Radioactive Waste Management

DSSC/406/02

Inventory for geological disposal

Differences Report

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Preface

This report is part of ongoing research by Radioactive Waste Management (RWM) and its contractors into implementing geological disposal for radioactive wastes in the UK.

Geological disposal is the UK Government's policy for the higher-activity radioactive wastes. The principle is isolation of the waste deep inside a suitable rock formation to prevent harmful quantities of radioactivity from reaching the surface. The waste will be placed in an engineered containment facility of tunnels and vaults constructed underground – a geological disposal facility (GDF). The facility will be designed so that multiple natural and man-made barriers work together to minimise the escape of radioactivity. Higher-activity radioactive wastes cover a range of categories including high level waste (HLW), spent nuclear fuel, intermediate level (ILW) and certain low level (LLW) radioactive wastes.

A GDF will be carefully designed and engineered. Typically, ILW and LLW would be encased in a cement grout and packaged in steel or concrete containers, for subsequent placement in the vaults. In time, the vaults would be backfilled with a cement-based material, completely surrounding the waste packages. Engineered barriers would be provided by the cement grout, the containers and the backfill. Natural barriers would be provided by geological formations surrounding the GDF and that lie between it and the accessible human environment. The concept for longer-lived HLW and spent nuclear fuel is slightly different: containers holding these materials would be placed directly into deposition tunnels, further apart from each other, again using engineered and natural barriers.

Executive Summary

RWM maintains an inventory of the higher activity radioactive waste destined for geological disposal. This report presents the differences between the 2019 inventory for geological disposal (IGD) and the previous iteration (the 2016 IGD).

The IGD is based on Government policy, industry plans and other assumptions. The key assumptions remain unchanged between 2016 and 2019; 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 key source of data for the IGD. The most significant changes are:

- a decrease in the quantity of uranium from civil fuel enrichment, civil spent fuel reprocessing and defence programmes
- an increase in the quantity of legacy spent fuel, as a result of revised estimates in the UK RWI
- a decrease in low level waste as a result of graphite from final site clearance at Magnox stations being identified as suitable for disposal to the LLWR
- a re-evaluation of some plutonium contaminated materials (PCM) that has resulted in reduced waste volumes and a revised density and therefore changes to the masses of various materials

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

- despite a decrease in the overall quantity of waste for disposal, there has been a small increase in packaged volume, primarily as a result of reduced waste loading factors for some Sellafield legacy decommissioning wastes
- there has been a corresponding increase in the total number of disposal units
- the total activity has increased slightly, mainly associated with the increased quantities of legacy spent fuels and high level waste
- the most significant changes to the materials in the inventory arise as a result of the re-evaluation of PCM wastes, with reductions in several material types. Most notable are a 24% decrease in organics and a 20% decrease in metals

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 have the greatest impact, and this impact is dominated by a small number of waste streams

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1 Introduction

1.1 The generic Disposal System Safety Case

RWM was established as the organisation responsible for delivering a programme for the safe, secure and permanent 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, 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 system of multiple man-made and natural barriers designed to prevent harmful quantities of radioactivity and non-radioactive contaminants from being released to the surface environment.

To identify potentially suitable sites for a GDF, the Government has developed an approach based on consent: working with interested communities that are willing to participate in the siting process [2]. No site has yet been identified for a GDF.

In order to make progress while potential 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 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

[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.

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) that is 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 concepts.

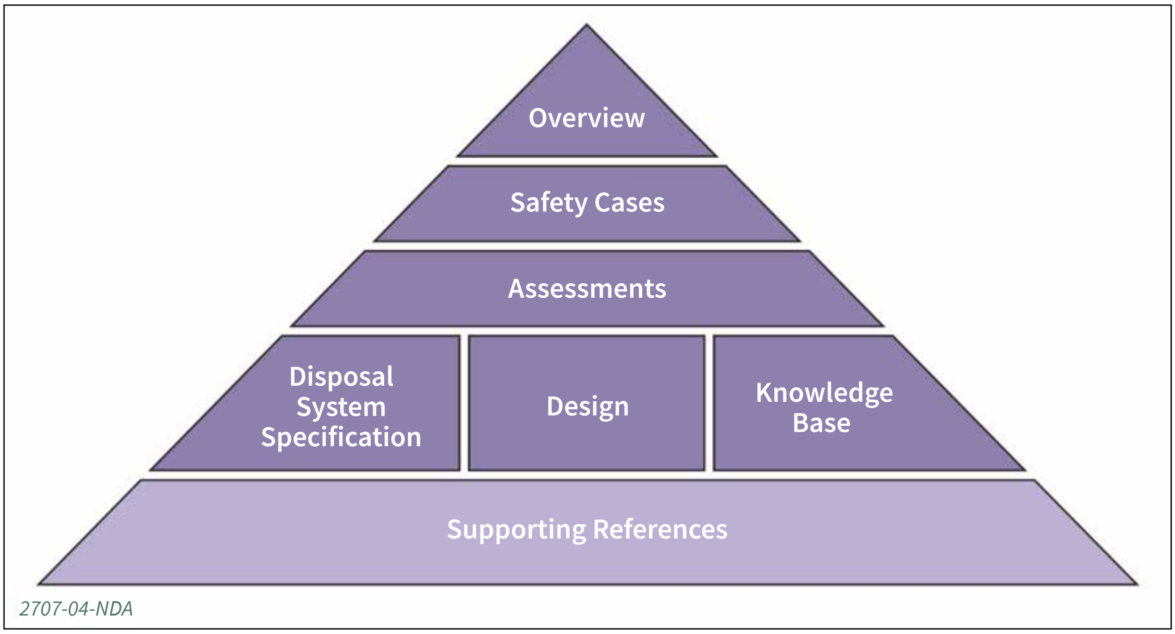
High level information on the inventory for disposal, the illustrative disposal concepts and other aspects of the disposal system is collated in a technical background document (the Technical Background) [3] that supports this generic Disposal System Safety Case.

The generic Disposal System Safety Case (DSSC) plays a key role in the iterative development of a geological disposal system. This 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 demonstrates that geological disposal can be implemented safely, and also forms a benchmark for RWM to provide waste producers with advice on packaging 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 DSSC documents and summarises the safety arguments that support geological disposal. The safety cases present the safety arguments for the transportation of radioactive wastes to the GDF, the operation of the facility and long-term safety following 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. These documents are underpinned by an extensive set of supporting references. A full list of the documents in 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 inventory for geological disposal (IGD) 'differences report', which sets out the differences between the 2019 IGD [4] and the previous version (the 2016 IGD [5]); it is one of five reports that deal with various aspects of the 2019 IGD and previous IGDs. The other four reports are:

- the 'Main report' [4], which describes the principal features of the 2019 IGD
- the 'Method report' [6], which describes how IGDs are developed and updated
- the 'Implications report' [7], which describes the implications of the changes introduced by the 2019 IGD for the generic DSSC
- the 'Alternative scenarios report' [8], which provides information on how changes to the scenario for future arisings would affect the 2013 IGD [9], and which is updated in this report.

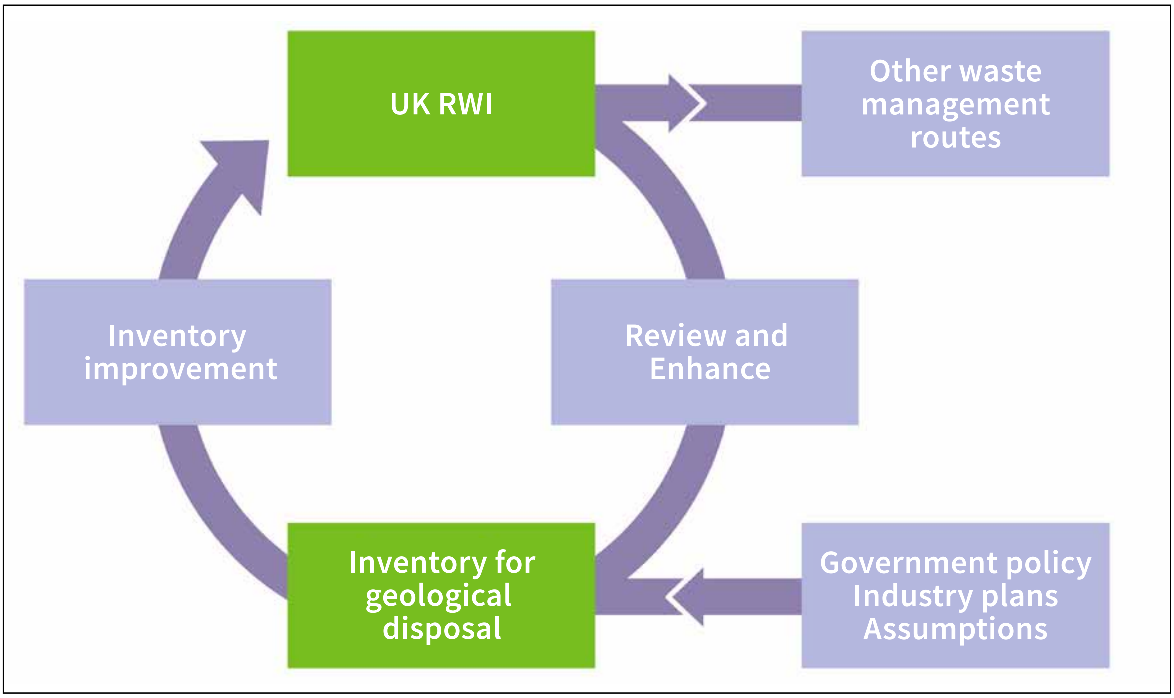
The IGD is based largely on the UK Radioactive Waste and Materials Inventory (UK RWI). The UK has been producing RWIs for over 30 years. The production process has been improved iteratively and is now well-established. Each UK RWI contains details of stocks and arisings of all radioactive waste from 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 (e.g. waste that is destined for the Low Level Waste Repository (LLWR)) is removed from the UK RWI dataset and the remaining data are reviewed and, where appropriate, enhanced[2]. The dataset is further enhanced to take account of Government policy, industry plans and other assumptions to

[2] *For the purposes of this work, 'review' is defined as the process of identifying omissions, differences and inconsistencies within the 2019 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 2019 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.*

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 continuous improvements in the UK RWI data and, consequently, the IGD.

Figure 2 - The iterative development of the inventory for geological disposal



The most recent version of the UK RWI [10] is based on a stock date of 1st April 2019 and is referred to here as the 2019 UK RWI. The generic DSSC was published in 2016 and was based on the 2013 IGD [9], which in turn was based on the 2013 UK RWI [11]. The 2019 IGD is based on the 2019 UK RWI and is a 'light update'[3] to the 2016 IGD.

This report sets out the differences between the 2019 and 2016 IGDs. It also updates the alternative scenarios so that they are consistent with the 2019 IGD. This report replaces the differences report for the 2016 IGD [12].

1.3 Objective

The objective of this report is to document the differences between the 2016 and the 2019 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 geological disposal design and assessment work.

[3] *The differences between a light and a full update are explained in the Method report [6].*

1.4 Scope

1.4.1 The 2019 inventory for geological disposal

The 2019 IGD is based on the 2019 UK RWI and is a 'light update' to the 2016 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 (e.g. calculations of metal geometry to support gas pathway analysis and the elemental composition of the waste) 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 [13] 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 (SF), plutonium and HEU[4] are assumed to be disposed of in a HHGW area.

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.

Priority scores[5] for materials and radionuclides in the IGD were established through discussions with RWM safety case owners and experts in the areas of inventory, wasteform, packaging, transport, criticality and GDF design. The priority scores assigned to each material type and radionuclide were originally carried out in preparation of the 2004 IGD and the assignments have been reviewed for each 'full' update since. The 2019 IGD priority assignments are unchanged since the last full update (the 2013 IGD). The priority scores and justifications are reported in the inventory method report [6]. The priority materials are highlighted in the reported data. When reporting activities on individual radionuclides, only priority 1 radionuclides are included.

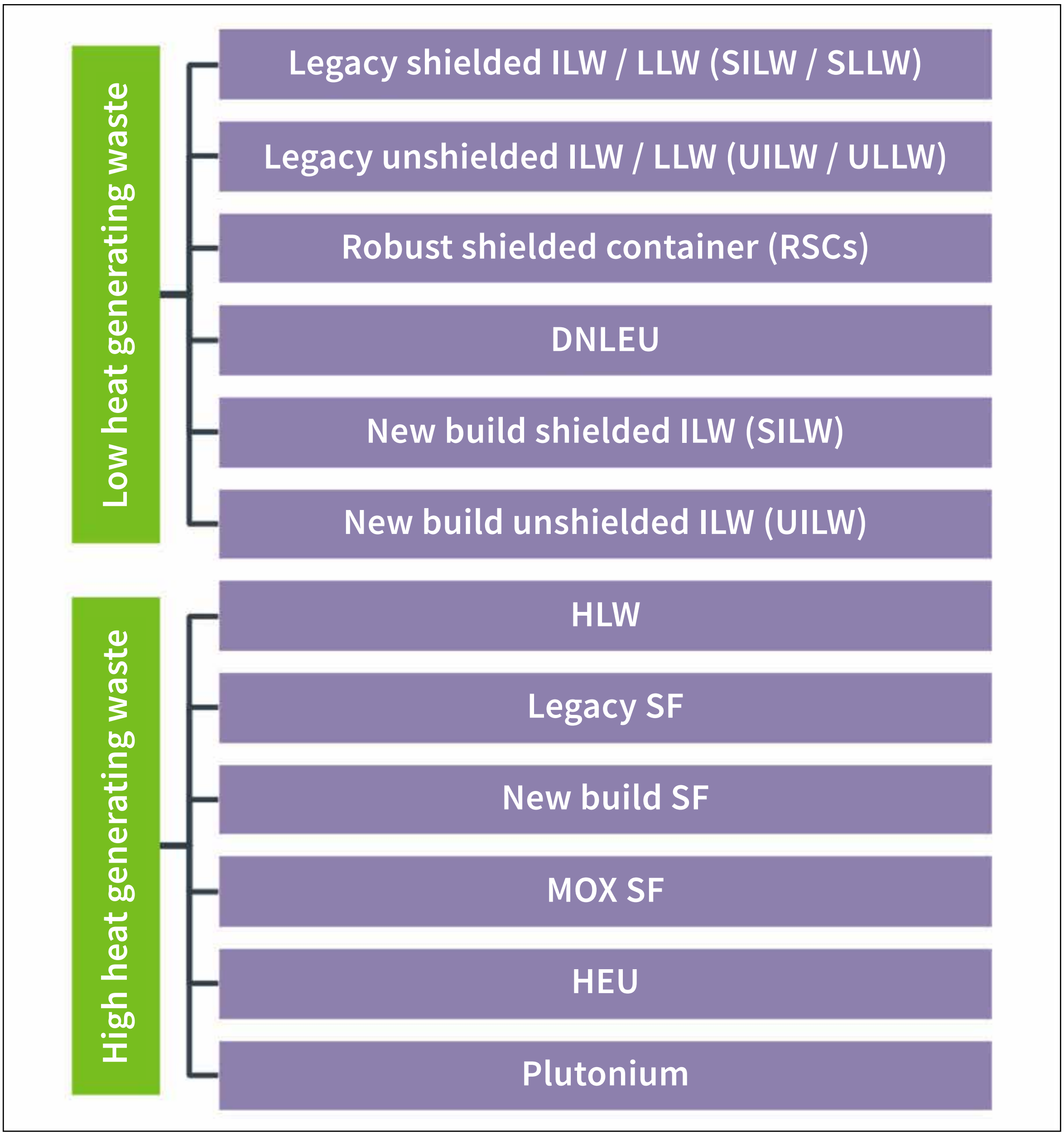
All data have been presented to three significant figures; this is considered to provide an appropriate quantification of the inventory data. In some cases, the data are not available or are not specified to three significant figures. In these cases, the data are presented to the level of precision to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

[4] *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.*

[5] *Priority scores are a measure of the importance of a data field to users of the IGD; scores range from 1 to 5, with priority score of 1 being the most important.*

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 raw data rounded to three significant figures. This approach ensures an appropriate and consistent level of precision in all the data.

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



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 was defined for the 2013 IGD and their impacts on the inventory for disposal were determined [8], these scenarios were carried forward to the 2016 IGD. In this report the definition of the scenarios is examined in the light of differences between the 2019 and 2016 IGD, and the definitions are changed where necessary. The impacts of the revised scenarios on the 2019 IGD are then evaluated.

1.5 Report structure

The remainder of the report is structured 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:

- Appendix A presents changes in waste streams
- Appendix B details the changes in quantities by waste group
- Appendix C contains summary tables
- Appendix D provides further data for the alternative scenarios

2 Changes to the scenario for the inventory for geological disposal

Summary of changes to the scenario for the inventory for geological disposal

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

The most significant changes to the scenarios are:

- a decrease in the quantity of DNLEU from civil fuel enrichment, civil spent fuel reprocessing and defence programmes
- an increase in the quantity of legacy SF, as a result of revised estimates in the UK RWI (these SFs were previously assumed to be reprocessed)

There has been no change to Government policy for the management of higher activity radioactive waste (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:

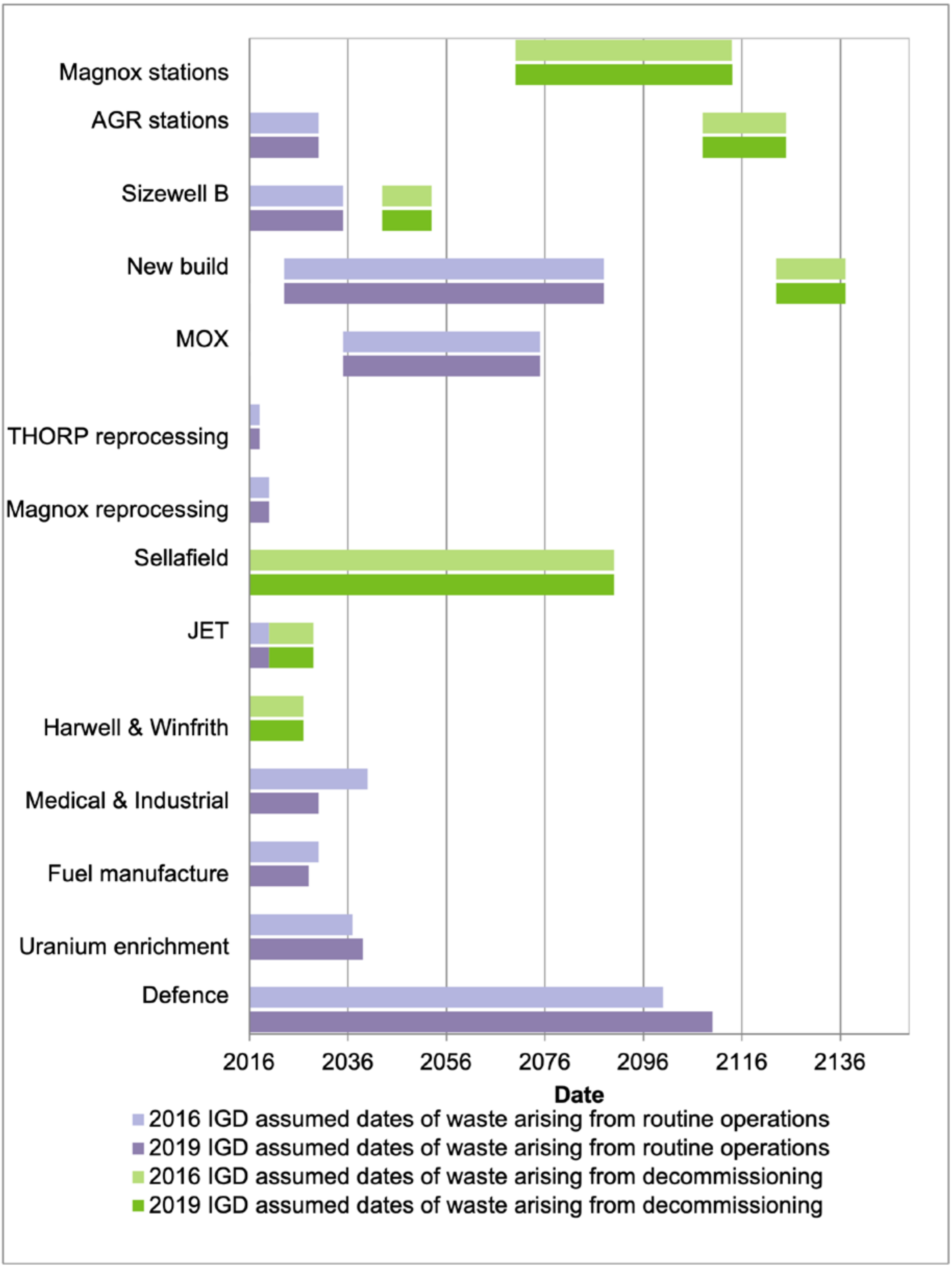
- changes have been made to assumed dates of operation
- there are improvements to the inventory, including those from better characterisation

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 2016 and 2019 IGDs; full details are provided in **Table 1**. Key changes include:

- reduced operational period for medical and industrial activities
- reduced operational period for fuel manufacture
- increased operational period for uranium enrichment
- increased operational period for defence activities

Figure 4 - Assumed dates of operation and decommissioning in the 2016 and 2019 IGDs[6]



6 *Decommissioning of the Magnox reprocessing plant and Thermal Oxide Reprocessing Plant (THORP) are covered by Sellafield decommissioning. No decommissioning dates have been specified for 'Fuel fabrication', 'Medical and industrial', 'Enrichment' or MOD as either no HAW decommissioning waste is anticipated or the waste producer has not included an estimate of the decommissioning waste.*

Table 1 - Key assumptions for the 2016 and 2019 IGDs (differences in bold text)

Sector	2016 assumptions	2019 assumptions
Policy	HAW to be managed under Scottish Government's policy is excluded	
Civil nuclear power stations	AGRs: operate between 41 and 47 years (site dependent) Deferral of Magnox & AGR final stage decommissioning for up to ~85 years after shutdown; all decommissioning complete by 2125 Sizewell B: operates for 40 years; prompt decommissioning complete by 2053 16 GW(e) new build programme comprising 6 UK EPRs and 6 AP1000s	
Enrichment	Continues to 2037 at Capenhurst	Continues to **2039** at Capenhurst
Spent fuel reprocessing	Magnox fuel reprocessing continues until 2020 (55,000 tU in total) 5,500 tU AGR SF is not reprocessed Oxide fuel reprocessing completed in 2018 (5,000 tU) AGR fuel and 4,4000 tU overseas LWR fuel) All reprocessing facilities fully decommissioned by 2090 Sizewell B SF, new build SFs and MOX SFs are not reprocessed	
Research and Development	Joint European Torus (JET) operates until 2020 Harwell and Winfrith facilities fully decommissioned by 2027 Sellafield[7] decommissioned by 2090	
Defence	Nuclear weapons programme: waste estimated to 2080 Nuclear powered submarine programme waste estimated to 2100	Nuclear weapons programme: waste estimated to 2080 Nuclear powered submarine programme waste estimated to **2110**
Medical and industrial	GE Healthcare waste estimated to arise until 2040	GE healthcare waste estimated to arise until **2030**

[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 2019 IGD is based on the 2019 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) from future decommissioning projects at Sellafield, and PCM operational and decommissioning arisings at AWE
- a revised estimate of ILW mild steel from decommissioning at Sizewell B
- an additional 7,220 HAW packages in store, as increasing amounts of legacy wastes are being retrieved from stores and packaged for long-term management

In addition, the 2019 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 2019 IGD are reported in **Appendix A1** and include:

- Magnox Swarf Storage Silo (MSSS) streams now split by compartment
- waste streams for spent fuel previously assumed to be reprocessed (eg WAGR SF)
- wastes previously reported under a different identifier, including conditioned streams

Waste streams no longer included in the IGD are reported in **Appendix A2** and include:

- Magnox Final Stage Clearance (FSC) Graphite waste streams that are suitable for disposal to the LLWR
- waste streams diverted from geological disposal to the LLWR, for incineration or metal treatment
- waste that has been conditioned

2.2.2 Quantities of legacy spent fuels

The quantities of legacy spent fuels have been updated to reflect changes in the UK RWI. Three additional legacy spent fuel streams have been identified for the 2019 IGD; it had previously been assumed that these would be reprocessed. Whilst the UK RWI includes data on the quantity of spent fuels[8], 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 2019 IGD; the new streams have been considered by analogy to other SF streams. A summary of key parameters is provided in **Table 2**. Only the cooling times of the stocks have changed (to reflect the elapsed time between the 2016 and 2019 IGDs).

[8] *Changes to quantities of spent fuels are reported in* ***Table 3****.*

Table 2 - Key parameters in the calculation of the spent fuel inventories

Spent fuel type	Enrichment [%]	Burn-up [GWd/tHM[9]]	Cooling time [yrs]
AGR (pre-2013)	2.9	28	12
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	42
Windscale (WAGR) fuel	2.85	18.2	38
Winfrith (SGHWR) fuel	3.9	40	29
Misc. LWR	3.9	40	19
PFR fuel	(Pu) 29.5	189	22

2.2.3 Packaging assumptions for DNLEU

MOD's 2011 Nuclear Liabilities Management Strategy [19] indicates that MOD uranium exist in a similar form to the NDA uranium. The packaging assumptions for Defence DNLEU have been updated (from grouting in 500 l drums) to be consistent with those for civil Magnox depleted uranium (MDU): packaging in 200 litre mild steel drums, overpacked in 500 litre drums and in a 2.4 m transport disposal container (TDC).

There have been no changes to the packaging of the other DNLEU streams.

2.2.4 Summary of changes

Table 3 provides details of the quantities of wastes and materials broken down by waste group. Changes in this table are discussed further in section 3. Where the changes are a result of revised assumptions, they are discussed later in section 2 (eg, changes to the assumptions regarding defence materials are discussed in section 2.5).

[9] *Heavy metal, i.e. uranium and plutonium.*

Table 3 - Waste and material quantities in the 2016 and 2019 IGDs (differences in bold)

Waste / material	2016 IGD	2019 IGD
LLW	All UK RWI LLW unsuitable for near-surface disposal	
	(stored volume 8,880 m3)	(stored volume **3,830 m^3**)
ILW	All UK RWI ILW[10]	
	(stored volume 265,000 m3)	(stored volume **221,000 m^3**)
HLW	All UK RWI HLW from reprocessing 55,000 tU Magnox SF and 5,000 tU AGR SF	
	(7,650 waste vitrification plant (WVP) canisters)	(**7,660** WVP canisters)
Legacy spent fuel	5,500 tU AGR SF 1,050 tU Sizewell B PWR SF 760 tU metallic SF 10 tHM PFR SF	5,500 tU AGR SF 1,050 tU Sizewell B PWR SF **723 tU metallic SF** **68 tU SGHWR SF** **20.8 tU WAGR SF** **66 tU Miscellaneous LWR SF** 10 tHM PFR SF
	Irradiated submarine fuel not quantified	
HEU	1.0 tU from civil programmes and 21.9 tU from defence programmes	
DNLEU	200,000 tU from civil fuel enrichment and civil spent fuel reprocessing 15,000 tU from defence programmes	**184,000** tU from civil fuel enrichment and civil spent fuel reprocessing **8,000** tU from defence programmes
Pu	5.75 tPu separated Pu residues from reprocessing of civil SFs (representing 5% of the 115 tPu UK owned Pu unsuitable for re-use as MOX fuel)	
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 tPu) and all MOD plutonium (7.6 tPu) reused in 1,460 tHM MOX SF	

[10] *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 radioactive waste (HAW) in Scotland has not changed between the 2016 and 2019 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 [14] 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[11] is for the HAW arising in Scotland to be managed in near-surface facilities[12] [15] 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 2016 and 2019 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 [16]. The UK Government has not made any decision on the fate of the UK's plutonium stocks, and a discussion of the options can be found in the NDA's 'Progress on plutonium consolidation, storage and disposition' paper [17]. The government would only be in a position to proceed when it was confident that its preferred option could be implemented safely and securely, was affordable, deliverable and offered value for money.

The 2016 and 2019 IGDs assume that there will be 115 t of UK-owned civil plutonium at the end of reprocessing 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 2016 and 2019 IGDs.

The 2019 IGD assumes a new build programme of 16 GW(e) that is comprised of six UK EPRs and six AP1000s. Consideration of the changes that would be introduced by the inclusion of the UK advanced boiling water reactor (ABWR) was included in the 2016 Differences report [12].

[11] *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.*

[12] *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 [15].*

2.5 Defence materials

There has been a change in the underpinning data for the defence DNLEU: the data in the 2016 IGD were taken from the 1998 Strategic Defence Review [18], while the 2019 IGD takes account of MOD's 2011 Nuclear Liabilities Management Strategy [19].

The Nuclear Liabilities Management Strategy states that MOD uranium liabilities are approximately 15% (by mass) of NDA uranium liabilities and the mass of MOD DNLEU has been updated to account for this. The packaging of Defence DNLEU has also been updated since the 2016 IGD (Section 2.2.3).

There have been no changes to the quantities of MOD HEU or Pu (see Table 3). Irradiated submarine fuel is included in both the 2016 and 2019 IGDs but is not quantified.

3 Changes to the inventory for geological disposal

Summary of changes to the inventory for geological disposal

The key changes to the quantity of waste are:

- LLW (stored volume -57%) as a result of LLW graphite from FSC at Magnox stations being identified as suitable for disposal to the LLWR
- legacy ILW (stored volume -16%) as a result of a re-assessment of Plutonium Contaminated Material
- DNLEU (mass -11%) from a reduction of defence DNLEU, depleted uranium (DU) tails and MDU

Overall, the packaged volume of the IGD has increased slightly (+4%) primarily as a result of reduced waste loading volumes for some Sellafield legacy UILW / ULLW decommissioning wastes. The overall changes to the activity are small (+1% at 2200) and are due to the increases in HLW and legacy fuels.

The re-evaluation of PCM has resulted in the mass of several materials being reduced (most notably, a reduction of 24% in the total quantity of organics and a reduction of 20% in the total quantity of metals).

This section summarises the changes to data from the 2016 and 2019 UK RWIs whilst Appendix B provides a breakdown by waste group.

3.1 Volumes

Table 4 shows the percentage changes to the ultimate stored quantities of waste for geological disposal in the 2019 IGD relative to the 2016 IGD.

Table 4 - Changes to the stored waste and material quantities that underpin the 2019 and 2016 IGDs

Waste and unit	2016 IGD	2019 IGD	Difference [%]
Legacy LLW [m^3]	8,880	3,830	-57%
Legacy ILW [m^3]	265,000	221,000	-16%
HLW [WVP cans[13]]	7,650	7,660	<0.1%
Legacy SFs [tHM]	7,320	7,440	2%
DNLEU [tU]	215,000	192,000	-11%
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%

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

- the stored volume of LLW has decreased (by approximately 57%) as a result of LLW graphite from FSC at Magnox stations being identified as suitable for disposal to the LLWR
- the stored volume of ILW has decreased (by approximately 16%). This change is mainly due to a re-assessment of PCM from future decommissioning projects at Sellafield and AWE. There has also been a decrease in the estimate of ILW mild steel from decommissioning at Sizewell B
- the quantity of DNLEU has decreased by approximately 11% as a result of a reduction of defence DNLEU, DU tails and MDU

The overall changes to the stored, conditioned and packaged volumes in the IGD are reported in **Table 5**. The quantity of stored waste has decreased by approximately 13%, while the increases in conditioned and packaged volumes are small (and are due to changes in assumptions regarding how the waste is packaged).

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

The changes to the packaged volume for each waste group are shown in **Table 6**. Analysis of the data shows that in terms of volume, it is the legacy UILW / ULLW waste group that is most significantly affected: the packaged volume has increased by 42,800 m^3 (13%).

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 2016 and 2019 IGDs

Volume	2016 IGD	2019 IGD	Difference [%]
Stored	393,000	342,000	-13%
Conditioned	518,000	522,000	1%
Packaged	744,000	773,000	4%

Table 6 - Changes to the packaged volume of each waste group

Waste Group	Packaged volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	99,300	92,600	-6.7%
Legacy UILW/ULLW	329,000	372,000	13%
RSCs	2,730	2,610	-4.3%
DNLEU	191,000	184,000	-3.7%
NB SILW	18,900	18,900	0%
NB UILW	22,100	22,100	0%
HLW	9,860	9,880	0.2%
Legacy SF	16,900	17,000	0.9%
NB SF	39,400	39,400	0%
MOX SF	11,900	11,900	0%
HEU	2,470	2,470	0%
Pu	620	620	0%

3.2 Disposal units

The number of disposal units has increased by 8% between the 2016 and 2019 IGDs.

Table 7 shows the number of disposal units associated with each waste group in the 2016 and 2019 IGDs, and the percentage change to these. It should be 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 packaged volume shown Table 6, the most significant increase in percentage and number of disposal units is to the legacy UILW / ULLW waste group.

There is also a large decrease in DNLEU; this is due to the decrease in DNLEU mass and a change to the packaging assumptions for the defence DNLEU, which have been updated to packaging in TDCs.

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

Waste group	Disposal unit [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	5,400	5,050	-6%
Legacy UILW/ULLW	109,000	126,000	16%
RSCs	962	948	-1%
DNLEU	12,300	8,380	-32%
NB SILW	10,100	10,100	0%
NB UILW	8,230	8,230	0%
HLW	2,550	2,550	0.2%
Legacy SF	4,120	4,160	1%
NB SF	8,940	8,940	0%
MOX SF	2,710	2,710	0%
HEU	779	779	0%
Pu	196	196	0%

3.3 Activities

The total activity is presented at 2040 and 2200 in **Table 8**. At 2040, the 2019 IGD has an activity that is approximately 4% greater than in the 2016 IGD. The difference is predominantly associated with HLW:

- there has been a volume increase in waste stream 2F01/C (Vitrified High Level Waste) and a revision to the specific activities
- a residue of liquid waste from liquor heels in the Highly Active Storage Tanks (HASTs) which will not be removed until after POCO operations, these liquor heels were not forecast in the 2016 IGD. The route for this removal has not been confirmed. For the 2019 IGD it has been assumed that the waste will be treated as other HLW and be vitrified
- there is also an increase in the legacy spent fuel

The increase at 2200 is approximately 1%, again due to the increased quantities of HLW and legacy SF. However, the percentage increase is smaller at 2200 as the activity of these wastes has decayed whilst the total inventory has increased (eg, as a result of the wastes arising from new build).

The evolution of the activity is shown in **Figure 5**. The difference in activity between the 2016 and 2019 IGDs is small at all times.

Table 8 - The change in activity between the 2016 and 2019 IGDs

Date	Activity [TBq]		Difference [%]
	2016 IGD	2019 IGD	
2040	$2.48\ 10^{8}$	$2.58\ 10^{8}$	3.9%
2200	$2.79\ 10^{7}$	$2.82\ 10^{7}$	1.2%

Figure 5 - The evolution of the activity in the 2016 and 2019 IGDs

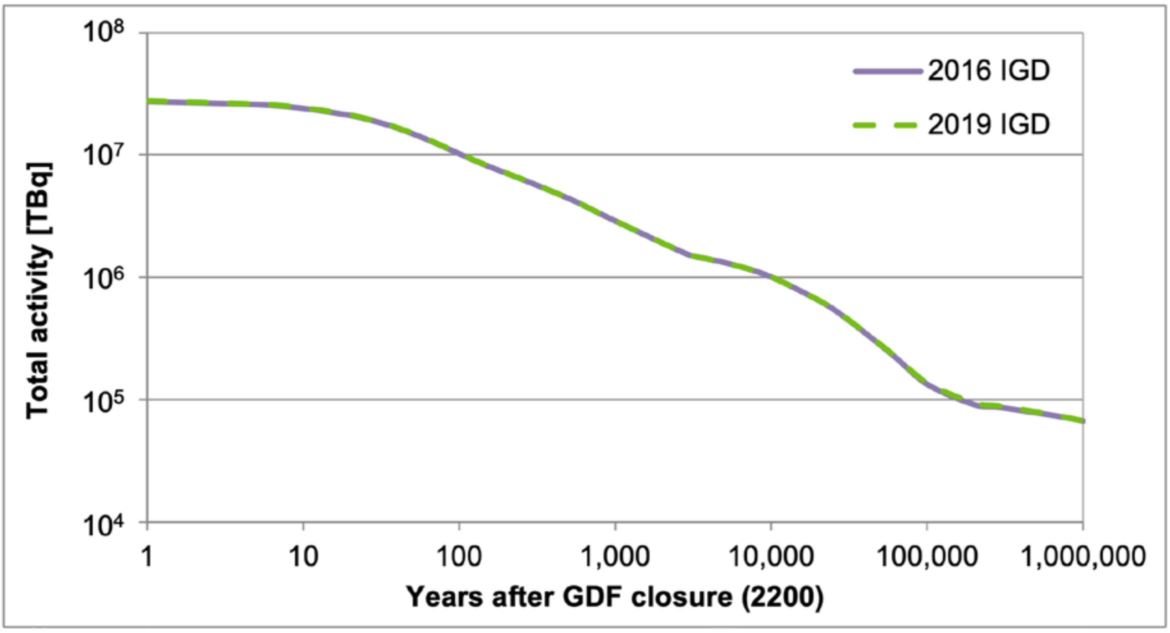


Table 9 presents the change in activity of each waste group at 2200. The legacy SILW / SLLW, RSCs and HLW waste groups have the largest percentage changes. The increase in the legacy SILW / SLLW and RSCs waste groups are due to waste stream 3S306 (Decommissioning: Stainless Steel ILW) being reassigned to legacy SILW / SLLW and RSCs package types. Nevertheless, since the activity associated with these wastes is small relative to HLW and SF, their effect on the GDF total is minimal.

The activities of the priority 1 radionuclides at 2200 are presented in **Table 10**. The small increases in the activity of Se-79, Tc-99, Cs-135 and Np-237 are the result of a volume increase in waste stream 2F01/C (Vitrified High Level Waste). The increase in the activity of U-235 and some of the activity increases in Tc-99 and Np-237 are a result of a review of some DNLEU waste streams (see **section B4.3**). The decrease in U-238 activity is the result of a reduction in the total mass of DNLEU.

The decrease in the activity of Cl-36 is the result of waste stream 5C08 (ILW Concrete Lined Drums) where the waste is being transferred to Sellafield, the volume of waste has decreased and the specific activity has also decreased. The associated Sellafield waste stream 2D201 (ILW Concrete Lined Drums from Harwell) has no activity data for Cl-36. This issue has been raised with Sellafield and will be reviewed again ahead of the 2022 iteration of the inventory.

Table 9 - Changes to the waste group activities at 2200 between the 2016 and 2019 IGDs

Waste group	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	13,800	19,400	41%
Legacy UILW/ULLW	372,000	398,000	7%
RSCs	1,110	3,180	186%
DNLEU	9,560	9,800	3%
NB SILW	154	154	0%
NB UILW	793,000	793,000	0%
HLW	1.20 10^6	1.46 10^6	22%
Legacy SF	2.73 10^6	2.78 10^6	2%
NB SF	19.0 10^6	19.0 10^6	0%
MOX SF	3.70 10^6	3.70 10^6	0%
HEU	53.8	53.7	-0.2%
Pu	43,700	43,700	0%

Table 10 - Changes to the activities of the priority 1 radionuclides between the 2016 and 2019 IGDs at 2200

Radionuclide	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
C-14	17,500	17,800	1.7%
Cl-36	115	110	-4.3%
Co-60	2.12	2.12	0%
Se-79	99.9	103	3.1%
Kr-85	1,250	1,250	0%
Tc-99	19,800	20,700	4.5%
I-129	43.3	43.6	0.7%
Cs-135	944	986	4.4%
Cs-137	5,140,000	5,210,000	1.4%
U-233	2.49	2.49	0%
U-235	60.4	72.2	19.5%
U-238	2,940	2,850	-3.1%
Np-237	851	881	3.5%

Table 11 presents the changes in the activity of gaseous radionuclides in ILW and LLW of interest during the GDF operational period at 2200; Table 12 presents the changes in the peak activity of these radionuclides during the operational period (assumed to be 2040 – 2200). In both cases the changes are small.

Table 11 - Change in the activity at 2200 of the radionuclides that are important to RWM's gas pathway analysis in LHGW in the 2016 and 2019 IGDs

Radionuclide	Activity [TBq]		Difference [%]
	2016 IGD	2019 IGD	
H-3	893	893	0.8%
C-14	14,300	14,500	1.7%
Ra-226	8.90	9.04	1.6%

Table 12 - Change in the peak activity of the key gaseous radionuclides in LHGW between 2040 and 2200 in the 2016 and 2019 IGDs

Radionuclide	Activity [TBq]		Difference [%]
	2016 IGD	2019 IGD	
H-3	33,100	33,100	<0.1%
C-14	14,400	14,600	1.7%
Ra-226	9.42	9.55	1.3%

3.4 Materials data

Materials present in the GDF are estimated for two sources:

- materials associated with waste packages
- materials from GDF construction and operating equipment

Other materials that are inadvertently left behind are referred to as 'stray materials' and have not been estimated.

3.4.1 Materials associated with waste packages

The changes to the material masses associated with waste packages in the 2016 and 2019 IGD are presented in **Table 13**. Two additional material categories have been added when gathering 2019 UK RWI data:

- additional metal, iron
- additional organic, hydrocarbons

These materials would previously have been reported under other materials; for example, iron would previously have been accounted for under 'other ferrous metals'. The new materials provide a more detailed breakdown of the composition of the waste.

A number of the changes to the materials data are a result of a re-assessment of PCM from future decommissioning projects in waste stream 2D90 (-39,947 m^3). The density of the waste stream has also been re-evaluated. The change to this waste stream accounts for the large change in other ferrous metals, aluminium (and alloys), cellulose, halogenated and non-halogenated plastics, rubbers, other organics, asbestos and rubble.

The reduction in nickel (and alloys) and the increase in the total unspecified mass is a result of the 2019 IGD being a light update that does not include a full review and enhancement of the data[14].

[14] *The 2019 IGD is a 'light update'. For a light update the full review and enhancement process is not carried out; unspecified material in new waste streams will not be reassigned. Full details of the method to produce the IGD can be found in reference [6].*

Table 13 - The changes to the material masses between the 2016 and 2019 IGDs ("iron" and "hydrocarbons" are new material types in the 2019 IGD)

	Material	Mass [t] 2016 IGD	Mass [t] 2019 IGD	Difference [%]
Metals	Stainless steel	40,200	36,300	-10%
	Other ferrous metals	71,000	46,100	-35%
	Magnox/magnesium	6,300	6,670	6%
	Aluminium (and alloys)	1,730	1,030	-41%
	Zircaloy/zirconium	6,290	6,330	0.6%
	Copper (and alloys)	291	305	5%
	Nickel (and alloys)	434	282	-35%
	Uranium	1,720	1,820	6%
	Lead	805	754	-6%
	Iron	0	3,190	N/A
	Other metals	322	297	-8%
	Total Metals	129,000	103,000	-20%
Organics	Cellulose	2,170	1,070	-51%
	Halogenated plastics	3,630	3,100	-15%
	Non-halogenated plastics	2,180	1,480	-32%
	Rubbers	1,700	1,100	-35%
	Organic ion ex. resins	3,470	3,460	-0.1%
	Hydrocarbons	0	45.3	N/A
	Other organics	475	114	-76%
	Total organics	13,600	10,400	-24%
Other materials	Graphite	78,400	70,700	-10%
	Asbestos	311	65.9	-79%

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Other materials	**Sludges & flocs**	22,000	20,900	-5%
	Cementitious materials	55,000	57,400	4%
	Ion exchange resins	4,760	5,160	8%
	Heavy metal oxide	280,000	253,000	-10%
	Glass, ceramics & sand	3,720	4,010	8%
	Soil and rubble	2,970	1,070	-64%
	Other inorganics	13,100	10,400	-21%
	Total other materials	460,000	422,000	-8%
	Total Unspecified	1,680	2,840	69%
	Total	604,000	539,000	-11%

3.4.2 Materials from GDF construction and operating equipment

Some materials used in the construction and operation of the GDF will remain underground after closure; this is included in the IGD for the first time in 2019 (for this reason, no comparison is presented). The exact nature and quantity of this equipment will not be fully determined until the GDF site has been selected and the GDF design finalised. However, estimates have been made based on:

- the illustrative generic GDF designs in each of the three host rocks considered in RWM's generic DSSC: higher strength rock, lower strength sedimentary rock and evaporate rock
- existing equipment commonly used to construct and operate underground facilities
- other equipment associated with nuclear facilities

The equipment is further broken down into constituent key material types.

It is noted that the GDF designs, the equipment used, and the material composition of this equipment, are all subject to change.

The construction and operating materials that will remain underground after closure are estimated:

- per vault for LHGW and per disposal tunnel for HHGW; this allows the estimates to be scaled to the appropriate number of vaults / tunnels
- for the whole GDF for the 'shafts and drift' and common service areas'

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 in the IGD. The definitions of the alternative scenarios for the 2016 IGD were revised to be consistent with the 2019 IGD. The impacts of the revised scenarios on the inventory for disposal were then examined.

In general, the impacts of the alternative scenarios on the 2019 IGD are the same or similar to those on the 2016 IGD. The greatest impact continues to be that from uncertainties in the waste volume and radioactivity and these are dominated by a small number of waste streams.

The IGD is based on a single scenario for the arisings of wastes and their conditioning and packaging. Alternative scenarios were defined to explore how changes in assumptions and data uncertainties impact on the IGD [8].

Assessing all the possible changes in assumptions and data uncertainties in individual scenarios is not practical. A pragmatic approach was adopted: only assessing scenarios that highlight key changes in assumptions or waste quantities and characteristics.

There were two stages in updating this work for the 2019 IGD:

- determining whether the definitions of the alternative scenarios needed to be 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 the definitions of alternative scenarios

Twelve alternative scenarios were defined for the 2013 IGD and these were carried forward to the 2016 IGD. The differences between the 2013 and 2016 IGDs have already been documented [12], and the implications assessed [20]. Table 14 shows the differences in the baseline assumptions and the data between the 2016 and 2019 IGDs that are relevant to the definitions of these scenarios. Each of the scenarios that is affected by changes between the 2016 and 2019 IGD is discussed in the following sub-sections.

Table 14 - Differences between the 2016 and 2019 IGDs that are relevant to the definitions of alternative scenarios

No	Scenario	Difference between the 2016 and 2019 IGDs
1	Reprocessing more oxide fuel	No change
2	Reprocessing less Magnox fuel	Less Magnox fuel remains to be reprocessed due to ongoing reprocessing
3	Lifetime extensions for existing reactors	No change
4	Use of UK RWI uncertainty factors	Changes to waste streams between 2016 and 2019 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	No change
8	Change in new build programme	No change
9	Inclusion of foreign wastes and materials	No change
10	Alternative packaging assumptions	No change
11	Exclusion of graphite wastes	Changes to waste streams between 2016 and 2019 UK RWIs
12	Exclusion of ILW / LLW boundary wastes	Changes to waste streams between 2016 and 2019 UK RWIs

4.2 Scenario 2: Reprocessing less Magnox fuel

The current UK policy is that all Magnox spent fuel will be reprocessed. 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 proportionate 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 2016 and 2019. As a result, it is no longer appropriate to assume that 2,000 tU Magnox SF is not reprocessed. For the 2019 IGD alternative scenario the assumption is that 800 tU 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 (-60%) is due to the reduced mass of Magnox spent fuel not reprocessed. The decrease in the packaged volume and the number of disposal units of the DNLEU is also due to the reduced mass of Magnox spent fuel not reprocessed, while the decrease in the total activity (-56%) additionally reflects updated radionuclide data for material stream MU014 (Magnox Depleted Uranium (in 210 litre stainless steel drums) following a review of DNLEU data.

To determine the legacy UILW / ULLW change, the contribution of oxide fuel reprocessing to the ILW streams has previously had to be accounted for. With oxide fuel reprocessing having completed, an assumption no longer needs to be made regarding the relative contributions of oxide and Magnox fuel reprocessing. The increased impact on the legacy UILW / ULLW indicates that the assumption that was made did not reflect the reality.

As would be expected, the reduced quantity of Magnox SF available means that that overall impact of this scenario has been reduced for the 2019 IGD.

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

Waste group	Volume change [m³]		Difference [%]
	2016 IGD	2019 IGD	
Legacy UILW/ULLW	-2,460	-3,560	45%
DNLEU	-1,570	-629	-60%
HLW	-240	-96	-60%
Legacy SF	9,170	3,670	-60%
MOX SF	-511	-204	-60%
Total	4,390	-821	-119%

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

Waste group	Disp. Units change [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy UILW/ULLW	-1,080	-1,560	44%
DNLEU	-62	-25	-60%
HLW	-63	-25	-60%
Legacy SF	2,260	904	-60%
MOX SF	-116	-47	-59%
Total	941	-752	-180%

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

Waste group	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Legacy UILW/ULLW	-1,160	-1,230	6%
DNLEU	-97.8	-45.1	-54%
HLW	-29,200	-11,700	-60%
Legacy SF	172,000	68,600	-60%
MOX SF	-158,000	-63,400	-60%
Total	-17,300	-7,690	-56%

4.3 Scenario 4: use of the 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, RSCs and HLW waste groups. From these, the following inventories are considered:

- lower uncertainty volume (reference volumes multiplied by lower uncertainty factor)
- upper uncertainty volume (reference volumes multiplied by upper uncertainty factor)
- lower uncertainty activity (reference volumes with lower uncertainty specific activities)
- upper uncertainty activity (reference volumes with upper uncertainty specific activities)

4.3.1 Volumes and number of disposal units

Table 18 to Table 21 present the impact of applying volume uncertainty factors on the packaged volume and number of disposal units in the 2016 and 2019 IGDs. The differences in the packaged volume and the number of disposal units are due to:

- a reduction in uncertainty associated with HLW from POCO: HLW waste steam 2F38/C (Vitrified High Level Waste from POCO) in the 2016 IGD has been incorporated into waste stream 2F01/C (Vitrified High Level Waste)
- changes in waste volumes for many legacy UILW / ULLW waste streams

Table 18 - Changes in the lower packaged volume for those waste groups affected by Scenario 4

Waste group	Volume change [m³]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-20,600	-21,000	2%
Legacy UILW/ULLW	-85,300	-97,800	15%
RSCs	-424	-430	1%
HLW	-2,580	-1,350	-47%
Total	-109,000	-121,000	11%

Table 19 - Changes in the upper packaged volume for those waste groups affected by Scenario 4

Waste group	Volume change [m³]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	21,800	21,200	-3%
Legacy UILW/ULLW	325,000	404,000	24%
RSCs	432	436	1%
HLW	18,100	1,650	-91%
Total	366,000	427,000	17%

Table 20 - Changes in the lower number of disposal units for those waste groups affected by Scenario 4

Waste group	Disp. units change [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-1,110	-1,130	2%
Legacy UILW/ULLW	-27,500	-32,400	18%
RSCs	-163	-174	6%
HLW	-666	-350	-47%
Total	-29,500	-34,000	16%

Table 21 - Changes in the upper number of disposal units for those waste groups affected by Scenario 4

Waste group	Disp. units change [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	1,160	1,140	-2%
Legacy UILW/ULLW	101,000	132,000	30%
RSCs	165	174	6%
HLW	4,690	427	-91%
Total	107,000	133,000	24%

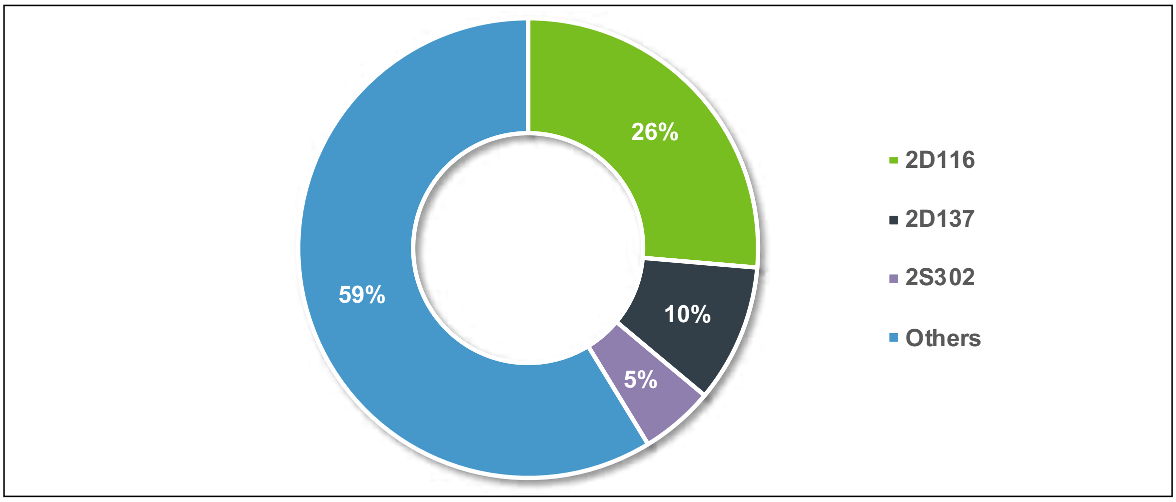
Figure 6 illustrates the percentage contributions from individual waste streams to the decrease in packaged volume associated with lower volume uncertainty factors. Three waste streams (from a total of 543) contribute 41% of this volume decrease[15].

Two of these waste streams are the same top contributors as in the 2016 IGD:

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

Two operational streams 2D08 and 2D09 (Magnox Cladding and Miscellaneous Solid Waste) were major contributors in the 2016 IGD; these waste streams have been sub-divided by their storage facility compartment number at Sellafield. The result of this is that they no longer appear in the top contributors; however, the sum of their contributions to the decrease in packaged volume is unchanged from the 2016 IGD and the facility remains a major contributor to the uncertainty.

Figure 6 - Waste stream percentage contribution to the reduced packaged volume associated with lower uncertainty in the 2019 IGD



[15] *Further information on these waste streams (and others discussed in this section) can be found in the documents section of the UK Radioactive Waste Inventory website.*

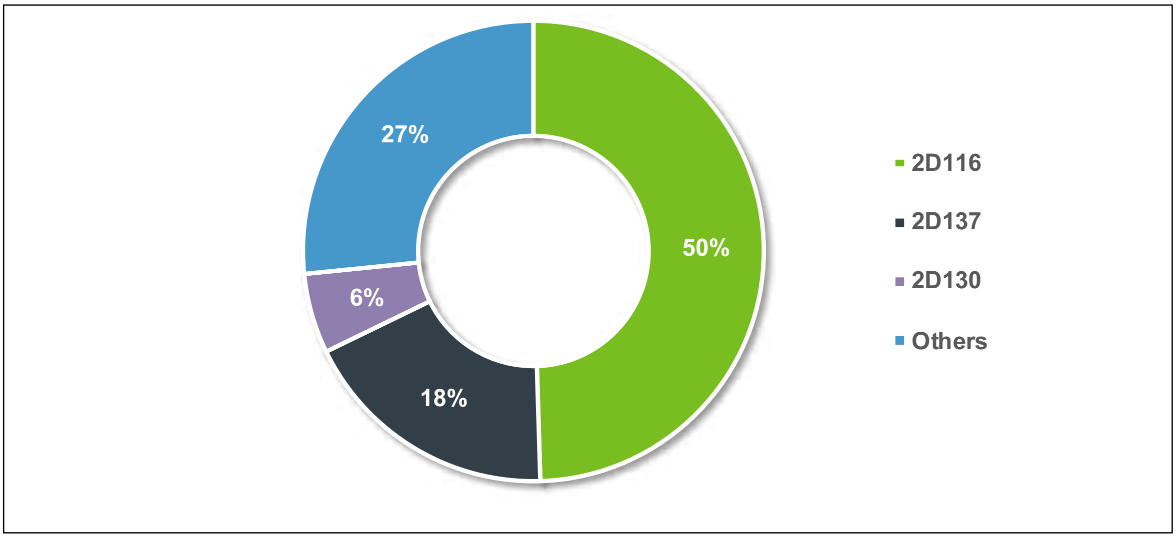
Figure 7 illustrates the percentage contributions from individual waste streams to the increase in packaged volume associated with upper volume uncertainty factors. Five waste streams (from a total of 543) contribute 78% of this volume increase.

Two of these waste streams are the same top contributors as in the 2016 IGD:

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

Both these waste streams have upper volume uncertainty factors of 3 and lower volume uncertainty factors of 0.7 so make greater contributions to the upper volume uncertainty in Figure 7 than the lower volume uncertainty shown in Figure 6.

Figure 7 - Waste stream percentage contribution to the increased packaged volume associated with upper volume uncertainty in the 2019 IGD



The impact of the upper volume uncertainty factors is greater than in the previous assessment due to changes in volume of legacy UILW / ULLW and the changes to the packaging assumptions for the major contributors. The waste streams that make the most significant contributions to the upper volume uncertainty in the 2019 IGD are largely the same as those in the 2016 IGD. The overall change in the lower uncertainty factors is only significant for HLW.

4.3.2 Activities

Table 22 shows the impact of applying lower and upper uncertainty factors to the total activity at 2200 in the 2016 and 2019 IGDs. The increased impact of the lower uncertainty is due to the increased volume of waste stream 2F01/C (Vitrified High Level Waste) and waste from liquor heels remaining in waste stream 2D02. The reduced impact of the upper uncertainty is due mainly to small decreases in waste volumes of Miscellaneous Activated Components & Fuel Stringer debris in waste streams 3K30, 3L25 and 3N38, which are significant contributors to the total upper activity uncertainty.

Table 22 - The impact of the activity uncertainty on the total activity at 2200

Activity Uncertainty	Activity change at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Lower uncertainty	-714,000	-807,000	13.1%
Upper uncertainty	12,200,000	11,900,000	-2.8%

Figure 8 and **Figure 9** show the percentage contributions from individual waste streams to the overall impact of the 2019 IGD upper and lower activity uncertainty scenarios, respectively. Five waste streams contribute about 75% of the impact in both cases. For the lower activity uncertainty, these are the same five streams as in the 2016 IGD; for the upper activity uncertainty, four of the five waste streams are the same as the 2016 IGD. Waste stream 2F01/C (Vitrified High Level Waste) is now a key contributor as a result of the increase in waste volume for this waste stream.

The changes in the total activities of the priority 1 radionuclides at 2200 between the 2016 and 2019 IGDs are presented in **Appendix D1**. Most of the changes are not significant, although there is an increase of 81 % in the upper activity uncertainty of I-129. This is the result of an increase in the I-129 stock specific activity for waste stream 2D27/C (Encapsulated Floc from Effluent Treatment).

Overall, the activity uncertainty associated with the 2019 IGD is bounded by that associated with the 2016 IGD.

Figure 8 - Waste stream percentage contribution to the total activity associated with lower activity uncertainty in the 2019 IGD

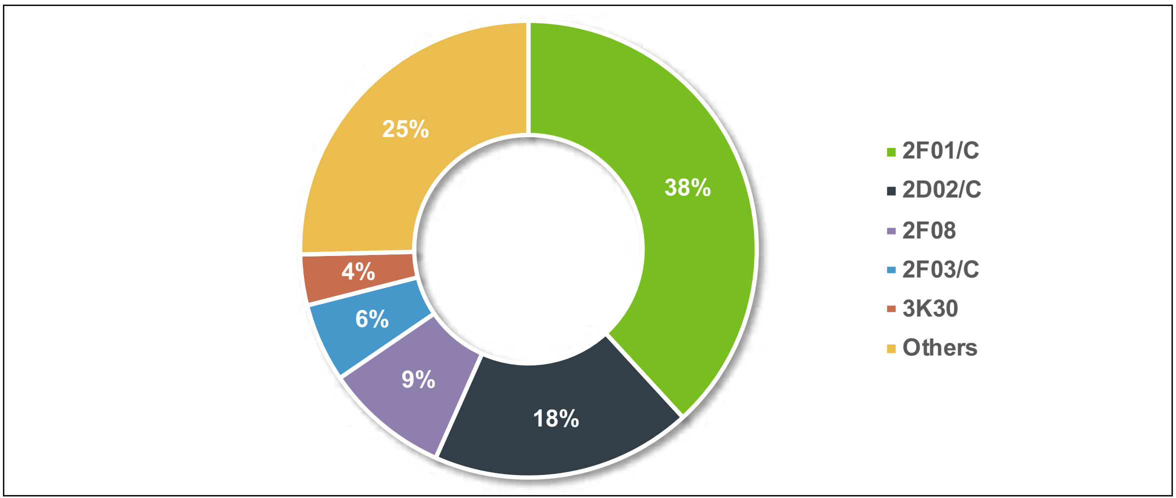
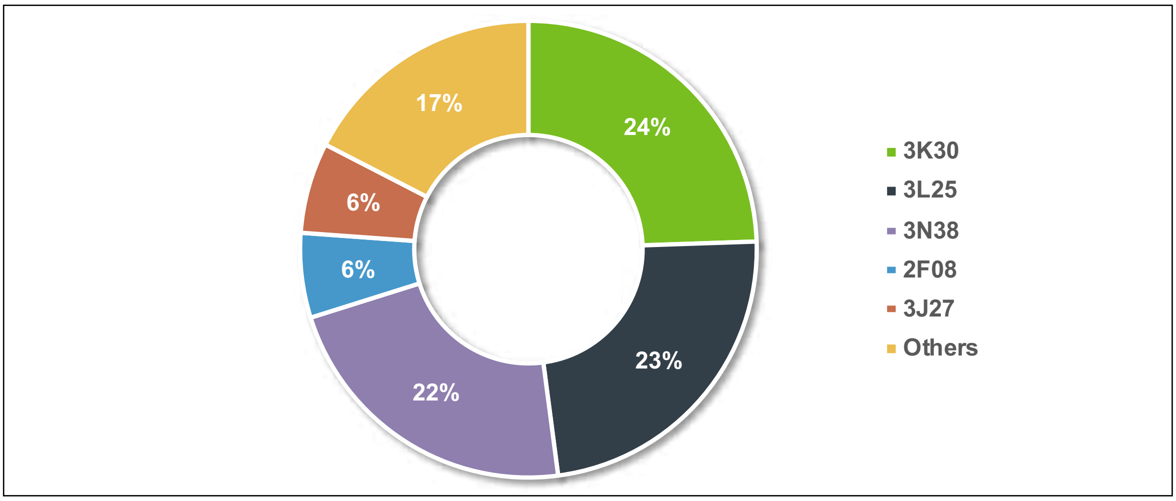


Figure 9 - Waste stream percentage contribution to the total activity associated with the upper activity uncertainty in the 2019 IGD



4.4 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 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 2016 and 2019 IGDs assuming an alternative disposal route for graphite. The wastes categorised as graphite are unchanged between the 2016 and 2019 IGDs.

Table 23 and Table 24 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 25 compares the impact of graphite not being disposed of to the GDF on the total activity at 2200.

The changes in the legacy SILW / SLLW waste group in Table 23 and Table 24 are due to LLW graphite from FSC at Magnox stations being identified as suitable for disposal to the LLWR. There is also a decrease in the volume of waste stream 5C302 (BEPO Reactor Decommissioning ILW).

The increase in the legacy UILW / ULLW waste group is due to an increase in packaged volume for waste stream 2S302 (Windscale Pile1 and Pile 2 Graphite and Aluminium Charge Pans), as a result of a decrease in assumed waste package loading.

The change in the legacy UILW / ULLW waste group in Table 25 is due to activity decreases in waste streams 2F07 (AGR Graphite Fuel Assembly Components) and 2S302, as a result of decreases in their stored volumes.

Table 23 - Changes in the packaged volume for those waste groups affected by Scenario 11

Waste Group	Change in packaged volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-68,400	-61,900	-9%
Legacy UILW/ULLW	-28,000	-33,200	19%
Total	-96,400	-95,100	-1%

Table 24 - Changes in the number of disposal units for those waste groups affected by Scenario 11

Waste Group	Change in number of disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-3,500	-3,170	-9%
Legacy UILW/ULLW	-10,200	-11,600	14%
Total	-13,700	-14,800	8%

Table 25 - Changes in the total activity at 2200 for those waste groups affected by Scenario 11

Waste Group	Change in total activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-6,440	-6,440	<0.1%
Legacy UILW/ULLW	-2,730	-2,520	-7.6%
Total	-9,170	-8,960	-2.3%

4.5 Scenario 12: Exclusion of 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 IGD. All other ILW streams expected to be managed as LLW are included in the IGD. The 2016 UK RWI includes 36 ILW streams that waste producers expect to manage as LLW through disposal at the LLWR, by using radioactive decay storage and / or decontamination processes; the 2019 UK RWI includes 37 such streams (See Table D3 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 IGD would be a reduction in ILW for disposal to the GDF. This section shows the differences between the 2016 and 2019 IGDs for ILW / LLW boundary wastes:

- Table 26 and Table 27 present the change to the packaged volume and the number of disposal units. The increases associated with the legacy UILW / ULLW are due to a large increase in the arising volume of waste stream 2D42 (Magnox Pond Furniture), new waste stream 1A12 (ILW Containing Tritium) and waste stream 7A108 (Decommissioning LLW Requiring Further Assay Through Recategorization Programme) which was not included in the 2016 IGD. The decrease for RSCs is associated with the removal of waste stream 9E47 (Desiccant) due to its disposal
- Table 28 presents the change to the total activity at 2200. The large increase in the total activity of the legacy UILW / ULLW waste group is due to the increase in the arising volume of waste stream 2D42 (Magnox Pond Furniture)

Whilst some of the changes shown in Table 26 to Table 28 are significant in percentage terms, the absolute values are small and the conclusions that this scenario would have a small impact on the activity and volume of waste in the IGD remain valid.

4.5.1 Near-surface disposal

The NDA identified a potential gap in the UK's disposal system. The NDA believes that there is a proportion of ILW that could be more appropriately managed in near-surface disposal (NSD) facilities and initiated an investigation to explore the technical feasibility of this disposal capability. A range of possible NSD options have been explored and these are described in the NDA's Near-Surface Disposal Strategic Position Paper [22].

The disposal of radioactive waste in near-surface facilities is already used for LLW (LLWR in Cumbria and the Dounreay LLW facility). This option is currently limited to LLW. However, the NDA are exploring the benefits of developing similar facilities for disposing of some of the less hazardous proportion of ILW. They are assessing the technical, environmental and economic case for purpose built engineered facilities located either at the surface or up to tens of metres below ground. If NSD is implemented, it would not replace a GDF and would be developed in tandem to provide an earlier and more cost-effective solution for a limited proportion of the less hazardous wastes in the ILW category. Although containing a very small fraction of the radioactivity within the radioactive waste inventory, this could nonetheless represent significant volumes of waste material. The diversion of any waste to a potential future NSD facility should only result in minimal impact on the overall design and operations of a GDF.

A quantitative analysis of this scenario has not been carried out for the 2019 IGD; however, NDA's position paper does show the volumes of waste that may be suitable for the two main near-surface options.

Table 26 - Changes in the packaged volume for those waste groups affected by Scenario 12

Waste Group	Change in packaged volume [m³]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-232	-229	-1%
Legacy UILW/ULLW	-7,190	-8,990	25%
RSC	-259	-225	-13%
Total	-7,680	-9,450	23%

Table 27 - Changes in the numbers of disposal units for those waste groups affected by Scenario 12

Waste Group	Change in number of disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-12	-12	0%
Legacy UILW/ULLW	-2,320	-2,890	25%
RSC	-48	-42	-13%
Total	-2,380	-2,940	24%

Table 28 - Changes in the total activity at 2200 for those waste groups affected by Scenario 12

Waste Group	Change in total activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
Legacy SILW/SLLW	-0.0263	-0.0264	1%
Legacy UILW/ULLW	-118	-180	53%
RSC	-0.0283	-0.0253	-11%
Total	-118	-180	53%

5 Conclusions

Summary of conclusions

The IGD has been updated following the publication of the 2019 UK RWI. The key underpinning assumptions are unchanged between the 2016 and 2019 IGDs. Changes to the packaged volume of waste (+4%), activity (+1% at 2200) and number of disposal units (+8%) are small and are primarily associated with reduced waste loading volumes for some Sellafield legacy UILW / ULLW decommissioning wastes and increases in HLW and legacy fuels.

The uncertainties associated with the 2019 IGD and the 2016 IGD have been explored through a range of alternative inventory scenarios. The changes in these scenarios between the 2016 and 2019 IGD are small.

Whilst the key underpinning assumptions have not changed between 2016 and 2019, there have been several changes to the wastes in the inventory:

- a decrease in the quantity of DNLEU from civil fuel enrichment, civil spent fuel reprocessing and defence programmes
- an increase in the quantity of legacy SF as a result of revised estimates in the UK RWI
- a decrease in LLW as a result of graphite from FSC at Magnox stations being identified as suitable for disposal to the LLWR
- a re-evaluation of some PCM wastes that has resulted in reduced waste volumes and, together with revised waste density, led to changes to the masses of various materials

The impact of these changes on the IGD has been assessed:

- despite a decrease in the overall quantity of waste for disposal, there has been a small increase in packaged volume, primarily as a result of reduced waste loading volumes for some Sellafield legacy UILW / ULLW decommissioning wastes
- there has been an increase in the total number of disposal units, primarily as a result of reduced waste loading volumes for some Sellafield legacy UILW / ULLW decommissioning wastes

- 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 wastes, with reductions in several material types. Most notable is a 24% decrease in organics and a 20% decrease in metals

Alternative scenarios are used to explore the effects of changes in assumptions and uncertainties in the 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 2019 IGD have been evaluated. For most of the alternative scenarios the impact on the inventory for disposal is unchanged.

For both the 2016 and 2019 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 2019 IGD
- scenario 4 (use of UK RWI uncertainty estimates)
    - the impact of this scenario on the IGD has increased for the upper volume uncertainty factors (+17% packaged volume)
    - the impact of this scenario on the IGD has increased for the lower uncertainty factors (+11% packaged volume, +13% activity)
    - the impact of this scenario on the IGD has decreased for the upper activity uncertainty factors (-3% activity)
- scenario 11 (exclusion of graphite wastes) impact has decreased due to LLW graphite from FSC at Magnox stations being identified as suitable for disposal to the LLWR so they are no longer included in the waste streams sent to the IGD
- scenario 12 (exclusion of ILW/LLW boundary wastes) impact has increased due to volume increases and a number of changes to waste streams. There are significant changes in percentage terms, but the absolute values are small

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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
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
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
EPR	EPR is now used by AREVA as a reactor name, it was previously used to mean European Pressurized Reactor and Evolutionary Power Reactor
FSC	Final site clearance
GDF	Geological Disposal Facility
GWd/tU	Gigawatt days per tonne of uranium (1 tonne = 1,000 kg)
GW(e)	Gigawatts electrical
HAW	Higher activity radioactive waste
HEU	Highly enriched uranium
HHGW	High heat generating waste
HLW	High level waste
IGD	Inventory for geological disposal
ILW	Intermediate level waste
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

Term	Definition
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
MDU	Magnox depleted uranium
MOD	Ministry of Defence
MOX	Mixed oxide fuel
MSSS	Magnox Swarf Storage Silo
NB	New build
NSD	Near-surface disposal
Packaged volume	The packaged waste volume is the displacement volume of a container used to package a wasteform multiplied where appropriate by the number of packages
PCM	Plutonium contaminated materials
PFR	Prototype Fast Reactor
POCO	Post-operational clean out
Priority 1 radionuclide	Highest priority score for those radionuclides having greatest effect on wasteform, packaging, transport, criticality and GDF design
Pu	Plutonium
PWR	Pressurised Water Reactor
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
SGHWR	Steam-generating heavy water reactor
SILW	Shielded ILW
SILW waste package	Waste package not requiring additional shielding
SLLW	Shielded LLW
TDC	Transport and disposal container
tHM	Tonnes of heavy metal (1 tonne = 1,000 kg)
THORP	Thermal oxide reprocessing plant
TPU	THORP product uranium
tU	Tonnes of uranium (1 tonne = 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
WAGR	Windscale advanced gas-cooled reactor
WVP	Waste Vitrification Plant

Appendix A – Waste stream changes

A1 New waste streams in the 2019 IGD

Table A1 - New waste streams in the 2019 IGD

Waste stream ID	Waste stream name	Packaged volume [m³]
1A12	ILW Containing Tritium	226
2D02b/C[16]	Vitrified High Level Waste – from liquor heels	1,190
2D08.1	MSSS Compartment 1	2,170
2D08.2	MSSS Compartment 2	2,170
2D08.3	MSSS Compartment 3	2,170
2D08.4	MSSS Compartment 4	2,170
2D08.5	MSSS Compartment 5	2,170
2D08.6	MSSS Compartment 6	2,170
2D09.1	MSSS Compartment 7	2,120
2D09.2	MSSS Compartment 8	2,120
2D09.3	MSSS Compartment 9	2,120
2D09.4	MSSS Compartment 10	2,120
2D09.5	MSSS Compartment 12	2,120
2D11/C	Conditioned Pond Sludge	89.6
2D201	ILW Concrete Lined Drums from Harwell	519
2D202/C	Dragon Fuel from Winfrith	4.00
2D22.1	MSSS Compartment 13	2,150
2D22.2	MSSS Compartment 14	2,150
2D24.1	MSSS Compartment 16	1,500
2D24.2	MSSS Compartment 17	1,660
2D24.3	MSSS Compartment 18	1,660
2D35.1	MSSS Compartment 19	1,660
2D35.2	MSSS Compartment 20	1,660
2D35.3	MSSS Compartment 21	1,710

[16] *2D02 is not new to the UK RWI. However, it has previously been assumed to have zero volume remaining. The 2019 UK RWI includes liquor heels that will remain. These have been incorporated into the 2019 IGD as waste stream 2D02b/C, which is assumed to be conditioned and packaged in the same way as other HLW streams.*

Waste stream ID	Waste stream name	Packaged volume [m^3]
2D35.4	MSSS Compartment 22	1,710
2D74/C	Conditioned Pile Fuel Storage Pond Ion Exchange Material	7.99
2N17	Legacy Drums (Bulk)	42.5
5G25	DRAGON High Active Components	0.214
6C33/C	NDS Contact Handled ILW	5.14
6N04	Near Beam Metallic	23.7
7A108	Decommissioning LLW Requiring Further Assay Through the Recategorization Programme	76.22
7V29	Vulcan Contact Handled ILW	9.31
8A23	ILW FROM LCF	14.9
9A33/C	FED Graphite	416
9A87	Fuel Fragments/High Dose Rate Items	5.16
9A88	Fuel Fragments/High Dose Rate Items	5.28
9A917	Empty Drums and Liners	26.9
9B17/C	Miscellaneous Contaminated Items	65.2
9B55/C	Ponds Decontamination Sludge	66
9B59/C	FED Magnox	13.2
9B79/C	FED Magnox – Solid Secondary Waste	2.64
9B81/C	FED Magnox – Secondary Ion Exchange Resin (Co-Treat)	2.64
9B82/C	FED Magnox Dissolution Secondary Waste (Sludge)	7.92
9B84/C	FED Magnox – Secondary Granular Activated Carbon (GAC)	3.82
9B85/C	FED Magnox – Secondary Ion Exchange Resin (Cs-Treat)	1.32
9B86/C	Sludge	7.91
9B87/C	Miscellaneous Contaminated Items	2.64
9C02/C	PWTP Ion Exchange Material	59.1
9C24	FED Magnox (lugs and splitters)	2.24
9C70	Cyclone dust	1.32
9D15	PWTP Fine Filters	35.5
9E56/C	Ion Siv Unit Cartridges & Post Filters	5.28
9E961/C	Ion Siv Unit Cartridges & Pre Filters	5.28
9E962/C	Ion Siv Unit Cartridges	2.64
9F47	Fuel Fragments	1.32
9G35/C	FED Magnox	26.2
9H26/C	DSC4 Uranic Corrosion Debris	3.95
9H33	Graphite ILW	0.026
9H34	Pile Cap, Dry Fuel Store and associated areas	5.41
9H932	Flask Filling Area Sludge	1.32
M2D301	Windscale fuel	42.28
M2D302	Winfrith fuel	138.22
M2D303	Miscellaneous LWR fuel	135.71

Waste stream ID	Waste stream name	Packaged volume [m³]
MU012A	Miscellaneous DNLEU – LEU residues	85.64
MU012B	Miscellaneous DNLEU – LEU metal billets	395.73
MU012C	Miscellaneous DNLEU – Natural uranium residues	756.04
MU012D	Miscellaneous DNLEU – Depleted uranium residues	431.20
MU017	DU Tails	114,538
MU019	Uranium Tetrafluoride	135.86

A2 Deleted waste streams in the 2019 IGD

Table A2 - Deleted waste streams

Waste stream ID	Waste stream name	Comment	Packaged volume [m³]
2D08	Magnox Cladding and Miscellaneous Solid Waste	Replaced by new MSSS streams with waste split by compartment	12,100
2D09	Magnox Cladding and Miscellaneous Solid Waste	Replaced by new MSSS streams with waste split by compartment	10,000
2D22	Magnox Cladding and Miscellaneous Solid Waste	Replaced by new MSSS streams with waste split by compartment	3,650
2D24	Magnox Cladding and Miscellaneous Solid Waste	Replaced by new MSSS streams with waste split by compartment	4,810
2D35	Magnox Cladding and Miscellaneous Solid Waste	Replaced by new MSSS streams with waste split by compartment	3,990
2D85.3/C	SPP1 Secondary Waste ILW	Secondary waste accounted for in relevant primary stream	79.2
2D86.3/C	BEP Secondary Waste ILW	Secondary waste accounted for in relevant primary stream	145
2D87.1.3/C	SDP Secondary Waste	Secondary waste accounted for in relevant primary stream	8,480
2D87.2.3	SWR Secondary ILW	Secondary waste accounted for in relevant primary stream	169
2D96.1	FGMSP Bay Solid Waste to BEP	Combined with 2D96.2 non-fuel bearing pond solids	1,580
2D96.3	Magazines in Magnox Fuel Storage Pond	Fuel-bearing component routed to 2D80.1 (SDF to FHP), the remainder to 2D96.2 (non-fuel bearing solids)	68.7
2F38/C	Vitrified High Level Waste from POCO	Incorporated into 2F01/C	1,910
2N01	Plutonium Contaminated Material; Drummed (Legacy Drums)	Re named and waste reclassified as LLW for 2019, all waste disposed of via LAW routing	41.7
2S10/C	WAGR Stringer Graphite Debris – Conditioned	Waste consigned	59.3
3S307	Decommissioning: Concrete ILW	ILW concrete no longer expected at Sizewell B	47.7
5H08	ILW Non-Incinerable Materials	Included in 5H07 following successful results in the Materials Detritiation Facility.	29.0
6K101	Am/Be Sources	Transferred to Sellafield	0.001

Waste stream ID	Waste stream name	Comment	Packaged volume [m³]
6K102	Cadmium and Aluminium Linings	Waste reclassified from ILW to VLLW, planned to go to VLLW landfill	0.354
6K103	Control Rods	Transferred to Sellafield	0.001
6K104	Core Support Plate	Transferred to Sellafield	0.035
6K105	Graphite Columns	Consigned to LLWR	4.71
6K107	Miscellaneous Stainless Steel Items	Transferred to Sellafield	0.024
9A316	Graphite LLW	Expected to be consigned to the LLW Repository and identified as suitable for disposal to the LLWR	40.8
9A916	Empty BPS Sludge Cans	Waste consigned	5.44
9B02	Ion Exchange Material	All waste conditioned	11.9
9B15	Sludge	All waste conditioned	43.5
9B17	Miscellaneous Contaminated Items	All waste conditioned	43.6
9B316	Graphite LLW	Identified as suitable for disposal to the LLW Repository	266
9B33	Contaminated Gravel	All waste shipped	26.1
9B36	Contaminated Gravel	All waste shipped	23.9
9B37	Contaminated Gravel	All waste shipped	28.7
9B55	Ponds Decontamination Sludge	All waste conditioned.	66
9B63	Contaminated Gravel	Co-packaged with 9B15/C	8.70
9B65	Sand and Gravel in Sand Pressure Filters – PWTP & AETP	Co-packaged with 9B55/C & 9B83/C.	38.4
9B79	FED Magnox – Solid Secondary Waste	No further arisings	3.33
9B80	FED Magnox Dissolution Secondary Waste (Filters)	Co-packaged with 9B17/C.	7.29
9B81	FED Magnox – Secondary Ion Exchange Resin (Co-Treat)	All waste conditioned.	5.28
9B82	FED Magnox Dissolution Secondary Waste (Sludge)	All waste conditioned.	21.8
9B84	FED Magnox – Secondary Granular Activated Carbon (GAC)	All waste conditioned	7.86
9B85	FED Magnox – Secondary Ion Exchange Resin (Cs-Treat)	All waste conditioned	1.32
9B964	FAVORIT Plant	Co-packaged with 9B17/C	13.1
9C17	Magnox Dissolution Plant Sludge	Reclassified as LLW. Meets LLWR WAC	11.1
9C20	AETP Sludge	Reclassified as LLW. Meets LLWR WAC	5.44
9C67	CRU1 Ion-exchange resin	Combined with stream 9C58	6.60
9D316	Graphite LLW	Identified as suitable for disposal to the LLW Repository	58.1
9D919	Settling Tank Bitumen Linings	Work scope deleted	11.9
9E315	Graphite LLW	Identified as suitable for disposal to the LLW Repository	2,340

Waste stream ID	Waste stream name	Comment	Packaged volume [m^3]
9E47	Desiccant	All waste shipped	34.4
9E55	Ion Siv Unit Pre Filters	Consigned to the LLWR	10.9
9E56	Ion Siv Unit Cartridges	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type)	5.28
9E57	Ion Siv Unit Post Filters	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type)	9.24
9E961	Ion Siv Unit Cartridges	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type)	11.7
9E962	Ion Siv Unit Cartridges	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type)	8.93
9E963	Ion Siv Unit Cartridges	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type)	5.28
9E964	Ion Siv Unit Pre Filters	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type).	1.99
9E965	Ion Siv Unit Pre Filters	Conditioned in streams 9C56/C, 9C961/C, 9C962/C (based on container type).	1.99
9G316	Graphite LLW	Identified as suitable for disposal to the LLW Repository	59.3
9H26	DSC4 Uranic Corrosion Debris	All waste conditioned.	4.40
9H315	Graphite LLW	Identified as suitable for disposal to the LLW Repository	3,380
9H931	Dry Store Cell 4 Skip Debris	Combined with stream 9H26	1.23
MU012	Miscellaneous DNLEU	Stream split into four parts	1,820
MU015	DU tails (unirradiated) in DV-70	MU015 and MU016 combined and reported in new stream MU017	111,000
MU016	DU tails (irradiated) in DV-70	MU015 and MU016 combined and reported in new stream MU017	12,400

Appendix B – Details of changes by waste group

B1 Legacy SILW / SLLW

B1.1 Volumes

As can be seen in **Table B1**, the volumes of waste associated with this waste group have decreased slightly. The reasons for the changes are varied and are due to changes in volume estimates and packaging assumptions, e.g. the rerouting of Magnox LLW graphite that is now LAW.

Table B1 - The change in the volume of waste in the Legacy SILW / SLLW waste group between the 2016 and 2019 IGD

Volume	Volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Stored	63,900	59,000	-8%
Conditioned	79,300	73,200	-8%
Packaged	99,300	92,600	-7%

B1.2 Disposal units

Table B2 shows that there has been an overall decrease of approximately 6% in the number of disposal units. Whilst the overall change is not significant there are some notable changes to the different types of waste packages: 2 m boxes are now proposed for some PWR decommissioning stainless steel instead of 3 m^3 boxes; there is a reduction in 4 m boxes as a result of Magnox LLW graphite being reclassified as LAW. The number of 6 m^3 HD boxes has increased due to the reassignment of Hinkley Point A ion exchange materials from 500 litre drums (UILW) and the number of 6 m^3 SD boxes has decreased mainly due to reassessment of container type for decommissioning wastes at Winfrith.

Table B2 - The change in the number of disposal units in the Legacy SILW / SLLW waste group between the 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
2 m box (200 mm concrete)	0	24	N/A
4 m box (0 mm concrete)	2,730	2,420	-11%
4 m box (100 mm concrete)	1,230	1,220	-0.2%
4 m box (200 mm concrete)	363	363	0%
6 m³ concrete box (HD)	170	214	26%
6 m³ concrete box (SD)	910	806	-11%
Total	5,400	5,050	-6%

B1.3 Activities

The total activity at 2040 has increased by approximately 2% from 15,100 TBq to 15,500 TBq. At 2200 the activity has increased by approximately 41% from 13,800 TBq to 19,400 TBq, this is the result of some of waste stream 3S306 (Decommissioning: Stainless Steel ILW) being reassigned to an SILW package type.

Table B3 and Table B4 show the changes in the activities at 2040 and 2200 of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments.

There are large increases in the activity of I-129, Cs-137 at 2040 and 2220; this is the result of waste streams 9D28 and 9D29 (Ion exchange material) now being packaged in 6 m³ boxes. There is also an increase in the H-3 activity at 2040 and 2200 that results from an increase in the volume of waste stream 5H306 (JET Decommissioning Activated ILW).

There are decreases in activity of U-235 and U-238 at 2040 and 2200; this is the result of a decrease in the volume of waste stream 9D23 (Sludge). The decrease in the activity of Se-79 at 2040 and 2200 is because it is no longer quantified for waste stream 9G18/C (Ion Exchange Material – Conditioned Waste), because it is not expected to be present in significant quantities. The decrease in the activity of Tc-99 at 2040 and 2200 is the result of an update to the specific activity for waste stream 9G107/C (Ion Exchange Material).

Table B3 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	65.5	64.8	-1.1%
	Cl-36	0.484	0.513	6.0%
	Co-60	1,390	1,300	-6.6%
	Se-79	$3.50\ 10^{-4}$	$3.12\ 10^{-4}$	-10.9%
	Kr-85	0.727	0.727	< -0.1%
	Tc-99	0.192	0.137	-28.6%
	I-129	$2.27\ 10^{-4}$	$2.90\ 10^{-4}$	27.6%
	Cs-135	0.0456	0.0418	-8.5%
	Cs-137	221	292	32.1%
	U-233	0.056	0.052	-7.1%
	U-235	$4.19\ 10^{-4}$	$3.69\ 10^{-4}$	-11.9%
	U-238	0.0316	0.0254	-19.5%
	Np-237	0.0351	0.0337	-4.1%
Gas	**H-3**	4,460	5,030	12.9%
	C-14	65.5	64.8	-1.1%
	Ra-226	0.0135	0.0127	-5.8%

Table B4 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	6,400	6,400	0.1%
	Cl-36	26.2	26.2	0.1%
	Co-60	$1.62\ 10^{-3}$	$1.64\ 10^{-3}$	1.1%
	Se-79	$3.50\ 10^{-4}$	$3.12\ 10^{-4}$	-10.9%
	Kr-85	$2.36\ 10^{-5}$	$2.36\ 10^{-5}$	-0.1%
	Tc-99	0.394	0.377	-4.2%
	I-129	$2.27\ 10^{-4}$	$2.90\ 10^{-4}$	27.6%
	Cs-135	0.0456	0.0418	-8.5%
	Cs-137	5.61	7.4	32.1%
	U-233	0.056	0.052	-7.1%
	U-235	$4.19\ 10^{-4}$	$3.69\ 10^{-4}$	-11.9%
	U-238	0.0316	0.0254	-19.5%
	Np-237	0.0357	0.0342	-4.1%
Gas	**H-3**	0.895	0.989	10.4%
	C-14	6,400	6,400	0.1%
	Ra-226	0.0126	0.0119	-5.8%

B1.4 Materials

Table B5 shows the changes in the masses of the materials in the SILW / SLLW waste group. The overall change is small (approximately 7% decrease), and the changes to the different categories of materials are also small: 2% increase for metals, 8% increase for organics and a 7% decrease for other materials. However, some individual materials show significant changes and the reasons for these are:

- re-assessment of the material composition for Winfrith ion exchange material conditioned wastes resulting in increases in other ferrous metals
- re-assessment of material composition for Magnox mild steel (reactor) ILW resulting in increases in nickel
- a change from UILW to SILW packages for Solid Waste Complex Decommissioning ILW from Harwell resulting in increases in rubber and halogenated plastics
- a change in management strategy for Settling Tank Bitumen Linings at Magnox reactors resulting in decreases of other organics
- the change in package type (from SILW to RSC) for some Magnox contaminated gravel resulting in decreases in rubble
- changes to the composition and management strategy for some Magnox ion exchange materials resulting in increases in other inorganic materials
- iron and hydrocarbons are reported separately in the 2019 IGD for the first time

Table B5 - Changes to the material masses in Legacy SILW / SLLW between the 2016 and 2019 IGDs ("iron" and "hydrocarbons" are new material types in the 2019 IGD)

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	3,210	3,400	6%
	Other ferrous metals	14,500	11,700	-20%
	Magnox/magnesium	321	342	6%
	Aluminium (and alloys)	25.1	24.3	-3%
	Zircaloy/zirconium	30.6	41.2	35%
	Copper (and alloys)	13.2	15.6	18%
	Nickel (and alloys)	12.8	23.5	84%
	Uranium	0.082	0.082	0%
	Lead	3.1	3.1	0%
	Iron	0	3,100	N/A
	Other metals	37.1	27.4	-26%
	Total Metals	18,200	18,600	2%
Organics	Cellulose	11.9	16.2	36%
	Halogenated plastics	2.03	3.44	69%
	Non-halogenated plastics	278	299	8%
	Rubbers	0.218	0.897	311%
	Organic ion ex.resins	137	146	6.1
	Hydrocarbons	0	1.49	N/A
	Other organics	5.85	2.67	-54%
	Total organics	435	469	8%

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Other materials	Graphite	63,100	57,100	-10%
	Asbestos	0.3	0.3	0%
	Sludges & flocs	88	86.1	-2%
	Cementitious materials	1,730	1,690	-2%
	Ion exchange resins	193	170	-12%
	Heavy metal oxide	0	0	0%
	Glass, ceramics & sand	75	85.2	14%
	Soil and rubble	247	106	-57%
	Other inorganics	82.6	234	184%
	Total other materials	65,500	59,400	-9%
	Total Unspecified	354	241	-32%
	Total	84,500	78,800	-7%

B2 Legacy UILW / ULLW

B2.1 Volumes

Table B6 shows a decrease in stored volume due mainly to a reduction in estimates for PCM at Sellafield. The increases in conditioned and packaged volumes are mostly due to lower container waste loading volumes for some Sellafield ILW decommissioning wastes.

Table B6 - The change in the volume of waste in the Legacy UILW / ULLW waste group between the 2016 and 2019 IGD

Volume	Volume [m³]		Difference [%]
	2016 IGD	2019 IGD	
Stored	208,000	165,000	-21%
Conditioned	260,000	276,000	6%
Packaged	329,000	372,000	13%

B2.2 Disposal units

Table B7 shows an increase of approximately 16% in the number of disposal units between the 2016 and 2019 IGDs. Significant changes to the individual container types are:

- an increase in 3 m^3 Sellafield Enhanced boxes from Sellafield miscellaneous plant decommissioning and Windscale wastes being assigned to these packages
- an increase in enhanced 500 litre drums (basket) consistent with lower waste container loading volumes for some Sellafield ILW decommissioning wastes
- an increase in 3 m^3 boxes (side lifting) mainly due to the reassignment of waste streams 2D26 (Ion Exchange Material (Clinoptilolite) and sand) and 2D34 (Sludge from Sand Filters and Transfer) from 3 m^3 Sellafield boxes
- fewer 3 m^3 Sellafield boxes due to the reassignment of Sellafield miscellaneous plant decommissioning and Windscale wastes to other package types

Table B7 - The change in the number of disposal units in the Legacy UILW / ULLW waste group between the 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
3 m³ box (side lifting)	4,430	8,090	82%
3 m³ box (corners lifting)	689	685	-0.6%
3 m³ drum	545	520	-5%
3 m³ Sellafield box	54,600	35,700	-35%
3 m³ Sellafield Enhanced box	16,100	33,900	111%
500 litre drum	24,700	30,300	23%
Beta/gamma box	1,380	1,690	22%
Enhanced 500 l drum (basket)	6,180	15,000	142%
Enhanced 500 l drum (pre-ast)	206	208	1%
Total	109,000	126,000	16%

B2.3 Activities

The total activity at 2040 has increased by approximately 6% from 1,940,000 TBq to 2,070,000 TBq. At 2200 the activity has increased by approximately 7% from 372,000 TBq to 398,000 TBq. Table B8 and Table B9 show the changes in the activities at 2040 and 2200 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.

There is an increase in the activity of C-14 at 2040 and 2200; this is the result of an update to the activity data for the MSSS waste streams at Sellafield. There is a decrease in the activity of Cl-36 at 2040 and 2200; this is the result of changes to waste stream 5C08 (ILW Concrete Lined Drums), which is being transferred to Sellafield. The volume and specific activity of this waste stream have decreased.

For the radionuclides that are of interest to the gas pathway analysis, the H-3 activity has increased as a result of small increases in the volume and arisings profile of waste stream 6N01 (Neutron Targets). There is also new waste stream 1A12 (ILW Containing Tritium) that contributes to the activity increase.

Table B8 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	535	845	57.8%
	Cl-36	8.07	2.6	-67.8%
	Co-60	92,000	96,100	4.5%
	Se-79	0.555	0.466	-16.1%
	Kr-85	853	877	2.9%
	Tc-99	1,010	1,130	10.9%
	I-129	0.706	0.794	12.5%
	Cs-135	6.47	7.23	11.8%
	Cs-137	257,000	256,000	-0.3%
	U-233	0.983	0.896	-8.8%
	U-235	0.535	0.597	11.7%
	U-238	17.9	20	11.5%
	Np-237	106	117	10.2%
Gas	**H-3**	6,420	8,310	29.4%
	C-14	535	845	57.8%
	Ra-226	9.4	9.52	1.3%

Table B9 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	C-14	1,200	1,430	19.4%
	Cl-36	9.44	3.90	-58.7%
	Co-60	8.54 10^{-4}	8.05 10^{-4}	-5.7%
	Se-79	0.556	0.48	-13.6%
	Kr-85	0.0277	0.0285	2.8%
	Tc-99	1,020	1,150	12.5%
	I-129	0.707	0.799	13.0%
	Cs-135	6.47	7.24	11.9%
	Cs-137	6,570	6,570	< -0.1%
	U-233	1.07	0.991	-7.8%
	U-235	0.552	0.635	15.0%
	U-238	18.3	20.8	13.6%
	Np-237	108	120	10.9%
Gas	H-3	0.907	1.06	16.7%
	C-14	1,200	1,430	19.4%
	Ra-226	8.78	8.89	1.3%

B2.4 Materials

Table B10 shows the changes in the masses of the materials in the waste group. There is an overall decrease of approximately 17% and decreases of approximately 34% for metals and organics and 4% for other materials.

The principal reason for these changes is the re-assessment of the composition and density of waste stream 2D90 (Plutonium Contaminated Material: Drums); this impacts the masses of other ferrous metals, aluminium (and alloys), cellulose, halogenated and non-halogenated plastics, rubbers, other organics, asbestos and rubble.

There has been a reassessment of material composition for some AGR Miscellaneous Activated Components & Fuel Stringer Debris resulting in a decrease in nickel and alloys.

There is an increase in glass, ceramics and sand due to new ILW tritiated wastes from GE Healthcare in addition to small increases in the overall estimates of pond sludge and ion exchange material at Sellafield

Table B10 - Material masses in Legacy UILW / ULLW in the 2016 and 2019 IGDs (“iron” and “hydrocarbons” are new material types in the 2019 IGD)

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	28,000	23,000	-18%
	Other ferrous metals	39,100	17,800	-54%
	Magnox/magnesium	5,810	6,180	6%
	Aluminium (and alloys)	1,700	1,000	-41%
	Zircaloy/zirconium	1,260	1,280	2%
	Copper (and alloys)	278	289	4%
	Nickel (and alloys)	242	77.7	-68%
	Uranium	957	1,090	14%
	Lead	802	751	-6%
	Iron	0	87.6	N/A
	Other metals	284	269	-5%
	Total Metals	78,400	51,800	-34%

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Organics	Cellulose	2,130	1,030	-52%
	Halogenated plastics	3,600	3,070	-15%
	Non-halogenated plastics	1,710	962	-44%
	Rubbers	1,690	1,090	-35%
	Organic ion ex. resins	112	108	-3%
	Hydrocarbons	0	38.6	N/A
	Other organics	451	98.1	-78%
	Total organics	9,690	6,400	-34%
Other materials	Graphite	15,000	13,400	-11%
	Asbestos	309	64.5	-79%
	Sludges & flocs	21,200	20,200	-5%
	Cementitious materials	53,300	55,700	4%
	Ion exchange resins	2,520	2,940	17%
	Heavy metal oxide	0	0	0%
	Glass, ceramics & sand	473	738	56%
	Soil and rubble	2,640	794	-70%
	Other inorganics	12,900	10,000	-22%
	Total other materials	108,000	104,000	-4%
	Total Unspecified	1,300	2,560	97%
	Total	198,000	165,000	-17%

B3 RSCs

B3.1 Volumes

Table B11 shows that there has been a reduction in the volume of waste in this waste group as a result of changes in volume estimates and packaging assumptions, e.g. small volume reductions in FED graphite, resins, sludges and ion exchange material streams and some wastes being consigned for disposal via other routes (Empty BPS Sludge cans; 9A916).

Table B11 - The change in the volume of waste in the RSC waste group between the 2016 and 2019 IGD

Volume	Volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Stored	1,330	1,200	-10%
Conditioned	1,180	1,060	-10%
Packaged	2,730	2,610	-4%

B3.2 Disposal units

Table B12 shows that there has been a small overall decrease in the number of disposal units between the 2016 and 2019 IGDs. There is a more significant decrease (7%) in the number of 3 m^3 RS boxes due to the reassignment of some Magnox FED Graphite to 6 m^3 concrete boxes (SILW). Table B13 presents the numbers for each of the RS drums.

Table B12 - The change in the number of disposal units in the RSC waste group between the 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
RS drums	612	620	1.3%
RS boxes	354	330	-6.8%
Total	966	950	-1.7%

Table B13 - The number of 500 l RS drums in the 2016 and 2019 IGDs

Waste Container	Disposal units [-]	
	2016 IGD	2019 IGD
500 l RS drum (0 mm Pb)	478	425
500 l RS drum (20 mm Pb)	54	54
500 l RS drum (30 mm Pb)	16	0
500 l RS drum (40 mm Pb)	0	59
500 l RS drum (50 mm Pb)	8	29
500 l RS drum (80 mm Pb)	3	0
500 l RS drum (90 mm Pb)	38	38
500 l RS drum (120 mm Pb)	15	15

B3.3 Activities

The total activity at 2040 has decreased from 4,340 TBq to 4,200 TBq (about 3%). At 2200 the activity has increased by approximately 186% from 1,110 TBq to 3,180 TBq as a result of some of waste stream 3S306 (Decommissioning: Stainless Steel ILW) being reassigned to a 500 l RS drum.

Table B14 and Table B15 show the changes in the activities at 2040 and 2200 of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments.

There is a decrease in the activity of C-14 at 2040 as a result of waste stream 9A34 (FED Graphite) being re-assigned to a 6 m^3 box in the legacy SILW /SLLW waste group. The increase in C-14 and particularly in Co-60 activity at 2200 is a result of waste stream 3S306b now being packaged in an RSC; however, concentrations of the latter are by this time extremely low. The increase in the activity of Cl-36 at 2040 and 2200 is the result of an increase in the specific activity of waste stream 9H24 (Burst Can Detector Coolers). The increase in Kr-85 activity is a result of Magnox quantifying specific activity values for this radionuclide in their waste streams. The increase in Tc-99 activity at 2040 and 2200 is a result of: an increase in specific activity for 9B55/C (Ponds Decontamination Sludge) compared with the unconditioned waste stream 9B55 in the 2016 IGD; and waste stream 3S306b now being packaged in an RSC. The increase in I-129 activity at 2040 and 2200 is the result of changes to specific activity data for waste streams 9B55/C (Ponds Decontamination Sludge) and 9B17/C (Miscellaneous Contaminated Items) compared with the unconditioned waste streams in the 2016 IGD.

There are decreases in Cs-135, Cs-137 and Np-237 activities at 2040 and 2200, these are a result of volume decreases for waste streams 9B02/C (Ion Exchange Material) and 9C02 (PWTP Ion Exchange Material) and specific activity decreases for these waste streams and 9C36 (Ion Exchange Resin from Ponds). The decrease in U-233 activity is a result of waste stream 9A35 (FED Graphite) being re-assigned to a legacy SILW / SLLW container type. The decrease in U-235 activity is the result of a re-assessment of the specific activity of waste stream 9F38 (PWTP Filters – Sand and Gravel) and a lower volume for waste stream 9C02. The decrease in U-238 activity is the result of a volume decrease for waste stream 9C02 and the recategorisation of waste stream 9E55 (Ion Siv Unit Pre Filters) as LLW.

For the radionuclides that are of interest to the gas pathway analysis, there is a decrease in Ra-226 activity at 2040 and 2200, because no specific activity is now reported for waste stream 9F38 (PWTP Filters – Sand and Gravel). There is a decrease in H-3 activity at 2040 as a result of FED Graphite waste streams 9A34 and 9A35 being re-assigned to 6 m^3 boxes. There is a large increase in H-3 activity at 2200; this is the result of waste stream 3S306b now being packaged in an RSC.

Table B14 - Changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the RSCs waste group at 2040 between the 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	4.95	3.79	-23%
	Cl-36	0.254	0.666	162%
	Co-60	20.3	16.8	-17%
	Se-79	$7.79\ 10^{-5}$	$4.46\ 10^{-5}$	-43%
	Kr-85	0.104	0.184	78%
	Tc-99	0.031	0.0695	124%
	I-129	$4.47\ 10^{-5}$	$4.68\ 10^{-4}$	x10
	Cs-135	$7.59\ 10^{-3}$	$1.88\ 10^{-3}$	-75%
	Cs-137	479	189	-61%
	U-233	$157\ 10^{-4}$	$1.09\ 10^{-4}$	-31%
	U-235	$2.9\ 10^{-4}$	$1.15\ 10^{-4}$	-60%
	U-238	$9.63\ 10^{-3}$	$5.05\ 10^{-3}$	-48%
	Np-237	$7.92\ 10^{-3}$	$3.31\ 10^{-3}$	-58%
Gas	**H-3**	20.2	14.3	-29.2%
	C-14	4.95	3.79	-23.4%
	Ra-226	$1.14\ 10^{-4}$	$9.47\ 10^{-6}$	-91.7%

Table B15 - Changes in the activities of the priority 1 radionuclides and the radionuclides that are important to RWM's gas pathway analysis in the RSCs waste group at 2200 between the 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	5.69	8.88	56%
	Cl-36	0.254	0.671	164%
	Co-60	$2.37\ 10^{-8}$	$6.20\ 10^{-6}$	x262
	Se-79	$7.86\ 10^{-5}$	$453\ 10^{-5}$	-42%
	Kr-85	$1.12\ 10^{-5}$	$1.39\ 10^{-5}$	23%
	Tc-99	0.0326	0.0859	164%
	I-129	$5.01\ 10^{-5}$	$4.73\ 10^{-4}$	x8.5
	Cs-135	$7.65\ 10^{-3}$	$1.93\ 10^{-3}$	-75%
	Cs-137	12.4	5.03	-59%
	U-233	$1.63\ 10^{-4}$	$1.11\ 10^{-4}$	-32%
	U-235	$2.91\ 10^{-4}$	$1.16\ 10^{-4}$	-60%
	U-238	$9.64\ 10^{-3}$	$5.07\ 10^{-3}$	-47%
	Np-237	$8.06\ 10^{-3}$	$3.44\ 10^{-3}$	-57%
Gas	**H-3**	$2.56\ 10^{-3}$	0.0106	x3.1
	C-14	5.69	8.88	56%
	Ra-226	$1.08\ 10^{-4}$	$1.03\ 10^{-5}$	-90%

B3.4 Materials

Table B16 shows the changes in the masses of the materials in the waste group. The overall decrease is small (approximately 5%) and the decreases for the different categories of materials are also small; 9% for metal and organics and 4% for other materials. The reasons for these changes are numerous, some examples are:

- allocation of RSCs for PWR decommissioning ILW resulting in an increase to stainless steel
- a reduction in graphite, Magnox and aluminium and alloys due to reassessment of the composition for some FED graphite, FED Magnox, ion exchange material and catalyst waste streams
- re-categorisation of some FED zirconium to SILW resulting in a decrease for zirconium
- reporting of Magnox fuel fragments resulting in an increase for uranium
- reductions in cellulose, halogenated plastics and asbestos as a result of a reassessment of composition for Magnox Auxiliary Gas Systems waste
- re-categorisation of some Magnox contaminated gravel to RSCs resulting in increase for rubble

Table B16 - Changes to the material masses in RSCs between the 2016 and 2019 IGDs ("iron" and "hydrocarbons" are new material types in the 2019 IGD)

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	52.3	122	134%
	Other ferrous metals	445	354	-20%
	Magnox/magnesium	32.4	16.1	-50%
	Aluminium (and alloys)	2.89	1.09	-62%
	Zircaloy/zirconium	16.3	4.94	-70%
	Copper (and alloys)	0.214	0.0799	-63%
	Nickel (and alloys)	2.91	3.32	14%
	Uranium	0	0.0453	N/A
	Lead	0.143	0.143	-0.3%
	Iron	0	0	N/A
	Other metals	0.691	0.582	-16%
	Total Metals	553	503	-9%

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Organics	Cellulose	6.78	1.45	-79%
	Halogenated plastics	4.84	2.04	-58%
	Non-halogenated plastics	2.05	5.32	160%
	Rubbers	1.14	1.36	19%
	Organic ion ex. resins	111	103	-7%
	Hydrocarbons	0	5.25	N/A
	Other organics	11.3	5.85	-48%
	Total organics	137	124	-9%
Other materials	Graphite	277	245	-12%
	Asbestos	1.6	1.14	-28%
	Sludges & flocs	220	185	-16%
	Cementitious materials	8.72	5.21	-40%
	Ion exchange resins	24.9	17	-32%
	Heavy metal oxide	0	0	0%
	Glass, ceramics & sand	72.5	81.4	12%
	Soil and rubble	84	167	99%
	Other inorganics	130	85.9	-34%
	Total other materials	819	788	-4%
	Total Unspecified	29.8	48.5	63%
	Total	1540	1460	-5%

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 overall decrease of 23,000 tU DNLEU (11% of the total). The 2016 IGD estimate of TPU mass has been updated with the known quantity of TPU as Thorp reprocessing operations ceased in 2018. The mass of MDU in the 2016 IGD was based on the best available data in the public domain, this has been refined for the 2019 IGD based on MDU stocks. There is a revised estimate of overall stocks and future arisings for DU tails and there is a reduced mass of Defence DNLEU.

Table B17 - The quantity of DNLEU associated with each category in the 2016 and 2019 IGDs

DNLEU category	Waste container	Quantity [tU]	
		2016 IGD	2019 IGD
Magnox depleted uranium	Uranium TDC (2.4 m high)	23,100	23,100
Magnox depleted uranium	Uranium TDC (2.1 m high)	14,900	10,200
THORP product uranium	500 l drum (DNLEU)	5,000	4,720
DU tails	Uranium TDC (2.3 m high)	154,000	143,000
Defence DNLEU	Uranium TDC (2.4 m high)	15,000	8,000
Miscellaneous DNLEU	500 l drum (DNLEU)	3,000	2,830
Uranium tetrafluoride	500 l drum (DNLEU)	–	230

B4.1 Volumes

Table B18 shows that there has been a reduction in the volume of waste associated with the DNLEU waste group. This is a result of reduced estimates of separated uranium, DU tails and Defence DNLEU.

Table B18 - The change in the volume of waste in the DNLEU waste group between the 2016 and 2019 IGD

Volume	Volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Stored	99,100	97,200	-1.9%
Conditioned	139,000	134,000	-3.9%
Packaged	191,000	184,000	-3.7%

B4.2 Disposal units

Table B19 shows that there has been a decrease in the number of disposal units between the 2016 and 2019 IGDs. This is due to the reassignment of Defence DU from 500 l drums to Uranium TDCs (2.4m ht) containers and to reduced estimates of DNLEU.

Table B19 - The change in the number of disposal units in the DNLEU waste group between the 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
500 litre drum (DNLEU)	5,970	2,010	-66%
Uranium TDC (2.1m ht)	460	317	-31%
Uranium TDC (2.3m ht)	4,430	4,110	-7%
Uranium TDC (2.4m ht)	1,450	1,950	35%
Total	30,200	14,400	-52%

B4.3 Activities

The total activity associated with the DNLEU does not change significantly between 2040 and 2200. Instead, it remains relatively constant: as a result of the long half-lives of the uranium isotopes. The total activity of the waste group at 2040 has increased by approximately 1% from 9,560 TBq to 9,690 TBq. At 2200 the activity has increased by approximately 3% from 9,560 TBq to 9,800 TBq.

Table B20 and Table B21 show the changes in the activities at 2040 and 2200 of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments. The changes in the activities of the priority radionuclides are the result of an update to the assumptions regarding the quantities and characteristics of DNLEU streams between the 2016 and 2019 IGDs. This has resulted in increases in Tc-99, U-235 and Np-237 activities associated with Magnox depleted uranium streams (MU013 and MU014) and DU tails stream (MU017).

No Co-60 activity is now quantified in DNLEU streams because specific activities are not significant.

B4.4 Materials

Table B22 shows the masses of the materials in the DNLEU waste group. The overall decrease of approximately 10% reflects the reduction in the mass of DNLEU in the 2019 IGD.

Increases in the proportion of stainless steel and non-halogenated plastics are consistent with the change in packaging assumptions for Defence DU, which now consists of stainless steel 200 l drums and non-halogenated bags overpacked in 500 l drums and TDCs.

Table B20 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	C-14	$6.77\ 10^{-10}$	$7.18\ 10^{-10}$	6%
	Cl-36	0	0	0%
	Co-60	$1.64\ 10^{-20}$	0	-100%
	Se-79	$1.78\ 10^{-9}$	$1.87\ 10^{-9}$	5%
	Kr-85	0	0	0%
	Tc-99	0.645	30.8	x48
	I-129	$1.6\ 10^{-9}$	$1.69\ 10^{-9}$	6%
	Cs-135	$2.41\ 10^{-8}$	$2.53\ 10^{-8}$	5%
	Cs-137	$1.97\ 10^{-3}$	$1.99\ 10^{-3}$	1%
	U-233	$1.60\ 10^{-3}$	$5.95\ 10^{-4}$	-63%
	U-235	47.8	58.5	22%
	U-238	2,660	2,510	-6%
	Np-237	0.0166	2.42	x146
Gas	H-3	0	0	0%
	C-14	$6.77\ 10^{-10}$	$7.18\ 10^{-10}$	6%
	Ra-226	$6.10\ 10^{-3}$	$7.73\ 10^{-3}$	27%

Table B21 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	$6.64\ 10^{-10}$	$7.04\ 10^{-10}$	6%
	Cl-36	0	0	0%
	Co-60	$1.2\ 10^{-29}$	0	-100%
	Se-79	$1.78\ 10^{-9}$	$1.87\ 10^{-9}$	5%
	Kr-85	0	0	0%
	Tc-99	0.645	30.8	x48
	I-129	$1.60\ 10^{-9}$	$1.69\ 10^{-9}$	6%
	Cs-135	$2.41\ 10^{-8}$	$2.53\ 10^{-8}$	5%
	Cs-137	$4.98\ 10^{-5}$	$5.05\ 10^{-5}$	1%
	U-233	$1.61\ 10^{-3}$	$2.29\ 10^{-3}$	42%
	U-235	47.8	59.5	24%
	U-238	2660	2560	-4%
	Np-237	0.0166	2.44	x146
Gas	**H-3**	0	0	0%
	C-14	$6.64\ 10^{-10}$	$7.04\ 10^{-10}$	6%
	Ra-226	0.112	0.137	23%

Table B22 - Changes to the material masses in DNLEU between the 2016 and 2019 IGDs

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	3,430	4,220	23%
	Other ferrous metals[17]	14,100	13,400	-5%
	Total Metals	17,500	17,600	0.7%
Organics	Non-halogenated plastics	71.0	92.9	31%
	Total organics	71.0	92.9	31%
Other materials	Heavy metal oxide	254,000	227,000	-11%
	Total other materials	254,000	227,000	-11%
	Total	272,000	245,000	-10%

B5 HLW

In the 2016 IGD there were 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 POCO wastes. In the 2019 IGD the POCO wastes have been incorporated into the blend HLW stream. There is also a residue of liquid waste from liquor heels in the Highly Active Storage Tanks (HASTs) which will not be removed until after POCO operations, the liquor heels were not forecast in the 2016 IGD. The route for this removal has not been confirmed. For the 2019 IGD it has been assumed that the waste will be treated as other HLW and be vitrified.

B5.1 Volumes

Table B23 shows that there has been a small increase of 0.2% in the overall stored, conditioned and packaged volumes associated with HLW between the 2016 and 2019 IGD. The difference is associated with the addition of liquor heels in the HASTs.

[17] *Principally mild steel.*

Table B23 - The change in the volume of waste in the HLW waste group between the 2016 and 2019 IGDs

Volume	Volume [m³]		Difference [%]
	2016 IGD	2019 IGD	
Stored	1,500	1,500	0.2%
Conditioned	1,500	1,500	0.2%
Packaged	9,860	9,880	0.2%

B5.2 Disposal units

Table B24 shows that there has been an increase of 0.2% in the number of disposal units between the 2016 and 2019 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 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
HLW disposal container	2,550	2,550	0.2%

B5.3 Activities

The total activity at 2040 has increased by approximately 21% from 38,800,000 TBq to 47,100,000 TBq. At 2200 the activity has increased by approximately 22% from 1,200,000 TBq to 1,460,000 TBq. These differences are associated with a volume increase in waste stream 2F01/C (Vitrified High Level Waste) and the additional HLW waste stream from liquor heels which was not in the 2016 IGD.

Table B25 and **Table B26** show the changes in the activities at 2040 and 2200 of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments. The additional activity for H-3 and C-14 is associated with the additional HLW from liquor heels which was not in the 2016 IGD. There is also a volume increase in waste stream 2F01/C (Vitrified High Level Waste) which contributes to the increase in the activity of the other priority 1 radionuclides and Ra-226.

B5.4 Materials

Table B27 shows the changes in the masses of the materials. The changes are consistent with the increase in the total quantity of HLW due to a residue of liquor heels in the HASTs now reported in the IGD.

Table B25 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	C-14	0	1.11	N/A
	Cl-36	1.51	1.83	21%
	Co-60	545	703	29%
	Se-79	17.2	20.6	20%
	Kr-85	0	0	0%
	Tc-99	2,760	3,500	27%
	I-129	0.0905	0.108	20%
	Cs-135	185	224	21%
	Cs-137	$11.4\ 10^{6}$	$13.8\ 10^{6}$	21%
	U-233	$5.41\ 10^{-3}$	$6.43\ 10^{-3}$	19%
	U-235	$9.86\ 10^{-4}$	$1.16\ 10^{-3}$	18%
	U-238	0.0261	0.0301	16%
	Np-237	36.1	45	25%
Gas	H-3	0	10.5	N/A
	C-14	0	1.11	N/A
	Ra-226	$1.10\ 10^{-3}$	$1.34\ 10^{-3}$	22%

Table B26 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	C-14	0	1.09	N/A
	Cl-36	1.51	1.83	21%
	Co-60	$3.98\ 10^{-7}$	$5.14\ 10^{-7}$	29%
	Se-79	17.2	20.6	20%
	Kr-85	0	0	0%
	Tc-99	2760	3500	27%
	I-129	0.0905	0.108	20%
	Cs-135	185	224	21%
	Cs-137	288,000	349,000	21%
	U-233	0.036	0.0444	23%
	U-235	$1.03\ 10^{-3}$	$1.21\ 10^{-3}$	18%
	U-238	0.0261	0.0301	16%
	Np-237	51.1	63.4	24%
Gas	H-3	0	$1.30\ 10^{-3}$	N/A
	C-14	0	1.09	N/A
	Ra-226	$4.88\ 10^{-3}$	$6.07\ 10^{-3}$	24%

Table B27 - Changes to the material masses in HLW

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	651	653	0.3%
	Nickel (and alloys)	20.6	20.6	<-0.1%
	Total Metals	672	674	0.3%
Other materials	Glass, Ceramics & Sand	3020	3030	0.2%
	Total other materials	3020	3030	0.2%
	Total	3700	3700	0.2%

B6 Legacy SF

B6.1 Volumes

There has been an increase of less than 1% in each of the volume categories associated with the legacy SF waste group between the 2016 and 2019 IGD.

Table 3 gives the quantities for each type of fuel, and the small changes in volumes are shown below in **Table B28**. The 2019 IGD separately identifies SF from SGHWR, WAGR and miscellaneous LWR, which were previously assumed to be reprocessed. Revised estimates of the quantity of SF in the UK RWI have resulted in a small overall increase in the volume of the legacy SF waste group.

Table B28 - The change in the volume of waste in the Legacy SF waste group between the 2016 and 2019 IGDs

Volume	Volume [m^3]		Difference [%]
	2016 IGD	2019 IGD	
Stored	3,830	3,840	0.4%
Conditioned	3,830	3,840	0.4%
Packaged	16,900	17,000	0.9%

B6.2 Disposal units

Table B29 shows that there has been a small increase of approximately 1% in the number of disposal units between the 2016 and 2019 IGDs. This is consistent with the change in the volume of legacy SF. SGHWR SF from Winfrith and WAGR SF from Windscale are assumed to be packaged in AGR disposal containers and miscellaneous LWR SF is assumed to be packaged in PWR disposal containers.

Table B29 - Changes in the number of disposal units in the Legacy SF waste group between the 2016 and 2019 IGD

Waste container	Disposal units [-]		Difference [%]
	2016 IGD	2019 IGD	
AGR disposal container	2,670	2,720	1.6%
Magnox disposal container	859	817	-4.9%
PFR disposal container	19	19	0%
PWR disposal container	572	608	6.3%
Total	4,120	4,160	0.9%

B6.3 Activities

The total activity at 2040 has increased by approximately 2% from 66,100,000 TBq to 67,400,000 TBq. At 2200, the total activity has increased by approximately 2% from 2,730,000 TBq to 2,780,000 TBq.

Table B30 and Table B31 show the changes in the activities at 2040 and 2200 of the priority 1 radionuclides and the gaseous radionuclides that are important to RWM's operational and post-closure safety assessments. The increases in the U-233 activity at 2040 and 2200 are a result of the additional SGHWR, WAGR and miscellaneous LWR SFs.

B6.4 Materials

Table B32 shows the masses of the materials. The overall increase of approximately 2% reflects the changes in the volumes and types of spent fuel.

Table B30 - 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 2016 and 2019 IGDs

	Radionuclide	Activity at 2040 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	**C-14**	880	889	1.0%
	Cl-36	3.54	3.58	1.3%
	Co-60	234,000	250,000	6.8%
	Se-79	15.8	15.9	0.8%
	Kr-85	601,000	611,000	1.7%
	Tc-99	2,010	2,040	1.9%
	I-129	7.81	8	2.5%
	Cs-135	154	157	1.7%
	Cs-137	$15.9\ 10^{6}$	$16.2\ 10^{6}$	1.7%
	U-233	0.46	0.532	15.6%
	U-235	3.86	3.98	3.0%
	U-238	86.3	87.6	1.6%
	Np-237	53.9	56	3.8%
Gas	**H-3**	127,000	129,000	2.0%
	C-14	880	889	1.0%
	Ra-226	$5.80\ 10^{-4}$	$6.05\ 10^{-4}$	4.2%

Table B31 - 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 2200 between the 2016 and 2019 IGDs

	Radionuclide	Activity at 2200 [TBq]		Difference [%]
		2016 IGD	2019 IGD	
Priority 1	C-14	863	872	1.0%
	Cl-36	3.53	3.58	1.3%
	Co-60	$1.71\ 10^{-4}$	$1.83\ 10^{-4}$	6.8%
	Se-79	15.8	15.9	0.8%
	Kr-85	19.5	19.8	1.7%
	Tc-99	2,010	2,040	1.9%
	I-129	7.81	8	2.5%
	Cs-135	154	157	1.7%
	Cs-137	403,000	410,000	1.7%
	U-233	0.509	0.582	14.4%
	U-235	3.87	3.99	3.0%
	U-238	86.3	87.6	1.6%
	Np-237	85.7	88.9	3.8%
Gas	H-3	15.7	16	2.0%
	C-14	863	872	1.0%
	Ra-226	0.025	0.0256	2.5%

Table B32 - Changes to the material masses in Legacy SF

	Material	Mass [t]		Difference [%]
		2016 IGD	2019 IGD	
Metals	Stainless steel	1,620	1,620	0.4%
	Magnox / magnesium	137	130	-4.9%
	Zircaloy / Zirconium	269	286	6.3%
	Nickel (and alloys)	18.1	19.1	5.3%
	Uranium	760	723	-4.9%
	Total Metals	2,800	2,780	-0.7%
Other materials	Heavy metal oxide	7,440	7,620	2.4%
	Glass, Ceramics & Sand	42.9	42.9	0.0%
	Total other materials	7,490	7,660	2.3%
	Total	10,300	10,400	1.5%

B7 Waste groups with no changes

B7.1 New build

In the 2019 IGD there have been no changes to the 2016 assumptions regarding the assumed new build programme. As a result there have been no changes to the new build SILW, new build UILW or new build SF waste groups.

B7.2 MOX

In the 2019 IGD, there have been no changes to the 2016 assumptions regarding Pu and MOX. As a result, there is no change to the MOX waste group.

B7.3 HEU and Pu

In the 2019 IGD there have been no changes to the 2016 IGD assumptions regarding the quantities of Pu and HEU. As a result, 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 volumes between the 2016 and 2019 IGDs

Package type	Disposal units [-]		Conditioned volume [m^3]	
	2016 IGD	2019 IGD	2016 IGD	2019 IGD
Legacy SILW / SLLW				
2 m box[18]	0	24	0	74.3
4 m box[18]	4,320	4,010	73,100	67,200
6 m^3 concrete box[19]	1,080	1,020	6,190	5,860
Total	5,400	5,050	79,300	73,200
Legacy UILW / ULLW				
500 litre drum	31,000	45,500	58,300	86,900
beta gamma box	1,380	1,690	4,830	5,970
3 m^3 box (corner lifting)	71,300	70,200	184,000	160,000
3 m^3 box (side lifting)	4,430	8,090	11,800	21,500
3 m^3 drum	545	520	1,220	1,160
Total	109,000	126,000	260,000	276,000
RSCs				
500 l RS drums	609	619	300	241
3 m^3 RS box	354	330	883	820
Total	963	949	1,180	1,060
DNLEU				
500 litre drum (DNLEU)	5,970	2,010	11,200	3,780
Uranium TDC (2.1m ht)	459	316	8,630	5,940
Uranium TDC (2.3m ht)	4,430	4,110	87,800	81,500
Uranium TDC (2.4m ht)	1,450	1,950	31,700	42,700
Total DNLEU	12,300	8,380	139,000	134,000

[18] *Includes variants with different levels of internal shielding.*

[19] *Includes variants with different densities.*

Package type	Disposal units [-]		Conditioned volume [m³]	
	2016 IGD	2019 IGD	2016 IGD	2019 IGD
NB SILW				
500 l concrete drum	3,240	3,240	942	942
1 m³ concrete drum	6,840	6,840	4,480	4,480
4 m box	60	60	858	858
Total	10,100	10,100	6,280	6,280
NB UILW				
3 m³ box (side lifting)	960	960	2,550	2,550
3 m³ drum	7,270	7,270	16,200	16,200
Total	8,230	8,230	18,800	18,800
HLW				
HLW disposal container	2,550	2,550	1,500	1,500
Legacy SF				
AGR Disposal Container	2,670	2,710	2,360	2,400
Magnox Disposal Container	859	817	1030	976
PFR Disposal Container	19	19	10.9	10.9
PWR Disposal Container	572	608	426	452
Total	4,120	4,160	3,830	3,840
NB SF				
NB SF disposal container	8,940	8,940	5,890	5,890
MOX SF				
MOX disposal container	2,710	2,710	594	594
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 - Changes in the lower uncertainty activity for priority 1 radionuclide at 2200 for all waste groups affected by scenario 4 (see section 4.3)

Radionuclide	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
C-14	-6,520	-6,680	2.5%
Cl-36	-30.8	-27.7	-10%
Co-60	$-2.21\ 10^{-3}$	$-2.18\ 10^{-3}$	-1.0%
Se-79	-6.02	-7.13	18%
Kr-85	-0.0112	-0.0126	12%
Tc-99	-1,770	-2,130	21%
I-129	-0.538	-0.627	17%
Cs-135	-65.2	-78.5	20%
Cs-137	-100,000	-120,000	20%
U-233	-0.846	-0.773	-8.7%
U-235	-0.298	-0.352	18%
U-238	-9.4	-10.8	15%
Np-237	-100	-113	13%

The changes in the activities of the priority 1 radionuclides between the 2016 and 2019 IGD from the application of the lower uncertainty factors are similar for C-14, Co-60 and U-233, and differ for:

- Cl-36 which is affected by the volume decrease and specific activity decrease of waste stream 5C08 (ILW Concrete Lined Drums)
- Se-79 which is affected by the volume increases of waste stream 2F01/C (Vitrified High Level Waste) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)
- Kr-85 which is affected by the quantification of Kr-85 specific activity data for the waste streams 2D35.1 to 2D35.4 (MSSS compartments 19 to 22)
- Tc-99 which is affected by the volume increases of waste streams 2F01/C (Vitrified High Level Waste) and 2D27/C (Encapsulated Floc from Effluent Treatment)
- I-129 which is affected by the volume increases of waste streams 2F06/C (Encapsulated Barium Carbonate Slurry/MEB Crud), 2D27/C (Encapsulated Floc from Effluent Treatment) and 2D38/C (Encapsulated Magnox Cladding)
- Cs-135 which is affected by the volume increases of waste stream 2F01/C (Vitrified High Level Waste) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)
- Cs-137 which is affected by the volume increases of waste stream 2F01/C (Vitrified High Level Waste) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)
- U-235 which is affected by the volume increases of waste stream 2D96.2 (FGMSP Pond Solid Waste to BEP) and new waste stream 8A23 (ILW from LCF)
- U-238 which is affected by the volume increases of waste stream 2D96.2 (FGMSP Pond Solid Waste to BEP) and new waste stream 8A23 (ILW from LCF)
- Np-237 which is affected by the volume increases of waste streams 2F01/C (Vitrified High Level Waste), 2F10/C (Encapsulated Centrifuge Cake) and 2D27/C (Encapsulated Floc from Effluent Treatment) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)

Table D2 - Changes in the upper uncertainty activity for priority 1 radionuclide at 2200 for all waste groups affected by scenario 4 (see section 4.3)

Radionuclide	Activity at 2200 [TBq]		Difference [%]
	2016 IGD	2019 IGD	
C-14	68,200	67,000	-2%
Cl-36	296	275	-7%
Co-60	0.166	0.166	-0.3%
Se-79	9.4	11	17%
Kr-85	0.023	0.023	0.2%
Tc-99	8,970	10,200	14%
I-129	20.9	37.7	81%
Cs-135	104	123	19%
Cs-137	170,000	185,000	9%
U-233	2.88	2.7	-6%
U-235	2.48	3.08	24%
U-238	44.6	54	21%
Np-237	593	642	8%

The changes in the activities of the priority 1 radionuclides from the application of the upper uncertainty factor between the 2016 and 2019 IGD are similar except for:

- Se-79 which is affected by the volume increases of waste stream 2F01/C (Vitrified High Level Waste) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)
- Tc-99 which is affected by the volume increases of waste streams 2F01/C (Vitrified High Level Waste) and 2D27/C (Encapsulated Floc from Effluent Treatment)
- I-129 which is affected by an increase in the stock specific activity of waste stream 2D27/C (Encapsulated Floc from Effluent Treatment)
- Cs-135 which is affected by the volume increases of waste stream 2F01/C (Vitrified High Level Waste) and new waste stream 2D02b/C (Vitrified High Level Waste – from liquor heels)

- U-235 which is affected by the volume increases of waste streams 2D42 (Magnox Pond Furniture) and 2D96.2 (FGMSP Pond Solid Waste to BEP) and new waste stream 8A23 (ILW from LCF)
- U-238 which is affected by the volume increases of waste stream 2D42 (Magnox Pond Furniture) and new waste stream 8A23 (ILW from LCF)

D2 Scenario 12: exclusion of ILW / LLW boundary wastes

Table D3 - 2019 IGD ILW streams intended to be managed as LLW

Waste stream ID	Waste stream description	Waste group	Packaged volume [m³]	Disposal units [-]
1A08	Decay Stored Waste	UILW / ULLW	18.6	6
1A12	ILW Containing Tritium	UILW / ULLW	226	99
2D42	Magnox Pond Furniture	UILW / ULLW	5,020	1,530
2F15	LWR Pond Furniture (MEBs)	UILW / ULLW	1,860	570
3J04	Desiccants ILW	UILW / ULLW	234	90
3J20	Catalysts ILW	UILW / ULLW	10.2	4
3J25	Gag Pistons	UILW / ULLW	1.87	1.000
3K04	Desiccant	UILW / ULLW	119	46
3K22	Catalyst	UILW / ULLW	12.5	5
3K29	Bypass Blowdown Filters	UILW / ULLW	31.6	10
3L04	Desiccant	UILW / ULLW	57.9	23
3L19	Catalyst	UILW / ULLW	12.5	5
3M04	Desiccant	UILW / ULLW	133	52
3M17	Catalysts	UILW / ULLW	24.6	10
3N04	Desiccants and Catalysts	UILW / ULLW	365	140
3S310	Fuel Pond Solid Absorber Assemblies	SILW / SLLW	67.8	4
6N03	Reflectors	UILW / ULLW	3.19	2
7A108	Decommissioning LLW Requiring Further Assay Through the Recategorization Programme	UILW / ULLW	76.2	34
7D24	ILW Reactor Components	SILW / SLLW	20.7	2
7D29	Intermediate Level Waste Resin from Plant Decontamination (MODIX)	UILW / ULLW	54.7	24
7D40	ILW PCD Ion Exchange Resin	UILW / ULLW	44.8	18

Waste stream ID	Waste stream description	Waste group	Packaged volume [m³]	Disposal units [-]
7D41	ILW Submarine Ion Exchange Resin	UILW / ULLW	58.6	23
7E29	Intermediate Level Ion Exchange Resin (Decontamination)	UILW / ULLW	94.0	37
7J25	Luminised Waste	UILW / ULLW	11.5	6
9B13	Desiccant	RSC	59.9	12
9C14	Desiccant	RSC	52.1	10
9C54	Catalyst	RSC	3.33	1
9D18	Desiccant	RSC	36.7	7
9E24	FED Magnox	UILW / ULLW	103	32
9E25	FED Magnox	UILW / ULLW	103	32
9E26	FED Magnox	UILW / ULLW	108	33
9E27	FED Magnox	UILW / ULLW	108	33
9E28	FED Magnox	UILW / ULLW	97.6	30
9F14	Desiccant and Catalyst from Gas Conditioning Plant	RSC	5.68	2
9F18	Miscellaneous Drummed Contaminated and Activated Items	SILW / SLLW	141	8
9F42	AETP Filters – Sand and Gravel	RSC	30.2	6
9H02	Desiccant	RSC	37.2	7

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