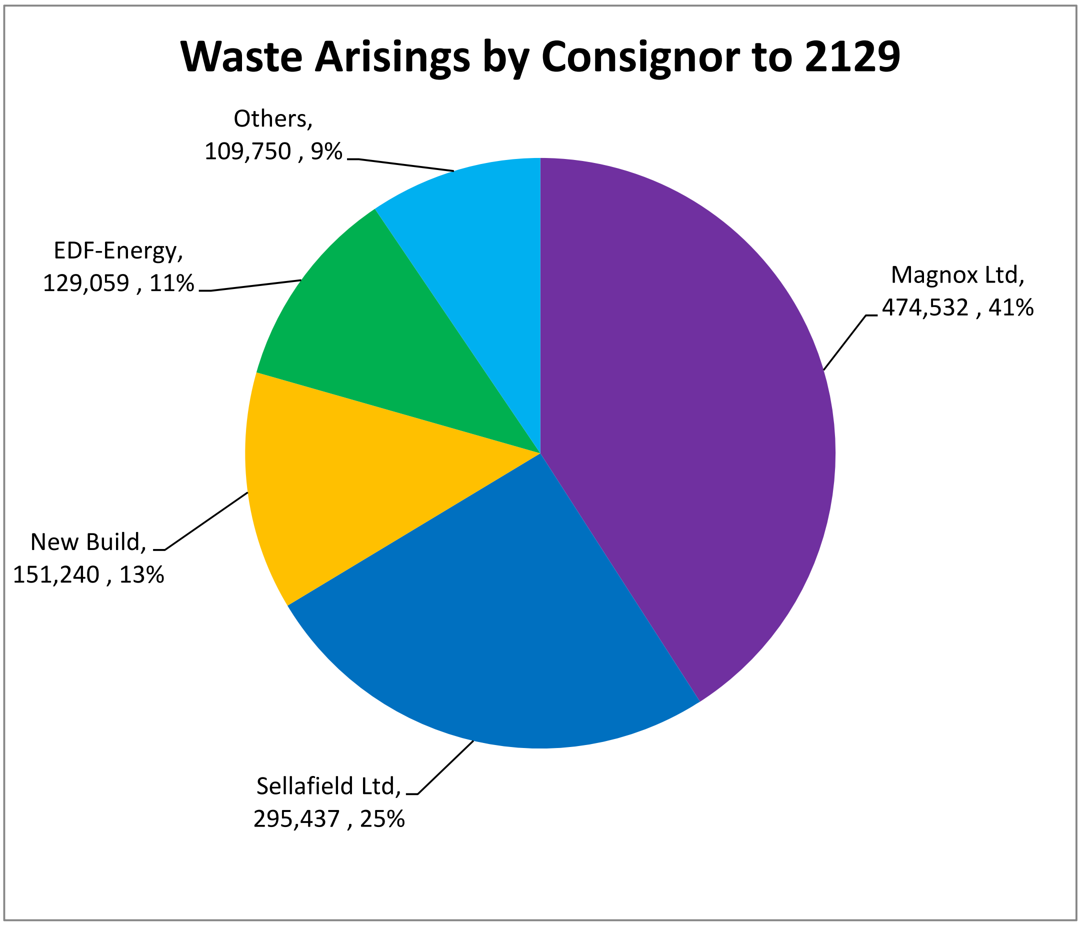
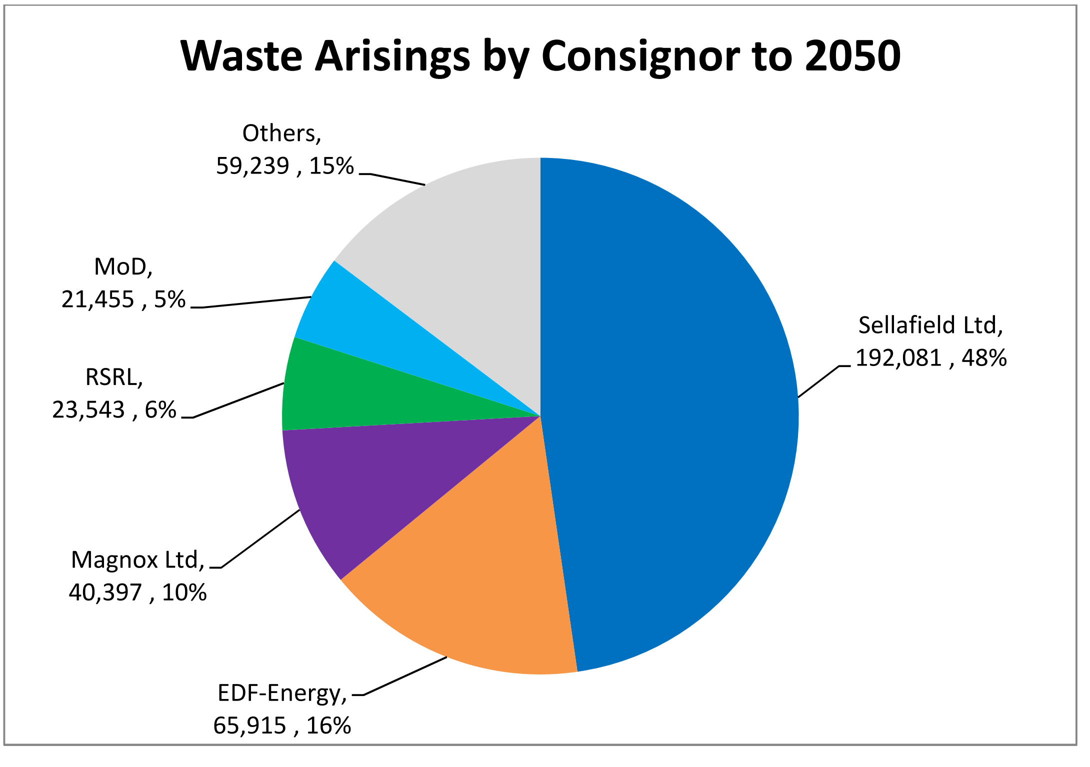


Figure 5 Waste consignors – inventory to 2050



Discussion of Uncertainties

There are a number of factors that lead to uncertainties in the volumes and timescales of arisings of wastes needing disposal at the LLWR. Uncertainties are discussed in this section.

The effect of some uncertainties can be explored using the PIER model and these are discussed first. Only ones where it is judged that the uncertainties have the potential to cause a significant effect are considered here. Case B is used as the reference case.

It was assumed for the 2011 ESC that all available space above Vault 8 in the final cap profile would be higher stacked with waste containers. Within the context of the ESC, this maximised the radiological inventory in Vault 8. It is unlikely that it will be possible to use all the available space because insufficient waste containers will be received before the vault needs to be closed. It has been assumed in the revised PIER calculations that all the currently stored waste containers in Vaults 8 and 9 plus six hundred new containers would be disposed in Vault 8 (see Table 1). It is currently unclear whether or not it will be possible to justify higher stacking of waste in Vault 8 because of uncertainties in the amount of voidage in existing waste containers (not accepted under the new Waste Acceptance Criteria derived from the 2011 ESC), which affect final cap performance. An illustrative calculation has been undertaken assuming no higher stacking in Vault 8. The available disposal volume in Vault 8 has been reduced in the calculation to that provided by the small volume at the north end of Vault 8 where no waste is currently disposed (6,000 m^3). The available volume in Vault 9 has been reduced by the volume of waste containers currently higher stacked in Vault 8 and stored in Vault 9 (36,000 m^3). The results are given in Table 4. The decrease in available disposal space leads to the earlier filling of most vaults by a few years.

Table 4 Effect of no higher stacking Vault 8

Vault	Fill Date	
	Reference Case B	No higher stacking in Vault 8
8	2013	2013
9	2023	2021
10	2035	2031
11	2048	2046
12	2073	2062
13	2077	2076
14	2086	2082
15	2090	2089
16	2092	2091
17	2095	2094
18	2097	2095
19	2098	2097

20	2099	2099
21	2129	2129

In order to enable diversion of wastes for incineration or metal treatment, the treatable wastes must be segregated. For a range of practical and safety reasons, complete segregation is often not possible. For the 2011 ESC, it was assumed that wastes can be segregated with a 75% efficiency and hence organic materials and metals may potentially be diverted for treatment. Available evidence has not suggested any reason to change this factor and the revised calculations reported above assumed the same 75% segregation factor (see Table 1). The choice of 75% is to some extent a judgment. Two further calculations have been undertaken, reducing the factor to 50% in one case and increasing it to the maximum possible 100% in the other. The results are given in Table 5. The results show that the efficiency of segregation does have a significant effect on vault-fill dates. The unrealistic assumption of complete segregation would still require Vault 11 to be constructed before 2050.

Table 5 Effects of altered waste segregation efficiency

Vault	Fill Date		
	Reference Case B – 0.75 Segregation Factor	**0.50 Segregation Factor**	**1.00 Segregation Factor**
8	2013	2013	2013
9	2023	2021	2027
10	2035	2028	2048
11	2048	2038	2075
12	2073	2048	2077
13	2077	2073	2086
14	2086	2077	2090
15	2090	2085	2094
16	2092	2088	2097
17	2095	2090	2099
18	2097	2092	2101
19	2098	2094	2102
20	2099	2095	2103
21	2129	2129	2129

A factor that has a significant effect on the quantities of waste that can be disposed in a vault is the packing fraction of waste in a disposal container. A packing fraction of 60% (of the internal volume of a container) was assumed in the 2011 ESC. It was recognised at the time that this was much higher than had been achieved in practice but it was thought that over the assumed hundred-year operational lifetime of the Repository more efficient packing of waste in a vault might be achievable. However, no evidence of an improvement has been seen thus far and on reflection 60% is an ambitious target certainly in the near future. For the revised calculations, where the interest is in the shorter-term, it seems appropriate to select a packing fraction being achieved now. Based on data on the amounts of grout used to fill the voidage in containers over the last two and half years, a packing fraction of 47% has been calculated and this fraction was used in the revised calculations (see Table 1). Two further calculations have been undertaken to illustrate the effect of this packing fraction, one with the 2011 ESC value of 60% and another with a reduced value of 40%. This latter value has been advised to LLWR as Magnox Ltd's planning assumption. Magnox Ltd is the largest source of LLW in the UKRWI. The results are given in Table 6. If Magnox Ltd's baseline assumption is correct for future waste disposals, Vault 13 would be required to be constructed by 2050. Even with an approximately 30% improvement in packing fraction (from 47 to 60%), construction of Vault 11 would still be required before 2050.

Table 6 Effects of container packing efficiency

Vault	Fill Date		
	Reference Case B – 0.472 Packing Factor	0.40 Packing Factor	0.60 Packing Factor
8	2013	2013	2013
9	2023	2021	2027
10	2035	2029	2048
11	2048	2040	2075
12	2073	2049	2078
13	2077	2074	2088
14	2086	2077	2093
15	2090	2083	2097
16	2092	2088	2100
17	2095	2090	2102
18	2097	2091	2107
19	2098	2093	2111
20	2099	2094	2114
21	2129	2129	2129

The efforts by the Nuclear Decommissioning Authority (NDA), waste producers and the LLWR to encourage and enable much improved waste diversion and treatment over the last few years have led to significant reductions in the amounts of waste being disposed at the LLWR. It should be recognised, however, that the overall volumes of radioactive waste are small compared with other wastes and the supply chain providing incineration and metal treatment is not robust. There are only a small number of service suppliers. Any one of a number of problems could lead to at least reduced diversion and treatment permanently or for a significant length of time. To illustrate the importance of treatment and diversion, a calculation has been undertaken assuming no incineration of organic materials and metal treatment (but retaining diversion of VLLW to landfill). The results are given in Table 7. With no incineration and metal treatment, construction of Vault 15 would need to begin before 2050.

Table 7 Effects of no waste diversion for incineration or metal treatment

Vault	Fill Date	
	Reference Case B	No Waste Diversion
8	2013	2013
9	2023	2019
10	2035	2024
11	2048	2028
12	2073	2032
13	2077	2042
14	2086	2051
15	2090	2074
16	2092	2076
17	2095	2079
18	2097	2081
19	2098	2086
20	2099	2088
21	2129	2129

Illustrative calculations have also been undertaken with the PIER model to show the effects of complete segregation and treatment of all organic and metal wastes. The results for both Cases B and C are shown in Table 8. In the reference Case B, construction of Vault 11 is still required before 2050. In Case C, where the unrealistic assumption of complete diversion and treatment of organic and metal wastes is made, along with 25% of the waste in LLW streams being segregated into VLLW and diverted to landfill, construction of Vault 10 would still be required before 2050.

Table 8 Complete segregation and treatment of organic and metal wastes

Vault	Fill Date		
	Case B (reference)	Case B (complete segregation)	Case C (complete segregation)
8	2013	2013	2013
9	2023	2027	2040
10	2035	2048	2076
11	2048	2075	2081
12	2073	2077	2089
13	2077	2086	2094
14	2086	2090	2100
15	2090	2094	2108

16	2092	2097	2129
17	2095	2099	2113
18	2097	2101	2129
19	2098	2102	-
20	2099	2103	-
21	2129	2129	-

The above discussion focusses on the uncertainties associated with specific parameters in the PIER model. It is also appropriate to consider the overall accuracy of the model. It is possible to examine bulk volumes of wastes disposed and diverted to gain some insight into the overall level of success of diversion and treatment and the accuracy of the data and assumptions used in the PIER model calculations. It should be noted that whilst the efforts to divert and treat wastes have clearly been very successful, the extent of that success is difficult to analyse in detail at a UKRWI waste stream level because data relating to which waste streams diverted wastes are derived from are not available.

Table 9 shows the total volumes of wastes disposed and diverted to different management routes in the period April 2012 to September 2014.

Table 9 Wastes disposed and diverted

Management Route	Volume (m^3)	Percentage
Disposal at LLWR	5,051	20
Metal treatment	4,739	19
Incineration	4,938	20
Landfill disposal	10,053	41

The revised PIER model calculations suggest that approximately 35,000 m^3 of waste should have arisen with 25,000 m^3 being for disposal over the two-and-half-year period. These volumes exclude wastes from low-activity LLW streams. The 10,000 m^3 difference compares well with the data given in Table 9 for metal treatment and incineration, however, it is not known what fraction of these treated wastes originated from low-activity LLW streams that the PIER model assumes would be diverted to landfill (in Case B). It should also be noted that recent actual data and future estimates are being compared here.

The landfill disposal figure in Table 9 includes waste labelled as low-activity LLW in the UKRWI. It is not in general known whether the approximately 10,000 m^3 of low-activity LLW shown in Table 9 was derived from low-activity LLW streams or from segregation of low-activity LLW out of waste streams labelled LLW in the UKRWI. It is known that approximately 5,000 m^3 was derived from a single RSRL Ltd VLLW stream (5C300). Hence, up to 5,000 m^3 may be waste segregated and diverted from LLW streams, reducing the apparent over-estimation of wastes for disposal.

There are a number of further possible reasons for the over-estimate of disposal volumes. One is simply that there are over-estimates of waste volumes in the underlying UKRWI. On the other hand, it may be that waste consignment may be slower than assumed overall for the UKRWI either because of slower progress in decommissioning or the 'levelling' of waste volumes across the life of a waste stream generally assumed in the UKRWI. It is also possible that the NDA's incentivisation of its estate to improve waste diversion and treatment has led to some advanced diversion of divertible and treatable wastes at the expense of wastes requiring disposal. It is plausible to argue that more of the volumes of waste for disposal calculated by the PIER model will still arise.

There are a number of other reasons why the volumes of wastes needing to be disposed over the next few decades might alter and hence the disposal capacity required change. Some of these reasons might lead to significant increases in the need for disposal capacity.

The success in diverting and treating LLW and hence reducing the volume of wastes disposed at the LLWR over the last few years has been noted above. Similar efforts are now being made with wastes currently labelled as Intermediate Level Wastes (ILW). Some of these wastes might now be suitable for disposal at the LLWR for a range of reasons, for example:

- better characterisation;
- segregation out of a LLW portion;
- radioactive decay leading to the wastes meeting the LLW definition.

The LLWR is currently assessing two proposals for disposing of two types of waste from 15 waste streams originally characterised as ILW. These are not included in the PIER calculations.

Some of the low-activity LLW waste streams in the UKRWI have large volumes. It is likely that it will not be possible to divert all these wastes to landfill facilities and that some of this waste will require disposal as LLW at the LLWR.

The LLWR currently receives little NORM (naturally occurring radioactive material) waste for disposal. Most such wastes are not included in the UKRWI and data on their volumes are limited. It is known that there are large volumes that will need management by some route. Some NORM contains significant quantities of radium and the radiological capacity of the LLWR to take radium is limited, nevertheless, LLWR might receive and accede to requests in the future to dispose of more NORM waste.

The waste arising profile in Figure 1 shows that the majority of LLW requiring disposal at the LLWR will arise in the period after about 2070. These wastes largely arise from final stage decommissioning of the United Kingdom's gas-cooled reactor fleet. The assumption underlying the current UKRWI data is that the reactors will be left, after defuelling and initial decommissioning, for some decades before final stage decommissioning. Consideration is being given to bringing forward the final stage decommissioning. Were final stage decommissioning to be accelerated and take place over the next few decades it would lead to very large increases in the disposal capacity required over the same timescales.

Source of the LLW

The LLWR is the United Kingdom's national facility for the disposal of LLW. In the context of the planning application, however, it should be noted that between fifty and sixty percent of the LLW in the 2013 UKRWI arising up to 2050 comes from within Cumbria, the great majority of it from Sellafield and resulting from decommissioning.

Conclusions from Reported Calculations

Based on the results of the revised PIER model calculations presented and discussed above, there is a high probability that in the next few decades up to 2050 there will be a need to construct at least two further vaults, Vaults 10 and 11, at the LLWR and possibly more. In a number of the cases considered here, construction of Vault 12 would be required before 2050.

Whilst there are uncertainties about the volumes and timescales of waste arisings, based on current experience and foreseeable progress with waste diversion and treatment, there is every reason to believe that a number of further disposal vaults will be required and certainly Vaults 10 and 11.

There being less waste than reported in the UKRWI and further improvements in LLW management over those assumed for the revised PIER model calculations might reduce the volumes of waste requiring disposal over the next few decades; however, other uncertainties in waste volumes and timescales of arisings are such that much larger volumes of disposal capacity might be required than would be provided by Vaults 10 and 11.

Based on the revised PIER model calculations, it is likely that Vault 11 will be required to be constructed within the timescales needed to develop an alternative disposal facility. Developing an alternative facility would require engaging with stakeholders, identifying an alternative site, gaining the necessary regulatory and planning permissions, and constructing the facility. These activities would take many years or even decades.

Much of the disposal volume provided by Vaults 10 and 11 will be required for wastes from decommissioning high-hazard facilities at Sellafield.

Results for Reduced Vault Volumes

Following discussions with Council planning officers based on the above results and analysis, two further calculations with the PIER model have been undertaken with adjusted vault volumes. The calculations are based on the suggestion that any planning permission would be time-limited to 2050.

In the first new calculation, the volumes of Vaults 10 and 11 have been reduced such that the disposal volume that would be available in the remaining capacity in Vaults 8 and 9 and any new capacity in Vaults 9A, 10 and 11 is such that it could accommodate the volume of waste arising up to 2050 reduced by ten percent. Were planning permission to be granted for the small additional volume provided by Vault 9A, plus two new vaults with the assumed reduced volume, it would present a further incentive to the industry to reduce the volumes of LLW requiring vault disposal at the LLWR. (Hence, the ten percent reduction has been applied to the wastes predicted to arise from now, 2015.)

The revised Case B inventory assumed for the results given in Table 3 has been used for both the new calculations. The volume of processed wastes predicted to arise between 2013 (the start of the 2013 UKRWI) and 2050 is 245,000 m^3. With a ten percent reduction in wastes arising from 2015 of 20,000 m^3, the volume of waste that would require disposal is 224,000 m^3 (numbers rounded). The 20,000 m^3 of processed waste requires a vault volume of 50,000 m^3 for disposal.

The vault volumes assumed in the first new calculation are given in Table 10.

Table 10 Revised vault disposal capacities for the ten percent volume reduction to 2050

Vault	Volume (m^3)
Vault 8	308,000
Vault 9	247,000
Vault 9A	23,000
Vault 10	120,000
Vault 11	120,000
Vault 12	125,000
Vault 13	141,000
Vault 14	162,000
Vault 15	153,000
Vault 16	98,000
Vault 17	122,000
Vault 18	72,000
Vault 19	67,000
Vault 20	61,000

The reduced volumes of Vaults 10 and 11, sized for the reduction in the volume of the waste arising by ten percent, are 120,000 m^3 each assuming equal volumes.

The revised fill dates are given in Table 11.

Table 11 Fill dates for vaults for the ten percent volume reduction to 2050

Vault	Fill Date
8	2013
9	2023
10	2030
11	2045
12	2060
13	2076

14	2081
15	2088
16	2090
17	2094
18	2095
19	2097
20	2099
21	2129

With the smaller volume of Vaults 10 and 11, the PIER model calculates that Vaults 10 and 11 will fill at the earlier dates of 2030 and 2045.

For the second new calculation, the volumes of Vaults 10 and 11 have been set to accommodate all the waste calculated to arise to 2050 based on the 2013 UKRWI (and the assumptions in the PIER model discussed earlier in the paper), without any ten percent reduction.

The vault volumes assumed in the second new calculation are given in Table 12.

Table 12 Revised vault disposal capacities to finish filling Vault 11 in 2050

Vault	Volume (m^3)
Vault 8	308,000
Vault 9	247,000
Vault 9A	23,000
Vault 10	162,000
Vault 11	162,000
Vault 12	125,000
Vault 13	141,000
Vault 14	162,000
Vault 15	153,000
Vault 16	98,000
Vault 17	122,000
Vault 18	72,000
Vault 19	67,000
Vault 20	61,000

The volumes of Vaults 10 and 11, sized to ensure Vault 11 is filled during 2050, are 162,000 m^3, assuming equal volumes.

The revised fill dates are given in Table 13.

Table 13 Fill dates for vaults with vault 11 filling in 2050

Vault	Fill Date
8	2013
9	2023
10	2034
11	2050
12	2075
13	2078
14	2087
15	2090
16	2093
17	2095
18	2097
19	2099
20	2100
21	2129

1 Harper A, User Guide for PIER V 2.2: A Tool for Calculating the Forward Inventory of LLWR, Serco/TAS/003756/013 Issue 2, April 2011
2 Harper A, ESC 2011: The Disposed and Forward Inventory, Serco Report Serco/E003756/12 Issue 2, April 2011.