Radioactive Waste Management

DSSC/406/01

Inventory for geological disposal

Differences Report

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Preface

Radioactive Waste Management Limited (RWM) has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for the geological disposal of the higher activity radioactive wastes in the UK. As a pioneer of nuclear technology, the UK has accumulated a legacy of higher activity wastes and material from electricity generation, defence activities and other industrial, medical and research activities. Most of this radioactive waste has already arisen and is being stored on an interim basis at nuclear sites across the UK. More will arise in the future from the continued operation and decommissioning of existing facilities and the operation and subsequent decommissioning of future nuclear power stations.

Geological disposal is the UK Governments’ policy for higher activity radioactive wastes. The principle of geological disposal is to isolate these wastes deep underground inside a suitable rock formation, to ensure that no harmful quantities of radioactivity will reach the surface environment. To achieve this, the wastes will be placed in an engineered underground facility – a geological disposal facility (GDF). The facility design will be based on a multi-barrier concept where natural and man-made barriers work together to isolate and contain the radioactive wastes.

To identify potentially suitable sites where a GDF could be located, the Government has developed a consent-based approach based on working with interested communities that are willing to participate in the siting process. The siting process is on-going and no site has yet been identified for a GDF.

Prior to site identification, RWM is undertaking preparatory studies which consider a number of generic geological host environments and a range of illustrative disposal concepts. As part of this work, RWM maintains a generic Disposal System Safety Case (DSSC). The generic DSSC is an integrated suite of documents which together give confidence that geological disposal can be implemented safely in the UK.

Executive Summary

RWM maintains an inventory of the higher activity radioactive waste destined for geological disposal. This report presents the differences between the 2016 inventory for geological disposal (IGD) and the previous iteration (the 2013 IGD).

The IGD is based on Government policy, industry plans and other assumptions. The key assumptions remain unchanged. However, there have been some changes to the assumptions (and data) that are reported in the UK radioactive waste inventory (UK RWI), which is a principal source of data for the IGD. The most significant changes are:

- an increase in the quantity of depleted, natural and low-enriched uranium (DNLEU) as a result of an increase in the assumed period of enrichment operations at Capenhurst
- an increase in the quantity of advanced gas cooled reactor (AGR) spent fuel (SF) as a result of AGR lifetime extensions
- an increase in the quantity of high level waste (HLW) as a result of an increased estimate of post operational clean out (POCO) wastes
- a change from robust shielded containers (RSCs) to 6 m^3 boxes for packaging some wastes at some Magnox stations, and
- a re-evaluation of some plutonium contaminated material (PCM) wastes that has resulted in a revised density and therefore changes to the masses of various materials

In addition to these changes, RWM has also improved the packaging assumptions for DNLEU to provide a more realistic estimate of the number of waste packages.

The impact of these changes on a number of key parameters has been assessed:

- the packaged volume of waste has reduced slightly (-3%), primarily as a result of improved assumptions being adopted for the packaging of DNLEU
- there has been no significant change in the number of disposal units
- the total activity has increased slightly (+2% at 2200), mainly associated with the increased quantities of legacy spent fuels and HLW
- the most significant changes to the materials in the inventory arise as a result of the re-evaluation of PCM streams with reductions in several material types, most notably a reduction of 17% in the total quantity of organics. Other notable changes include a 16% increase in the quantity of heavy metal oxide as a result of the increased arisings of DNLEU

Uncertainty in the IGD is explored through the consideration of a number of alternative scenarios. The impact of the changes to the inventory on these scenarios has also been evaluated in this report:

- the uncertainties in volume and radioactivity continue to have the greatest impact, and this impact is dominated by a small number of waste streams
- data are now provided to enable the impact of including the UK advanced boiling water reactor (ABWR) to be quantified.

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1 Introduction

1.1 The generic Disposal System Safety Case

RWM has been established as the delivery organisation responsible for the implementation of a safe, sustainable and publicly acceptable programme for geological disposal of the UK's higher activity radioactive waste. Information on the approach of the UK Government and devolved administrations of Wales and Northern Ireland[1] to implementing geological disposal, and RWM's role in the process, is included in an overview of the generic Disposal System Safety Case (the Overview) [1].

A geological disposal facility (GDF) will be a highly-engineered facility, located deep underground, where the waste will be isolated within a multi-barrier system of engineered and natural barriers designed to prevent the release of harmful quantities of radioactivity and non-radioactive contaminants to the surface environment. To identify potentially suitable sites where a GDF could be located, the Government is developing a voluntarism approach based on working with interested communities that are willing to participate in the siting process [2]. Development of the siting process is ongoing and no site has yet been identified for a GDF.

In order to progress the programme for geological disposal while potential disposal sites are being sought, RWM has developed illustrative disposal concepts for three types of host rock. These host rocks are typical of those being considered in other countries, and have been chosen because they represent the range that may need to be addressed when developing a GDF in the UK. The host rocks considered are:

- higher strength rock, for example, granite
- lower strength sedimentary rock, for example, clay
- evaporite rock, for example, halite

The inventory for disposal in the GDF is defined in the Government White Paper on implementing geological disposal [2]. The inventory includes the higher activity radioactive wastes and nuclear materials that could, potentially, be declared as wastes in the future. For the purposes of developing disposal concepts, these wastes have been grouped as follows:

- high heat generating wastes (HHGW): that is, spent fuel from existing and future power stations and high level waste (HLW) from spent fuel reprocessing. High fissile activity wastes, that is, plutonium (Pu) and highly enriched uranium (HEU), are also included in this group. These have similar disposal requirements, even though they don't generate significant amounts of heat.
- low heat generating wastes (LHGW): that is, intermediate level waste (ILW) arising from the operation and decommissioning of reactors and other nuclear facilities, together with a small amount of low level waste (LLW) unsuitable for near surface disposal, and stocks of depleted, natural and low-enriched uranium (DNLEU).

RWM has developed six illustrative disposal concepts, comprising separate concepts for HHGW and LHGW for each of the three host rock types. Designs and safety assessments for the GDF are based on these illustrative disposal concepts.

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[1] Hereafter, references to Government mean the UK Government including the devolved administrations of Wales and Northern Ireland. Scottish Government policy is that the long term management of higher activity radioactive waste should be in near-surface facilities and that these should be located as near as possible to the site where the waste is produced.

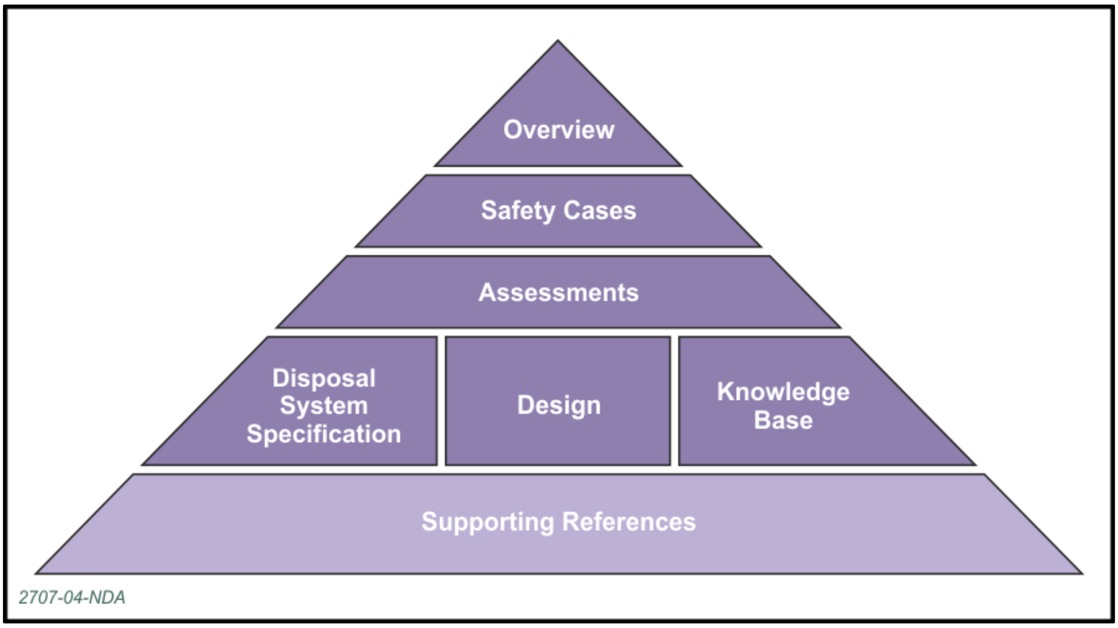
High level information on the inventory for disposal, the illustrative disposal concepts and other aspects of the disposal system is collated in a technical background document (the Technical Background) [3] that supports this generic Disposal System Safety Case.

The generic Disposal System Safety Case (DSSC) plays a key role in the iterative development of a geological disposal system. This iterative development process starts with the identification of the requirements for the disposal system, from which a disposal system specification is developed. Designs, based on the illustrative disposal concepts, are developed to meet these requirements, which are then assessed for safety and environmental impacts. An ongoing programme of research and development informs these activities. Conclusions from the safety and environmental assessments identify where further research is needed, and these advances in understanding feed back into the disposal system specification and facility designs.

The generic DSSC provides a demonstration that geological disposal can be implemented safely. The generic DSSC also forms a benchmark against which RWM provides advice to waste producers on the packaging of wastes for disposal.

Document types that make up the generic DSSC are shown in Figure 1. The Overview provides a point of entry to the suite of DSSC documents and presents an overview of the safety arguments that support geological disposal. The safety cases present the safety arguments for the transportation of radioactive wastes to the GDF, for the operation of the facility, and for long-term safety following facility closure. The assessments support the safety cases and also address non-radiological, health and socio-economic considerations. The disposal system specification, design and knowledge base provide the basis for these assessments. Underpinning these documents is an extensive set of supporting references. A full list of the documents that make up the generic DSSC, together with details of the flow of information between them, is given in the Overview.

Figure 1 Structure of the generic DSSC



1.2 Introduction to the 'Differences Report'

This document is the '2016 inventory for geological disposal: differences report'. It is one of five reports that deal with various aspects of the 2016 inventory for geological disposal (IGD). The other four reports are:

- the 'Main report' [4], which describes the principal features of the 2016 IGD
- the 'Method report' [5], which describes how IGDs are developed and updated
- the 'Implications report'[6], which describes the implications of the 2016 IGD for the generic DSSC
- the 'Alternative scenarios report' [7], which provides information on how changes to the scenario for future waste arisings would affect the previous version of the IGD (the 2013 IGD [8][2]).

The IGD is based largely on the UK Radioactive Waste and Materials Inventory (RWI). The UK has been producing RWIs for over 30 years. The production process has been improved iteratively and is now well-established. Each UK RWI contains details of stocks and arisings of all radioactive waste from existing sources (often called legacy wastes).

Currently, the UK RWI is updated every three years, after which the IGD is updated, as shown in Figure 2. Waste that will be managed through other routes (eg waste that is destined for Low Level Waste Repository (LLWR)) is removed from the UK RWI dataset and the remaining data are reviewed and, where appropriate, enhanced[3]. The dataset is further enhanced to take account of Government policy, industry plans and other assumptions to produce the IGD. Finally, following the production of the UK RWI (and IGD), NDA and key users of the UK RWI (LLWR and RWM) meet with waste producers to discuss key inventory improvements. In addition, further characterisation of wastes is carried out to support decommissioning, leading to improvements in the inventory data. This iterative process drives continued improvements in the UK RWI data and, as a consequence, the IGD.

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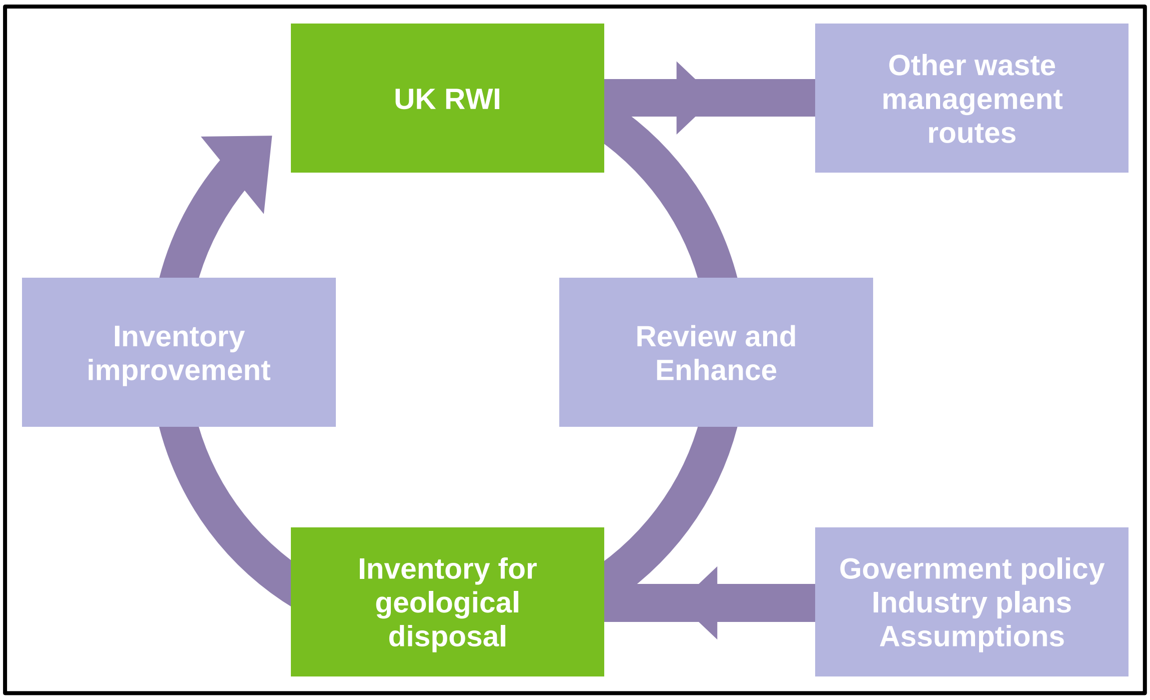
[2] Originally published as the '2013 Derived Inventory', it is referred to here as the 2013 IGD.

[3] For the purposes of this work, 'review' is defined as the process of identifying omissions, differences and inconsistencies within the 2016 UK RWI itself, and with other sources of data. 'Enhancement' is defined as the process of filling gaps and providing fully justified numeric and other data where these are not reported in the 2016 UK RWI. For example, the UK RWI only provides the mass of spent fuels. The enhancement process adds the radionuclide activities and materials and packaging assumptions.

Figure 2 The iterative development of the inventory for geological disposal



The most recent version of the UK RWI [9] is based on a stock date of 1st April 2016 and is referred to here as the 2016 UK RWI. The generic DSSC was published in 2017 and was based on the 2013 IGD [8], which in turn was based on the previous 2013 UK RWI [10]. The 2016 IGD is based on the 2016 UK RWI and is a 'light update'[4] of the 2013 IGD.

This report sets out the differences between the 2016 IGD and the 2013 IGD. It also updates the alternative scenarios report [7] so that it is consistent with the 2016 IGD. The report is new to the generic DSSC suite of documents.

1.3 Objective

The objective of this report is to document the differences between the 2013 and 2016 IGDs in order to support an assessment of the impact of the changes on the conclusions of the generic DSSC [1].

This report presents detailed technical information and is targeted at an audience of scientists and engineers, in particular RWM staff and contractors who will use this information as a basis for generic geological disposal design and assessment work.

1.4 Scope

1.4.1 The 2016 inventory for geological disposal

The 2016 IGD is based on the 2016 UK RWI and is a 'light update' from the 2013 IGD. In a 'light update', the full review and enhancement process is not carried out: where waste streams are unchanged, the enhancements from the previous inventory are carried over. In addition, some calculations (for example, calculations of metal geometry to support the gas

[4] The differences between a light and a full update are explained in the Method report [5].

pathway analysis) are not carried out. As a result, a comparison of these data is excluded from the scope of this report.

1.4.2 Waste groups

RWM's generic disposal facility designs [11] recognise the different packaging and disposal processes for different types of waste: LLW, ILW and DNLEU are assumed to be disposed of in a LHGW area; HLW, spent fuels, plutonium and HEU are assumed to be disposed of in a HHGW area[5].

The inventory for geological disposal has been broken down into waste groups (shown in purple in Figure 3) that have been chosen to reflect the different sources of waste and how they will be disposed of in the GDF. The sources of waste considered are:

- legacy: wastes and materials that already exist or that will arise in the future as a result of the operation of existing nuclear facilities
- new build: wastes and spent fuels from the proposed new build programme
- use of mixed oxide (MOX) fuel: at this stage only MOX SF is included

1.4.3 Data

Summary data are presented in Section 3, with a more detailed breakdown of the data by waste groups presented in the appendices. The data presented are those that are required to support an assessment of the implications of the inventory changes on the generic DSSC.

All data have been presented to three significant figures; this is considered to provide an appropriate quantification of the inventory data. In some cases, the data are not available or are not specified to three significant figures. In these cases, the data are presented to the level of precision to which they are known.

As a result of the rounding, some tables will show totals that may not represent the sum of the rounded data that are presented within the tables. Instead, the totals represent the sum of the data rounded to three significant figures. This approach ensures an appropriate and consistent level of precision in all of the data.

1.4.4 Alternative scenarios

Alternative scenarios are used to explore the effects on the IGD of changes in assumptions and uncertainties in data. A range of scenarios were defined for the 2013 IGD and their impacts on the inventory for disposal were determined [7]. In this report the definitions of the scenarios are examined in the light of the differences between the 2016 IGD and the 2013 IGD, and the definitions are changed where necessary. The impacts of the revised scenarios on the 2016 IGD are then evaluated.

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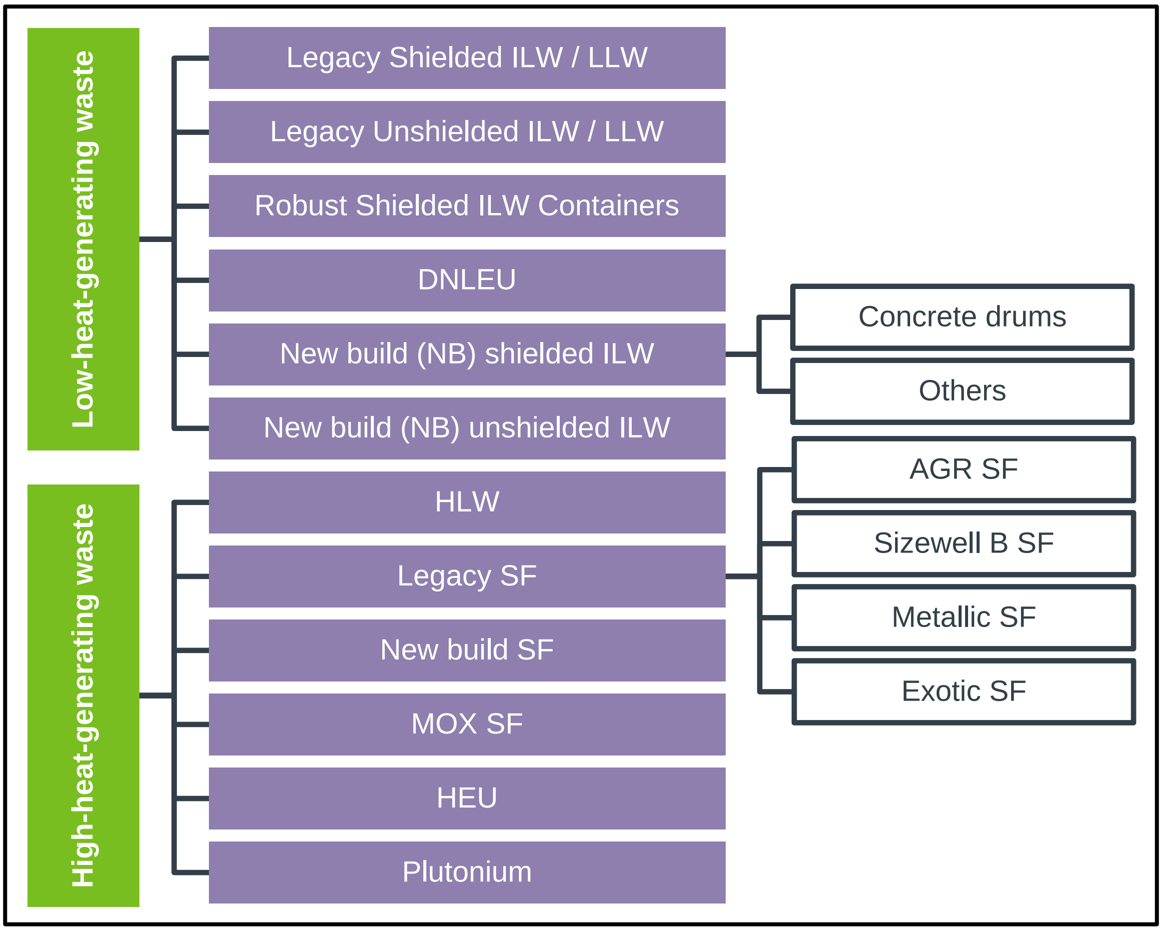
[5] HEU does not generate significant heat; it is included in the HHGW area as its disposal concept is very similar to that of the other HHGW.

Figure 3 **The two high-level partitions of the inventory (green boxes), the waste groups (purple boxes) and the sub-groups (white boxes)**



1.5 Report structure

The remainder of this document will report the changes between the 2016 IGD and the 2013 IGD as follows:

- Section 2: summary of changes in assumptions used as the basis for the IGD
- Section 3: summary of changes to quantities in the IGD
- Section 4: summary of changes to alternative scenarios and their impacts on the IGD
- Section 5: conclusions

In addition, this report contains four appendices which contain further detail:

- Appendix A : changes in waste streams
- 0: changes in quantities by waste group
- Appendix C : summary tables
- Appendix D : alternative scenarios

2 Changes to the scenario for the inventory for geological disposal

Summary of the changes to the scenario for the inventory

The changes to the scenario for the IGD are relatively small and arise from changes to industry plans and to the UKRWI. There have been no changes to Government policy.

The most significant changes to the scenario are: extensions to the lifetimes of some AGRs, a longer assumed duration of enrichment activities at Capenhurst, increases in quantities of legacy ILW and HLW and revised packaging assumptions for DNLEU.

There have been no changes to Government policy for the management of HAW.

The IGD is compiled using data sourced predominantly from the UK RWI. The data for future waste arisings in the UK RWI are projections made by the organisations that operate the sites where radioactive waste is generated. The projections are based on assumptions as to the nature, scale and timing of future operations and activities. In summary:

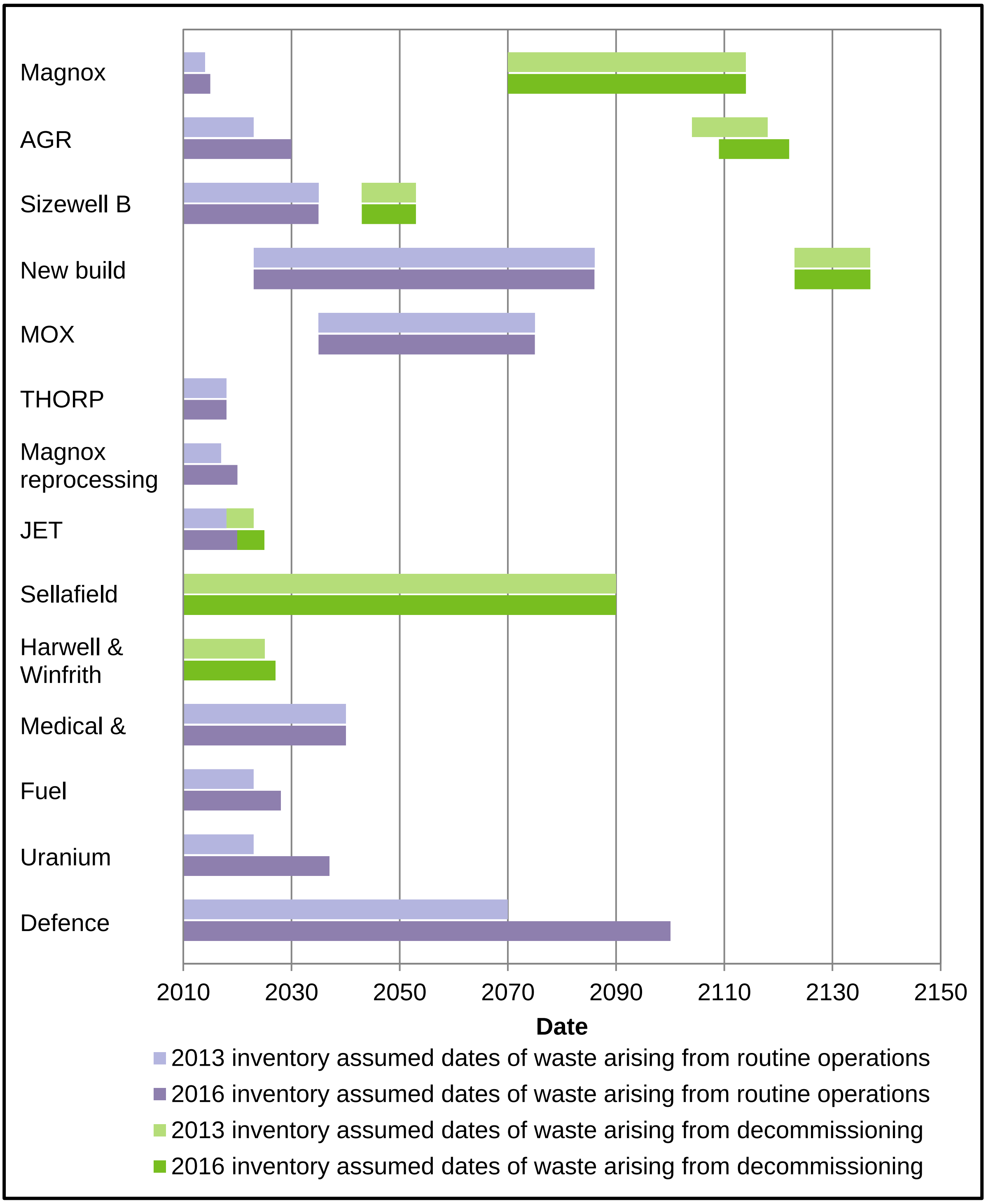
- changes have been made to assumed dates of operation and decommissioning
- there are improvements to the inventory, including those from better characterisation (affecting, for example, the number and types of packages used)

2.1 Changes to assumed dates of operation and decommissioning

Figure 4 provides a high-level overview of the timings of the different activities in the 2013 and 2016 IGDs; full details are provided in Table 1. Key changes include:

- lifetime extensions to AGRs
- extended operational period for uranium enrichment activities

Figure 4 The assumed dates of operation and decommissioning in the 2013 and 2016 IGDs[6]



6 Decommissioning of the Magnox reprocessing plant and THORP are covered by Sellafield decommissioning. No decommissioning dates have been specified for 'Fuel fabrication', 'Medical and industrial', 'Enrichment' or Defence as there is either no HAW decommissioning waste arising or the waste producer has not included an estimate of the decommissioning waste.

Table 1 Key assumptions for the 2013 and 2016 IGDs (differences in bold text)

Sector	2013 assumptions	2016 assumptions
Policy	HAW to be managed under Scottish Government's policy is excluded	
Civil nuclear power stations	Magnox: Wylfa operates to 2014 AGRs – Operate for between 35 and 47 years (site dependent) Deferral of Magnox & AGR final stage decommissioning for up to ~85 years after shutdown; all decommissioning complete by 2118	Magnox: Wylfa shut down in **2015** AGRs – Operate for between **41** and 47 years (site dependent). Dungeness B +10y; Heysham 1 & Hartlepool +5y; Heysham 2 & Torness +7y Deferral of Magnox & AGR final stage decommissioning for up to ~85 years after shutdown; all decommissioning complete by **2125**
	Sizewell B PWR – operates for 40 years; prompt decommissioning complete by 2053 16GW(e) new build programme comprising 6 UK EPRs and 6 AP1000s	
Enrichment	Continues to 2023 at Capenhurst	Continues to **2037** at Capenhurst
Spent fuel reprocessing	Magnox fuel reprocessing continues until 2017 (55,000 tU in total) 4,500 tU AGR SF is not reprocessed	Magnox fuel reprocessing continues until **2020** (55,000 tU in total) **5,500 tU** AGR SF is not reprocessed
	Oxide fuel reprocessing continues until 2018 (5,000 tU AGR fuel and 4,400 tU overseas LWR fuel) All reprocessing facilities fully decommissioned by 2120 Sizewell B SF, new build SFs and MOX SFs are not reprocessed	
Research & Development	JET operates to 2018 Harwell & Winfrith facilities fully decommissioned by 2025 Sellafield[7] decommissioned by 2090	JET operates to **2020** Harwell & Winfrith facilities fully decommissioned by **2027** Sellafield[7] decommissioned by 2090
Defence	Nuclear weapon programme – waste estimated to 2060 Nuclear powered submarine programme -waste estimated to 2070	Nuclear weapon programme – waste estimated to **2080** Nuclear powered submarine programme -waste estimated to **2100**
Medical & Industrial	GE Healthcare waste estimated to 2040	

7 Includes the historically separate site of Windscale

2.2 Changes to key assumptions for waste quantities and packaging

2.2.1 UK RWI changes

The 2016 IGD is based on the 2016 UK RWI and changes that are present in the UK RWI are incorporated into the IGD. Improvements to waste characterisation data, development of packaging plans and progress in packaging include:

- a re-assessment of: plutonium contaminated material (PCM) arisings at Sellafield; PCM operations waste at the LLWR; and PCM decommissioning arisings at AWE and Harwell
- revised forecasts of encapsulated floc, ion exchange material and encapsulated Magnox cladding at Sellafield
- reclassification of ILW Magnox fuel element debris (FED) and pond fuel skips as LLW at Magnox stations
- a change from robust shielded containers (RSCs) to 6 m^3 boxes for packaging some wastes at Magnox stations, and
- an additional 5,200 HAW packages in store

In addition, the 2016 IGD includes new waste streams, most of which represent wastes that have previously been reported under a different identifier. The reason for such renumbering of streams is usually associated with evolving plans for waste retrieval, processing and packaging, or where waste is now being packaged (indicated by a /C suffix in the identifier). There are also some new streams for individual wastes forecast to arise from current and future operations that were not previously reported. New waste streams in the 2016 IGD are reported in Appendix A1 and include:

- Magnox FED at Bradwell, Hinkley Point A, Oldbury and Sizewell A, where dissolution of FED is no longer the preferred strategy
- ‘problematic’ wastes at Sellafield not previously reported[8]
- wastes from Rutherford Appleton Laboratory (RAL) not previously reported[9]
- wastes reclassified as HAW, and
- wastes previously reported under a different identifier, including conditioned streams

Waste streams no longer included in the IGD are reported in Appendix 0 and include those:

- diverted from geological disposal to the LLWR, or for incineration or metal treatment
- associated with the dissolution treatment strategy for Magnox FED (see above), and
- reclassified as low active waste (LAW)

[8] Problematic radioactive waste, in the nuclear industry, describes any waste which has no defined waste treatment and disposal route available or for which existing routes are significantly suboptimal. Problematic wastes comprise a range of materials, generally of small volume. Examples can include oils, laboratory chemicals, resins and sludges.

[9] The wastes from RAL do not make a significant contribution to the inventory.

2.2.2 Quantities of legacy SFs

The quantities of legacy spent fuels have been updated to reflect changes in the UK RWI.

Whilst the UK RWI includes data on the quantity of spent fuels[10], it does not include any details of the materials that comprise the fuels, or their radionuclide inventories. It is necessary for RWM to make assumptions that allow the inventories to be calculated and these have not changed for the 2016 IGD. A summary of the key parameters is provided in Table 2 only the cooling times of the stocks have changed (to reflect the elapsed time between the 2013 and 2016 IGDs).

Table 2 Key parameters in the calculation of the fuel inventories

Spent fuel type	Enrichment [%]	Burn-up [GWd/tHM]	Cooling time [years]
AGR (pre-2013)	2.9	28	9
AGR (post-2013)	3.2 / 3.78	33	Arises as 1 yr cooled
Sizewell B (pre-2013)	4.2	45	11
Sizewell B (post-2013)	4.4	55	Arises as 1 yr cooled
Metallic fuels	0.71	4.1	39
Exotic fuels	(Pu) 29.5	189	22

2.2.3 Packaging assumptions for DNLEU

The 2016 IGD does not introduce any new package types. Whilst there have been no significant changes to the packaging assumptions for the majority of wastes, a modification has been made to the assumed waste loading for the uranium transport and disposal containers. The DNLEU is (or will be) packaged and stored in containers, and the 2013 IGD assumed that the quantity of DNLEU per container was at the lower end of the distribution. This resulted in more containers of DNLEU, and therefore more transport and disposal containers (TDCs) were required to overpack these for disposal. The 2016 IGD adopts an average value for the quantity of DNLEU per container. This reduces the number of containers required for the storage and disposal of DNLEU. The assumed loading is more realistic and reduces the conservatism in the number of packages that would be produced (though it is noted that at this stage no waste has been packaged). The effect of this change is a reduction in the number of disposal containers required to package the DNLEU.

2.2.4 Summary of changes

Table 3 provides details of the assumptions broken down by waste group.

[10] Changes to the quantities of spent fuels are reported in Table 3.

Table 3 Waste and material quantities in the 2013 and 2016 IGDs (differences in bold)

Waste / material	2013 IGD	2016 IGD
LLW	2013 UK RWI LLW reported as unsuitable for near-surface disposal (stored volume 9,330 m^3)	2016 UK RWI LLW reported as unsuitable for near-surface disposal (stored volume **8,880 m^3**)
ILW	All 2013 UK RWI ILW[11] (stored volume 259,000 m^3)	All 2016 UK RWI ILW[11] (stored volume **265,000 m^3**)
HLW	All 2013 UK RWI HLW from reprocessing 55,000 tU Magnox SF and 5,000 tU AGR SF (7,200 WVP canisters)	All 2016 UK RWI HLW from reprocessing 55,000 tU Magnox SF and 5,000 tU AGR SF (**7,650** WVP canisters)
Legacy SF	4,500 tU AGR SF 1,050 tU Sizewell B PWR SF 740 tU metallic SF 10 tHM exotic SF Irradiated submarine fuel (not quantified)	5,500 tU AGR SF 1,050 tU Sizewell B PWR SF 760 tU metallic SF 10 tHM exotic SF Irradiated submarine fuel (not quantified)
HEU	1.0 tU from civil programmes 21.9 tU from defence programmes	
DNLEU	170,000 tU from civil programmes 15,000 tU from defence programmes	**200,000 tU** from civil programmes 15,000 tU from defence programmes
Pu	5.75 tHM separated Pu residues from civil SF reprocessing (unsuitable for re-use as MOX fuel) treated as waste	
NB ILW	ILW from a 16 GW(e) new build programme (stored volume 8,440 m^3)	
NB SF	14,300 tU new build SFs	
MOX SF	95% of civil plutonium (109.3 tHM) and all MOD plutonium (7.6 tHM) reused in 1,460 tHM MOX SF	

[11] Excluding ILW managed under the Scottish Government's policy for HAW and ILW streams with an established management route for decontamination or incineration.

2.3 Government policy

2.3.1 Management of HAW in Scotland

The management of higher activity radioactive waste (HAW) in Scotland has not changed between the 2013 and 2016 IGDs.

Radioactive waste disposal is a devolved issue and policies differ across the UK. The policies of the UK Government and Northern Ireland Executive [2] as well as the Welsh Government [12] are that HAW in England and Wales should be managed in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support its optimised implementation.

The Scottish Government's policy[12] is for the HAW arising in Scotland to be managed in near-surface facilities[13] [13] and this waste is therefore excluded from the IGD.

2.3.2 Management of plutonium

The way in which plutonium is assumed to be managed has not changed between the 2013 and 2016 IGDs.

The UK Government's preferred policy for the long-term management of plutonium is that it should be re-used in the form of mixed oxide fuel [14]. The UK Government has not made any decision on the fate of the UK's plutonium stocks, and the NDA's Position Paper [15] also identified CANDU and PRISM reactors as credible options for the re-use of plutonium. Only when the UK Government is satisfied that its preferred policy could be implemented safely, securely and in a way that offers value for money, will it be in a position to proceed.

The 2013 and 2016 IGDs assume that the UK-owned plutonium at the end of reprocessing will be 115 t and that 95% of this will be converted into MOX fuel and irradiated in light water reactors.

2.4 Industry plans

2.4.1 New build

The assumptions regarding new build have not changed between the 2013 and 2016 IGDs.

The 2016 IGD assumes a new build programme of 16 GW(e) that is comprised of six UK EPRs and six AP1000s. However, since the 2013 IGD was compiled, the Generic Design Assessment (GDA) disposability assessment reports for the UK ABWR [16, 17] have been published. The changes to the alternative scenarios are presented in section 4, which includes a consideration of the changes introduced by the inclusion of the UK advanced boiling water reactor (ABWR).

2.5 Defence materials

The way in which defence materials are assumed to be managed has not changed between the 2013 and 2016 IGDs.

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12 The policy does not cover radioactive wastes arising from the nuclear submarine bases on the Clyde, the Vulcan naval reactor test establishment, or the decommissioning and dismantling of redundant nuclear submarines. The policy does not apply to wastes that have been dealt with under the policies of previous governments.

13 Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how the waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements. See paragraph 1.19 of reference [13].

Irradiated submarine fuel is included in the 2016 IGD but is not quantified. The 1998 Strategic Defence Review [18] remains the source for the quantities of defence HEU, DNLEU and Pu. These materials are assumed to be managed alongside the equivalent civil materials.

3 Changes to the inventory for geological disposal

Summary of changes to the inventory

The key changes to the quantity of waste are:

- DNLEU (+16%) from Capenhurst operations
- legacy SFs (+16%) mainly as a result of AGR lifetime extensions
- HLW (+6%) as a result of increased estimates of POCO wastes

Overall the packaged volume of the IGD has decreased slightly (-3%) primarily as a result of more realistic assumptions being used for the packaging of DNLEU. The overall changes to the activity are small (+2% at 2200) and are dominated by the increase in AGR SF and HLW.

The re-evaluation of some PCM waste streams has resulted in the mass of several materials being reduced (most notably, a reduction of 17% in the total quantity of organics).

This section summarises the changes to data from the 2013 to 2016 UK RWIs whilst Appendix A provides a breakdown by waste group.

Volumes

Table 4 shows the percentage changes to the stored quantities of waste in the 2016 IGD relative to the 2013 IGD.

Table 4 Changes to the stored waste and material quantities that underpin the 2016 and 2013 IGDs

Waste and unit	2013 IGD	2016 IGD	Difference [%]
Legacy LLW [m^3]	9,330	8,880	-5%
Legacy ILW [m^3]	259,000	265,000	2%
HLW [WVP cans[14]]	7,200	7,650	6%
Legacy SFs [tHM]	6,300	7,320	16%
DNLEU [tU]	185,000	215,000	16%
HEU [tU]	22.9	22.9	0%
Pu [tHM]	5.75	5.75	0%
NB ILW [m^3]	8,440	8,440	0%
NB SFs [tU]	14,300	14,300	0%
MOX SF [tHM]	1,460	1,460	0%

14 The vitrified HLW product is stored in waste vitrification plant canisters (WVP cans).

As the assumptions regarding new build, MOX, Pu and HEU have not changed, there is no change to the quantity of waste associated with these. There are some small changes to the other types of wastes:

- the stored volume of LLW has decreased slightly (by around 5%), mainly as a result of waste stream 7A108 (Decommissioning LLW above the LLWR limit) no longer being included in the IGD; this stream is assumed to be disposed of to the LLWR
- the stored volume of ILW has increased slightly (by approximately 2%). This change is mainly a result of an increase in the volume of waste reported at Sellafield with the key contributions being: an increase in the quantity of PCM, an increase in the quantity of AGR graphite fuel assembly components, wastes that have been transferred from Harwell site, and the fact that some further wastes have been conditioned (particularly encapsulation of floc from effluent treatment, PCM and AGR fuel cladding)[15]. The increased lifetimes of the AGR fleet contribute only a small increase to the volume of raw waste. The inclusion of wastes from Rutherford Appleton Laboratory has negligible impact
- the stored volume of HLW has increased slightly (by approximately 6%) as a result of a revised estimate of the HLW that will arise from the post-operational clean-out of the reprocessing facilities
- the quantity of legacy SFs has increased by 16%. The majority of this increase (1,000 tU) is associated with AGR SF, which has increased for two reasons: an increase in the quantity arising as a result of lifetime extensions to the AGR fleet; and a reduced quantity being reprocessed. The other contributor to the increase is a revised estimate of the “other fuels” (assumed to be legacy ponds fuels); this provides an additional 20 tHM
- the quantity of DNLEU has increased by 16% as a result of an increase in the assumed operational period for uranium enrichment activities (from 2023 to 2037); this contributes an additional 30,000 tU

Overall, the changes to the quantities of stored waste in the IGD are not significant. Although the quantities of some of the stored wastes have increased slightly, the total stored volume of wastes in the IGD has reduced by approximately 1.5%; this is a result of a revision to the assumptions regarding how the DNLEU is stored, which more accurately reflects the actual position for the wastes that are in stock.

The change to the stored, conditioned and packaged volumes of the IGD are reported in Table 5. It can be seen that in addition to a modest reduction in the stored volume of waste, there are modest reductions to the conditioned and packaged volumes of the waste.

The changes to the packaged volume of each waste group are presented in Table 6. It can be seen that the most significant percentage change is in the RSC waste group, and this is consistent with the change from using RSCs to using 6 m^3 boxes at Magnox sites discussed in Section 2.2.1. Analysis of the data shows that in terms of the volume, it is the DNLEU waste group that is most significantly affected: the packaged volume has reduced by nearly 27,000 m^3.

The largest percentage increase is to the legacy SF waste group, primarily as a result of the additional AGR SF from the lifetime extensions. The largest increase in packaged volume is associated with the Legacy SILW / SLLW waste group.

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[15] The stored volume refers to the volume of waste as it is currently stored. For wastes that have been conditioned, this includes the volume of the conditioning matrix.

Table 6 focuses on the packaged volume. Appendix C presents a more detailed summary of the changes to the conditioned volume and the number of disposal units associated with each package type.

Table 5 Changes to the total volume of waste between the 2013 and 2016 IGDs

Volume	Volume [m³]		Difference [%]
	2013 IGD	2016 IGD	
Stored	399,000	393,000	-1.5%
Conditioned	536,000	518,000	-3.4%
Packaged	764,000	744,000	-2.6%

Table 6 Changes to the packaged volume of each waste group

Waste group	Packaged volume [m³]		Difference [%]
	2013 IGD	2016 IGD	
Legacy SILW / SLLW	93,000	99,300	7%
Legacy UILW / ULLW	327,000	329,000	1%
RSCs	7,280	2,730	-63%
DNLEU	217,000	191,000	-12%
NB SILW	18,900	18,900	0%
NB UILW	22,100	22,100	0%
HLW	9,290	9,860	6%
Legacy SF	14,800	16,900	14%
NB SF	39,400	39,400	0%
MOX SF	11,900	11,900	0%
HEU	2,470	2,470	0%
Pu	620	620	0%

3.1 Disposal units

The number of disposal units has not changed (both the 2013 and 2016 IGDs report 165,000).

Table 7 shows the number of disposal units associated with each waste group in the 2013 and 2016 IGDs, and the percentage change to these. It is noted that four 500 l drums are disposed of together in a stillage and that this is a single disposal unit.

As would be expected given the changes to the packaged volume shown in Table 6, the most significant percentage change is to the RSC waste group, which has a reduction of nearly 60% in the number of disposal units. Because the payload of the 6 m^3 boxes is greater than that of the RSCs, this change reduces the number of disposal units (other inventory changes, including the increased quantity of waste, counteract this change).

In terms of the actual number of disposal units, the change to the RSCs represents the largest change, although the change in the number of disposal units associated with the Legacy UILW / ULLW waste group is similar. Other notable changes are to the Legacy SF, the HLW and the DNLEU. All of these differences are explained by the changes described in Section 2.2.1. In addition, there are no longer any 2 m boxes in the IGD.

Table 7 The changes to the number of disposal units in each waste group

Waste group	Disposal units [-]		Difference [%]
	2013 IGD	2016 IGD	
Legacy SILW / SLLW	4,850	5,400	11%
Legacy UILW / ULLW	108,000	109,000	1%
RSCs	2,270	962	-58%
DNLEU	13,200	12,300	-7%
NB SILW	10,100	10,100	0%
NB UILW	8,230	8,230	0%
HLW	2,400	2,550	6%
Legacy SF	3,610	4,120	14%
NB SF	8,940	8,940	0%
MOX SF	2,710	2,710	0%
HEU	779	779	0%
Pu	196	196	0%
Total	165,000	165,000	0%

3.2 Activities

The total activity is presented at 2040 and at 2200 in Table 8. At 2040, the 2016 IGD has an activity that is approximately 7% greater than that in the 2013 IGD. This difference is predominantly associated with the additional spent fuel from the increased operational lifetime of the AGR fleet and, to a lesser extent, the increase in the quantity of HLW. The increase at 2200 is approximately 2%. Again it is the increased quantity of AGR SF and HLW that dominate this increase. However, the percentage increase is smaller as the activity from these wastes has decayed whilst the total inventory has increased (as a result of, for example, new build wastes and spent fuels arising).

The evolution of the total activity is shown in Figure 5 and it can be seen that the difference is small. At GDF closure the difference is approximately 2% of the total, whilst at 1,000,000 years after GDF closure the difference is approximately 10% of the total. This is because the activity at very long times is dominated by the uranium (and its daughters) and there has been an increase in the quantity of uranium in the inventory (dominated by a 30,000 tU (16%) increase in the quantity of DNLEU).

Table 8 The change in activity between the 2013 and 2016 IGDs

Date	Activity [TBq]		Difference (%)
	2013 IGD	2016 IGD	
2040	231,000,000	248,000,000	7%
2200	27,300,000	27,900,000	2%

Figure 5 The evolution of the activity in the 2013 and 2016 IGDs

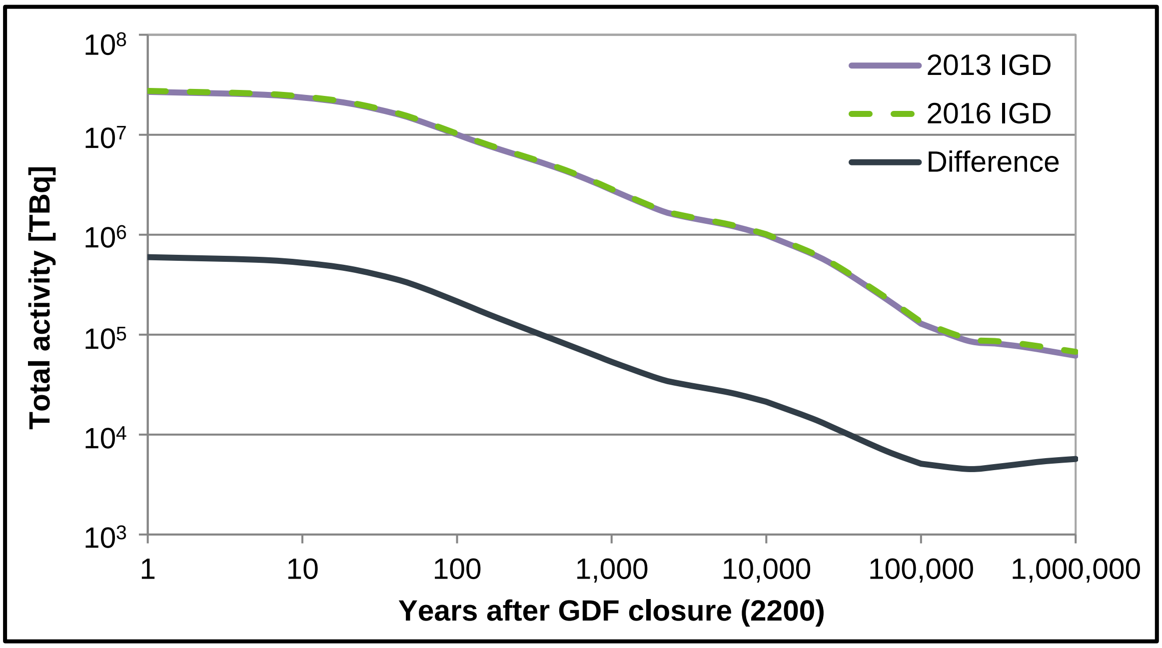


Table 9 presents the change in the activity of each waste group at 2200. The HLW, Legacy SF and DNLEU waste groups have the largest percentage changes. The Legacy SILW / SLLW waste group shows a noticeable decrease (despite more waste being in this waste group). This is largely due to a single waste stream with relatively high activity (3M22: Miscellaneous activated components & fuel stringer debris) being reassigned to a UILW package type.

Table 9 Changes to the waste group activities at 2200 between the 2013 and 2016 IGDs

Waste group	Activity at 2200 [TBq]		Difference [%]
	2013 IGD	2016 IGD	
Legacy SILW / SLLW	15,900	13,800	-14%
Legacy UILW / ULLW	355,000	372,000	5%
RSCs	1,180	1,110	-6%
DNLEU	8,370	9,560	14%
NB SILW	154	154	0%
NB UILW	793,000	793,000	0%
HLW	1,090,000	1,200,000	11%
Legacy SF	2,250,000	2,730,000	21%
NB SF	19,000,000	19,000,000	0%
MOX SF	3,700,000	3,700,000	0%
HEU	54	54	0%
Pu	43,700	43,700	0%

The activities of key radionuclides at 2200 are presented in Table 10. It can be seen that there is a small increase in the activities of most of the fission products, consistent with the inclusion of additional spent fuel. However, activation products (C-14, Cl-36 and Co-60) are relatively unchanged as their activity is dominated by activated ILW and NB SF assemblies. There is also a more significant increase in the U-235 and U-238 that is consistent with the additional arisings of DNLEU. There is an increase in the quantity of U-233 associated with the legacy SFs. However, the increase in the activity of U-233 from the legacy SFs is outweighed by the decrease associated with revised estimates of ILW activities in the UK RWI. Changes to other key radionuclides are negligible.

Table 11 presents the changes in the activity of those gaseous radionuclides in ILW and LLW of interest in the GDF operational period at 2200: it can be seen that the changes are small.

Table 12 presents the changes in the peak activity of those gaseous radionuclides in ILW and LLW of interest in the GDF operational period. Again, it can be seen that the changes are small.

Table 10 The change in the activities of the priority 1 radionuclides between the 2013 and 2016 IGDs.

Radionuclide	Activity at 2200 [TBq]		Difference [%]
	2013 IGD	2016 IGD	
C-14	17,600	17,500	-0.2%
Cl-36	114	115	1%
Co-60	2.12	2.12	~0%
Se-79	96.8	100	3%
Kr-85	1,250	1,250	0.5%
Tc-99	19,100	19,800	3%
I-129	42.1	43.3	3%
Cs-135	919	944	3%
Cs-137	5,040,000	5,140,000	2%
U-233	2.51	2.49	-1%
U-235	53.8	60.4	12%
U-238	2,560	2,940	15%
Np-237	837	851	2%

Table 11 The change in the activity at 2200 of the radionuclides that are important to RWM's gas pathway analysis in LHGW in the 2013 and 2016 IGDs

Radionuclide	Activity at 2200 [TBq]		Difference [%]
	2013 IGD	2016 IGD	
H-3	894	893	-0.2%
C-14	14,400	14,300	-1%
Ra-226	8.63	8.90	3%

Table 12 The change in the peak activity of the radionuclides that are important to RWM’s gas pathway analysis in LHGW between 2040 and 2200 in the 2013 and 2016 IGDs

Radionuclide	Peak activity [TBq]		Difference [%]
	2013 IGD	2016 IGD	
H-3	33,200	33,100	
C-14	14,500	14,400	
Ra-226	9.14	9.42	

3.3 Materials data

The changes to the materials data between the 2013 and 2016 IGDs are presented in Table 13. There have been some changes to the material categories that are used when gathering the UK RWI data, for example some metal alloys that were reported separately have now been grouped into a single field (for example, Brass, Bronze and Copper are now reported as ‘Copper (and alloys)’). As a result there are some minor changes to the way that the data are reported and the material fields presented here may not match those presented in the 2013 IGD reports. The changes are:

- ‘Aluminium (and alloys)’ is reported here; this corresponds to ‘Aluminium’ and ‘Boral’ in the 2013 IGD
- ‘Copper (and alloys)’ is reported here; this corresponds to ‘Copper’, ‘Brass’ and ‘Bronze’ in the 2013 IGD
- ‘Nickel (and alloys)’ is reported here; this corresponds to ‘Inconel’, ‘Monel’ and ‘Nimonic’ in the 2013 IGD
- ‘Cementitious materials’ is reported here; the 2013 IGD reported ‘Cement, concrete and sand’
- ‘Glass, ceramics and sand’ is reported here; the 2013 IGD reported sand in the ‘Cement, concrete and sand’ material group, while ‘Glass’ and ‘Ceramics’ were reported separately
- ‘Soil and rubble’ is reported here; the 2013 IGD reported ‘rubble’ and ‘soil’ separately

A number of the changes to the materials data are a result of the improved data associated with PCM waste streams. In particular, a re-evaluated density for waste stream 2D06 has resulted in a lower mass of materials associated with it. The changes to the PCM streams are the main contributors to changes to Copper (and alloys), and organic materials; these changes also make a significant contribution to the differences in stainless steel (where the improved assumption regarding how Magnox depleted uranium (MDU) is stored also makes a significant contribution) and lead, where changes to ‘Magnox cladding and miscellaneous solid waste’ streams (2D08 and 2D09) also make a significant contribution.

The reduction in aluminium (and alloys) is a result of changes to waste stream 2F15, possibly as a result of the changes to the reporting fields (outlined above). The increase in heavy metal oxide is primarily a result of the additional DNLEU associated with the assumption that enrichment operations continue for a longer period of time. A smaller contributor to the increase in the heavy metal oxide is the additional AGR SF, which is also the main cause of the increase in graphite (which forms the fuel element sleeve).

The increases in the ‘Total unspecified’ (65%) (as well as ‘other metals’ (28%) and ‘other inorganics’ (38%)) is a result of the 2016 IGD being a light update that does not include a full review and enhancement of the data.

Table 13 The changes to the material masses between the 2013 and 2016 IGDs

	Material	Mass [t]		Difference [%]
		2013 IGD	2016 IGD	
Metals	Stainless Steel	47,000	40,200	-14%
	Other ferrous metals	69,400	71,000	2%
	Magnox / magnesium	6,510	6,300	-3%
	Aluminium (and alloys)	1,930	1,730	-10%
	Zircaloy / zirconium	6,270	6,290	0%
	Copper (and alloys)	413	291	-29%
	Nickel (and alloys)	429	434	1%
	Uranium	1,680	1,720	2%
	Lead	1,130	805	-29%
	Other metals	252	322	28%
	Total metals	135,000	129,000	-4%
Organics	Cellulose	2,620	2,170	-17%
	Halogenated plastics	4,770	3,630	-24%
	Non-halogenated plastics	2,880	2,180	-25%
	Rubbers	1,970	1,700	-14%
	Organic ion ex. resins	3,630	3,470	-5%
	Other organics	490	475	-3%
	Total organics	16,400	13,600	-17%
Other materials	Graphite	76,800	78,400	2%
	Asbestos	298	311	5%
	Sludges & flocs	22,900	22,000	-4%
	Cementitious materials	53,900	55,000	2%
	Ion exchange resins	5,460	4,760	-13%
	Heavy metal oxide	243,000	280,000	15%
	Glass, ceramics and sand	3,350	3,720	11%
	Soil and rubble	2,580	2,970	15%
	Other inorganics	9,550	13,100	38%

	Total other materials	**418,000**	**460,000**	**10%**
	Total unspecified	**1,020**	**1,680**	**65%**
	Total	**570,000**	**604,000**	**6%**

4 Alternative scenarios

Summary of changes to the alternative inventory scenarios

Alternative scenarios are used to explore the effects of changes in assumptions and uncertainties in data on the IGD. The definitions of the alternative scenarios for the 2013 IGD were revised to be consistent with the 2016 IGD. The impacts of the revised scenarios on the inventory for disposal were then examined.

In general, the impacts of alternative scenarios on the 2016 IGD are the same or smaller than those on the 2013 IGD. The greatest impact continues to be that from uncertainties in waste volume and radioactivity and these are dominated by a small number of waste streams. Data are now provided to allow the impact of including the UK ABWR to be quantified.

The IGD is based on a single scenario for the arisings of wastes and materials for geological disposal and their conditioning and packaging. In order to explore the effects on the inventory of changes in assumptions and uncertainties in data, a number of alternative scenarios were defined and their impacts on the 2013 IGD analysed [7].

Assessing all the possible changes in assumptions and uncertainties in data in individual scenarios would be impractical. The pragmatic approach of only including scenarios that highlight key changes in the waste quantities, waste characteristics or assumptions was adopted.

There are two stages in updating this work for the 2016 IGD:

- determining whether the definitions of the alternative scenarios need to revised to be consistent with the baseline assumptions and data for the IGD
- analysing the impacts of the revised alternative scenarios on the waste volumes, numbers of packages and activities for the relevant waste groups

4.1 Changes to definitions of alternative scenarios

Twelve alternative scenarios were defined for the 2013 IGD [16]. Table 14 shows the differences in the baseline assumptions and data between the 2013 and 2016 IGDs that are relevant to the definitions of these scenarios.

Each of the scenarios where there is a change to its definition between the 2013 and 2016 IGDs is discussed in the following sub-sections.

Table 14 Differences between the 2013 and 2016 IGDs that are relevant to the definitions of alternative scenarios

No	Scenario	Difference between the 2013 and 2016 IGD
1	Reprocessing more oxide fuel	No change
2	Reprocessing less Magnox fuel	Less Magnox fuel to be reprocessed
3	Lifetime extensions for existing reactors	AGR lifetime extensions included in 2016 IGD
4	Use of UK RWI uncertainty factors	Changes to waste streams between 2013 and 2016 IGDs
5	Products of management of plutonium	No change
6	Removal of some LLW from the LLWR	No change
7	Changes in the quantities of DNLEU	Revised packaging assumptions
8	Change in new build programme	Additional data for UK ABWR reactor
9	Inclusion of foreign wastes and materials	No change
10	Alternative packaging assumptions	Impact of alternative packaging
11	Exclusion of graphite wastes	Changes to waste streams between 2013 and 2016 UK RWIs
12	Exclusion of ILW / LLW boundary wastes	

4.2 Scenario 2: Reprocessing less Magnox fuel

In the 2013 and 2016 IGDs it is assumed that there will be 55,000 tU of Magnox spent fuel, and the current UK policy is that all Magnox spent fuel will be reprocessed. The aim is to complete Magnox reprocessing by December 2020. Should the Magnox reprocessing plant not remain operational for long enough to complete spent fuel reprocessing, this would have the following impacts on the IGD:

- a reduction in the quantity of DNLEU, HLW and operational ILW associated with the reprocessing
- the quantity of MOX spent fuel would reduce as less separated plutonium would be available for reuse
- the quantity of metallic SF would increase

Additional Magnox SF has been reprocessed between 2013 and 2016. As a result, it is no longer appropriate to assume that 3,000tU Magnox SF is not reprocessed. For the 2016 IGD alternative scenario the assumption is that 2,000tU is not reprocessed. Table 15 to Table 17 present the changes in the packaged volume, the number of disposal units and total activity for the waste groups that are affected by this scenario: the decrease in HLW, legacy SF and MOX SF (-33%) is due to the reduced mass of Magnox spent fuel not reprocessed. The decrease in the activity of the DNLEU is due to the reduced mass of Magnox spent fuel not reprocessed, while the change in packaged volume and number of packages (-47%) is a result of the reduced mass of Magnox spent fuel not reprocessed together with the modification made to the assumed waste loading for the uranium transport and disposal containers as discussed in Section 2.2.3. The change in legacy UILW / ULLW is due to volume changes for the waste streams in the 2016 IGD that are affected by the change in Magnox reprocessing:

- 2D27/C Encapsulated Floc from Effluent Treatment
- 2D38/C Encapsulated Magnox Cladding

As would be expected, the reduced quantity of Magnox SF available means that that impact of this scenario has been reduced for the 2016 IGD.

Table 15 Changes in the packaged volume for those waste groups affected by Scenario 2

Waste group	Change in packaged volume [m^3]		
	2013 IGD	2016 IGD	Difference [%]
Legacy UILW / ULLW	-3,180	-2,460	-23%
DNLEU	-2,980	-1,570	-47%
HLW	-360	-240	-33%
Legacy SF	+13,800	+9,170	-33%
MOX SF	-766	-511	-33%
Total	+6,470	+4,390	-32%

Table 16 Changes in the number of disposal units for those waste groups affected by Scenario 2

Waste group	Change in number of disposal units [-]		
	2013 IGD	2016 IGD	Difference [%]
Legacy UILW / ULLW	-1,390	-1,080	-23%
DNLEU	-118	-62	-47%
HLW	-94	-63	-33%
Legacy SF	+3,390	+2,260	-33%
MOX SF	-174	-116	-33%
Total	+1,610	+941	-42%

Table 17 Change in the total activity at 2200 for those waste groups affected by Scenario 2

Waste group	Change in total activity at 2200 [TBq]		
	2013 IGD	2016 IGD	Difference [%]
Legacy UILW / ULLW	-2,840	-1,160	-59%
DNLEU	-147	-97.8	-33%
HLW	-43,800	-29,200	-33%
Legacy SF	+257,000	+172,000	-33%
MOX SF	-238,000	-158,000	-33%
Total	-27,000	-17,300	-36%

4.3 Scenario 3: Lifetime extensions for existing reactors

The 2013 IGD scenario assumed lifetime extensions for AGR reactors and the Sizewell B pressurised water reactor (PWR). Since the publication of the 2013 IGD, AGR lifetime extensions have been granted and are included in the 2016 IGD. Therefore only a 20-year lifetime extension to the Sizewell B PWR is considered for the 2016 IGD.

There has been no change in the data for Sizewell B waste streams between the 2013 and 2016 IGDs that would affect the packaged volume, the number of disposal units or total activity at 2200 for a 20-year increase in the lifetime of Sizewell B. The impacts of the lifetime extension to Sizewell B on the packaged volume, the number of disposal containers and the total activity at 2200 are indicated in Table 18 and are the same as for the 2013 IGD. These changes represent increases to the 2013 and 2016 IGDs of less than 1% in the total packaged volume and the total number of disposal containers, and less than 2% in the total activity.

The overall impact of this scenario has reduced as the AGR lifetime extensions are no longer considered. However, the impact of a lifetime extension to Sizewell B has not changed between the 2013 and 2016 IGDs.

Table 18 Changes in the packaged volume, number of disposal units and activity at 2200 for those waste groups in the 2013 and 2016 IGD that are affected by a lifetime extension for Sizewell B

Waste group	Packaged volume [m^3]	No. disposal units [-]	Activity at 2200 [TBq]
Legacy UILW / ULLW	+130	+51	+2,420
RSCs	+97.9	+75	+5.38
Legacy SF	+1,120	+297	+498,000
Total	+1,350	+422	+500,000

4.4 Scenario 4: Use of UK RWI uncertainty factors

The UK RWI presents uncertainties in both the volume of the waste and the specific activity of each radionuclide in the waste. Uncertainty factors are only available for waste streams in the UK RWI, so this scenario only affects the legacy SILW / SLLW, legacy UILW / ULLW, RSC and HLW waste groups. From these, the following inventories are created:

- lower uncertainty volume
- upper uncertainty volume
- lower uncertainty activity
- upper uncertainty activity

4.4.1 Volumes and number of disposal units

Table 19 to Table 22 present the impact of applying volume uncertainty factors on the packaged volume and the number of disposal units in the 2013 and 2016 IGDs. The differences in the changes to packaged volume and the number of disposal units are due to:

- revised uncertainty factors for legacy SILW / SLLW waste streams at Wylfa
- lower uncertainty factors for SL legacy UILW / ULLW waste streams
- the change from using RSCs to using 6 m^3 boxes at Magnox sites
- a revised estimate of the HLW that will arise from the post-operational clean-out of the reprocessing facilities, which has a high volume uncertainty factor

Table 19 Changes in the lower packaged volume resulting from volume uncertainty for those waste groups affected by Scenario 4

Waste group	Change in lower packaged volume [m^3]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-32,200	-20,600	-36%
Legacy UILW / ULLW	-70,700	-85,300	21%
RSCs	-1,070	-424	-61%
HLW	-2,070	-2,580	24%
Total	-106,000	-109,000	3%

Table 20 Changes in the upper packaged volume resulting from volume uncertainty for those waste groups affected by Scenario 4

Waste group	Change in upper packaged volume [m^3]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	+33,600	+21,800	-35%
Legacy UILW / ULLW	+324,000	+325,000	~0%
RSCs	+1,280	+432	-66%
HLW	+12,500	+18,100	45%
Total	+372,000	+366,000	-2%

Table 21 Changes in the lower number of disposal units resulting from volume uncertainty for those waste groups affected by Scenario 4

Waste group	Change in lower number of disposal units [-]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-1,660	-1,110	-33%
Legacy UILW / ULLW	-22,700	-27,500	21%
RSCs	-305	-164	-47%
HLW	-536	-666	24%
Total	-25,300	-29,500	17%

Table 22 Changes in the upper number of disposal units resulting from volume uncertainty for those waste groups affected by Scenario 4

Waste group	Change in upper number of disposal units [-]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	+1,720	+1,160	-32%
Legacy UILW / ULLW	+101,000	+101,000	~0%
RSCs	+365	+164	-55%
HLW	+3,240	+4,690	45%
Total	+106,000	+107,000	1%

Figure 6 illustrates the percentage contributions from individual waste streams to the decrease in packaged volume associated with lower volume uncertainty factors. Five waste streams (from a total of 533) contribute 44% of this volume decrease.

Two of the five waste streams are the same top two contributors as in the 2013 IGD:

- 2D116 (Miscellaneous Plants Initial/Interim Decommissioning: Processing Plants, Tanks, Silos, etc)
- 2D137 (Miscellaneous Plants Final Decommissioning: Processing Plants, Tanks, Silos, etc)

Two decommissioning waste streams at Wylfa, 9H311 (Final Dismantling & Site Clearance: Graphite ILW) and 9H315 (Final Dismantling & Site Clearance: Graphite LLW) were major contributors in the 2013 IGD due to their large volume uncertainty factors. In the 2016 IGD volume uncertainty factors at Wylfa have been updated and as a result these streams are no longer major contributors.

Figure 6 Waste stream percentage contribution to the reduced packaged volume associated with lower volume uncertainty in the 2016

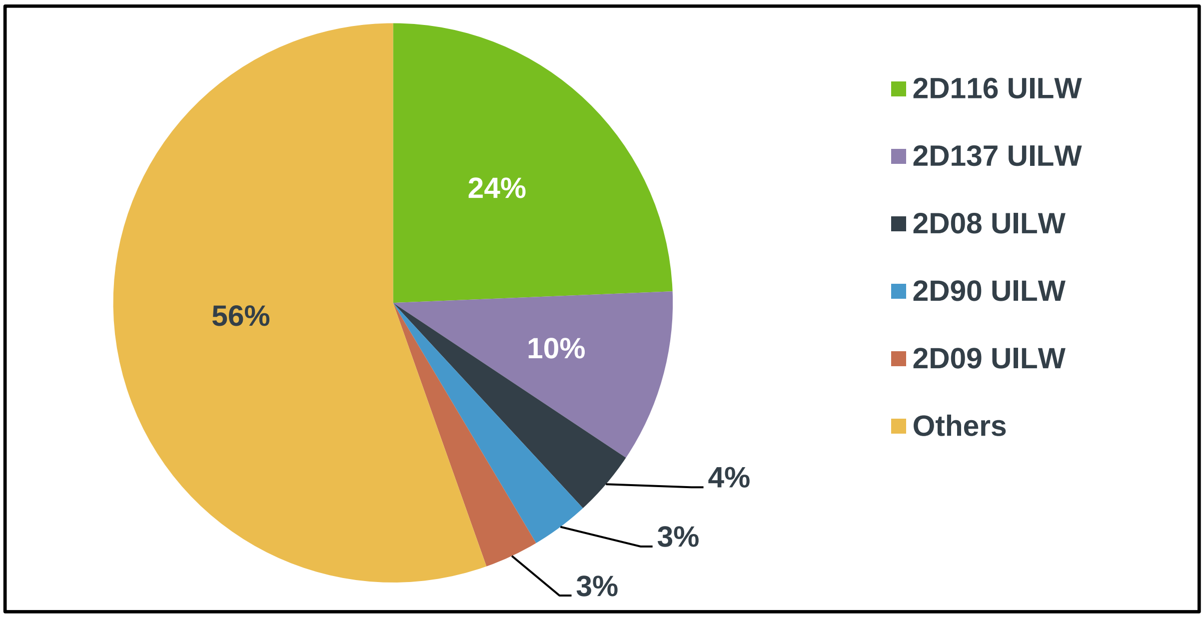


Figure 7 illustrates the percentage contributions from individual waste streams to the increase in packaged volume associated with upper volume uncertainty factors. Five waste streams (from a total of 533) contribute 76% of this volume decrease.

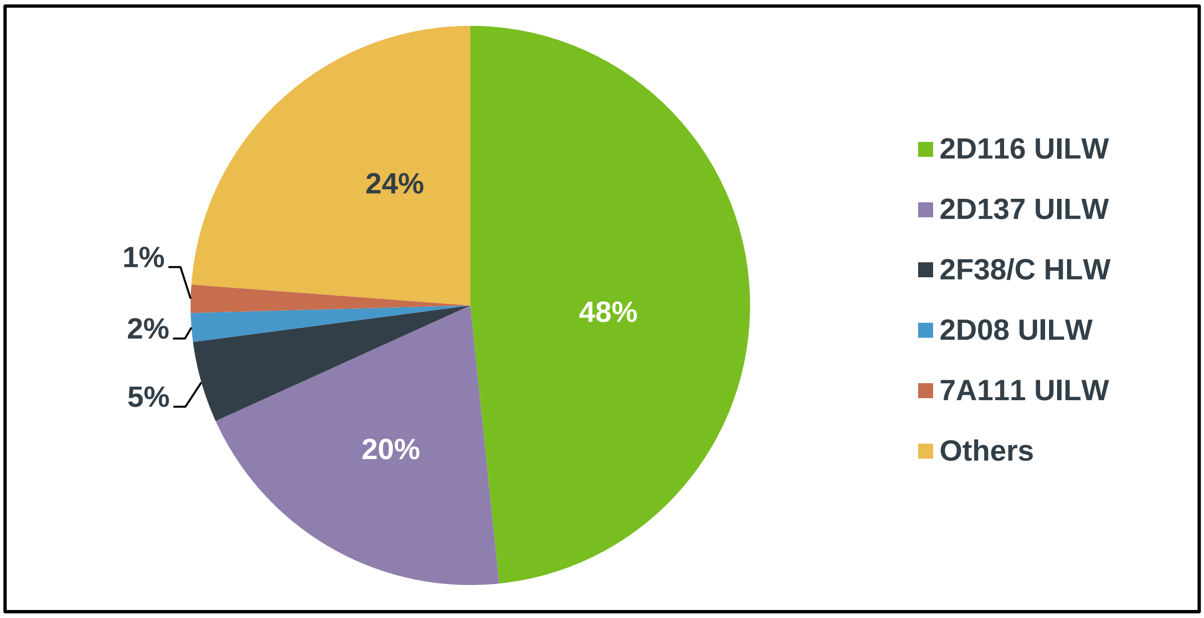
Four of the five waste streams are the same major contributors as in the 2013 IGD:

- 2D116 (Miscellaneous Plants Initial/Interim Decommissioning: Processing Plants, Tanks, Silos, etc)
- 2D137 (Miscellaneous Plants Final Decommissioning: Processing Plants, Tanks, Silos, etc)
- 2F38/C (Vitrified High Level Waste from POCO)
- 7A111 at Aldermaston (Decommissioning Waste PCM ILW)

Wylfa waste stream 9H311 (Final Dismantling & Site Clearance: Graphite ILW) has had its volume uncertainty factors updated and as a result is no longer a major contributor.

Overall, the impact of the upper volume uncertainty factors is bounded by the previous assessment except in the case of HLW. The waste streams that make the most significant contributions to the upper volume uncertainty in the 2016 IGD are largely the same as those in the 2013 IGD. The impact of the lower uncertainty factors has also been considered and the overall changes are not significant.

Figure 7 Waste stream percentage contribution to the additional packaged volume associated with upper volume uncertainty in the 2016 IGD



4.4.2 Activities

Table 23 presents the impact of applying lower and upper uncertainty factors to the total activity at 2200 in the 2013 and 2016 IGDs. The increase in the lower uncertainty is due to an increase in the volume and the specific activity data of HLW waste stream 2F01/C (vitrified high level waste). The decrease in the upper uncertainty is due to the re-assessment of the radionuclide uncertainty factors for waste stream 3S306 (Sizewell B decommissioning stainless steel ILW).

Table 23 Changes in the total activity at 2200 resulting from activity uncertainty for all waste groups affected by Scenario 4

	Change in total activity at 2200 [TBq]		
	2013 IGD	**2016 IGD**	**Difference [%]**
Lower uncertainty	-668,000	-714,000	7%
Upper uncertainty	+26,900,000	+12,200,000	-55%

Figure 8 illustrates the percentage contributions from individual waste streams to the decrease in activity associated with lower uncertainty factors. Five waste streams (from a total of 533) contribute 77% of this activity decrease. These five waste streams are the same major contributors as in the 2013 IGD.

Figure 9 illustrates the percentage contributions from individual waste streams to the increase in activity associated with upper uncertainty factors. Five waste streams (from a total of 533) contribute 82% of this activity increase. In the 2013 IGD the upper activity uncertainty was dominated by waste stream 3S306, which had a low total activity, but an uncertainty factor of 1,000 for each radionuclide present. EDF Energy has reviewed the derivation of the activity values for this waste stream and has concluded that the activity values are accurate and that the subsequent allocation of uncertainty factors of 1,000 was unwarranted. The activity uncertainty factors have been updated for the 2016 UK RWI to a value of 10 for most radionuclides.

The other major contributors are the same waste streams as in the 2013 IGD.

The changes in the total activities of the priority 1 radionuclides at 2200 between the 2013 and 2016 IGDs are presented in Appendix D1. Most of the changes are not significant. However, for I-129 the upper activity uncertainty has increased by a factor of approximately 8. This is a result of an increase in the stock specific activity of waste stream 2D27/C (encapsulated floc from effluent treatment), which has an uncertainty factor of 1,000. This uncertainty may well decrease when the UK RWI is updated.

Overall, the activity uncertainty associated with the 2016 IGD is bounded by that associated with the 2013 IGD. However, for radionuclide I-129, there is a significant increase in the upper activity uncertainty; this is discussed further in the “Implications Report” [6].

Figure 8 Waste stream percentage contribution to the total activity associated with lower activity uncertainty in the 2016 IGD

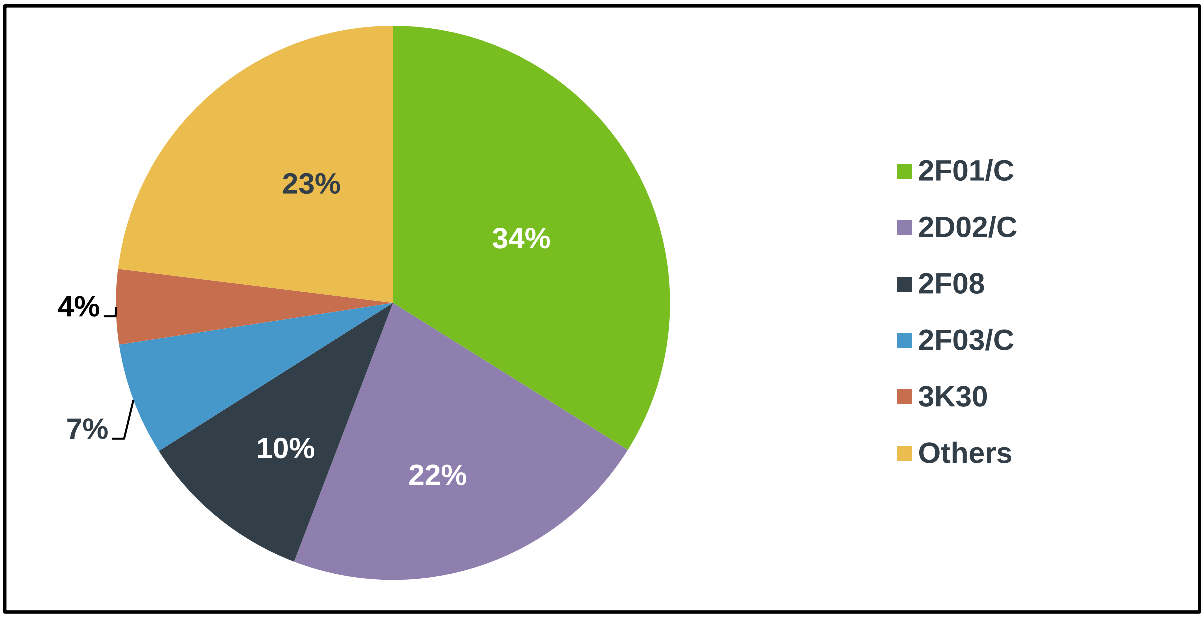
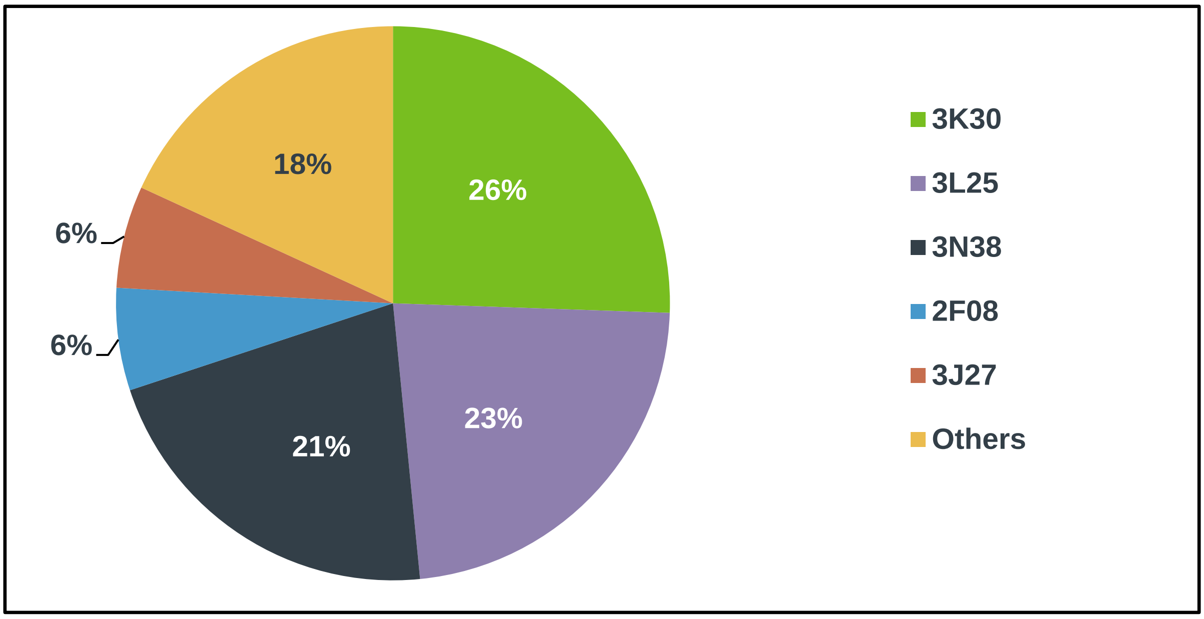


Figure 9 Waste stream percentage contribution to the total activity associated with upper activity uncertainty in the 2016 IGD



4.5 Scenario 7: Changes in quantities of DNLEU for geological disposal

DNLEU in the IGD comes from a number of sources:

- MDU arising from the reprocessing of spent Magnox fuel
- THORP product uranium (TPU) arising from the reprocessing of spent oxide fuels
- Depleted uranium (DU) tails from enrichment activities
- DU from defence enrichment
- Miscellaneous DNLEU

The 2013 IGD scenarios report [7] only included a breakdown of DNLEU by package type, for use in assessing the impacts of packaging changes. There are a range of packaging assumptions for DNLEU that depend on the source of the material and so the impact of changes to the DNLEU inventory depends on the source of the DNLEU that has changed.

The 2016 IGD uses more realistic assumptions regarding how the MDU and DU tails are stored and disposed of (see appendix B4.2 for details). This has resulted in a change to the packaged volumes and the number of disposal units per tU for the associated DNLEU waste streams. Table 24 and Table 25 compare the impact of these changes on the packaged volumes and the number of disposal units for the 2013 and 2016 IGDs.

Table 24 Breakdown of the packaged volume for DNLEU

DNLEU waste stream	Packaged volume / tU [m^3]		
	2013 IGD	2016 IGD	Difference [%]
MDU (earlier arisings)	3.62	1.82	-50%
MDU (later arisings)	0.994	0.786	-21%
DU tails (unirradiated)	0.849	0.801	-6%
DU tails (irradiated)	0.849	0.801	-6%

Table 25 Breakdown of the number of disposal units for DNLEU

DNLEU waste stream	No. of disposal units / tU [-]		
	2013 IGD	2016 IGD	Difference [%]
MDU (earlier arisings)	0.125	0.062	-50%
MDU (later arisings)	0.039	0.031	-21%
DU tails (unirradiated)	0.030	0.029	-6%
DU tails (irradiated)	0.030	0.029	-6%

4.6 Scenario 8: Change in new build programme

In the 2013 IGD it was assumed that a 16 GW(e) new build programme would be composed of six UK EPRs and six AP1000s. The 2016 IGD retains this assumption as it is a 'light update'. In order to allow the impact of changes to the size and composition of the new build programme to be assessed data were presented on a 'per reactor' basis for the AP1000 and UK EPR in the 2013 IGD alternative scenarios report [7].

Horizon Nuclear Power is proposing to build two UK ABWRs at Wylfa and two at Oldbury with at least 5.4 GW(e) total capacity. No inventory data were available for the UK ABWR so only information on numbers of packages were given for the 2013 IGD alternative scenario [7]. Following the publication of the GDA disposability assessment reports for the UK ABWR [16, 17], inventory information for a single UK ABWR is presented below.

Potential changes to the new build programme include the construction of a Hualong One reactor at Bradwell, and use of a different reactor design at Moorside. These are discussed in Section 4.6.2.

4.6.1 UK ABWR

The UK ABWR is assumed to operate for 60 years and activity data are presented at 50 years after reactor shutdown. The inventory information is based on the GDA disposability assessment reports [16, 17]. The radionuclide inventory is based on a fuel burn-up of 60 GWd/tU as this maximises the inventory of higher actinides.

Table 26 presents the packaged volume, the number of disposal units and total activity 50 years after reactor shutdown of ILW and spent fuel for a single UK ABWR reactor.

Table 26 The packaged volume, number of disposal units and activity at 50 years after reactor shutdown of waste groups for a UK ABWR reactor

Waste group	Packaged volume [m^3]	Number of disposal units [-]	Activity [TBq]
New build SILW	781	39	6.75
New build UILW	1,870	678	414,000
New build SF	2,520	667	6,040,000

The activities of the priority 1 radionuclides at 50 years after reactor shutdown and the materials in the waste for the UK ABWR are presented in Tables D3 and D4 in Appendix D2. The data are presented for each waste group.

4.6.2 Other reactor types

EDF Energy and China General Nuclear Corporation (CGN) intend to develop a new nuclear power station at Bradwell. It is proposed that this will be of the Hualong One design, which is currently going through the GDA process. When inventory data are available for the Hualong One reactor these will be included in this alternative scenario.

Until 2017, NuGen Ltd planned to construct three AP1000 reactors at Moorside. It is now expected that NuGen will be sold to the South Korean company KEPCO, who may wish to construct reactors of the APR1400 design. This possibility may need to be considered in a future update of this scenario.

4.7 Scenario 10: Alternative packaging assumptions

Alternative packaging assumptions for wastes, including the use of new or alternative packages would affect the IGD packaged volume and the number of disposal units. The 2013 IGD Scenarios report [7] discusses a number of options:

- thermal treatment
- use of RSCs
- variant containers for HLW and SF
- use of MPCs

The 2013 IGD analysis for HLW/SF containers and use of MPCs is still valid for the 2016 IGD. Changes relating to the assumptions to thermal treatment and the use of RSC are discussed below.

Thermal treatment of ILW

Since the 2013 IGD NDA has assessed the requirements for a thermal treatment capability in the UK. The discussion in the 2013 IGD scenarios report is still relevant but an integrated project team (IPT) focussed on thermal treatment has been established [19]. The aim is to establish a demonstration facility on the Sellafield site; this is regarded as the first step in the development of an operational full-scale thermal treatment capability [20] which will further inform this discussion.

Use of robust shielded containers (RSCs)

In the 2013 IGD Magnox Limited had implemented wide use of RSCs as a waste container at all of its reactor sites except Hunterston A and Trawsfynydd. In the 2016 IGD Magnox Limited has revised its packaging assumptions and many waste streams that were to be packaged in RSCs are to be packaged in 6 m^3 boxes. Since RSCs are used exclusively for the packaging of Magnox waste the numbers of RSCs used will decrease and therefore no further consideration will be given to an increase in the use of RSCs as an alternative scenario.

4.8 Scenario 11: Exclusion of graphite wastes

The NDA's work [21] has demonstrated that the management of graphite waste by geological disposal provides a robust baseline strategy suitable for planning purposes. In the case of reactor decommissioning graphite, which is the bulk of the graphite inventory, there will be time to develop and assess alternative strategies during the extended period of reactor quiescence. NDA has identified factors that would drive a review of the baseline strategy and will ensure that these are considered in future decisions on the management of graphite waste.

This section shows the differences between the 2013 and 2016 IGDs for an alternative disposal route for graphite. The wastes considered to be graphite are unchanged between the 2013 and 2016 IGDs.

Table 27 and Table 28 compare the impact of graphite wastes not being disposed of to the GDF on the packaged volume and the number of disposal units, while Table 29 compares the impact of graphite wastes not being disposed of to the GDF on the total activity at 2200.

The changes in the legacy UILW / ULLW waste group in Table 27 and Table 28 are due to an increase in the volume of waste stream 2F07 (AGR Graphite Fuel Assembly Components) as a result of the lifetime extensions to the AGR power plant fleet. This has also led to an increased impact on the total activity of legacy UILW / ULLW at 2200 due to waste arisings continuing for a further 10 years (up to 2036).

Table 27 Changes in the packaged volume for those waste groups affected by Scenario 11

Waste group	Change in packaged volume [m^3]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-67,300	-68,400	2%
Legacy UILW / ULLW	-25,600	-28,000	9%
Total	-92,900	-96,400	4%

Table 28 Changes in the number of disposal units for those waste groups affected by Scenario 11

Waste group	Change in number of disposal units [-]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-3,410	-3,500	3%
Legacy UILW / ULLW	-9,160	-10,200	11%
Total	-12,600	-13,700	9%

Table 29 Change in the total activity at 2200 for those waste groups affected by affected Scenario 11

Waste group	Change in total activity at 2200 [TBq]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-6,420	-6,440	<1%
Legacy UILW / ULLW	-763	-2,730	258%
Total	-7,190	-9,170	28%

4.9 Scenario 12: Exclusion of ILW / LLW boundary wastes

Boundary wastes are defined as ILW and LLW with a concentration of specific radionuclides that prohibits or significantly challenges its acceptability at existing and planned future disposal facilities for LLW, but that could be practicably managed as LLW (on the basis of radiochemical and physiochemical properties) through application of some treatment process or decay storage.

Only those ILW streams where there is an established decontamination or incineration process are excluded from the IGDs. All other ILW streams expected to be managed as LLW are included in the IGD. The 2013 UK RWI includes 42 ILW streams that waste producers expect to manage as LLW through near-surface disposal by using radioactive decay storage and / or decontamination processes; the 2016 UK RWI includes 48 such streams (See Table D5 for details). Some combustible wastes are expected to be incinerated and some metal wastes are expected to be recycled.

The impact of removing these streams from the IGDs would be a reduction in ILW for disposal to the GDF. This section shows the differences between the 2013 and 2016 IGDs for ILW / LLW boundary wastes:

- Table 30 and Table 31 present the change to the packaged volume and the number of disposal units. The increases associated with the legacy SILW / SLLW are due to a new waste stream 3S310 (Fuel Pond Solid Absorber Assemblies); the decrease for RSCs is associated with a reduction in the volumes of some of the waste streams and the removal of waste stream 9A18 (Desiccant) due to disposal
- Table 32 presents the change to the total activity at 2200. The large change in the total activity of the legacy UILW / ULLW waste group is due to waste stream 7V24 (Metallic ILW from Vulcan) not being included as a boundary waste in the 2016 IGD

Whilst some of the changes shown in Table 30 to Table 32 are significant in percentage terms, the absolute values are small and the conclusion that this scenario would have a small impact on the activity and volume of waste in the IGD remains valid.

Table 30 Changes in the packaged volume for those waste groups affected by Scenario 12

Waste group	Change in packaged volume [m^3]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-144	-232	62%
Legacy UILW / ULLW	-8,370	-7,190	-14%
RSCs	-491	-259	-47%
Total	-9,000	-7,680	-15%

Table 31 Changes in the number of disposal units for those waste groups affected by Scenario 12

Waste group	Change in number of disposal units		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	-7	-11	57%
Legacy UILW / ULLW	-2,670	-2,320	-13%
RSCs	-90	-48	-47%
Total	-2,770	-2,380	-14%

Table 32 Change in the total activity at 2200 for those waste groups affected by affected Scenario 12

Waste group	Change in total activity at 2200 [TBq]		
	2013 IGD	2016 IGD	Difference [%]
Legacy SILW / SLLW	$-3.10\ 10^{-2}$	$-2.63\ 10^{-2}$	-15%
Legacy UILW / ULLW	-1,410	-118	-92%
RSCs	$-3.97\ 10^{-2}$	$-2.83\ 10^{-2}$	-29%
Total	-1,410	-118	-92%

5 Conclusions

Summary of changes to the inventory

The IGD has been updated following the publication of the 2016 UK RWI. The key underpinning assumptions are unchanged between the 2013 and 2016 IGDs. Changes to the packaged volume of waste (-3%), activity (+2% at 2200) and number of disposal units (<1%) are small and are associated with improved assumptions regarding the packaging of DNLEU and changes to the waste producers' plans (e.g. lifetime extensions to the AGR fleet, use of different packages for some decommissioning ILW).

The uncertainties associated with the 2016 IGD and 2013 IGD have been explored through a range of alternative inventory scenarios. The changes in these alternative scenarios between the 2013 and 2016 IGDs are small.

Alternative scenarios are used to explore the effects of changes in assumptions and uncertainties in data on the inventory for disposal. The effects of the changes to the inventory on the definitions of the alternative scenarios have been determined and the impacts of the scenarios on the 2016 IGD have been evaluated. For most of the alternative scenarios the impact on the inventory for disposal is unchanged or reduced.

Whilst the key underpinning assumptions have not changed, there have been a number of changes to some wastes in the inventory:

- an increase in the quantity of DNLEU as a result of an increase in the assumed period of enrichment operations at Capenhurst
- an increase in the quantity of AGR SF as a result of AGR lifetime extensions
- an increase in HLW as a result of an increased estimate of POCO wastes
- a change from robust shielded containers (RSCs) to 6 m^3 boxes for packaging some wastes at some Magnox stations, and
- a re-evaluation of some PCM wastes that has resulted in a revised density and therefore changes to the masses of various materials, most notably a reduction of 17% in the total quantity of organics

The impact of these changes on a number of key quantities has been assessed:

- despite an increase in the overall quantity of waste for disposal, the volume of waste has reduced slightly, primarily as a result of more realistic assumptions being adopted for the packaging of DNLEU
- there has been no significant change in the total number of disposal units. However, there has been a significant reduction in the number of RSCs associated with the change to 6 m^3 boxes at some Magnox stations
- the total activity has increased slightly, mainly associated with the increased quantities of legacy spent fuels and HLW
- the most significant changes to the materials in the inventory arise as a result of the re-evaluation of PCM streams, with reductions in several material types. Most notable is a 17% decrease in the total quantity of organics. Other changes include a significant increase in heavy metal oxide as a result of the increased arisings of DNLEU

This report has discussed the changes in the definitions of alternative scenarios between the 2013 and 2016 IGDs and changes in the impacts of these scenarios on the inventory for disposal. For both IGDs the uncertainties in volume and radioactivity have the greatest impact, and this impact is dominated by a small number of waste streams.

The change in the impact of each of the alternative scenarios on the IGD is:

- scenario 2 (less reprocessing of Magnox fuel) impact has decreased as the mass of Magnox spent fuel not reprocessed is less for the 2016 IGD
- scenario 3 (lifetime extensions for existing reactors) impact has decreased as the AGR lifetime extensions are included in the 2016 IGD
- scenario 4 (use of UK RWI uncertainty estimates)
    - the impact of this scenario on the IGD has decreased for the upper uncertainty factors (-2% packaged volume, -55% activity), although the uncertainty associated with I-129 has increased significantly (by around a factor of 8)
    - the impact of this scenario on the IGD has increased for the lower uncertainty factors (+3% packaged volume, +7% activity)
- scenario 11 (exclusion of graphite wastes) impact has increased due to the increase in AGR graphite fuel assembly components from the increased lifetime extensions to the AGR power plant fleet
- scenario 12 (exclusion of ILW/LLW boundary wastes) impact has decreased due to some waste stream changes

References

1 Radioactive Waste Management, *Geological Disposal: Overview of the Generic Disposal System Safety Case,* DSSC/101/01, December 2016.

2 Department of Energy and Climate Change, *Implementing Geological Disposal - A framework for the long term management of higher activity waste,* URN 14D/235, July 2014.

3 Radioactive Waste Management, *Geological Disposal: Technical Background to the generic Disposal System Safety Case,* DSSC/421/01, December 2016.

4 Radioactive Waste Management, *Inventory for geological disposal: Main report*, DSSC/403/02, 2018.

5 Radioactive Waste Management, *Geological Disposal: Inventory for geological disposal: method report,* DSSC/405/01, 2018.

6 Radioactive Waste Management, *Geological Disposal: Implications of the 2016 UK RWI on the generic Disposal System Safety Case*, DSSC/407/0, 2018.

7 Radioactive Waste Management, *Geological Disposal: Derived Inventory*: *Scenarios Report*, DSSC/404/01, 2016.

8 Radioactive Waste Management, *Geological Disposal: The 2013 Derived Inventory*, DSSC/403/01, 2016.

9 BEIS & NDA, *Radioactive Wastes in the UK: UK Radioactive Waste Inventory Report*, ISBN: 978-1-905985-33-3, March 2017.

10 DECC & NDA, *Radioactive Wastes in the UK: A Summary of the 2013 Inventory*, URN14D043, NDA/ST/STY(14)/0013, February 2014.

11 Radioactive Waste Management, *Geological Disposal: Generic Disposal Facility Design*, DSSC/412/01, 2016.

12 Welsh Government, *Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste*, WG23160, 2015.

13 Scottish Government, *Scotland's Higher Activity Radioactive Waste Policy 2011*, ISBN: 978-0-7559-9892-0, 2011.

14 DECC, *Management of the UK's Plutonium Stocks: A consultation response on the long-term management of UK-owned separated civil plutonium*, URN 11D/819, 2011.

15 NDA, *Position Paper: Progress on approaches to the management of separated plutonium*, SMS/TS/B1-PLUT/002/A, 2014.

16 Radioactive Waste Management, *Assessment Report: Generic Design Assessment: Disposability Assessment for wastes and spent fuel arising from operation of the UK ABWR, Part 1: main report*, RWM Technical Note No. 23788023, 2016.

17 Radioactive Waste Management, *Assessment Report: Generic Design Assessment: Disposability Assessment for waste and spent fuel arising from operation of the UK ABWR, Part 2: supporting data*, RWM Technical Note No. 23718693, 2016.

18 *The Strategic Defence Review White Paper*, Cm3999, 1998.

19 Nuclear Decommissioning Authority, *Strategy: Effective from April 2016*, SG/2016/53, March 2016.

20 Radioactive Waste Management, *Geological Disposal: Review of Alternative Radioactive Waste Management Options,* NDA Report no. NDA/RWM/146, March 2016.

21 NDA, *Higher Activity Waste: Strategic Position Paper on the Management of Waste Graphite*, SMS/TS/D1-HAW-6/003/PP, 2014.

Glossary

Term	Definition
ABWR	Advanced boiling water reactor. Horizon Nuclear Power are proposing to build UK ABWRs at Wylfa and Oldbury
AGR	Advanced gas-cooled reactor
AP1000	Pressurised water reactor sold by Westinghouse Electric Company
BFS	Blast furnace slag
Conditioned volume	The conditioned waste volume is the volume of the wasteform (waste plus immobilising medium) within the container
Cooling time	Average time after the irradiation of fuel elements in a reactor stops
CSA	Criticality safety assessment
Disposal unit	A waste package, or group of waste packages, which is handled as a single unit for the purposes of transport and/or disposal
DNLEU	Depleted, natural and low enriched uranium
DSSC	Disposal System Safety Case
DU	Depleted uranium
DU tails	Depleted uranium left over from enrichment operations
EBS	Engineered barrier system
EPR	EPR is now used by AREVA as a reactor name, it was previously used to mean European Pressurized Reactor and Evolutionary Power Reactor
ESC	Environmental safety case
FED	Fuel element debris
GDA	Generic Design Assessment
GDF	Geological disposal facility
gESA	generic Environmental Safety Assessment
gOSC	generic Operational Safety Case
gTSC	Generic Transport Safety Case
GWd/tU	Gigawatt days per ton of uranium (1 ton = 1,000 kg)
GW(e)	Gigawatts electrical
HAW	Higher activity radioactive waste
HEU	Highly enriched uranium

Term	Definition
HHGW	High heat generating waste
HLW	High level waste
IAEA	International Atomic Energy Agency
IGD	Inventory for geological disposal
ILW	Intermediate level waste
ISA	Isosaccharinic acid
ISO	International organisation for standardization
JET	Joint European Torus
LAW	Low active waste
Legacy waste	Radioactive waste which already exists or whose arising is committed in future by the operation of an existing facility
LEU	Low enriched uranium
LHGW	Low heat generating waste. Some wastes have negligible heat output; these are included in this category
LLW	Low level waste
LLWR	Low Level Waste Repository
LWR	Light Water Reactor
MBGWS	Mixed Beta Gamma Waste Store
MDU	Magnox depleted uranium
MOD	Ministry of Defence
MOX	Mixed oxide fuel
MSSS	Magnox Swarf Storage Silo
NB	New build
OESA	Operational environmental safety assessment
OPC	Ordinary Portland cement
OSC	Operational safety case
Packaged volume	Volume occupied by waste package when waste has been packaged
Payload	Usable internal volume of a waste package
PCM	Plutonium contaminated materials

Term	Definition
PCSA	Post-closure safety assessment
PCSR	Pre-construction Safety Report
PFA	Pulverised fuel ash
PFR	Prototype fast reactor
POCO	Post-operational clean-out
ppm	Parts per million
Priority 1 radionuclide	Highest priority score for those radionuclides having greatest effect on, wasteform, packaging, transport, criticality and GDF design
Pu	Plutonium
PVC	Polyvinyl chloride
PWR	Pressurised Water Reactor
RAL	Rutherford Appleton Laboratory
RGL	Regulatory guidance level
RPCM	Radiological protection criteria manual
RS	Robust shielded
RSC	Robust shielded container
RSC	Robust shielded container
SF(s)	Spent fuel(s): nuclear fuel removed from a reactor following irradiation that is no longer usable in its present form because of depletion of fissile material, poison build-up or radiation damage.
SILW	Shielded ILW
SILW waste package	Waste package not requiring additional shielding
SLLW	Shielded LLW
SRL	Scientific readiness level: A scale calibrating the scientific maturity of underpinning science between 1 and 6 where 1 is the least mature and 6 the most established understanding
SS	Stainless steel
Superplasticiser	Commonly used to improve the flow characteristics of cements and concrete and also allow the water to cement ratio to be reduced (this produces stronger concretes). Superplasticisers could enhance the solubility of actinides
SWTC	Standard Waste Transport Container

Term	Definition
TDC	Transport and disposal container
tHM	Tons of heavy metal (1 ton = 1,000 kg)
THORP	Thermal Oxide Reprocessing Plant
TPS	Transport package safety
TPU	THORP product uranium
TSC	Transport safety case
TSD	Transport system design
TSSA	Transport system safety assessment
tU	Tons of uranium (1 ton = 1,000 kg)
UILW	Unshielded ILW
UILW waste package	Waste package requiring additional shielding
UK RWI	UK radioactive waste inventory (also referred to as UK RWMI - UK radioactive waste and materials inventory)
ULLW	Unshielded LLW
VLLW	Very low level waste
WVP	Waste Vitrification Plant

Appendix A – Waste stream changes

A1 New waste streams

Table A1 New waste streams in the 2016 IGD

Waste stream ID	Waste stream name	Packaged volume [m^3]
2D200	Contact Handled ILW from Harwell	578
2D64	Magnox Interfacial Crud - ILW	22.8
2D95.5	Sludge in SPP1 Buffer	54.7
2D97	Miscellaneous Trench Silt ILW/LLW	557
2F28	Interfacial Crud - ILW/LLW	0.49
2Y60	Miscellaneous Minor Wastes - ILW	110
3S12/C	CVCS Resins and Spent Resins (ILW) - Conditioned waste	210
3S310	Fuel Pond Solid Absorber Assemblies	67.8
5C335	LETP HLA Tanks ILW	0.607
5G23	Thorium Metal	1.9
5H11	Materials Research Facility ILW	2.33
6C31/C	NDS Contact Handled ILW	18.5
6N01	Neutron Targets	0.588
6N02	Moderators	1.76
6N03	Reflectors	2.88
7J23	Miscellaneous ILW	19.6
7J25	Luminised Waste	11.5
9A03/C	Ion Exchange Material	38.1
9A44/C	Miscellaneous Activated Components	14.4
9B02/C	Ion Exchange Material	39.6
9B15/C	Sludge	3.96
9B83/C	Graphite Filter Dust Pots	9.24
9B85	FED Magnox - Secondary Ion Exchange Resin (Cs-Treat)	1.32
9B964	FAVORIT Plant	13.1

Waste stream ID	Waste stream name	Packaged volume [m^3]
9C20	AETP Sludge	5.44
9C67	CRU1 Ion-exchange resin	6.6
9C68	Sand & Gravel ST2	32.7
9D33	FED Magnox R1	391
9D34	FED Magnox R2	403
9D41	FED Magnox - R1	308
9D42	FED Magnox - R2	284
9D67	FED Sludge - R1	35.5
9D68	FED Sludge - R2	35.5
9D69	FED Sludge - R1	71.1
9D70	FED Sludge - R2	71.1
9D925	Ponds & Magnox Vault ILW Scabblings	5.29
9D926	ILW Skip Millings	0.123
9D930	Bradwell ILW skips	3.27
9D931	Sellafield ILW skip	11.9
9E961	Ion Siv Unit Cartridges	11.7
9E962	Ion Siv Unit Cartridges	8.93
9E963	Ion Siv Unit Cartridges	5.28
9E964	Ion Siv Unit Pre Filters	1.99
9E965	Ion Siv Unit Pre Filters	1.99
9F45	Fuel Bottle	2.64
9G107/C	Ion Exchange Material	457
9G123	Ponds North Void FED debris	1.7
9G124	Loose Particulate Waste North and South FED vaults	4.6
9G125	R2 Pressure Vessel Sampling Inspection Equipment	3.56
9G126	DWTP Sand Filtration Vessel	3.56
9G129	Active Waste Vaults ILW	2.47
9G130	Flux Detectors	1.81

Waste stream ID	Waste stream name	Packaged volume [m^3]
9G131	AETP Sand & Sludge	11.7
9G78/C	MSV and RV1 WRATS	3.27
9G79	Ponds Sampling Drain 7 Components	14.7

A2 Deleted waste streams

Table A2 Waste streams that appeared in the 2013 IGD but which are no longer present in the 2016 IGD

<table>
<tr><th>ID</th><th>Stream Name</th><th>Comment</th><th>Packaged Volume [m^3]</th></tr>
<tr><td colspan="4">Legacy SILW / SLLW</td></tr>
<tr><td>7A108</td><td>Decommissioning LLW Above the LLWR Limit</td><td>May not be suitable for LLWR</td><td>571</td></tr>
<tr><td>9G107</td><td>Care and Maintenance Preparation: Ion Exchange Material</td><td>Now conditioned as 9G107/C</td><td>439</td></tr>
<tr><td>9G113</td><td>CDVAR Plates</td><td>Reclassified as LLW</td><td>16.6</td></tr>
<tr><td>9G19</td><td>Ion Exchange Material</td><td>Now part of 9G107/C</td><td>30.9</td></tr>
<tr><td colspan="4">Legacy UILW / ULLW</td></tr>
<tr><td>1B05</td><td>ILW Containing Carbon-14 Excluding Free Liquid</td><td rowspan="3">Waste will be incinerated</td><td>49.0</td></tr>
<tr><td>1B07</td><td>ILW Containing Tritium and Carbon-14</td><td>1.84</td></tr>
<tr><td>1B10</td><td>ILW Containing Carbon-14 Free Liquid</td><td>16.5</td></tr>
<tr><td>3L24</td><td>Bypass Blowdown Filters</td><td>Sent for metal treatment</td><td>56.1</td></tr>
<tr><td>6C31</td><td>NDS Contact Handled ILW</td><td>Now 6C31/C</td><td>10.3</td></tr>
<tr><td>6K106</td><td>Irradiation Tubes</td><td>Transferred to Sellafield</td><td>0.059</td></tr>
<tr><td>7E27</td><td>Submarine Ion Exchange Resin</td><td>Now in 7E29</td><td>11.6</td></tr>
<tr><td>9C45</td><td>Fuel Skips in Pond</td><td>Reclassified as LLW</td><td>169</td></tr>
<tr><td>9G14</td><td>Desiccant</td><td>Waste is incinerated</td><td>37.6</td></tr>
<tr><td>9G17</td><td>Sludge</td><td>Now in 9G78</td><td>10.6</td></tr>
<tr><td>9G55</td><td>Oil</td><td>All waste disposed</td><td>0.490</td></tr>
<tr><td>9G75</td><td>Sludge - RV3</td><td>Now in 9G107/C</td><td>5.53</td></tr>
<tr><td colspan="4">RSCs</td></tr>
<tr><td>9A03</td><td>Ion Exchange Material</td><td>Conditioned as 9A03/C</td><td>27.0</td></tr>
<tr><td>9A18</td><td>Desiccant</td><td>Disposed</td><td>57.2</td></tr>
<tr><td>9A44</td><td>Miscellaneous Activated Components</td><td>Conditioned as 9A44/C</td><td>148</td></tr>
<tr><td>9A76</td><td>Contaminated Gravel</td><td>Disposed as LLW</td><td>47.0</td></tr>
</table>

ID	Stream Name	Comment	Packaged Volume [m³]
9A917	Empty Drums and Liners	Will be processed with 9A25 and 9A57-59	174
9B13/C	Desiccant	Now in 9B13 – should not have been reported as conditioned	61.1
9B18/C	Miscellaneous Contaminated Items	Now in 9B65 & 9B17	4.35
9B35	Contaminated Gravel	Reclassified as LLW and transferred to 9B21	6.01
9B40	Contaminated Gravel		2.39
9B41	Contaminated Gravel		2.39
9B42	Contaminated Gravel		2.39
9B53	Pond Fuel Skips ILW	Now at Hinkley Point A (9D930)	6.53
9B60	Contaminated Gravel	Waste reclassified as LLW and transferred to 9B21	5.98
9B61	Contaminated Gravel		5.98
9B62	Contaminated Gravel		6.09
9B64	Ion Exchange Resin PWTP	All waste disposed	16.2
9B83	Graphite Filter Dust Pots	Conditioned as 9B83/C	22.6
9B914	Miscellaneous Contaminated Items PWTP & AETP decommissioning	Reclassified as LLW	410
9C39	Ion Siv Unit Cartridges	Now at Oldbury (9E961)	20.2
9C42	Ion Siv Unit Cartridges	Now at Oldbury (9E962)	17.4
9C48	Pond Skip Decontamination Sludge	Skips will not be decontaminated	3.92
9C49	Pond Skip Decontamination Sludge		3.26
9C63	AETP Sludge	Captured in 9C16 & 9C20	72.9
9D85	FED Dissolution Secondary Waste (Ion Exchange Resin)	Dissolution is no longer the treatment strategy	16.9
9D86	FED Dissolution Secondary Waste (Sludge)		28.2
9D87	FED Dissolution Secondary Waste (Filters)		16.9
9E62	Pond Skip Decontamination Sludge	Change in strategy	8.49

ID	Stream Name	Comment	Packaged Volume [m^3]
9E64	FED Secondary Arisings - Sludge	Change in strategy	44.7
9E65	FED Secondary Arisings - Ion Exchange	Change in strategy	5.44
9E66	FED Secondary Arisings - Filters	Change in strategy	5.44
9E67	Pond Wall Paint and Concrete Fines from Water Jetting	Change in strategy	30.5
9F32	Ion Siv Unit Cartridges	Now at Oldbury (9E963)	4.36
9F914	Magnox FED Dissolution Sludge	Change in strategy	10.5
9F915	FED Dissolution Filtration Media	Change in strategy	6.31
9F916	FED Dissolution Ion Exchange Media	Change in strategy	6.31

Appendix B – Details of changes by waste group

B1 Legacy SILW / SLLW

B1.1 Volumes

As can be seen in Table B1, the volume of waste associated with this waste group has increased slightly. The reasons for the changes to this waste group are varied and are due to changes in volume estimates and packaging assumptions. For example, the increased use of 6 m^3 boxes (instead of RSCs) at some Magnox stations.

Table B1 The change in the volume of waste in the Legacy SILW / SLLW waste group between the 2013 and 2016 IGD

Volume	Volume [m^3]		Difference (%)
	2013 IGD	2016 IGD	
Stored	62,200	63,900	2.8%
Conditioned	76,300	79,300	3.9%
Packaged	93,000	99,300	6.8%

B1.2 Disposal Units

Table B2 shows that there has been an overall increase of approximately 11% in the number of disposal units in the Legacy SILW / SLLW waste group. Whilst the overall change in the number of disposal units is not significant, there are some significant changes to the different types of waste packages: there are no longer any 2 m boxes in the IGD, and the number of 6 m^3 boxes has increased, consistent with the move to using 6 m^3 boxes instead of RSCs at some Magnox sites.

Table B2 The change in the number of disposal units in the Legacy SILW / SLLW waste group between the 2013 and 2016 IGDs

Waste container	Disposal units [-]		Difference (%)
	2013 IGD	2016 IGD	
2 m box (100mm concrete)	75	0	-100%
4 m box (0mm concrete)	2,760	2,730	-1%
4 m box (100mm concrete)	1,190	1,230	3%
4 m box (200mm concrete)	399	362	-9%
6 m^3 box (high density)	96	169	78%
6 m^3 box (low density)	330	909	176%
Total	4,850	5,400	11%

B1.3 Activities

The total activity of the waste group at 2040 has decreased by approximately 59% from 36,800 TBq to 15,100 TBq. This reduction is largely a result of a change in packaging assumptions for AGR miscellaneous activated components and fuel stringer debris (which are now packaged in unshielded containers). At 2200 the activity has decreased by approximately 13% from 15,900 TBq to 13,800 TBq. However, there have been some significant increases in the activities of individual radionuclides. Table B3 and Table B4 show the changes in the activities of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments at 2040 and 2200, respectively. There are some significant increases in the activity at 2200 of Co-60 (x 210), I-129 (x 10) and U-238 (x 9.5). These changes, whilst significant in percentage terms, should be viewed in the context of the actual activities, which are low in all three cases. The changes are largely a result of wastes that were previously in the RSC waste group, and that have been brought into the Legacy SILW / SLLW waste group as a result of 6 m^3 boxes being used in place of RSCs. There has been a reduction in the activity of the gaseous radionuclides that are important to RWM's gas pathway analysis during the GDF operational period. The reduction in the activity of C-14 is minimal. The reduction in Ra-226 is largely the result of changes to waste producers' plans, with waste stream 5G04 now assumed to be disposed of in an unshielded package. The reduction in the activity of H-3 is largely the result of a revised estimate for waste stream 5H301 (Tritiated but non-activated JET Decommissioning).

Table B3 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the SILW / SLLW waste group at 2040 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	70.8	65.5	-7%
	Cl-36	0.260	0.484	86%
	Co-60	3,140	1,390	-56%
	Se-79	$3.30\ 10^{-4}$	$3.50\ 10^{-4}$	6%
	Kr-85	0.779	0.727	-7%
	Tc-99	$9.89\ 10^{-2}$	0.192	94%
	I-129	$2.06\ 10^{-5}$	$2.27\ 10^{-4}$	x 10
	Cs-135	$4.81\ 10^{-2}$	$4.56\ 10^{-2}$	-5%
	Cs-137	148	221	50%
	U-233	$5.96\ 10^{-2}$	$5.60\ 10^{-2}$	-6%
	U-235	$1.91\ 10^{-4}$	$4.19\ 10^{-4}$	119%
	U-238	$2.99\ 10^{-3}$	$3.16\ 10^{-2}$	x 9.5
	Np-237	$2.84\ 10^{-2}$	$3.51\ 10^{-2}$	24%
Gas	H-3	16,900	4,460	-74%
	C-14	70.8	65.5	-7%
	Ra-226	$7.79\ 10^{-2}$	$1.35\ 10^{-2}$	-83%

Table B4 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the SILW / SLLW waste group at 2200 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	6,400	6,400	~0%
	Cl-36	26.0	26.2	1%
	Co-60	$7.69\ 10^{-6}$	$1.62\ 10^{-3}$	x 210
	Se-79	$3.30\ 10^{-4}$	$3.50\ 10^{-4}$	6%
	Kr-85	$2.53\ 10^{-5}$	$2.36\ 10^{-5}$	-7%
	Tc-99	0.301	0.394	31%
	I-129	$2.06\ 10^{-5}$	$2.27\ 10^{-4}$	x 10
	Cs-135	$4.81\ 10^{-2}$	$4.56\ 10^{-2}$	-5%
	Cs-137	3.75	5.61	50%
	U-233	$5.96\ 10^{-2}$	$5.60\ 10^{-2}$	-6%
	U-235	$1.91\ 10^{-4}$	$4.19\ 10^{-4}$	119%
	U-238	$2.99\ 10^{-3}$	$3.16\ 10^{-2}$	x 9.5
	Np-237	$2.87\ 10^{-2}$	$3.57\ 10^{-2}$	25%
Gas	H-3	2.41	0.90	-63%
	C-14	6,400	6,400	~0%
	Ra-226	$7.27\ 10^{-2}$	$1.26\ 10^{-2}$	-83%

B1.4 Materials

Table B5 shows the changes in the masses of the different materials in the waste group. The overall change is small (a 2% increase), and the increases to the different categories of materials are also small: 4% for metals, 7% for organics and 2% for other materials. However, some materials have had significant changes and the reasons for these are:

- uranium has been introduced from JET decommissioning ILW: waste stream 5H301
- the use of 6 m^3 boxes in place of RSCs (see Section 2.2.1) is largely responsible for the increases in 'other inorganics', 'soil and rubble', 'other organics', and 'glass, ceramics and sand'
- the change in the management strategy for some Magnox FED (from dissolution to disposal) has resulted in increases in Magnox and 'sludges and flocs'
- the change in the management strategy for Magnox FED and the inclusion of post irradiation examination wastes is responsible for the increase in Zircaloy

- the reduction in ‘rubber’ and ‘halogenated plastics; is a result of waste stream 7A108 now being disposed of in an unshielded waste package

Table B5 Changes to the material masses in Legacy SILW / SLLW

	Material	Mass [t] 2013 IGD	Mass [t] 2016 IGD	Difference [%]
Metals	Stainless Steel	2,900	3,210	11%
	Other ferrous metals	14,500	14,500	~0%
	Magnox / magnesium	16.0	321	x 19
	Aluminium (and alloys)	23.9	25.1	5%
	Zircaloy / zirconium	16.6	30.6	84%
	Copper (and alloys)	23.5	13.2	-44%
	Nickel (and alloys)	9.06	12.8	41%
	Uranium	0	8.20 10^{-2}	x 50
	Lead	5.79	3.10	-46%
	Other metals	24.6	37.1	51%
	Total metals	17,500	18,200	4%
Organics	Cellulose	8.69	11.9	37%
	Halogenated plastics	14.6	2.03	-86%
	Non-halogenated plastics	281	278	-1%
	Rubbers	2.87	0.218	-92%
	Organic ion ex. resins	97.4	137	41%
	Other organics	0.200	5.85	x 28
	Total organics	405	435	7%
Other materials	Graphite	62,500	63,100	1%
	Asbestos	0.269	0.300	12%
	Sludges & flocs	0	88.0	x 50
	Cementitious materials	1,650	1,730	5%
	Ion exchange resins	167	193	16%
	Heavy metal oxide	0	0	0%
	Glass, ceramics and sand	2.87	75.0	x 25
	Soil and rubble	5.38	247	x 45
	Other inorganics	0	82.6	x 50

	Total other materials	**64,300**	**65,500**	**2%**
	Total unspecified	**315**	**354**	**12%**
	Total	**82,500**	**84,500**	**2%**

B2 Legacy UILW / ULLW

B2.1 Volumes

Table B6 shows that there has been only a small increase in the quantity of waste in this waste group, mainly as a result of revised estimates from waste producers.

Table B6 The change in the volume of waste in the Legacy UILW / ULLW waste group between the 2013 and 2016 IGDs

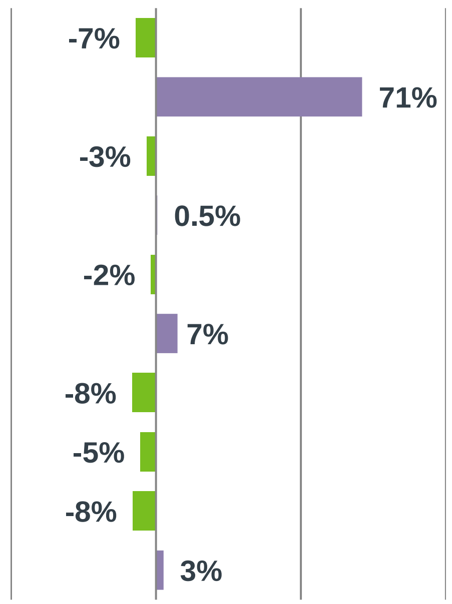
Volume	Volume [m^3]		Difference [%]
	2013 IGD	2016 IGD	
Stored	203,000	208,000	2.6%
Conditioned	259,000	260,000	0.6%
Packaged	327,000	329,000	0.7%

B2.2 Disposal Units

Table B7 shows that there has been a slight increase in the number of disposal units in the Legacy UILW / ULLW waste group between the 2013 and 2016 IGDs. Of the individual waste container types, only the 3 m^3 box (square corners) has seen a significant change; this is associated with the assumption that the defence programme wastes continue to arise for longer (waste stream 7G104 Long-Lived ILW from Decommissioned Submarines).

Table B7 The change in the number of disposal units in the Legacy UILW / ULLW waste group between the 2013 and 2016 IGDs[16]

Waste container	Disposal units [-]		Difference [%]
	2013 IGD	2016 IGD	
3 m³ box	4,770	4,430	-7%
3 m³ box (square corners)	402	688	71%
3 m³ drum	563	545	-3%
3 m³ Sellafield box	54,300	54,600	0.5%
3 m³ Sellafield Enhanced box	16,300	16,100	-2%
500 l drum	22,900	24,700	7%
Beta/gamma box	1,500	1,380	-8%
Enhanced 500 l drum (basket)	6,530	6,180	-5%
Enhanced 500 l drum (pre-cast)	223	205	-8%
Total	108,000	109,000	3%



B2.3 Activities

The total activity of the Legacy UILW / ULLW waste group has increased slightly: from 1,890,000 TBq to 1,940,000 TBq at 2040 (an increase of approximately 3%) and from 355,000 TBq to 372,000 TBq at 2200 (an increase of approximately 5%). Whilst the change in the total activity is small, the changes to individual radionuclides can be large.

Table B8 and Table B9 show the activities of priority 1 radionuclides in this waste group. The significant increase in the activity of Co-60 at 2040 is a result of additional waste from the lifetime extensions to the AGR fleet. The activity of Co-60 at 2200 has decreased as waste stream 3J24 is now part of the Legacy SILW / SLLW waste group. The other radionuclide showing a significant change is Se-79; this change is principally a result of a change in the estimated activity associated with waste stream 2D08.

For the radionuclides that are of interest to the gas pathway analysis: the change in Ra-226 is minimal; the activity of C-14 has reduced mainly as a result of waste stream 1B05 being removed from the IGD (it is now expected to be incinerated); and the increase in H-3 is mainly a result of wastes from RAL being included (despite their very small volume, the RAL moderators have a high H-3 specific activity as a result of the activation of both metals and the methane moderator) and AGR lifetime extensions.

16 The 3 m³ Sellafield box and the Enhanced 3 m³ Sellafield Box are instances of the 3 m³ box (square corners); the Enhanced 500 l drum (pre-cast) and the Enhanced 500 l drum (basket) are instances of the 500 l drum.

Table B8 **The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the UILW / ULLW waste group at 2040 between the 2013 and 2016 IGDs**

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	672	535	-20%
	Cl-36	8.04	8.07	~0%
	Co-60	43,600	92,000	111%
	Se-79	0.384	0.555	45%
	Kr-85	778	853	10%
	Tc-99	916	1010	11%
	I-129	0.62	0.706	14%
	Cs-135	7.6	6.47	-15%
	Cs-137	315,000	257,000	-18%
	U-233	1.04	0.983	-6%
	U-235	0.567	0.535	-6%
	U-238	18.1	17.9	-1%
	Np-237	108	106	-2%
Gas	H-3	5,600	6,420	15%
	C-14	672	535	-20%
	Ra-226	9.04	9.40	4%

Table B9 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM’s gas pathway analysis in the UILW / ULLW waste group at 2200 between the 2013 and 2016 IGD

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	1,350	1,200	-11%
	Cl-36	9.44	9.44	~0%
	Co-60	2.69E-03	8.54E-04	-68%
	Se-79	0.387	0.556	44%
	Kr-85	2.53 10^{-2}	2.77 10^{-2}	10%
	Tc-99	917.00	1,020	12%
	I-129	0.621	0.707	14%
	Cs-135	7.64	6.47	-15%
	Cs-137	8,120	6,570	-19%
	U-233	1.14	1.07	-6%
	U-235	0.591	0.552	-7%
	U-238	18.6	18.3	-1%
	Np-237	110	108	-2%
Gas	H-3	0.809	0.907	12%
	C-14	1,350	1,200	-11%
	Ra-226	8.44	8.78	4%

B2.4 Materials

Table B10 shows the changes in the masses of the different materials in the waste group. The overall change is small (-1%), and the changes to the metals (-5%) and other materials (+4%) are also small. The organic content has reduced by 20%. Some materials have had significant changes and the principal reasons for these changes are revised characterisation of the wastes. In particular, revised characterisation of PCM streams is responsible for the majority of the changes.

Some materials have seen increases. The increase in soil and rubble is the result of the revised characterisation of the PCM wastes, while the increase in organic ion exchange resins is a result of revisions to packaging assumptions, which result in additional wastes in the legacy UILW / ULLW waste group.

The increase in ‘unspecified’ is a result of the 2016 IGD being a light update to the 2013 IGD: the full review and enhancement process has not been carried out.

Table B10 Changes to the material masses in Legacy UILW / ULLW

	Material	Mass [t]		Difference [%]
		2013 IGD	2016 IGD	
Metals	Stainless Steel	32,300	28,000	-13%
	Other ferrous metals	38,300	39,100	2%
	Magnox / magnesium	6,270	5,810	-7%
	Aluminium (and alloys)	1,900	1,700	-11%
	Zircaloy / zirconium	1,240	1,260	2%
	Copper (and alloys)	389	278	-29%
	Nickel (and alloys)	241	242	0%
	Uranium	941	957	2%
	Lead	1,120	802	-28%
	Other metals	227	284	25%
	Total metals	82,900	78,400	-5%
Organics	Cellulose	2,580	2,130	-17%
	Halogenated plastics	4,720	3,600	-24%
	Non-halogenated plastics	2,330	1,710	-27%
	Rubbers	1,950	1,690	-13%
	Organic ion ex. resins	52	112	116%
	Other organics	457	451	-1%
	Total organics	12,100	9,690	-20%
Other materials	Graphite	13,900	15,000	8%
	Asbestos	295	309	5%
	Sludges & flocs	22,200	21,200	-5%
	Cementitious materials	52,100	53,300	2%
	Ion exchange resins	3,230	2,520	-22%
	Heavy metal oxide	0	0	0%
	Glass, ceramics and sand	429	473	10%
	Soil and rubble	2,180	2,640	21%
	Other inorganics	9,440	12,900	37%

	Total other materials	104,000	108,000	4%
	Total unspecified	584	1,300	123%
	Total	199,000	198,000	-1%

B3 RSCs

B3.1 Volumes

Table B11 shows that there has been a significant reduction in the volume of waste associated with the RSC waste group. This is a result of a change from RSCs to 6 m^3 boxes for packaging some wastes at some Magnox stations.

Table B11 The change in the volume of waste in the RSC waste group between the 2013 and 2016 IGDs

Volume	Volume [m^3]		Difference [%]
	2013 IGD	2016 IGD	
Stored	2,840	1,330	-53%
Conditioned	3,460	1,180	-66%
Packaged	7,280	2,730	-63%

B3.2 Disposal Units

Table B12 shows the change in the number of disposal units for the waste containers in the RSC waste group. As would be expected, there has been a significant reduction as a result of a change from robust shielded containers (RSCs) to 6 m^3 boxes for packaging some wastes at some Magnox stations. The individual types of 500 l robust shielded (RS) drums would show extreme percentage changes as a result of the small number of units. They are therefore shown separately in Table B13 so that the overall trends can be more clearly seen.

Table B12 The change in the number of disposal units in the RSC waste group between the 2013 and 2016 IGDs

Waste container	Disposal units [-]		Difference [%]
	2013 IGD	2016 IGD	
3 m^3 RS box	1,040	354	-66%
500 l RS drums	1,230	609	-51%
Total	2,270	962	-58%

Table B13 The number of 500 l RS drums in the 2013 and 2016 IGDs

Waste container	Disposal units [-]	
	2013 IGD	2016 IGD
500 l RS drum (0 mm Pb)	683	477
500 l RS drum (20 mm Pb)	369	53
500 l RS drum (30 mm Pb)	146	16
500 l RS drum (50 mm Pb)	0	7
500 l RS drum (60 mm Pb)	2	0
500 l RS drum (80 mm Pb)	1	3
500 l RS drum (90 mm Pb)	5	38
500 l RS drum (120 mm Pb)	28	15

B3.3 Activities

The activity has dropped: from 5,350 TBq to 4,340 TBq at 2040 (a drop of approximately 19%); and from 1,180 TBq to 1,110 TBq at 2200 (a drop of only 6%). The percentage drop in total activity is less than the percentage drop in volume as the highest activity wastes are retained in RSCs. The drop in the activity of the individual radionuclides is dependent on the wastes that have had their packaging assumptions changed. At 2200, two radionuclides show an increase in activity (Co-60 and Kr-85), both of which have a very low activity. The increases are associated with changes in the characterisation of the wastes.

Table B14 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the RSC waste group at 2040 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	7.58	4.95	-35%
	Cl-36	0.446	0.254	-43%
	Co-60	23.9	20.3	-15%
	Se-79	$1.39\ 10^{-4}$	$7.79\ 10^{-5}$	-44%
	Kr-85	0.204	0.104	-49%
	Tc-99	$7.82\ 10^{-2}$	$3.10\ 10^{-2}$	-60%
	I-129	$4.57\ 10^{-4}$	$4.47\ 10^{-5}$	-90%
	Cs-135	$7.73\ 10^{-3}$	$7.59\ 10^{-3}$	-2%
	Cs-137	832	479	-42%
	U-233	$1.70\ 10^{-4}$	$1.57\ 10^{-4}$	-8%
	U-235	$5.19\ 10^{-4}$	$2.90\ 10^{-4}$	-44%
	U-238	$3.93\ 10^{-2}$	$9.63\ 10^{-3}$	-76%
	Np-237	$1.42\ 10^{-2}$	$7.92\ 10^{-3}$	-44%
Gas	H-3	38.6	20.20	-48%
	C-14	7.58	4.95	-35%
	Ra-226	$9.89\ 10^{-3}$	$1.14\ 10^{-4}$	-99%

Table B15 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the RSC waste group at 2200 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	7.43	5.69	-23%
	Cl-36	0.446	0.254	-43%
	Co-60	$1.74\ 10^{-8}$	$2.37\ 10^{-8}$	36%
	Se-79	$1.39\ 10^{-4}$	$7.86\ 10^{-5}$	-43%
	Kr-85	$6.60\ 10^{-6}$	$1.12\ 10^{-5}$	70%
	Tc-99	$7.82\ 10^{-2}$	$3.26\ 10^{-2}$	-58%
	I-129	$4.57\ 10^{-4}$	$5.01\ 10^{-5}$	-89%
	Cs-135	$7.73\ 10^{-3}$	$7.65\ 10^{-3}$	-1%
	Cs-137	21.1	12.4	-41%
	U-233	$1.80\ 10^{-4}$	$1.63\ 10^{-4}$	-10%
	U-235	$5.20\ 10^{-4}$	$2.91\ 10^{-4}$	-44%
	U-238	$3.93\ 10^{-2}$	$9.64\ 10^{-3}$	-75%
	Np-237	$1.48\ 10^{-2}$	$8.06\ 10^{-3}$	-46%
Gas	H-3	$4.80\ 10^{-3}$	$2.56\ 10^{-3}$	-47%
	C-14	7.43	5.69	-23%
	Ra-226	$9.23\ 10^{-3}$	$1.08\ 10^{-4}$	-99%

B3.4 Materials

Changes to the waste producer's plans result in some wastes from some Magnox stations being packaged in 6 m^3 boxes rather than RSCs. This has resulted in a decrease in the quantity of waste in RSCs and, as a result, a reduction in the mass of many of the materials. Overall there has been a 42% reduction in mass. The change to metals is small (-2%), while the changes to organics (-71%) and other materials (-45%) are more significant. However, as can be seen in Table B16, there are some materials that see an increase in their mass. These changes are largely a result of revised characterisation of the wastes. In the case of glass, ceramics and sand, the large change is a result of the way that the materials have been grouped: for the 2013 IGD, sand was reported in 'cement, concrete and sand' (roughly equivalent to the 'cementitious materials' reported in the 2016 IGD). For the 2016 IGD, sand is reported separately (and is grouped with glass and ceramics in Table B16).

Table B16 Changes to the material masses in RSCs

	Material	Mass [t]		Difference [%]
		2013 IGD	2016 IGD	
Metals	Stainless Steel	187	52.3	-72%
	Other ferrous metals	251	445	77%
	Magnox / magnesium	90.7	32.4	-64%
	Aluminium (and alloys)	1.53	2.89	89%
	Zircaloy / zirconium	28.9	16.3	-44%
	Copper (and alloys)	0.214	0.214	0%
	Nickel (and alloys)	2.62	2.91	11%
	Uranium	0.191	0	-100%
	Lead	0.143	0.143	0%
	Other metals	0.338	0.625	85%
	Total metals	562	553	-2%
Organics	Cellulose	24	6.78	-72%
	Halogenated plastics	17.8	4.84	-73%
	Non-halogenated plastics	22.7	2.05	-91%
	Rubbers	5.51	1.14	-79%
	Organic ion ex. resins	377	111	-71%
	Other organics	17.6	11.3	-57%
	Total organics	464	137	-71%
Other materials	Graphite	493	277	-44%
	Asbestos	2.57	1.6	-38%
	Sludges & flocs	319	220	-31%
	Cementitious materials	164	8.72	-95%
	Ion exchange resins	39.3	24.9	-37%
	Heavy metal oxide	0	0	0%
	Glass, ceramics and sand	7.77	72.5	x 8.3
	Soil and rubble	391	84	-79%
	Other inorganics	78.7	130	65%

	Total other materials	**1500**	**819**	**-45%**
	Total unspecified	**119**	**29.8**	**-75%**
	Total	**2,650**	**1,540**	**-42%**

B4 DNLEU

The DNLEU has arisen from two primary sources: Magnox depleted uranium (MDU) and THORP product uranium (TPU) arise from reprocessing of spent fuels, while depleted uranium tails arise from enrichment activities at Capenhurst. In addition, there is a small amount of 'miscellaneous DNLEU' that has arisen from a variety of sources. The DNLEU associated with each of the sources is shown in Table B17. There is an increase of 30,000 tU (16% of the total) in the quantity of unirradiated DU tails associated with the increased operational period that is assumed for enrichment activities.

Table B17 The quantity of DNLEU associated with each category in the 2013 and 2016 IGDs

DNLEU category	Waste container	Quantity [tU]	
		2013 IGD	2016 IGD
Magnox depleted uranium	TDC (2.4 m high)	23,100	23,100
Magnox depleted uranium	TDC (2.1 m high)	14,900	14,900
THORP product uranium	500 l drum	5,000	5,000
DU tails (irradiated)	TDC (2.3 m high)	15,500	15,500
DU tails (unirradiated)	TDC (2.3 m high)	108,500	138,500
Miscellaneous DNLEU	500 l drum	3,000	3,000
Defence DU	500 l drum	15,000	15,000

B4.1 Volumes

Table B18 shows that although the quantity of DNLEU has increased, there has been a reduction in the volume. This is associated with more realistic assumptions being made regarding how the DNLEU is stored and disposed of (see section 2.2.3 for details). The DNLEU is currently (or will be) stored in drums and in the 2013 IGD the quantity of DNLEU that was assumed to be stored in the drums was assumed to be at the lower end of the range; this maximised the number of packages. Now, a more realistic average quantity of DNLEU per drum has been adopted. This has reduced the number of drums and, as a consequence, reduced the number of transport and disposal containers (TDCs) that are used for the transport and disposal of the DNLEU. In addition, the assumed densities of the powders have been updated in line with the other changes.

Table B18 The change in the volume of waste in the DNLEU waste group between the 2013 and 2016 IGDs

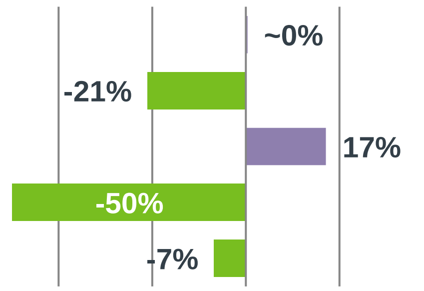
Volume	Volume [m^3]		Difference (%)
	2013 IGD	2016 IGD	
Stored	111,000	99,100	-10.9%
Conditioned	160,000	139,000	-13.1%
Packaged	217,000	191,000	-12.3%

B4.2 Disposal Units

Table B19 shows that overall there has been a small reduction in the number of disposal units associated with DNLEU. The increase in the 2.3 m high TDCs is associated with the increased quantity of DU tails arising from enrichment activities, while the reduction to the number of 2.1 m high and 2.4 m high TDCs is a result of the more realistic assumptions that are now made regarding how the DNLEU will be disposed of. These changes to assumptions only affect the DNLEU that is packaged in TDCs. As a result, the number of 500 l drums is not affected by this change (and shows only a very small increase).

Table B19 The change in the number of disposal units in the DNLEU waste group between the 2013 and 2016 IGDs

Waste container	Disposal units [-]		Difference [%]
	2013 IGD	2016 IGD	
500 l drum (DNLEU)	5,950	5,970	~0%
Uranium TDC (2.1 m high)	581	460	-21%
Uranium TDC (2.3 m high)	3,780	4,430	17%
Uranium TDC (2.4 m high)	2,890	1,450	-50%
Total	13,200	12,300	-7%



B4.3 Activities

The total activity associated with the DNLEU does not change significantly between 2040 and 2200. Instead, it remains relatively constant; this is a result of the long half-lives of the uranium isotopes. In the 2013 IGD the activity is 8,370 TBq while in the 2016 IGD it is 9,560 TBq (a difference of approximately 14%). The activity of the DNLEU will increase with time as the daughters of the uranium isotopes grow in. Table B20 and Table B21 show the changes in the activities of the radionuclides associated with the DNLEU at 2040 and 2200. The changes to the activities of U-235 and U-238 are 14% and 16%, respectively, in-line with what would be expected given the 16% increase in the total quantity of DNLEU. As the DU tails do not have significant levels of impurities, it is expected that the changes to the activities of the other radionuclides would be small, and this is what is seen. All of the impurities shown have very low activities.

Table B20 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the DNLEU waste group at 2040 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	$6.77\ 10^{-10}$	$6.77\ 10^{-10}$	~0%
	Cl-36	0	0	0%
	Co-60	$1.62\ 10^{-20}$	$1.64\ 10^{-20}$	1%
	Se-79	$1.78\ 10^{-9}$	$1.78\ 10^{-9}$	~0%
	Kr-85	0	0	0%
	Tc-99	0.645	0.645	~0%
	I-129	$1.60\ 10^{-9}$	$1.60\ 10^{-9}$	~0%
	Cs-135	$2.41\ 10^{-8}$	$2.41\ 10^{-8}$	~0%
	Cs-137	$1.98\ 10^{-3}$	$1.97\ 10^{-3}$	-0.7%
	U-233	$1.60\ 10^{-3}$	$1.60\ 10^{-3}$	~0%
	U-235	41.8	47.8	14%
	U-238	2,290	2,660	16%
	Np-237	$1.66\ 10^{-2}$	$1.66\ 10^{-2}$	<1%
Gas	H-3	0	0	0%
	C-14	$6.79\ 10^{-10}$	$6.77\ 10^{-10}$	~0%
	Ra-226	$6.03\ 10^{-3}$	$6.10\ 10^{-3}$	1%

Table B21 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the DNLEU waste group at 2200 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	$6.64\ 10^{-10}$	$6.64\ 10^{-10}$	~0%
	Cl-36	0	0	0%
	Co-60	$1.19\ 10^{-29}$	$1.20\ 10^{-29}$	1%
	Se-79	$1.78\ 10^{-9}$	$1.78\ 10^{-9}$	~0%
	Kr-85	0	0	0%
	Tc-99	0.645	0.645	~0%
	I-129	$1.60\ 10^{-9}$	$1.60\ 10^{-9}$	~0%
	Cs-135	$2.41\ 10^{-8}$	$2.41\ 10^{-8}$	~0%
	Cs-137	$5.02\ 10^{-5}$	$4.98\ 10^{-5}$	-0.7%
	U-233	$1.61\ 10^{-3}$	$1.61\ 10^{-3}$	~0%
	U-235	41.8	47.8	14%
	U-238	2,290	2,660	16%
	Np-237	$1.66\ 10^{-2}$	$1.66\ 10^{-2}$	0%
Gas	H-3	0	0	0%
	C-14	$6.66\ 10^{-10}$	$6.64\ 10^{-10}$	-0.3%
	Ra-226	0.108	0.112	3%

B4.4 Materials

Table B22 shows the masses of the different materials in the DNLEU waste group. As a result of the more realistic assumptions regarding how the DNLEU is stored, the number of drums in which the DNLEU is stored has been reduced. Because these drums are considered to be part of the waste, this has resulted in a significant decrease in the quantity of stainless steel (and non-halogenated plastics that are contained in these drums). The heavy metal oxide has increased in proportion to the overall increase in DNLEU, while the small increase in other ferrous metals is a result of a combination of the more realistic packaging assumptions and the increased quantity of DNLEU.

Table B22 Changes to the material masses in DNLEU

	Material	Mass [t]		Difference [%]
		2013 IGD	2016 IGD	
Metals	Stainless Steel	6,400	3,430	-46%
	Other ferrous metals	13,400	14,100	5%
	Total metals	19,800	17,500	-12%
Org.	Non-halogenated plastics	137	71.0	-48%
	Total organics	137	71.0	-48%
Other	Heavy metal oxide	219,000	254,000	16%
	Total other materials	219,000	254,000	16%
	Total	239,000	272,000	14%

B5 HLW

There are three broad categories of HLW: Magnox HLW, where the source of the vitrified product is only Magnox reprocessing; blend HLW, where the source of the vitrified product is a mixture of Magnox and thermal oxide reprocessing; and post-operational clean-out (POCO) wastes. Since the 2013 IGD, HLW from Magnox reprocessing has ceased to arise and all future arisings of HLW will be either blend HLW or POCO.

B5.1 Volumes

Table B23 shows that there has been an increase of 6.2% in the overall stored, conditioned, and packaged volumes associated with HLW between the 2013 and 2016 IGDs. This increase is associated with a revised estimate of the POCO wastes. There have been changes to some of the other waste streams: the quantity of Magnox HLW has reduced by approximately 16% while the quantity of blend HLW has increased by approximately 22%; these two changes roughly cancel each other out in terms of the total volume.

Table B23 The change in the volume of waste in the HLW waste group between the 2013 and 2016 IGDs

Volume	Volume [m^3]		Difference [%]
	2013 IGD	2016 IGD	
Stored	1,410	1,500	6.2%
Conditioned	1,410	1,500	6.2%
Packaged	9,290	9,860	6.2%

B5.2 Disposal Units

Table B24 shows that there has been an increase of 6.2% in the number of disposal units in the HLW waste group, between the 2013 and 2016 IGD. This is consistent with the change in the volume of HLW.

Table B24 The change in the number of disposal units in the HLW waste group between the 2013 and 2016 IGDs.

Waste container	Disposal units [-]		Difference [%]
	2013 IGD	2016 IGD	
HLW Disposal Container	2,400	2,550	6.2%

B5.3 Activities

The activity of the HLW waste group at 2040 has increased from 35,200,000 TBq in the 2013 IGD to 38,800,000 TBq in the 2016 IGD (an increase of approximately 10%). At 2200, an increase of 10% is also seen (from 1,090,000 TBq to 1,200,000 TBq). Table B25 and Table B26 show the changes in the priority 1 radionuclides and radionuclides that are relevant to RWM's gas pathway analysis between the 2013 and 2016 IGDs at 2040 and 2200. In addition to the increase in the quantity of POCO HLW, the specific activities of other HLW waste streams have been revised.

Whilst it might be expected that the increased quantity of POCO HLW would be responsible for the increases in activity, this is not always the case. It can be seen that there has been a significant increase in the activity of Co-60; this is primarily a result of a revised fingerprint for the blend HLW (and an increase in the quantity of blend HLW). Indeed, the revised activity data for the blend HLW stream is primarily responsible for the main differences in individual radionuclide activities: in addition to the increase in Co-60, it is responsible for the increases in Cl-36, Tc-99, U-233 and Np-237 (ie the five largest increases in activity at 2200 are all attributable to the revised characteristics of the blend HLW stream).

In terms of the radionuclides that are relevant to the gas pathway analysis, there is no H-3 or C-14 in the HLW. There has been an increase in the Ra-226 associated with the HLW and this is attributable to changes in the characterisation and quantity of the blend HLW.

Table B25 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the HLW waste group at 2040 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	0	0	0%
	Cl-36	1.29	1.51	17%
	Co-60	408	545	34%
	Se-79	16.7	17.2	3%
	Kr-85	0	0	0%
	Tc-99	2,470	2,760	12%
	I-129	8.78 10^{-2}	9.05 10^{-2}	3%
	Cs-135	183	185	1%
	Cs-137	10,400,000	11,400,000	10%
	U-233	4.97 10^{-3}	5.41 10^{-3}	9%
	U-235	9.43 10^{-4}	9.86 10^{-4}	5%
	U-238	2.61 10^{-2}	2.61 10^{-2}	~0%
	Np-237	31.0	36.1	16%
Gas	H-3	0	0	0%
	C-14	0	0	0%
	Ra-226	1.08 10^{-3}	1.10 10^{-3}	2%

Table B26 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the HLW waste group at 2200 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	0	0	0%
	Cl-36	1.29	1.51	17%
	Co-60	$2.98\ 10^{-7}$	$3.98\ 10^{-7}$	34%
	Se-79	16.7	17.2	3%
	Kr-85	0	0	0%
	Tc-99	2,460	2,760	12%
	I-129	$8.78\ 10^{-2}$	$9.05\ 10^{-2}$	3%
	Cs-135	183	185	1%
	Cs-137	262,000	288,000	10%
	U-233	$3.14\ 10^{-2}$	$3.60\ 10^{-2}$	15%
	U-235	$9.81\ 10^{-4}$	$1.03\ 10^{-3}$	5%
	U-238	$2.61\ 10^{-2}$	$2.61\ 10^{-2}$	<1%
	Np-237	44.2	51.1	16%
Gas	H-3	0	0	0%
	C-14	0	0	0%
	Ra-226	$4.58\ 10^{-3}$	$4.88\ 10^{-3}$	7%

B5.4 Materials data

Table B27 presents the changes to the materials in the HLW waste group. The changes are consistent with the increase in the total quantity of HLW. The only exception to this is a 100% reduction in the other ferrous metals. This has been reassigned as stainless steel. However, as the quantity is so small in relation to the overall quantity of stainless steel, it is overshadowed by the increase associated with the extra HLW.

Table B27 Changes to the material masses in HLW

	Material	Mass [t]		Difference [%]
		2013 IGD	2016 IGD	
Metals	Stainless Steel	612	651	6%
	Other ferrous metals	1.18	0	-100%
	Nickel (and alloys)	20.6	20.6	0%
	Total metals	634	672	6%
Other	Glass, ceramics and sand	2,850	3,020	6%
	Total other materials	2,850	3,020	6%
	Total unspecified	0	0	0%
	Total	3,480	3,700	6%

B6 Legacy SF Waste Group Data

B6.1 Volumes

There has been an increase of approximately 14% in each of the volume categories associated with the Legacy SF waste group between the 2013 and 2016 IGD. This reflects the lifetime extensions to the AGR fleet and additional ‘other fuel’ reported at Sellafield (this has been assumed to be low burn-up Magnox fuel). Table 3 provides details of the quantity of each of the types of fuel and the changes in volumes are shown below in Table B28.

Table B28 The change in the volume of waste in the Legacy SF waste group between the 2013 and 2016 IGD

Volume	Volume [m^3]		Difference [%]
	2013 IGD	2016 IGD	
Stored	3,370	3,830	13.6%
Conditioned	3,370	3,830	13.6%
Packaged	14,800	16,900	14.4%

B6.2 Disposal Units

There has been an increase of approximately 14% in the number of disposal units associated with the legacy SF waste group, between the 2013 and 2016 IGD. The overall change corresponds with the changes in volume displayed above in Table B1. However, there has been a greater increase (22%) associated with the disposal units relating to AGR SF.

Table B29 The change in the number of disposal units in the Legacy SF waste group between the 2013 and 2016 IGDs

Waste container	Disposal units [-]		Difference (%)
	2013 IGD	2016 IGD	
AGR disposal container	2,190	2,670	22%
Magnox disposal container	836	859	3%
PFR disposal container	19	19	0%
PWR disposal container	572	572	0%
Total	3,610	4,120	14%

B6.3 Activities

Given the increase in the quantity of spent fuel, it would be expected that the total activity would increase between the 2013 and 2016 IGDs. This is the case: at 2040 the activity of the legacy SF waste group has increased by approximately 26% from 52,300,000 TBq to 66,100,000 TBq whilst at 2200 the activity has increased by approximately 21% from 2,250,000 TBq to 2.730,000 TBq. This increase is related to the increase in the total quantity of legacy spent fuel.

Table B30 and Table B31 show the changes to the activities of the priority 1 radionuclides and those that are of interest to RWM's gas pathway analysis between the 2013 and 2016 IGDs. It would be expected that there would be increases in the activities of all radionuclides and at 2200, this is the case. However, at 2040, Ra-226 has a lower activity in the 2016 IGD. This is because the AGR SF arises at a later date and there is less time for decay of these shorter-lived radionuclides.

It is notable that some radionuclides have activity increases that are greater than the increase in the quantity of SF: eg, Kr-85 (half-life of around 11 years) and Co-60 (half-life of around 5.3 years). This is because they are shorter-lived radionuclides: the fact that the AGR SF arises until a later date means that the most recent arisings of SF have not had as long to decay. For longer-lived radionuclides, such as U-238, the increase in activity is roughly proportional to the increase in SF.

Table B30 **The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the Legacy SF waste group at 2040 between the 2013 and 2016 IGDs**

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	762	880	16%
	Cl-36	3.09	3.54	14%
	Co-60	180,000	234,000	30%
	Se-79	13.5	15.8	17%
	Kr-85	425,000	601,000	41%
	Tc-99	1,780.0	2,010.0	13%
	I-129	6.64	7.81	18%
	Cs-135	130.0	154.0	19%
	Cs-137	12,700,000	15,900,000	25%
	U-233	0.42	0.46	9%
	U-235	3.25	3.86	19%
	U-238	74.3	86.3	16%
	Np-237	47.8	53.9	13%
Gas	H-3	111,000	127,000	14%
	C-14	762	880	16%
	Ra-226	$5.84\ 10^{-4}$	$5.80\ 10^{-4}$	-1%

Table B31 The changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the RSC waste group at 2200 between the 2013 and 2016 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2013 IGD	2016 IGD	
Priority 1	C-14	747	863	16%
	Cl-36	3.09	3.53	14%
	Co-60	$1.31\ 10^{-4}$	$1.71\ 10^{-4}$	30%
	Se-79	13.5	15.8	17%
	Kr-85	13.8	19.5	41%
	Tc-99	1,780	2,010	13%
	I-129	6.64	7.81	18%
	Cs-135	130	154	19%
	Cs-137	322,000	403,000	25%
	U-233	0.465	0.509	9%
	U-235	3.25	3.87	19%
	U-238	74.3	86.3	16%
	Np-237	75.9	85.7	13%
Gas	H-3	13.8	15.7	14%
	C-14	747	863	16%
	Ra-226	$2.19\ 10^{-2}$	$2.50\ 10^{-2}$	14%

B6.4 Materials

Table B32 shows the changes to the materials in the legacy SF waste group. Given the increase in the quantity of legacy SF, it would be expected that the material masses would increase. Where the AGR SF is the only contributor to a material, the increase is the same as the increase in AGR SF (ie 22%), and likewise for the metallic SF (3%). Where other SFs contribute to a material type, the increase is lower.

Table B32 Changes to the material masses in Legacy SF

	Material	Mass [t] 2013 IGD	Mass [t] 2016 IGD	Difference [%]
Metals	Stainless Steel	1,380	1,620	17%
	Magnox / magnesium	133	137	3%
	Zircaloy / zirconium	269	269	0%
	Nickel (and alloys)	18.1	18.1	0%
	Uranium	740	760	3%
	Total metals	2,540	2,800	10%
Others	Heavy metal oxide	6,310	7,440	18%
	Glass, ceramics and sand	35.1	42.9	22%
	Total other materials	6,340	7,490	18%
	Total	8,890	10,300	16%

B7 Waste groups with no changes

B7.1 New build

There have been no changes to the assumptions regarding the assumed new build programme between the 2013 and 2016 IGDs. As a result, there have been no changes to the new build SILW, new build UILW, or new build SF waste groups. Since the 2013 IGD scenarios report [15], inventory data have become available for UK ABWR wastes and SF. These data are given in Section 4.5.

B7.2 MOX

The assumptions regarding the total quantity of Pu, and the fraction of this Pu that can be re-used as MOX fuel have not changed since the 2013 IGD. In addition, the inventories that were developed for the 2013 IGD have not been revised. As such, there is no change to the MOX waste group.

B7.3 HEU and Pu

There have been no changes to the assumptions regarding the quantities of either the Pu or the HEU. In addition, there have been no changes to the inventories assigned to these materials.

Appendix C – Summary tables

C1 Conditioned volume and disposal units

Table C1 A summary of the changes to the number of disposal units and conditioned volume between the 2013 and 2016 IGDs

	Disposal units [-]		Conditioned volume [m^3]	
	2013 IGD	2016 IGD	2013 IGD	2016 IGD
Legacy SILW / SLLW				
2 m box[17]	75	0	334	0
4 m box[17]	4,350	4,320	73,600	73,100
6 m^3 concrete box[18]	426	1,080	2,440	6,190
Total Legacy SILW / SLLW	4,850	5,400	76,300	79,300
Legacy UILW / ULLW				
500 l drum[19]	29,700	31,000	56,300	58,300
MBGWS box	1,500	1,380	5,270	4,830
3 m^3 box (square corners)[20]	71,100	71,300	183,000	184,000
3 m^3 box (round corners)	4,770	4,430	12,700	11,800
3 m^3 drum	563	545	1,260	1,220
Total Legacy UILW / ULLW	108,000	109,000	259,000	260,000
RSCs				
500 l RS drum[17]	1,230	609	544	300
3 m^3 RS box	1,040	354	2,920	883
Total RSC	2,270	963	3,460	1,180

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17 Includes variants with different levels of internal shielding.

18 Includes WAGR boxes and variants with different densities, which are all instances of the 6 m^3 concrete box.

19 Includes ‘enhanced 500 l drums’, which are instances of the 500 l drum.

20 Includes 3 m^3 Sellafield boxes and 3 m^3 enhanced Sellafield boxes, which are both instances of the 3 m^3 box (square corners).

	Disposal units [-]		Conditioned volume [m^3]	
	2013 IGD	2016 IGD	2013 IGD	2016 IGD
DNLEU				
500 l drum	5,950	5,970	11,200	11,200
TDC 2.1	581	460	10,900	8,630
TDC 2.3	3,780	4,430	75,000	87,800
TDC 2.4	2,890	1,450	63,300	31,700
Total DNLEU	13,200	12,300	160,000	139,000
NB SILW				
500 l concrete drum[17]	3,240	3,240	942	942
1 m^3 concrete drum[17]	6,840	6,840	4,480	4,480
4 m box	60	60	858	858
Total NB SILW	10,100	10,100	6,280	6,280
NB UILW				
3 m^3 box (round corners)	960	960	2,550	2,550
3 m^3 drum	7,270	7,270	16,200	16,200
Total NB UILW	8,230	8,230	18,800	18,800
HLW				
HLW Disposal container	2,400	2,550	1,410	1,500
Legacy SF				
AGR disposal container	2,190	2,670	1,930	2,360
Magnox disposal container	836	859	999	1,030
PFR disposal container	19	19	11	11
PWR disposal container	572	572	426	426
Total Legacy SF	3,610	4,120	3,370	3,830
NB SF				
New build disposal container	8,940	8,940	5,890	5,890
MOX SF				
MOX disposal container	2,710	2,710	594	594

	Disposal units [-]		Conditioned volume [m^3]	
	2013 IGD	2016 IGD	2013 IGD	2016 IGD
HEU				
HEU / Pu disposal container	780	780	694	694
Pu				
HEU / Pu disposal container	196	196	174	174

Appendix D – Alternative scenarios

D1 Scenario 4: Use of UK RWI uncertainty factors

Table D1 Change in the lower uncertainty activity for priority 1 radionuclides at 2200 for all waste groups affected by Scenario 4 (see section 4.4)

Priority 1 radionuclide	Change in lower activity at 2200 [TBq]		
	2013 IGD	2016 IGD	Difference [%]
C-14	-6,610	-6,520	-1%
Cl-36	-30.8	-30.8	0%
Co-60	$-2.67\ 10^{-3}$	$-2.21\ 10^{-3}$	-17%
Se-79	-5.78	-6.02	4%
Kr-85	$-1.04\ 10^{-2}$	$-1.12\ 10^{-2}$	9%
Tc-99	-1,370	-1,770	29%
I-129	-0.465	-0.538	16%
Cs-135	-65.5	-65.2	0%
Cs-137	-92,900	-100,000	8%
U-233	-0.905	-0.846	-6%
U-235	-0.331	-0.298	-10%
U-238	-9.72	-9.40	-3%
Np-237	-99.2	-100	1%

The changes in the activities of the priority 1 radionuclides from the application of the lower uncertainty factor between the 2013 and 2016 IGD are very similar except for:

- Co-60 which is affected by a correction to the arising specific activity of waste stream 3J24 (Neutron Scatter Plugs)
- Tc-99 which is affected by the volume increase of waste stream 2F01/C (Vitrified High Level Waste) and an increase in the stock specific activity of waste stream 2D27/C (Encapsulated Floc from Effluent Treatment)
- I-129 which is affected by volume increases and an increase in the stock specific activity of waste stream 2D27/C (Encapsulated Floc from Effluent Treatment)
- U-235 which is affected by volume and specific activity updates

Table D2 Change in the upper activity for priority 1 radionuclides at 2200 for all waste groups affected by Scenario 4

Priority 1 radionuclide	Change in upper activity at 2200 [TBq]		
	2013 IGD	2016 IGD	Difference [%]
C-14	+103,000	+68,200	-34%
C-l36	+328	+296	-10%
Co-60	+0.319	+0.166	-48%
Se-79	+8.99	+9.40	5%
Kr-85	2.13 10-2	2.30 10-2	8%
Tc-99	+7,950	+8,970	13%
I-129	+2.33	+20.9	794%
Cs-135	+105	+104	-2%
Cs-137	+155,000	+170,000	10%
U-233	+2.95	+2.88	-2%
U-235	+1.77	+2.48	40%
U-238	+43.9	+44.6	2%
Np-237	+574	+593	3%

The changes in the activities of the priority 1 radionuclides from the application of the upper uncertainty factor between the 2013 and 2016 IGD are very similar except:

- C-14 which is affected by the update of the uncertainty factor of waste stream 3S306 (Sizewell B decommissioning stainless steel ILW) from 1,000 to 10
- Co-60 which is affected by a correction to the arising specific activity of waste stream 3J24 (Neutron Scatter Plugs) and the update of the uncertainty factor of waste stream 3S306 (Sizewell B decommissioning stainless steel ILW) from 1,000 to 10
- Tc-99 which is affected by an increase in the stock specific activity of waste stream 2D27/C (Encapsulated Floc from Effluent Treatment)
- I-129 which is affected by volume increases and an increase in the stock specific activity and associated uncertainty factor to 1,000 of waste stream 2D27/C (Encapsulated Floc from Effluent Treatment) all other radionuclides for this waste stream have an uncertainty factor of 10. Sellafield Limited recognises this issue and it has been noted for the next UK RWI
- U-235 which is affected by a change in the uncertainty factor for waste stream 7A111 (Decommissioning Waste Uranium Contaminated ILW) from 10 to 100

D2 Scenario 8: Change in new build programme

Table D3 Activities of the priority 1 radionuclides in the different waste groups for a UK ABWR reactor at 50 years after shutdown

Priority 1 radionuclide	Activity [TBq]		
	New build SILW	New build UILW	New build SF
C-14	$4.22\ 10^{-3}$	671	203
Cl-36	$2.44\ 10^{-4}$	$7.64\ 10^{-2}$	10.2
Co-60	$1.77\ 10^{-2}$	1,870	3.00
Se-79	$2.82\ 10^{-8}$	$6.28\ 10^{-2}$	5.71
Kr-85	-	0.515	5,750
Tc-99	$1.44\ 10^{-4}$	9.78	1,230
I-129	$3.31\ 10^{-12}$	0.365	3.14
Cs-135	-	$2.05\ 10^{-2}$	47.1
Cs-137	$2.98\ 10^{-6}$	1,100	1,610,000
U-233	$2.74\ 10^{-15}$	$4.88\ 10^{-3}$	$1.82\ 10^{-2}$
U-235	$7.34\ 10^{-7}$	$4.82\ 10^{-5}$	0.684
U-238	$1.59\ 10^{-5}$	$9.33\ 10^{-4}$	15.4
Np-237	$1.60\ 10^{-11}$	$2.31\ 10^{-3}$	44.8

Table D4 Waste material masses in the different waste groups for a UK ABWR reactor

	Material	Total mass [tonnes]		
		New build SILW	New build UILW	New build SF
Metals	Stainless steel	19.4	446	53.5
	Other ferrous metals	627	0	0
	Magnox/magnesium	0	0	0
	Aluminium and alloys	0	0	0
	Zircaloy/zirconium	0	0	679
	Copper and alloys	0	0	0
	Nickel and alloys	0	0	3.20

	Uranium	0	0	0
	Other metals	0	16.2	10.4
	Total metals	646	462	746
Organics	Cellulose	0	0	0
	Halogenated plastics	0	0	0
	Non-halogenated plastics	0	0	0
	Rubbers	0	0	0
	Organic ion exchange resins	0	82.1	0
	Other organics	0	0	0
	Total organics	0	82.1	0
Other materials	Graphite	0	0	0
	Asbestos	0	0	0
	Sludges & flocs	0	31.8	0
	Cementitious materials	0	0	0
	Inorganic ion exchange materials	0	0	0
	Glass, ceramics & sand	0	2.25	0
	Soil, brick, stone & rubble	0	0	0
	Heavy metal oxide	0	0	1,630
	Other inorganics	0	0	0
	Total other materials	0	34.1	1,630
	Total unassigned	0	0	3.99
	Total (waste materials)	646	578	2,380

D3 Scenario 12: Exclusion of ILW / LLW boundary wastes

Table D5 2016 IGD ILW streams intended to be managed as LLW

Waste stream ID	Waste stream name	Waste group	Packaged volume [m^3]	Number of disposal units
1A08	Decay Stored Waste	UILW	69.6	22
2D42	Magnox Pond Furniture	UILW	3,290	1,010
2F15	LWR Pond Furniture (MEBs)	UILW	1,910	583
3J04	Desiccants ILW	UILW	293	113
3J20	Catalysts ILW	UILW	12.5	5
3J25	Gag Pistons	UILW	1.87	1
3K04	Desiccant	UILW	142	55
3K22	Catalyst	UILW	12.9	5
3K29	Bypass Blowdown Filters	UILW	40.8	13
3L04	Desiccant	UILW	113	44
3L19	Catalyst	UILW	13.3	6
3M04	Desiccant	UILW	261	100
3M17	Catalysts	UILW	24.6	10
3N04	Desiccants and Catalysts	UILW	344	132
3S310	Fuel Pond Solid Absorber Assemblies	SILW	67.8	4
5H08	ILW Non-Incinerable Materials	UILW	29.0	13
6N03	Reflectors	UILW	2.88	2
7D24	ILW Reactor Components	SILW	23.8	2
7D29	Intermediate Level Waste Resin from Plant Decontamination (MODIX)	UILW	40.6	18
7D40	ILW PCD Ion Exchange Resin	UILW	44.5	18
7D41	ILW Submarine Ion Exchange Resin	UILW	47.1	19
7E29	Intermediate Level Ion Exchange Resin (Decontamination)	UILW	93.6	36
7J25	Luminised Waste	UILW	11.5	6
9B13	Desiccant	RSC	59.9	12

Waste stream ID	Waste stream name	Waste group	Packaged volume [m^3]	Number of disposal units
9C14	Desiccant	RSC	52.1	10
9D18	Desiccant	RSC	36.7	7
9E24	FED Magnox	UILW	77.0	24
9E25	FED Magnox	UILW	77.0	24
9E26	FED Magnox	UILW	80.7	25
9E27	FED Magnox	UILW	80.7	25
9E28	FED Magnox	UILW	73.3	23
9E47	Desiccant	RSC	34.4	7
9F14	Desiccant and Catalyst from Gas Conditioning Plant	RSC	9.60	2
9F18	Miscellaneous Drummed Contaminated and Activated Items	SILW	141	8
9F42	AETP Filters - Sand and Gravel	RSC	29.0	6
9H02	Desiccant	RSC	37.2	7

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