Department for Business, Energy & Industrial Strategy

2019 UK Radioactive Waste Inventory

December 2019

2019 UK RADIOACTIVE WASTE INVENTORY

Report prepared for the Department for Business, Energy & Industrial Strategy (BEIS)
and the Nuclear Decommissioning Authority (NDA)
by Pöyry Energy Ltd and Wood Nuclear Ltd

PREFACE

The 2019 United Kingdom Radioactive Waste & Materials Inventory (the 2019 Inventory) provides detailed information on radioactive wastes and materials in the United Kingdom (UK). It is produced by the Department for Business, Energy & Industrial Strategy (BEIS) and the Nuclear Decommissioning Authority (NDA).

The 2019 Inventory provides information on radioactive waste stocks (at 1 April 2019) and forecasts of future waste arisings. Information on radioactive materials that may be classed as waste in the future is also presented. The 2019 Inventory aims to provide data in an open and transparent manner for those interested in radioactive wastes and materials.

Information collected for the 2019 Inventory is presented in a suite of four reports:

- 2019 UK Radioactive Waste Inventory
- 2019 UK Radioactive Material Inventory
- 2019 UK Radioactive Waste Detailed Data
- 2019 Summary of UK Radioactive Waste and Material Inventory for International Reporting.

All documents have been prepared using information supplied by the radioactive waste producers and custodians to the 2019 Inventory contractors, Wood and Pöyry Energy. This information was verified in accordance with arrangements established by Wood and Pöyry Energy in agreement with NDA.

This report presents information about the volumes and characteristics of radioactive wastes in stock at 1 April 2019 and projected future arisings, and an explanation of key changes since the 2016 Inventory is provided. The report also gives supporting information on the sources, categories and management of radioactive wastes in the UK.

Conditions of Publication

Feedback

We welcome feedback on the content, clarity and presentation of the 2019 Inventory reports. Please do not hesitate to contact us if you would like to provide feedback or if you would like further information about radioactive waste issues:

Nuclear Decommissioning Authority
Information Access Manager
Herdus House
Westlakes Science & Technology Park
Moor Row
Cumbria
CA24 3HU

Tel: 01925 802077

enquiries@nda.gov.uk

Contents

1 INTRODUCTION

1.1 The Inventory

An inventory of radioactive waste and materials in the UK is compiled every three years by the Department for Business, Energy & Industrial Strategy (BEIS) and the Nuclear Decommissioning Authority (NDA).

The inventory provides up-to-date information about radioactive waste to:

- Enable the UK to meet international reporting obligations
- Inform policy and strategy development
- Aid radioactive waste and material management planning
- Support stakeholder engagement.

The inventory is used by a wide range of stakeholders:

Government departments & agencies	Develop policies and strategies for managing UK radioactive waste and regulating nuclear operations
Supply chain organisations	Process waste and use data to support the planning, operation and performance of their facilities
Waste planners	Ensure that radioactive waste management facilities meet local and national needs
Researchers & academics	Develop innovative technologies and processes for managing the range of radioactive waste in the UK
Members of the public	Improve understanding about the types and quantities of radioactive waste produced in the UK

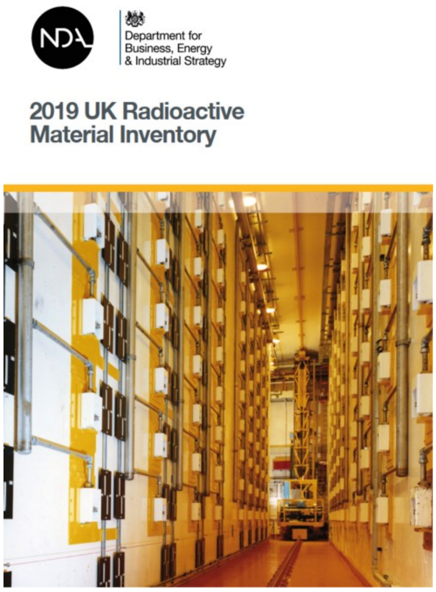
The 2019 UK Radioactive Waste & Materials Inventory (the 2019 Inventory) is the latest public record on the sources, quantities and properties of radioactive waste and materials in the UK at 1 April 2019 and predicted to arise after that date.

1.2 Inventory documents

The 2019 Inventory comprises four reports:

Radioactive Waste Inventory

Describes the sources, volume, composition and activity of radioactive waste in the UK, and a comparison with the previous inventory



Radioactive Material Inventory

Summarises the quantities of UK civil nuclear materials that might have to be managed as waste in the future

Waste Detailed Data

Provides further information on the radioactive waste inventory including a list of waste streams

Summary for International Reporting

Gives information to meet the UK's international reporting obligations in the field of radioactive waste and materials

As part of the commitment to openness, NDA has created a website dedicated to the Inventory, www.nda.gov.uk/ukinventory, where all of the 2019 Inventory reports can be found together with other information about radioactive waste.

1.3 This report

This report provides information on the 2019 UK Radioactive Waste Inventory:

- The inventory scope and process.
- Waste volumes, radioactivities and material compositions
- Assumptions used to estimate future radioactive waste arisings (the inventory scenario)
- Uncertainty in waste volumes and radioactivities
- How the 2019 Inventory compares with the 2016 Inventory
- Waste disposals and overseas waste.

It also provides supporting information on the origins and categorisation of UK radioactive waste, and how the waste is managed.

More detailed data are provided in the *2019 UK Radioactive Waste Detailed Data* report. This includes an analysis of waste volumes by region and from each organisation, 'Site Information Sheets' containing a description of the operations at each UK site that produces radioactive waste with volumes and radioactivities of the wastes. It also contains a list of waste streams in the 2019 Inventory and their volumes, the radionuclide composition of wastes, and a description of the inventory data reporting conventions.

ILW Store, Hunterston A

2 SOURCES OF RADIOACTIVE WASTE

2.1 Origin of radioactive waste

Material that has no further use, and is contaminated by, or incorporates, activity above certain levels defined in UK legislation[1,2] is known as radioactive waste.

Radioactive waste is the by-product of activities associated with the use of natural or man-made radioactive materials (such as uranium or irradiated nuclear fuel).

Transfer of radioactive material onto items it comes into contact with can lead to contamination and radioactive wastes being generated. Also items that have been subjected to neutron radiation (as in a nuclear reactor) can become radioactive as a result, a process known as activation[3].

Contaminated and activated process wastes will be generated during the operation of facilities that use radioactive materials. Also contaminated and activated components will arise as radioactive waste when facilities are eventually shut down and decommissioned.

In general, the waste that is produced in a nuclear power station or other facility during its operating lifetime is different in nature and radioactivity content from the waste that remains after the facility is shut down.

Operational waste

Operational waste consists principally of organic materials such as cellulose and plastic, metals and various inorganic materials. Examples of operational waste are redundant equipment, fuel element components, filters and ion exchange resins and sludges from the treatment of liquid effluents.

Decommissioning waste

Decommissioning waste consists mainly of building materials such as reinforced concrete, bricks, blocks and steelwork, larger items of plant and equipment including pipework, process vessels and ventilation systems, and soil from land remediation. Once a plant or facility using radioactive material has started up, equipment and structures can become radioactive, so decommissioning waste is certain to arise no matter how long or short its operational life.

As a pioneer in the development and use of nuclear technology, the UK has accumulated a substantial legacy of radioactive waste and nuclear materials from electricity generation, defence programmes and other industrial, medical and research activities. Some of this waste is already in storage, but much of it still forms part of existing facilities and will only become waste over the next century or so as plants are shut down, decommissioned and cleaned-up. Radioactive waste continues to be produced where radioactive substances are used. More information about how radioactive waste is generated is found on the UK Radioactive Waste Inventory website.

---

[1] *Radioactive Substances Act 1993 (as amended), 27 May 1993.*
[2] *Statutory Instruments 2016 No. 1154. Environmental Permitting (England and Wales) Regulations 2016 11 December 2016.*
[3] *Activation can also occur as a result of irradiation of materials with other particles (e.g. protons as in the ISIS facility at the Rutherford Appleton Laboratory).*

Radioactive waste from the nuclear power industry

The civil nuclear power industry is the source of most radioactive waste in the UK. This includes waste from:

- Manufacture of nuclear fuel
- Operation and decommissioning of nuclear power stations
- Reprocessing of spent nuclear fuel
- Research and development (R&D) programmes.

The manufacture of nuclear fuels (fuel fabrication and uranium enrichment) produces wastes that have only low levels of uranium contamination.

The UK has eight operating nuclear power stations - seven Advanced Gas-cooled Reactors (AGRs) and a Pressurised Water Reactor (PWR) - generating about 20-25% of the UK's electricity supply[4,5]. All 11 Magnox nuclear power stations have stopped producing electricity; they are now being decommissioned.

Reprocessing of spent Magnox reactor fuel takes place at Sellafield in Cumbria using chemical processes to recover uranium and plutonium[6]. This generates radioactive waste. The Magnox Reprocessing Plant is scheduled to complete its operations in 2020 once the remaining Magnox fuel has been reprocessed. Reprocessing of spent AGR fuel in the Thermal Oxide Reprocessing Plant (Thorp) came to an end in 2018.

Nearly all of the waste from nuclear energy R&D is a legacy of government-funded programmes stretching back to the 1940s. Many test and prototype reactors were operated at research sites across the country. These reactors and associated facilities are now shut down and site operations are concerned with decommissioning, dismantling and clean-up.

Other sources of radioactive waste

Radioactive waste sources in the UK outside the civil nuclear power industry comprise:

- Defence activities
- Research establishments
- Medical and industrial uses of radioactivity.

The main sources of defence waste are nuclear weapons production and operation of the UK fleet of nuclear-powered submarines. Smaller waste quantities arise from general use of radioactive materials within the armed forces and at defence establishments.

Research into fusion reactor technology continues at Culham Centre for Fusion Energy (CCFE) with the Joint European Torus (JET) and Mega Amp Spherical Tokamak (MAST) experiments. The Rutherford Appleton Laboratory supports the work of a diverse research community using its neutron sources.

---

[4] *Department for Business, Energy & Industrial Strategy, Digest of United Kingdom Energy Statistics 2019, July 2019.*
[5] *Department for Business, Energy & Industrial Strategy, Energy Trends, March 2019.*
[6] *Uranium and plutonium are included in the Radioactive Material Inventory.*

The remaining waste results from the use of radioactivity in medical diagnosis and treatment, and in industrial applications. These include sterilisation of medical equipment and food, and non-destructive testing of materials (for integrity, thickness, density). Some of the radioactive materials used in research, medicine and industry, which give rise to radioactive wastes, are produced in particle accelerators rather than in nuclear reactors.

2.2 Waste producers

Figure 1 shows the main sites in the UK where radioactive waste is produced. The waste producers are the NDA estate, EDF Energy, the Ministry of Defence, the United Kingdom Atomic Energy Authority, GE Healthcare Ltd, Urenco, the Rutherford Appleton Laboratory and Imperial College. The figure also shows the sites where radioactive waste is disposed.

Many, so-called, 'small users' of radioactive substances such as hospitals and industrial, educational and research establishments produce small quantities of radioactive wastes. Also there are a number of supply chain organisations treating UK radioactive wastes at facilities that may produce small amounts of secondary waste. In the 2019 Inventory, these 'small users', which includes the Rutherford Appleton Laboratory and the Imperial College Reactor Centre at Silwood Park, are collectively referred to as 'Minor Waste Producers'.

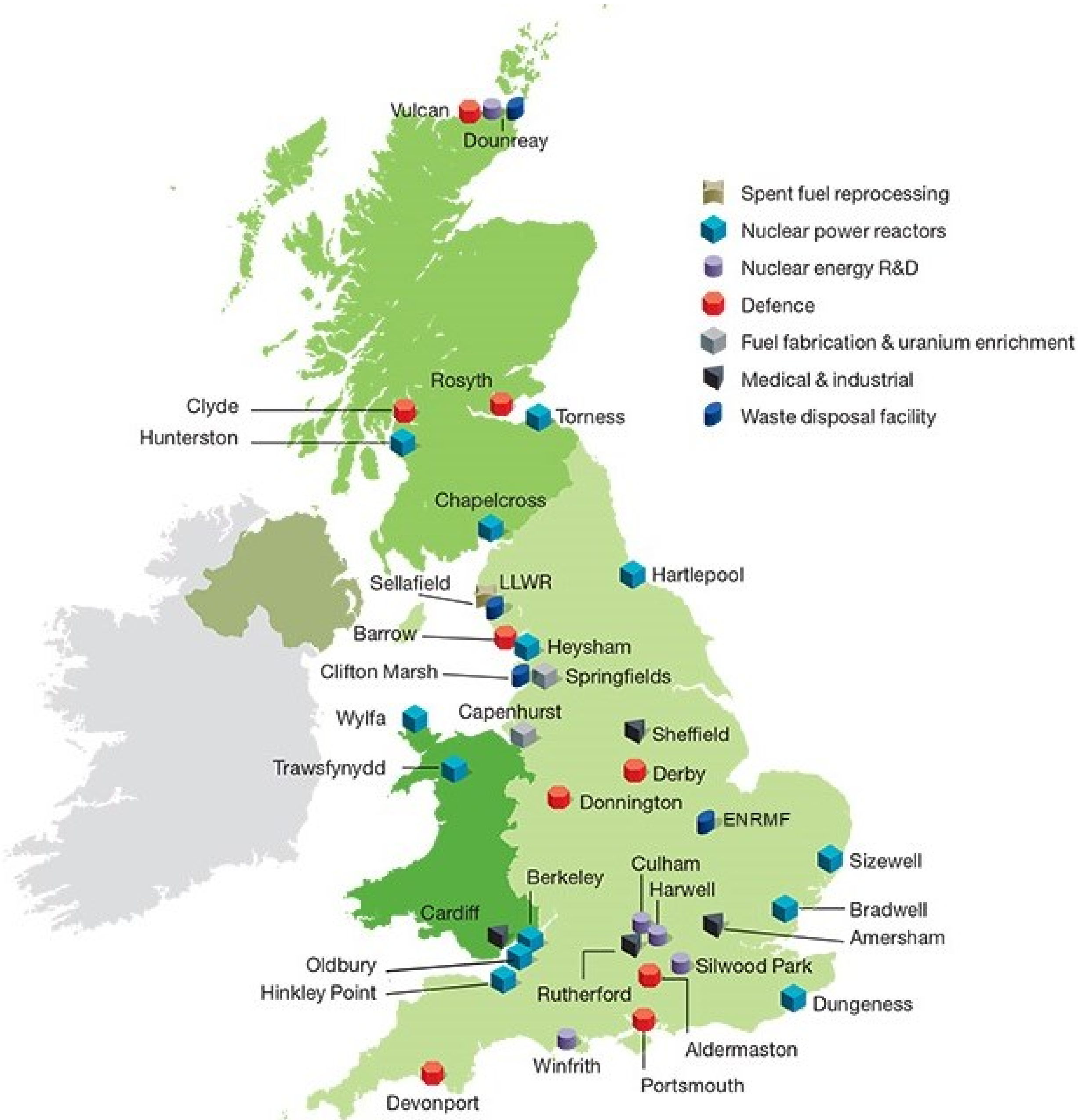
2.3 Waste disposal

Figure 1 also shows sites at which radioactive waste is disposed. The Low Level Waste Repository (LLWR) site is the UK's national LLW disposal facility. Its role is to ensure that the LLW generated in the UK is disposed of in a way that protects people and the environment. LLW Repository Ltd is also responsible for leading the implementation of the UK LLW strategy on behalf of the NDA, which it does through the National LLW Programme.

A key part of the UK LLW Strategy is the development of alternative waste management routes. For example, the National LLW Programme has been successful in diverting significant volumes of LLW from disposal at the LLWR site. The supply chain has developed landfill capability for the disposal of VLLW and lower-activity LLW wastes (Clifton Marsh and ENRMF), and has a critical role in providing a safe disposal route for wastes in support of the LLW National Programme. We have an obligation under the UK LLW strategy to make our LLW management facilities available to other nuclear and non-nuclear managers of radioactive waste, where it is practicable to do so.

On-site disposal is also undertaken by some of our SLCs. Sellafield has an on-site facility capable of accepting some lower-activity wastes and Dounreay Site Restoration Ltd (DSRL) has constructed a LLW disposal facility adjacent to the site to accept LLW from Dounreay and the neighbouring MOD Vulcan Naval Reactor Test Establishment.

Figure 1: Major waste producing sites and waste disposal facilities



Notes: 1. There are no major waste producing sites in Northern Ireland.
2. The Calder Hall nuclear power reactors are located at Sellafield.

3 CATEGORIES OF RADIOACTIVE WASTE

In the UK radioactive waste is classified according to how much activity it contains and the heat that this activity produces. Categories are High Level Waste (HLW), Intermediate Level Waste (ILW), Low Level Waste (LLW) and Very Low Level Waste (VLLW). The following diagrams give the definitions and characteristics of the different waste categories.

The following broader designations are also used in this report in the context of radioactive waste management (section 4) and waste disposals (section 12):

- Higher Activity Waste (HAW): comprises HLW, ILW and a small fraction of LLW
- Lower Activity Waste (LAW): comprises both LLW and VLLW.

HLW

HIGH LEVEL WASTE

Definition

Wastes in which the temperature may rise significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage or disposal facilities.

Characteristics

HLW is generated from reprocessing spent nuclear fuel at Sellafield. It is initially produced as a concentrated nitric acid solution containing waste fission products. The 2019 Inventory includes the nitric acid solutions awaiting conditioning in the Waste Vitrification Plant (WVP), some insoluble fission products that settle in the storage tanks, tank liquor heels, the glass product of conditioning, and small quantities of contaminated plant items from the WVP (mostly metal and ceramic).

Volume

~1,500 m^3 total packaged

Level of radioactivity

~12,000,000 TBq at 2100
(dominated by shorter-lived radionuclides)

Although the majority of radioactivity is associated with HLW, this waste category represents a very small volume relative to other categories in the 2019 Inventory. In contrast, very little radioactivity is associated with LLW and VLLW although these waste categories represent most of the waste volume in the 2019 Inventory.

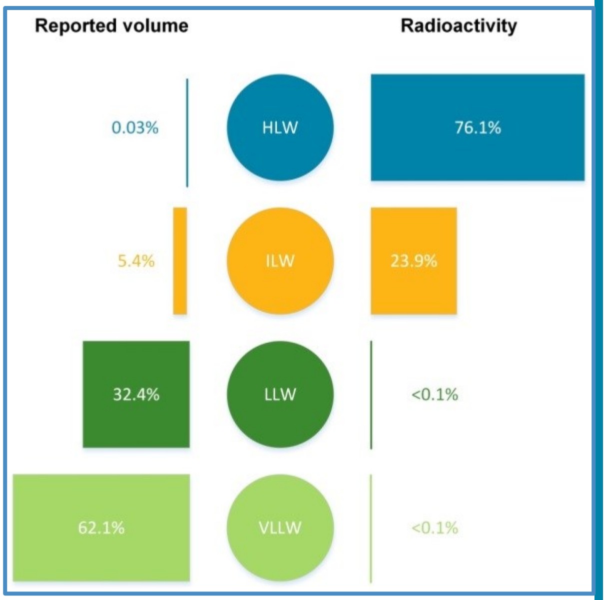


Figure to show the relationship between volume and activity of radioactive waste in the 2019 Inventory

ILW

INTERMEDIATE LEVEL WASTE

Definition

Wastes exceeding the upper boundaries for LLW, but which do not generate sufficient heat for this to be taken into account in the design of storage or disposal facilities.

Characteristics

The major components are steels, graphite, concrete, cement and sand, sludges, ion exchange resins and flocculants. There is a wide range of steel items, including plant items and equipment, fuel cladding and reactor components. Most graphite is in the form of moderator blocks from final stage reactor dismantling at Magnox and AGR power stations.

The majority of waste reported as cementitious materials is cement associated with conditioned waste. The remainder is mostly higher activity concrete from the decommissioning of buildings.

Volume

~500,000 m^3 total packaged

Level of radioactivity

~1,000,0000 TBq at 2100

ILW Magnox fuel cladding swarf

LLW

LOW LEVEL WASTE

Definition

Wastes having a radioactive content not exceeding 4 Gigabecquerels per tonne of alpha activity or 12 Gigabecquerels per tonne of beta/gamma activity.

Characteristics

The major components of LLW are building rubble, soil and steel items such as framework, pipework and reinforcement from the dismantling and demolition of nuclear reactors and other nuclear facilities and the clean-up of nuclear sites.

LLW also comprises miscellaneous contaminated wastes from the operation of nuclear facilities which is mainly scrap metal items, plastics and paper.

Volume

~1,280,00 m^3 total packaged

Level of radioactivity

~140 TBq at 2100

Drum of miscellaneous LLW

VLLW

VERY LOW LEVEL WASTE

Definition

A sub-category of LLW, it comprises waste that can be safely disposed of with municipal, commercial or industrial waste, or can be disposed of at specified landfill sites (see box below for details).

Very Low Level Waste comprises:

- High Volume VLLW – wastes with maximum concentrations of 4 MBq (megabecquerels) per tonne of total activity that can be disposed to specified landfill sites. There is an additional limit for tritium in wastes containing this radionuclide.
- Low Volume VLLW - wastes that can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste, each 0.1 m^3 of material containing less than 400 kBq (kilobecquerels) of total activity, or single items containing less than 40 kBq of total activity. There are additional limits for C-14 and tritium in wastes containing these radionuclides.

Characteristics

The major components of VLLW are building structural materials (principally concrete, with brick, metal and other materials) from the dismantling and demolition of nuclear facilities.

There are also smaller quantities of excavated soil from construction and demolition activities.

Volume

~2,690,000 m^3 total reported

Level of radioactivity

~11 TBq at 2100

Demolition work

4 OVERVIEW OF UK RADIOACTIVE WASTE MANAGEMENT

Key facts:

- Higher activity wastes (HLW, ILW) and some LLW unsuitable for disposal in existing facilities are being stored pending disposal in a Geological Disposal Facility (GDF).
- Integrated waste management and the opening up of alternative management routes mean that less LLW is expected to be disposed at the LLWR.

Responsibility for radioactive waste management in England rests with the UK Government, while responsibility in Scotland, Wales and Northern Ireland has been devolved to the Scottish Government, the Welsh Government and the Northern Ireland Executive respectively.

The management of all categories of radioactive waste involves a number of key stages:

- Planning and preparation
- Treatment and packaging
- Storage
- Disposal.

The Inventory is essential to successful planning and preparation, and includes information on how wastes are currently being managed and future plans such as treatment and packaging for storage and disposal of waste.

Government radioactive waste management policy is supported by a regulatory framework that aims to ensure that all radioactive wastes are safely and appropriately managed in ways that pose no unacceptable risks to people or the environment.

4.1 Integrated waste management

There are synergies between Higher Activity Waste policy and the LLW strategy which could be enabled by managing wastes using disposability assessment (i.e. considering the performance and safety of wastes), rather than radiological categories. Not all LLW can be safely disposed of at the LLWR; conversely some HAW may be better managed within a LLW facility. For some HAW at the intermediate level and low level waste boundary, particularly those wastes containing short-lived radionuclides, a more appropriate management route could be in a near-surface environment.

Diverse radioactive waste management and disposal solutions that can offer benefits over previous arrangements are part of an integrated waste management approach.

In 2019 the NDA published its integrated waste management strategy[7], which applies to all radioactive waste generated within the NDA estate (including materials that may become waste at some point in the future).

A central theme of UK radioactive waste management is the waste hierarchy[8] (see right), which sets out five steps for dealing with waste, ranked according to environmental impact. There is a preference for managing wastes at higher levels of the hierarchy, with prevention of waste where practicable, minimisation where creation is unavoidable, re-use and recycling where there are opportunities to do so, and ultimately disposal for wastes that can't be managed using any other method.

4.2 Lower Activity Waste (LAW) management

LAW comprises both LLW and VLLW.

Government policy for the long-term management of solid LLW (including VLLW) in the UK provides a high level framework of principles and outlines priorities for responsible and safe management of LLW. The policy addresses concerns around disposal capacity for large-scale facility decommissioning and environmental restoration being undertaken in the UK, and establishes a flexible, sustainable approach for managing solid low level radioactive waste in the long term[9].

The UK-wide strategy for managing LLW from the nuclear industry has three themes:

- Application of the waste hierarchy (see above) with its preference for managing LLW at higher levels (i.e. waste minimisation, reuse and recycling).
- The best use of existing LLW management assets
- The need for new fit-for-purpose waste management routes.

Government has also developed strategies for the management of LLW from the non-nuclear industry. There are synergies between these and the nuclear industry strategy in that they have similar strategic themes and rely on many of the same waste management routes.

---

[7] *Nuclear Decommissioning Authority, Integrated Waste Management Radioactive Waste Strategy, September 2019.*

[8] *The Waste Framework Directive (2008/98/EC), which is the primary European legislation for the management of waste, establishes the requirement on Member States to apply the waste hierarchy.*

[9] *Application of the waste hierarchy is central to the UK-wide strategy for managing LLW from the nuclear industry. This means managing LLW at higher levels of the hierarchy, such as reducing, reusing and recycling waste, and a move away from the past focus on disposal.*

Metal recycling

NDA leads the implementation of the solid LLW strategy on behalf of Government through a National Waste Programme. LLW Repository Ltd leads the delivery of the National Waste Programme across the nuclear industry on behalf of NDA.

The National Waste Programme delivers:

- The diversion of a significant quantity of LLW away from disposal at the LLWR through improved waste segregation and characterisation[10]
- The use of alternate treatments (e.g. incineration, metal treatment[11]) and disposal routes (e.g. authorised landfill sites[12]).
- Opportunities for improvement and the sharing of good practices.

Low Level Waste Repository

The LLWR disposal site remains a key strategic asset for the UK's management of solid LLW. Waste unsuitable for incineration, metal treatment or landfill disposal is immobilised in cement within mild steel ISO containers and disposed of at the LLWR.[13] Suitable LLW is first supercompacted to minimise its volume. In this process drums or boxes of waste are compacted under high pressure of up to 2,000 tonnes per square metre.[14]

Current disposals are made in an engineered facility with concrete-lined disposal vaults. A final cap will be constructed in stages over the vaults (and older trenches), and will be completed once the last disposals are made.

An aerial view of the LLWR showing containers in disposal vaults is shown on page 23.

[10] *Similarly, improved characterisation is resulting in the recategorisation of some waste from ILW to LLW (e.g. Magnox FED, Magnox reactor fuel skips).*
[11] *Recovered material can be released back into the scrap metals market for a variety of uses.*
[12] *Some LLW and VLLW can be disposed of at suitably authorised and permitted landfill sites. There are controls on the amount of radioactive waste that can be disposed.*
[13] *Some LLW may require geological disposal.*
[14] *Between 1959 and 1995 drummed, bagged and loose waste was disposed in a series of seven clay-lined trenches at the LLWR. As a result of compaction, the waste in the trenches occupies a volume of about 500,000m^3. The trenches have been covered by an interim soil cap; a final cap will be constructed over the trenches and vaults as part of site closure engineering.*

Dounreay LLW facility

A new shallow, engineered LLW disposal facility has been constructed next to the Dounreay site in Caithness. Waste transfers started in 2015.

The disposal facility will receive LLW from decommissioning at the Dounreay site, as well as retrieved and repackaged LLW from the historical disposal pits. It will also receive waste from the neighbouring Vulcan nuclear site that cannot be recycled. Suitable LLW is first supercompacted to minimise its volume. There is a dedicated 'Demolition LLW' vault for waste with radioactivity at the lower end of the LLW scale.

Views of the facility are shown on page 27.

4.3 Higher Activity Waste (HAW) management

HAW comprises HLW, ILW and such LLW that cannot be disposed of at present.

Current practice is that vitrified HLW[15] should be stored for at least 50 years before disposal. The period of storage allows the amount of heat produced by the waste to fall, which makes it easier to transport and dispose. Most ILW is stored at the producing sites, although some wastes are transferred off site to appropriate facilities (e.g. at Sellafield) when there is a clear and compelling strategic case to do so. Minor waste producers also make use of facilities at Sellafield and an ILW store at Harwell.

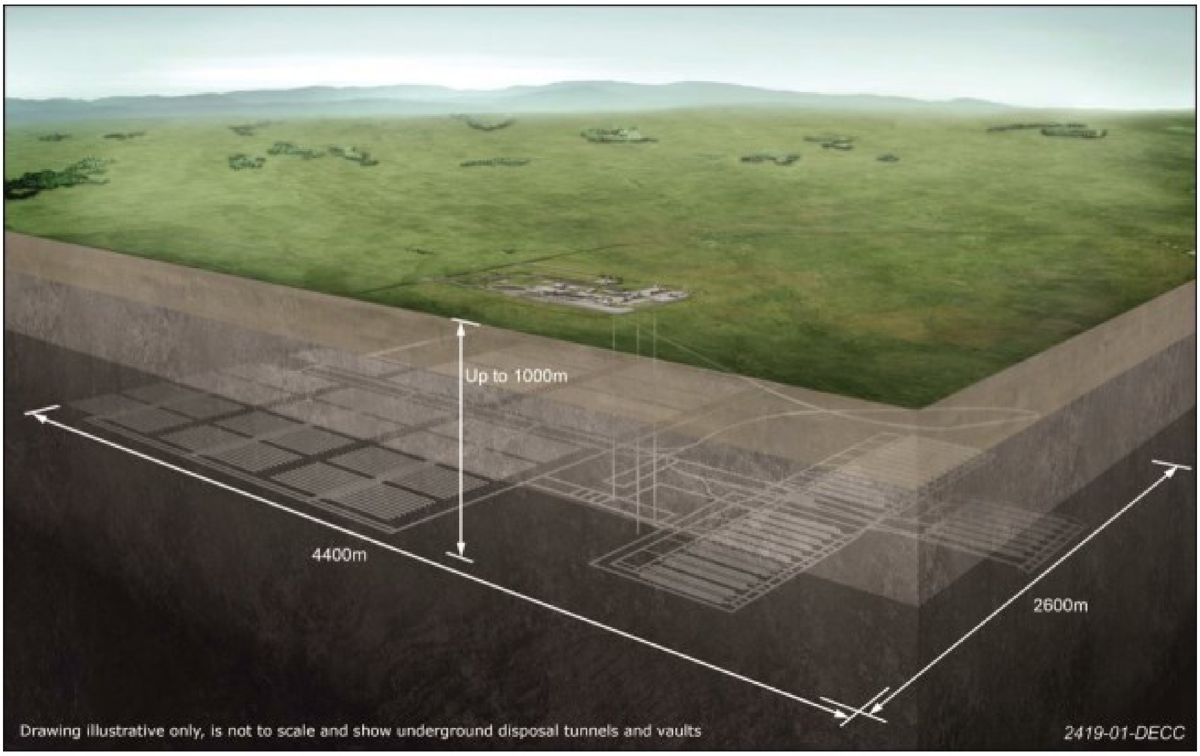
Treatment and packaging converts the raw waste into a form that is suitable for longer-term storage pending the development of a suitable disposal route. Typically, this process will cover a number of steps and employ a range of technologies.

The long-term management policy of the UK Government and devolved administrations for Wales and Northern Ireland is geological disposal[16,17]. This uses engineered barriers and hundreds of metres of rock overlying the disposal facility to isolate the waste so that no harmful amounts of activity reach the surface environment. The specially-engineered vaults and tunnels deep underground that will house the waste are called a Geological Disposal Facility (GDF).

The UK Government has recently launched a site selection process to find a volunteer host community with suitable geology for a GDF. The geological characteristics of the site are important for the long-term safety of the facility.

The precise layout and design of the facility will depend on the inventory for disposal and the specific geological characteristics at the site in question. An artist's impression of one potential layout of a GDF is shown below.

[15] *Vitrification is the process used at Sellafield to convert liquid HLW produced during spent fuel reprocessing into a borosilicate glass.*
[16] *Department of Business, Energy & Industrial Strategy. 'Implementing Geological Disposal – Working With Communities. An updated framework for the long-term management of higher activity waste', December 2018.*
[17] *Welsh Government, 'Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste', 2015.*



Possible design for a Geological Disposal Facility

The Scottish Government policy is that long-term management of higher activity wastes should be in near-surface facilities[18]. 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 waste packages, or waste, could be retrieved.

[18] *The Scottish Government, 'Scotland's Higher Activity Radioactive Waste Policy 2011', January 2011.*

Aerial view of LLW repository

5 SCOPE OF THE RADIOACTIVE WASTE INVENTORY

5.1 Radioactive wastes

The Inventory includes HLW, ILW and LLW, and some High Volume VLLW (HVVLLW) where there is reasonable certainty of the total waste arisings. This is illustrated in Table 1.

Table 1: Wastes reported in the Inventory

Category	Major waste producers	Minor waste producers
HLW		None produced
ILW		
LLW	See Note 1	See Note 2
VLLW sub category	See Note 3	See Note 4

Wastes included in the 2019 Inventory

Note 1: Some waste producers have chosen to report potentially contaminated land in the *2019 UK Radioactive Material Inventory* report until there is more certainty on the disposal route and the volumes that might arise.

Note 2: Excludes low volumes of waste that can be disposed of by 'controlled burial' at permitted landfill sites.

Note 3: Includes High Volume VLLW from facilities decommissioning and site clean-up at nuclear licensed sites. However some waste producers have chosen to report potentially contaminated land in the *2019 UK Radioactive Material Inventory* report until there is more certainty on the disposal route and volumes that might arise.

Note 4: Not reported in the Inventory. Such VLLW is of low volume and is disposed of separately, or with municipal, commercial and industrial wastes, at landfill sites.

The Inventory does not include:

- Liquid and gaseous wastes containing very low concentrations of activity that are routinely discharged to the environment in accordance with statutory regulations. Discharges are made within authorised limits, usually after some form of treatment
- Small quantities of solid wastes with very low concentrations of activity typically from hospitals, universities and the non-nuclear industry (so-called 'small users'), as well as devices such as tritium light sources and smoke detectors, that can be disposed of with domestic refuse to landfill, either directly or after incineration
- Naturally occurring radioactive materials (NORM), which accumulate as scale on pipework during the extraction of oil and gas. These scales have raised levels of activity and are treated as radioactive waste

- Estimates of waste and spent fuel from the future development of new nuclear power stations in the UK.[19]

Also, the Inventory does not include all secondary waste produced from waste treatment processes such as incineration and metal treatment. However, volumes are small.

Radioactive waste is divided into waste streams for the purpose of compiling the inventory. A waste stream includes waste or a collection of waste items at a particular site, usually in a particular facility and/or from a particular process or operation.

The Inventory covers radioactive wastes that existed on 1 April 2019 and those forecast to arise in the future, and for each radioactive waste stream gives its:

- Identification code
- Name
- Waste classification
- Volume in stock at 1 April 2019, and forecast in the future and the timing of these arisings
- Physical and chemical composition
- Radioactivity and radionuclide composition
- Current or planned treatment and packaging
- Current or planned disposal route.

Full information about each waste stream is contained within individual Waste Stream Data Sheets (WSDS). These are forms generated as MS Excel and Adobe pdf files, and are available on the UK Radioactive Waste Inventory website.

[19] New nuclear power stations built in the UK will produce spent fuel, but for the purposes of the inventory no new stations are assumed. An assumed new build programme is accounted for in LLWR's Environmental Safety Case and RWM's Inventory for Geological Disposal.

6 OVERVIEW OF THE INVENTORY PROCESS

Updating the Inventory is a major task which happens every three years. It involves engaging with radioactive waste producers and collecting information for over 1,300 radioactive waste streams and more than 60 radioactive material streams[20]. NDA published a strategic case for production of a three-yearly Inventory in 2018[21]. The Inventory process deployed in 2019 follows the preferred approach set out in the published Stage A & B paper. NDA deployed a contractor to deliver the 2019 Inventory.

The process for compiling the 2019 Inventory is illustrated below.

Develop plan and approach

- Develop and agree a plan, and the best way to work with waste producers and to record data.
- Take on board lessons learned from the previous exercise and implement recommendations where these are endorsed and are achievable. Address any changes in inventory requirements.
- Produce a specification and outline programme of work.

Confirm data requirements

- Review the data to be collected to confirm they continue to meet user needs and to ensure that the UK's international inventory reporting requirements can be met.
- Maintain an inventory data improvement plan for each waste producer.
- Update the inventory scenario for each site (see Section 7) before data collection.

Develop data collection tools

- Develop the data collection tools; the waste producers are involved in this process.
- Preload previous 2016 Inventory data for waste producers to update. Guidance and conventions are developed to help in compiling data in a consistent form.

Compile data and verify

- Inventory data are obtained from a number of sources - waste sampling, measurement and calculation. Waste producers are responsible for quality checking their data before submission.
- The inventory contractor processes the data and carries out independent checking. Checking confirms that data are consistent with the inventory data reporting conventions.

Publish reports and data

- 'Freeze' the inventory database once all data have been collected and checked with sites.
- The inventory contractor then produces a suite of reports that are reviewed and approved by the waste producers, NDA and BEIS. Finally, the inventory is ready for publication.

Review project

- After inventory publication, NDA works with all those involved to agree improvements for the next inventory cycle. This includes improvements to the process itself as well as identifying specific improvements to the data.
- NDA reviews the strategy for management of inventory data and updates the strategy as needed.

[20] *Radioactive waste producers also maintain their own inventories to support their ongoing site activities.*
[21] *Nuclear Decommissioning Authority, Management of Radioactive Waste & Materials Inventory Data, Credible Options Assessment (Stage A) and Selection of Preferred Options (Stage B), July 2018.*

Aerial view of the Dounreay LLW facility

Inside the Dounreay LLW facility

7 SCENARIO FOR FUTURE WASTE ARISINGS

The inventory scenario sets out the assumptions used by waste producers to estimate the amount of radioactive waste that will arise from their sites in future. The assumptions consider the nature, scale and timings of operations and activities at each site.

These assumptions were made at the 2019 Inventory stock date, 1 April 2019, and may change in future due to a range of commercial, policy or funding reasons, or as improved data become available.

Table 2 provides the key assumptions and programme dates used to forecast radioactive waste arisings at UK waste producing sites. Site information sheets in the companion *2019 UK Radioactive Waste Detailed Data* report provide further information on the basis for estimates of future waste arisings.

Table 2: List of assumptions used to estimate future waste arisings in the 2019 Inventory

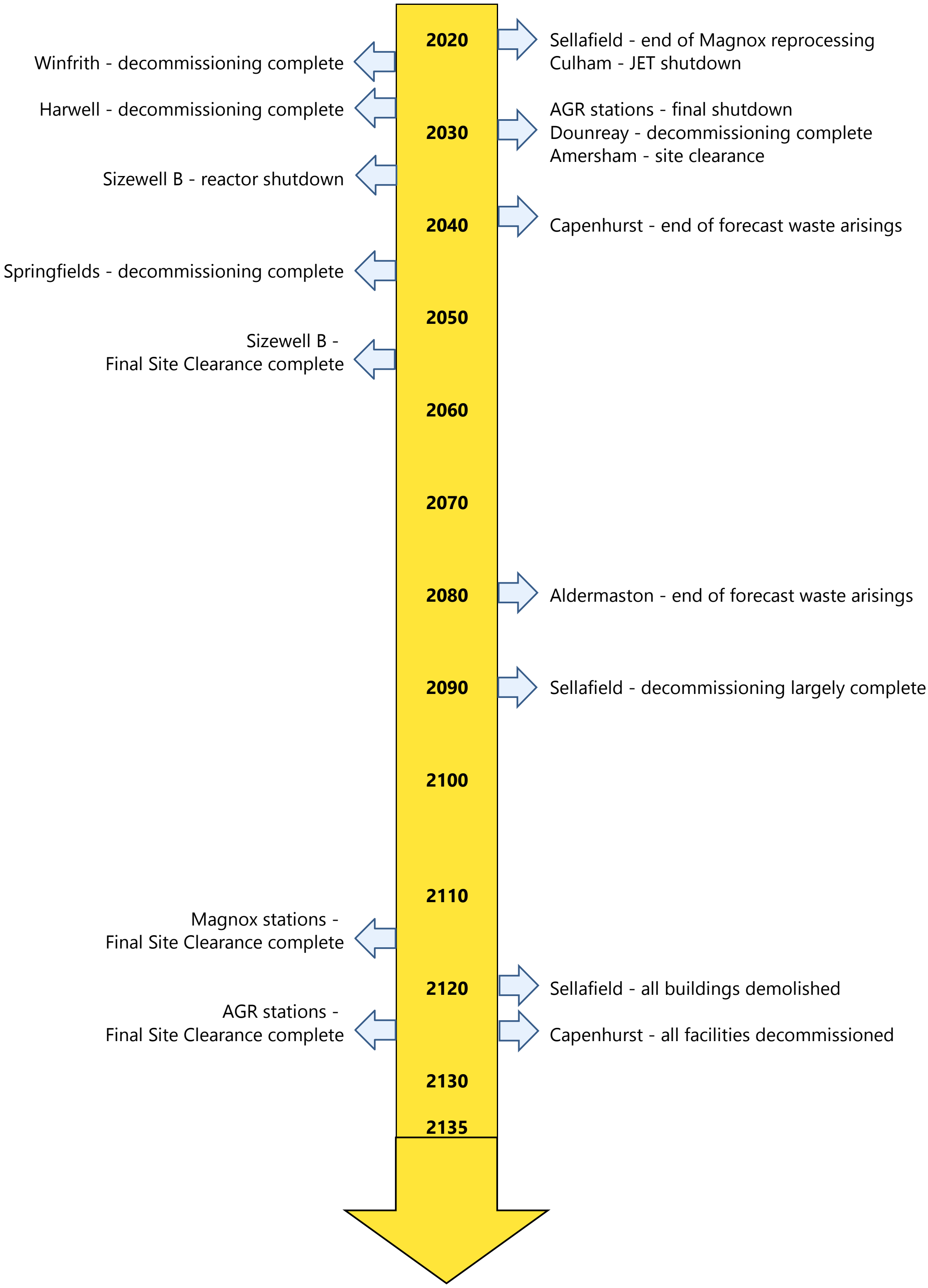
Organisation / site	Operations	Decommissioning
NDA sites:		
Sellafield	Magnox reprocessing plant operates to end of 2020 with lifetime throughput of ~55,000 tU	After end of spent fuel reprocessing the site will continue to focus on high hazard reduction and environmental remediation, including waste retrieval and treatment, Post Operational Clean Out (POCO) and the decommissioning of redundant facilities All site decommissioning activities will be largely completed by 2090 All buildings/waste stores (except product stores and supporting ancillary buildings) are assumed to be demolished by 2120
Magnox reactor sites[(1)]	All reactors are shut down	All defuelling and C&M preparations completed by 2034 Final site clearance work scheduled over the period 2070-2115
LLWR	Waste forecast to 2135	PCM store decommissioning complete 2023
Dounreay	All reactors and supporting facilities are shut down	All redundant facilities decommissioned by 2030
Harwell	All reactors and supporting facilities are shut down	All facilities decommissioned by 2027
Winfrith	All reactors and supporting facilities are shut down	All facilities decommissioned by 2023
Springfields	Oxide manufacture to continue until 2028	All facilities decommissioned by 2045 Final site clean-up and remediation ~2100

Organisation / site	Operations	Decommissioning
MOD sites:		
AWE	End of operations at 2080 (date when all currently operational facilities are decommissioned and all higher activity waste has been disposed to a GDF)	
Dockyards	Operations continue to 2110	Rosyth - submarine dismantling activities continue until the 2030s
Submarine decommissioning	-	Includes 27 submarines currently in scope of the Submarine Dismantling Project (SDP) programme, as well as any future classes of submarine that exit operational service and begin dismantling before 2110
EDFE sites:		
AGR power stations	Reactors shut down over period 2023-2030	All defuelling and C&M preparations completed by 2044 Final site clearance work scheduled over the period 2108-2125
Sizewell B PWR power station	Reactor operates to 2035	Defuelling and C&M Preparations 2035-2045 Reactor Dismantling & Final Site Clearance 2043-2053
UKAEA sites:		
Culham	JET operates to 2020	Decommissioning 2020-2029
Urenco sites:		
Capenhurst	Waste forecast to 2119	Decommissioning complete 2124
GE Healthcare sites:		
Amersham	Manufacturing operations cease in 2019	Decommissioning complete 2030
Minor waste producer sites:		
Imperial College CONSORT reactor	Reactor is shut down	Decommissioning complete 2020
Rutherford Appleton Laboratory	Waste forecast to 2037	

(1) Stations include Calder Hall on the Sellafield site.

Figure 2 provides a timeline of key events underpinning the 2019 Inventory.

Figure 2: Timeline of key events underpinning the 2019 Inventory



Demolition of former ponds complex at Bradwell Magnox station

8 WASTE VOLUMES

Key facts:

- At 1 April 2019 the total reported volume of waste is 133,000 m^3.
- Future waste arisings volume is estimated to be 4,420,000 m^3.
- Over 94% of the total waste volume is of low activity (LLW and VLLW).
- About 74% of the total waste volume is at Sellafield.

Radioactive waste quantities are reported by waste producers as:

- Stocks - waste at 1 April 2019 comprises radioactive materials that had been declared as waste and were being held at this date
- Future waste arisings - estimates of waste that will be generated based on key assumptions about the nature, scale and timing of future operations and activities (the inventory scenario).

Waste quantities in this section are presented in terms of reported volume and mass, packaged volume and the number of packages:

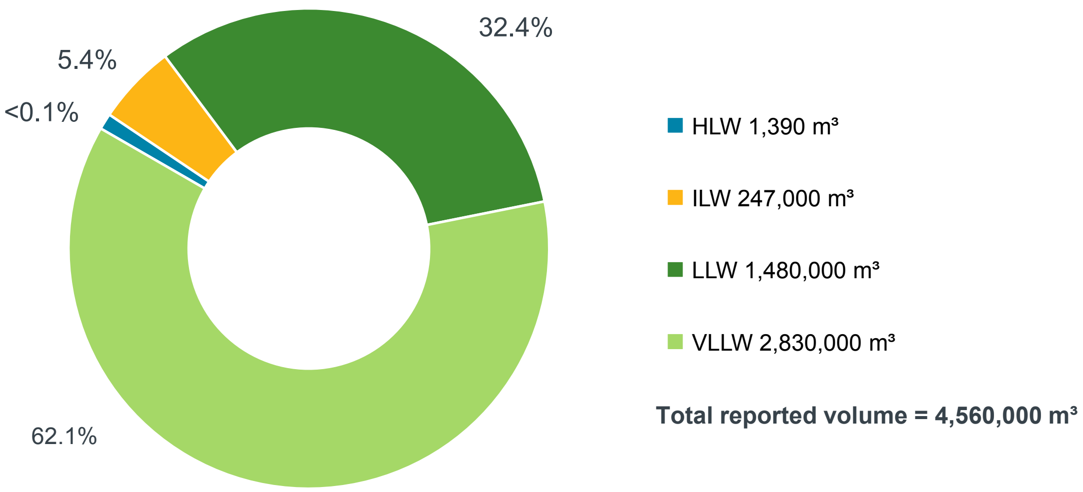
Reported volume	For stocks, the volume that waste occupies in tanks, vaults, silos, drums etc. in which it is contained. Some wastes are being conditioned directly in suitable containers for long-term management as they arise and others have been retrieved from stores and conditioned; for these wastes the reported volume at 1 April 2019 is also the conditioned volume[22]. For future arisings, the projected volume in general reflects current waste management practice. For most future arisings the reported volume is that for untreated or partly treated waste. For those waste streams where fresh arisings are being conditioned the reported volume is also the conditioned volume.
Reported mass	The mass of the waste corresponding to the reported volume.
Packaged volume	Packaging is the loading of waste into a container for long-term management. The packaged volume is the total volume taken up by the waste, any immobilising medium and the waste container. It represents a 'final' waste volume.
Number of packages	The number of waste containers corresponding to the packaged volume.

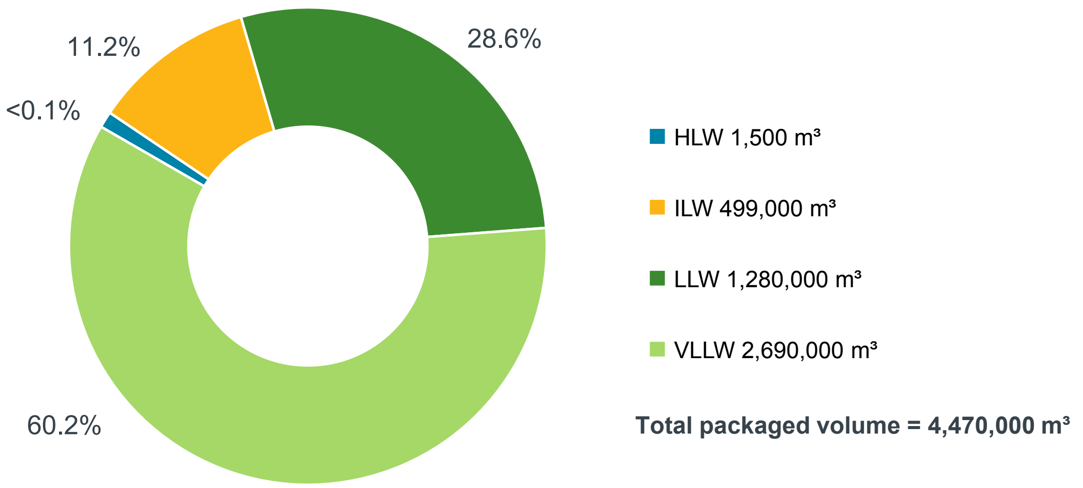
[22] *The conditioned volume is the volume of the wasteform (waste plus any immobilising medium) within the waste package.*

8.1 Summary for all wastes

Figure 3 illustrates the relative contributions of HLW, ILW, LLW and VLLW to the total radioactive waste volume in stocks plus future arisings from all sources for reported volumes (top chart) and for packaged volumes (bottom chart). Most waste is of low activity (LLW and VLLW).

Figure 3: Proportion of waste volume by type





Note: LLW includes 248,000 m^3 (reported volume) and 238,000 m^3 (packaged volume) of mixed LLW/VLLW corresponding to about 5% of total reported and packaged volumes.

Table 3 gives total reported waste volumes and corresponding masses, and total packaged waste volumes and corresponding numbers of packages, for each waste category existing at 1 April and estimated for future arisings up to 2135.

Table 3: Total wastes at 1 April 2019 and estimated for future arisings

Waste category	Reported volume (m^3)	Reported mass (tonnes)	Packaged volume (m^3)	Number of packages
HLW(1)	1,390	3,200	1,500	7,660
ILW	247,000	280,000	499,000	292,000
LLW	1,480,000(2)	1,900,000	1,280,000	22,300(3)
VLLW	2,830,000(4)	2,900,000	2,690,000	See Note 5
Total	**4,560,000**	**5,100,000**	**4,470,000**	**322,000**

(1) The volume and mass do not include waste from reprocessing overseas spent fuel that will be exported to the country of origin, and assume substitution arrangements are implemented (see Section 14 for further information).

(2) LLW includes 248,000 m^3 reported volume of mixed LLW/VLLW at Springfields.

(3) Includes only those wastes packaged for disposal at the LLWR and Dounreay LLW vaults (packaged volume 447,000 m^3). Excludes LLW streams and component parts of LLW streams whose characteristics make them suitable for recycling, incineration or appropriately permitted landfill disposal.

(4) Includes 2,700,000 m^3 reported volume from facility decommissioning at Sellafield. However the current best estimate, albeit based on limited decommissioning experience, is that 70% of this material may be 'out of scope' of regulatory control.

(5) As VLLW can be disposed to appropriately permitted landfill sites no package numbers are collated for this waste category in the Inventory.

Reported volumes show that about 3,080,000 m^3 (72%) of all low activity waste (i.e. LLW and VLLW) falls into the VLLW sub-category or is mixed LLW/VLLW[23]. Much of this waste is forecast to arise from decommissioning and site clearance activities. In general current arisings are disposed of at appropriately permitted landfill sites shortly after they arise.

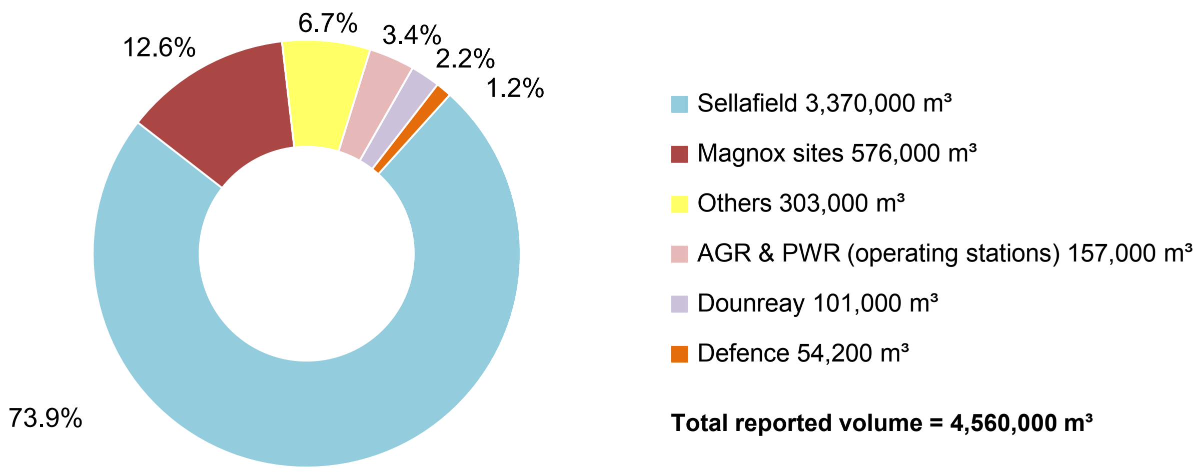
Approximately 2,700,000 m^3 (95%) of VLLW is forecast from plant decommissioning at Sellafield, including reprocessing and associated plants, storage and treatment plants and site service facilities. However, there is a large uncertainty in potential radioactive waste arisings from decommissioning and current expectations are that about 70% of this material may be out of scope of regulatory control (i.e. not radioactive for the purposes of UK legislation). As decommissioning projects at the site are progressed and opportunities for further characterisation arise the projected amounts of radioactive waste will continue to be refined.

Most radioactive waste in the UK originates from the nuclear power industry (see section 2). The majority of radioactive waste from the nuclear power industry is from historical operations that include Magnox reactors at eleven sites, Magnox and oxide fuel reprocessing at Sellafield, and R&D programmes at Sellafield, Dounreay, Harwell and Winfrith that included a number of research and prototype reactors. Waste volumes from the seven operating AGR power stations and the PWR power station at Sizewell B are lower than those from these legacy operations.

[23] *Springfields generates low activity wastes that have a range of activity concentrations spanning the LLW/VLLW boundary. The wastes are not separated into the two categories as they can be routinely disposed of to the landfill site at Clifton Marsh, which has a permit to accept radioactive wastes up to 200 Bq/g (i.e. comprising VLLW and LLW at the lower end of its activity range).*

Figure 4 illustrates the origin of radioactive waste.

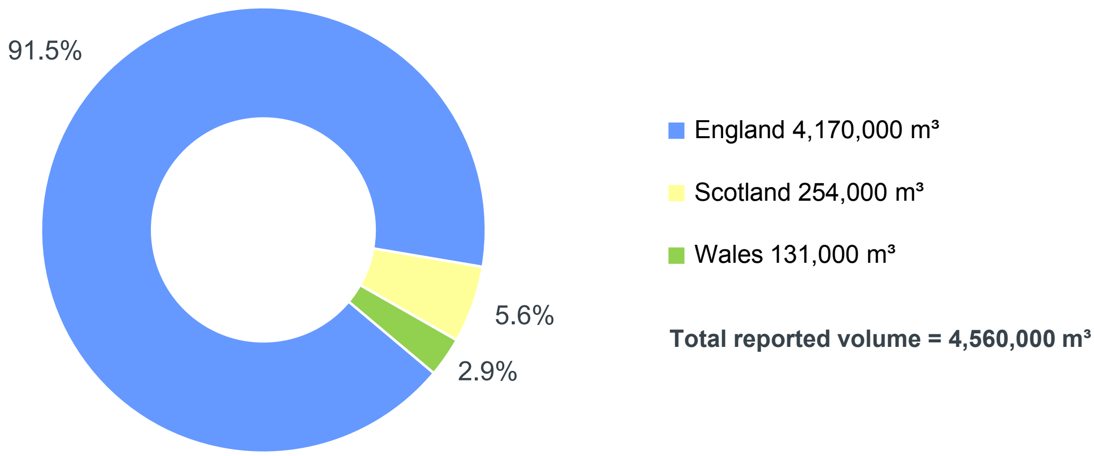
Figure 4 **Wastes by origin (% all wastes at 1 April 2019 and for projected future arisings)**



8.2 Volumes by region

Figure 5 illustrates the relative contributions of radioactive waste in England, Scotland and Wales to the total reported volume in the UK. There are currently no nuclear licensed sites in Northern Ireland; only very small quantities of radioactive waste are produced there from hospitals and industry. These wastes can be incinerated or disposed to landfill, and are not within the scope of the 2019 Inventory[24].

Figure 5: **Proportion of total waste reported volume by country (at 1 April 2019 and estimated for future arisings)**



In terms of reported volume, approximately 92% of all radioactive wastes in the UK at 1 April 2019 and in estimated future arisings up to 2135 are located in England, 5.6% in Scotland and 2.9% in Wales.

[24] *Some redundant radioactive sources are transferred for storage in the MBGWS at Sellafield and so are included in the Inventory.*

For England radioactive waste production is dominated by Sellafield. For Scotland most waste is from Dounreay and the legacy Magnox power station sites at Chapelcross and Hunterston. For Wales nearly all waste is from the legacy Magnox power station sites at Trawsfynydd and Wylfa.

The *2019 UK Radioactive Waste Detailed Data* report gives further information on waste volumes for England, Scotland and Wales, including volumes at 1 April 2019 and in projected future arisings, and for each waste category.

8.3 Volumes by waste category

Tables 4-7 give the reported waste volumes and corresponding masses at 1 April 2019, and the volumes already packaged at 1 April 2019 with corresponding numbers of packages, for each waste category. The tables also give figures for future radioactive waste arisings that are projections made by the organisations that operate sites. These projections are based on assumptions about the nature, scale and timing of future operations and activities at their sites (see Section 7). The 2019 Inventory includes forecast radioactive wastes from future operations and activities up to 2135.

High Level Waste

At 1 April 2019 the reported volume of HLW at Sellafield was about 2,150 m^3.

HLW is being safely stored at Sellafield pending the availability of a disposal route for this waste category. The quantity of packaged HLW being stored is increasing as waste, which is initially managed in a liquid form known as Highly Active Liquor (HAL), undergoes an evaporation process before vitrification into glass blocks within stainless steel canisters. At 1 April 2019 there were 6,101 packages of conditioned HLW in long-term storage.

Table 4: HLW at 1 April 2019 and estimated future arisings
Reported volumes, masses, packaged volumes and package numbers

		Reported volume (m^3)(1)	Reported mass (tonnes)(1)	Packaged volume (m^3)	No of packages
Stocks at 1.4.2019	Not yet packaged	1,240	1,600	-	-
	Already packaged	915	2,400	1,200	6,101
Future arisings		See note 2	See note 2	See note 2	See note 2
Total		**1,390**	**3,200**	**1,500**	**7,660**

(1) Volume and mass "not yet packaged" are for HAL; volume and mass "already packaged" are the conditioned volume and corresponding mass for waste that has been encapsulated in glass.

(2) From 1 April 2019 there is a net decrease in the reported volume and mass of HLW because accumulated HAL is being conditioned, which reduces its volume and mass by about two-thirds, and also because vitrified HLW is being exported to overseas customers.

Future arisings of HLW are forecast from continuing Magnox fuel reprocessing, which is scheduled to end in 2020. Reported volumes of HLW will actually fall in the future. There are two reasons for this. Firstly, and most significantly, due to evaporation and vitrification (the vitrified glass blocks are roughly one-third of the volume of the original HAL). Secondly future arisings of HLW are net of exports to overseas reprocessing customers (see Section 14 for more information).

Sellafield currently forecasts that operations to produce vitrified HLW will end in around 2021; although further vitrified wastes will arise during the subsequent Post Operational Clean Out (POCO) phase, which is expected to continue until 2029. Total HLW generated is forecast to be 7,660 waste packages (1,500 m^3 packaged volume).

Intermediate Level Waste

At 1 April 2019 the reported volume of ILW was about 102,000 m^3, of which about 76,100 m^3 (75%) was at Sellafield. Most of the other ILW was at the Magnox and AGR power stations (10,700 m^3 and 3,570 m^3 respectively), Dounreay (5,070 m^3), Aldermaston (4,460 m^3) and Harwell (1,240 m^3).

ILW is also being safely stored pending the availability of a disposal route for this waste category[25]. At 1 April 2019 there were 67,307 packages of ILW in long-term storage facilities. Of these 58,648 (87%) were at Sellafield.

**Table 5: ILW at 1 April 2019 and estimated future arisings
Reported volumes, masses, packaged volumes and package numbers**

		Reported volume (m^3)(1)	Reported mass (tonnes)(1)	Packaged volume (m^3)	No of packages
Stocks at 1.4.2019	Not yet packaged(2)	66,900	61,000	-	-
	Already packaged	35,100	66,000	46,300	67,307(3)
Future arisings		145,000	150,000	335,000	149,000
Total(4)		**247,000**	**280,000**	**499,000**	**292,000**

(1) Volume and mass "not yet packaged" are for untreated or partly treated waste; volume and mass "already packaged" are the conditioned volume and corresponding mass for wastes that have been encapsulated in a cement-based material or polymer.

(2) ILW "not yet packaged" includes 1,490 m^3 reported volume that is expected to be disposed of as LLW.

(3) ILW package numbers include 1,938 of 1803-type mild steel drums. These drums are expected to be overpacked in larger capacity boxes (6 drums per box).

(4) ILW includes 8,640 m^3 of waste that is expected to become LLW as a result of decontamination or decay storage. This comprises 1,490 m^3 at 1.4.2019 and 7,150 m^3 for future arisings.

The reported volume for forecast future arisings of ILW is about 145,000 m^3. About 72,300 m^3 (50%) is from Sellafield. Most of the other ILW is from Magnox power station sites (42,600 m^3) and AGR power station sites (20,800 m^3).

About 114,000 m^3 (78%) of all forecast future arisings are from decommissioning of existing reactors and other facilities. The remainder are from ongoing plant operations.

[25] *Discrete items of short-lived ILW may be suitable for near-surface disposal after a period of decay storage.*

Figure 6: ILW future arisings
Annual reported volumes

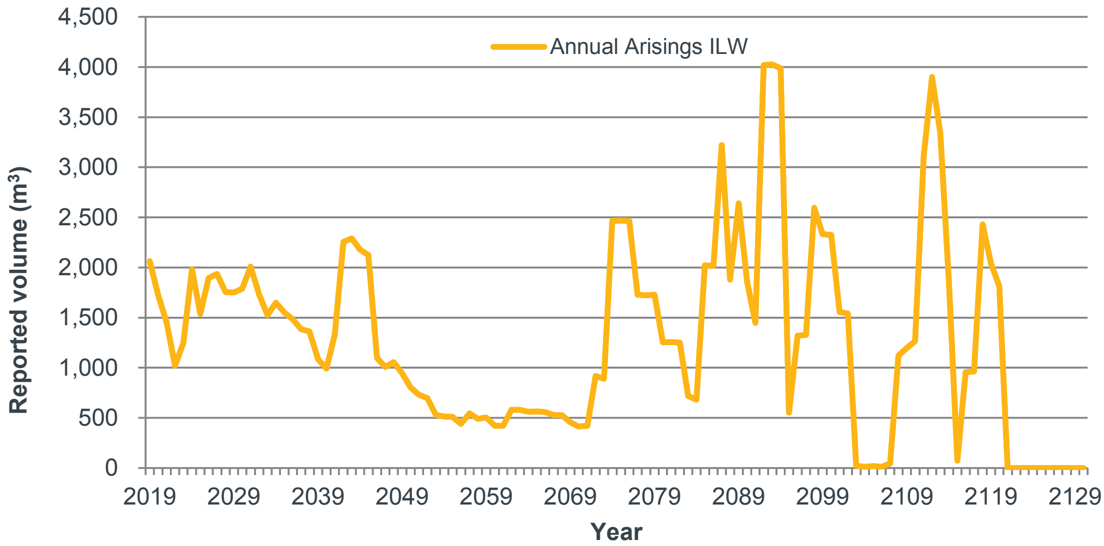


Figure 6 illustrates the pattern of future ILW arisings volumes. Forecast annual arisings of ILW average about 1,600 m^3 in the period up to about 2045, largely from legacy waste conditioning and facilities decommissioning at Sellafield. From 2045 to 2070 the annual arisings are largely from decommissioning at Sellafield. Final dismantling and site clearance at Magnox and AGR stations between 2070 and 2121 gives rise to higher but changeable annual volumes over this period.

Low Level Waste

At 1 April 2019 the reported volume of LLW was about 27,400 m^3, of which about 15,700 m^3 (57%) was at Dounreay. Most of the other LLW was at Sellafield (3,010 m^3), Aldermaston (1,780 m^3) and Harwell (1,330 m^3). Most LLW at 1 April 2019 was in temporary storage awaiting recycling if suitable, or disposal to landfill or the LLWR.

Table 6: LLW at 1 April 2019 and estimated future arisings
Reported volumes, masses, packaged volumes and package numbers

		Reported volume (m^3)(1)	Reported mass (tonnes)(1)	Packaged volume (m^3)	No of packages
Stocks at 1.4.2019	Not yet packaged(2)	22,700	28,000	-	-
	Already packaged	4,640	10,000	6,990	1,324
Future arisings(3)		1,450,000	1,800,000	1,240,000	20,800
Total		**1,480,000**	**1,900,000**	**1,250,000**	**22,300**

(1) Volume and mass "not yet packaged" are for untreated or partly treated waste; volume and mass "already packaged" are the conditioned volume and corresponding mass for wastes that have been encapsulated in a cement-based material or polymer.

(2) "Not yet packaged" includes 30 m^3 reported volume of mixed LLW/VLLW at Springfields.

(3) LLW includes 248,000 m^3 reported volume of mixed LLW/VLLW at Springfields.

The forecast future arisings of LLW are about 1,450,000 m^3. This includes about 248,000 m^3 of mixed LLW/VLLW from Springfields that can be routed to landfill.

About 467,000 m^3 (32%) of all forecast future LLW arisings are from Magnox power station sites (excluding Calder Hall). Much of the other LLW is from Sellafield (450,000 m^3 - including 39,400 m^3 from Calder Hall), Springfields (249,000 m^3), AGR power stations (109,000 m^3), and Dounreay (78,000 m^3).

Approximately 1,240,000 m^3 (86%) of all forecast future arisings of LLW are from the decommissioning of reactors and other facilities, and from site remediation. Only 209,000 m^3 (14%) are from plant operations; about 115,000 m^3 of which is from Sellafield.

Final stage decommissioning of reactors and ancillary plant at Magnox and AGR power stations is forecast to produce 478,000 m^3 and 61,000 m^3 of LLW respectively. Decommissioning of uranium processing and fabrication facilities at Springfields is forecast to produce 198,000 m^3 of LLW. Decommissioning of facilities at Sellafield is forecast to produce about 335,000 m^3 of LLW.

Figure 7: LLW future arisings
Annual reported volumes

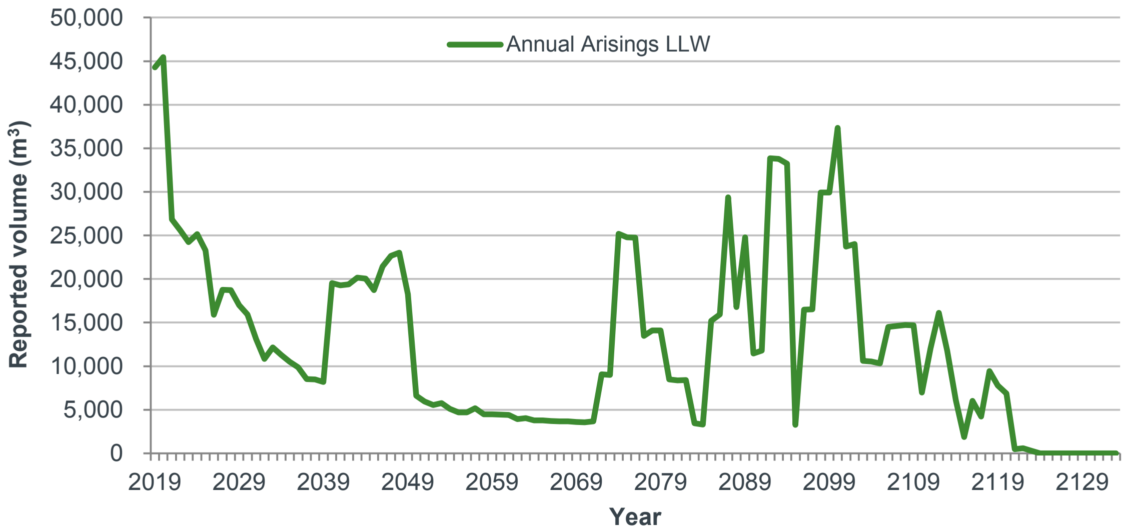


Figure 7 illustrates the pattern of future LLW arisings volumes. Forecast annual arisings decrease from about 45,000 m^3 to about 8,000 m^3 over the period up to 2040. This is the result of a number of factors including the completion of Magnox and oxide fuel reprocessing operations at Sellafield, the completion of Care and Maintenance (C&M) preparations at Magnox stations, the closure of AGR power stations, defuelling and C&M preparations, lower volumes of general waste at Springfields, and the completion of decommissioning activities at Dounreay, Harwell and Winfrith.

From 2040 up to 2050 forecast annual arisings are higher as a result of the decommissioning of uranium processing and fabrication facilities at Springfields. From 2050 up to about 2070 average annual arisings are lower at about 5,000 m^3, and much of this waste is from facilities decommissioning at Sellafield. Final dismantling and site clearance at Magnox and AGR stations between 2070 and 2121 give rise to higher but changeable annual volumes over this period.

Very Low Level Waste

At 1 April 2019 the reported volume of VLLW was about 1,040 m^3, of which 472 m^3 was at Harwell and 415 m^3 was at Hinkley Point A. All VLLW was in temporary storage awaiting treatment or disposal.

Table 7: VLLW at 1 April 2019 and estimated future arisings
Reported volumes, masses, packaged volumes and package numbers

		Reported volume (m^3)(1)	Reported mass (tonnes)(1)	Packaged volume (m^3)	No of packages(2)
Stocks at 1.4.2019	Not yet packaged	1,040	920	-	-
	Already packaged	0	0	0	-
Future arisings		2,830,000	2,900,000	2,690,000	-
Total		**2,830,000**	**2,900,000**	**2,690,000**	**-**

(1) Volume and mass "not yet packaged" are for untreated or partly treated waste; volume and mass "already packaged" are the conditioned volume and corresponding mass for wastes that have been encapsulated in a cement-based material or polymer.

(2) As VLLW can be disposed to appropriately permitted landfill sites no package numbers are collated for this waste category in the Inventory.

Figure 8 illustrates the pattern of future VLLW arisings volumes. The forecast future arisings of VLLW are about 2,830,000 m^3. About 2,760,000 m^3 (98%) of this volume is attributable to waste from the decommissioning of reprocessing and associated plants, waste storage and treatment plants, and site service facilities at Sellafield. However, there is a large uncertainty about how much of this will be managed as radioactive waste; current expectations are that about 70% of the material, which comprises concrete, brick and metal from building structures, may be out of scope of regulatory control. As decommissioning projects at the site are progressed and opportunities for further characterisation arise the projected amounts of radioactive waste will continue to be refined. Forecast annual arisings of VLLW are on average about 12,000 m^3 in the period up to 2040. Thereafter they increase due to planned decommissioning projects at Sellafield.

Figure 8: VLLW future arisings
Annual reported volumes

Aerial view of Sellafield site

9 RADIOACTIVITY IN WASTES

Key facts:

- Radioactivity in LLW and VLLW is significantly lower than that in HLW and ILW.
- Total radioactivity at 1 April 2019 (84 million TBq) is mainly in HLW.
- Total radioactivity reduces over time - by 2200 total radioactivity will be more than 40 times lower, in 1,000 years it will be 500 times lower and in 100,000 years it will be more nearly 6,500 times lower.

Information on radioactivity is important for managing the safe handling, storage, transport and disposal of radioactive wastes.

Waste producers report the radioactivity concentration of waste in stocks at the inventory reference date of 1 April 2019 or, for future waste arisings, at the time that the waste will be generated. Activities (in TBq) given in this section have been derived from reported radioactivity concentrations (in TBq/m^3) and volumes (in m^3) for each waste stream[26].

The radioactivity of waste reduces over time as it undergoes radioactive decay. This means that the total radioactivity of all wastes in the 2019 Inventory will change as new wastes arise and existing wastes decay. Hence we can only determine the total radioactivity of wastes by selecting reference points in time and calculating the radioactivity at those dates.

Total radioactivity is made up of the sum of the radioactivities of radionuclides (or radioisotopes) present in the wastes. The origin of a waste determines the types of radionuclide present (called a 'fingerprint').

In the 2019 Inventory there are about 100 waste streams where radioactivity concentration is not quantified, because characterisation work has yet to be completed. These streams have been reviewed, and the overall impact on total radioactivity and individual radionuclide activity estimates will be small. This is because these streams have relatively low volume and/or are expected to have relatively low radioactivity.

Because radioactivities in wastes can cover a wide range, it is sometimes necessary to use scientific notation in tables of data (e.g. 16,000 TBq is expressed as 1.6E+04 TBq and 0.00016 TBq is expressed as 1.6E-04 TBq).

Summed waste stream radioactivities reported in this section are rounded to two significant figures.

Information on the radionuclide composition for each waste category and how this composition changes over time as a result of radioactive decay can be found in the *2019 UK Radioactive Waste Detailed Data* report.

9.1 Summary for all wastes

To determine total radioactivity in waste at 1 April 2019, the radioactivities of all relevant waste streams are summed. This is valid, because the radioactivities of waste at 1 April 2019 refer to a particular point in time. For selected future dates, the total radioactivity of accumulated wastes is

[26] *For conditioned waste streams the radioactivity concentration and volume reported are those for the conditioned product.*

calculated by taking account of the radioactive decay of each waste stream. The period of decay for wastes that existed at 1 April 2019 is from that date, and for waste generated after 1 April 2019 is from the time that the waste is generated.

The radioactivities given in Table 8 are those for all wastes at 1 April 2019, 2050, 2100 and 2200. The values show that most of the activity is in HLW.

Table 8: Total activity of all wastes

Waste category	Total radioactivity (TBq)			
	At 1.4.2019	At 1.4.2050	At 1.4.2100	At 1.4.2200
HLW	80,000,000	37,000,000	12,000,000	1,500,000
ILW	4,100,000	2,000,000	1,000,000	460,000
LLW	32	180	140	89
VLLW	0.09	4.5	11	14
Total	**84,000,000**	**39,000,000**	**13,000,000**	**1,900,000**

Although the majority of radioactivity is associated with HLW, this waste category represents a very small volume relative to other categories in the 2019 Inventory. In contrast, very little radioactivity is associated with LLW and VLLW although these waste categories represent most of the waste volume in the 2019 Inventory (see Figure 3). Figure 9 below illustrates this relationship between radioactivity and volume for each waste category.

Figure 9 Relationship between the total reported volume and its radioactivity at 1.4.2200

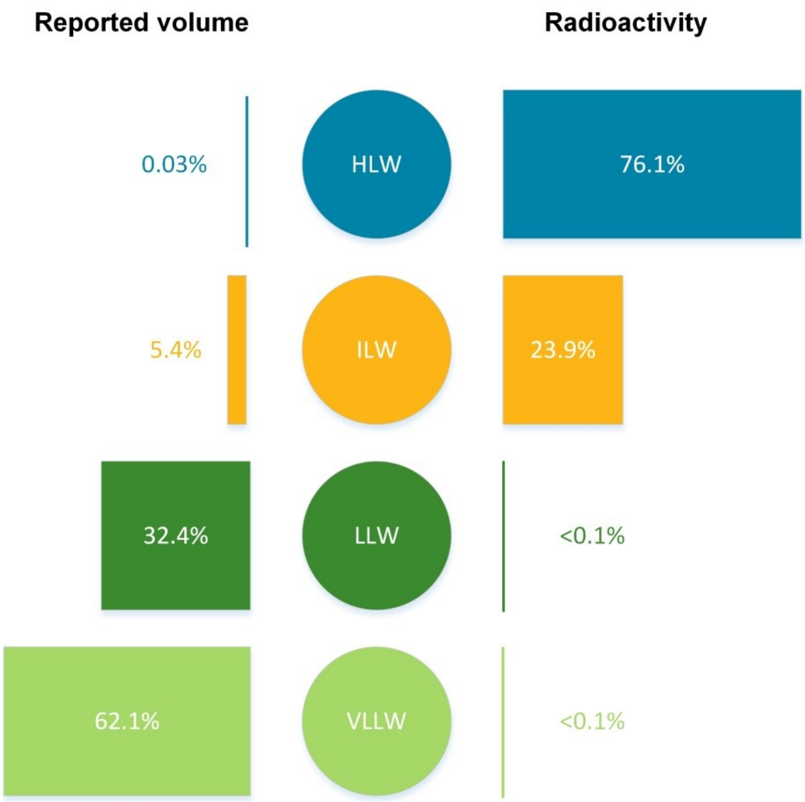
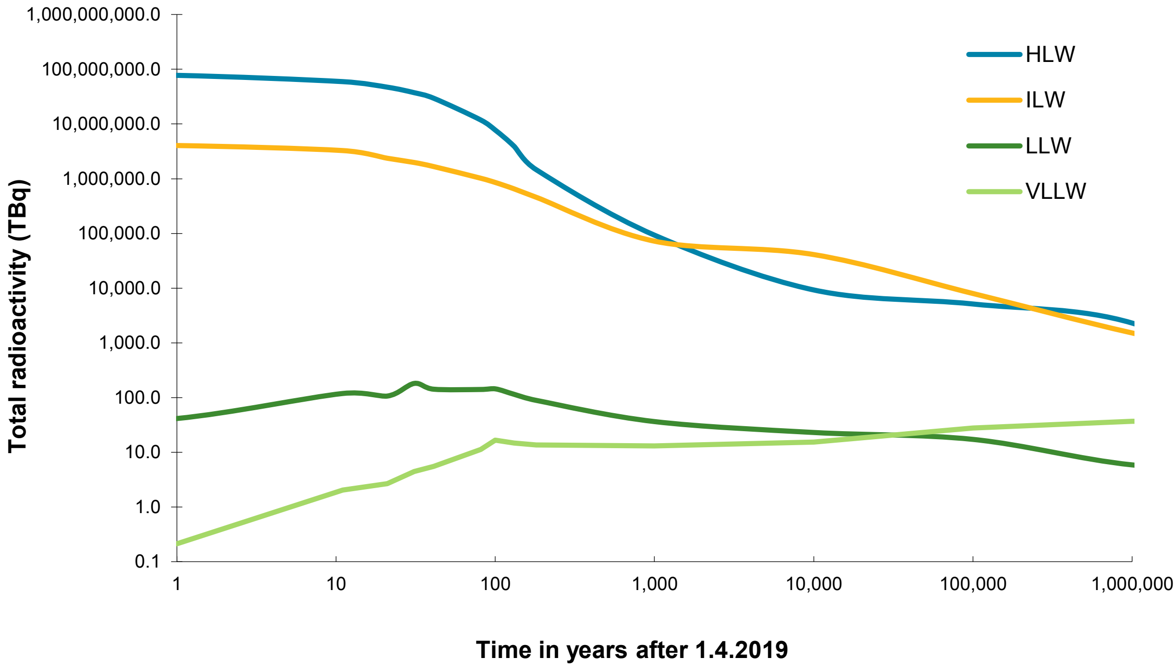


Figure 10 illustrates how the total radioactivities of HLW, ILW, LLW and VLLW change with time after 1 April 2019.

Figure 10: Total radioactivity of wastes as a function of time post 1 April 2019



There are a number of aspects to note:

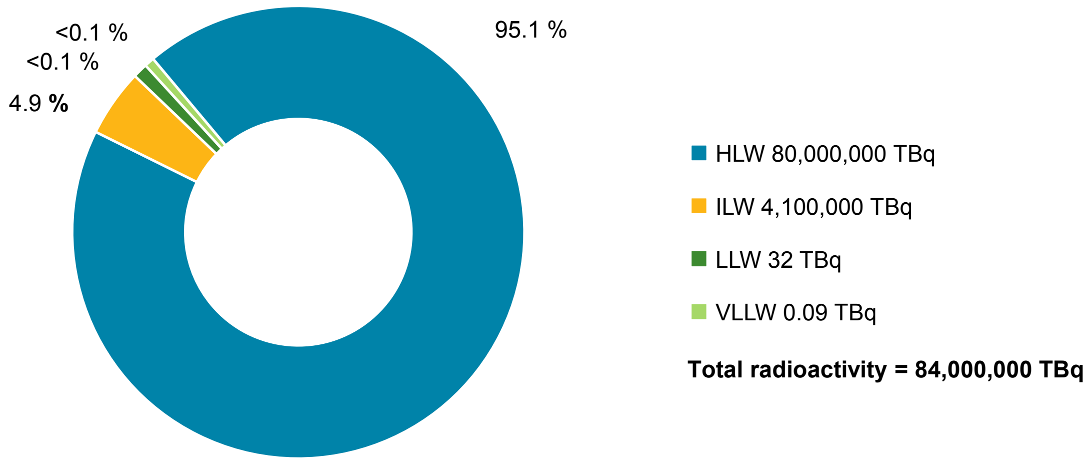
- Total radioactivities of HLW and ILW initially decrease slightly as the reduction in radioactivity from the decay of accumulated arisings is greater than the additional radioactivity in projected future arisings. In contrast total radioactivities of LLW and VLLW increase; this is because stocks at 1 April 2019 are relatively small and projected future arisings over the next 100 years are considerably larger (see Figures 7 and 8)
- Once all projected waste has arisen, total radioactivities fall in a manner that reflects the decay of the major radionuclide species. No HLW is projected to arise after 2029. There are no further arisings of ILW, LLW and VLLW beyond 2135 when the final stage decommissioning of all existing power reactors, the dismantling of all other nuclear plants and site clean-up activities are forecast to be complete
- The total radioactivities of HLW and ILW exhibit decreases of many orders of magnitude over time as radionuclide components with shorter half-lives decay
- LLW shows a markedly smaller decrease in radioactivity over time from its peak level than either HLW or ILW. This is because a relatively high proportion of the radioactivity at the time of generation is from uranium, which has a very long half-life
- There is an initial rise in the radioactivity of VLLW because large quantities of waste are generated over the next 100 years. Thereafter the radioactivity of VLLW is dominated by uranium and its daughter products.

9.2 Radioactivity at 1 April 2019

The total radioactivity of all wastes at 1 April 2019 was about 84,000,000 TBq. Figure 11 shows the relative contributions of HLW, ILW, LLW and VLLW to this total.

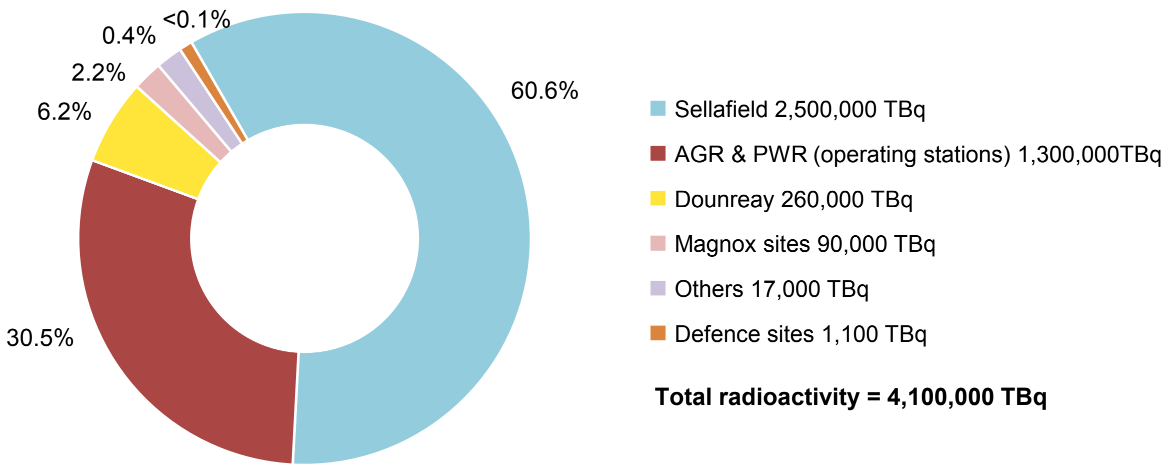
Most of the radioactivity was contained in HLW. The total radioactivity in ILW was lower, while the radioactivity contents of LLW and VLLW were comparatively very small. HLW is produced from spent fuel reprocessing at Sellafield. Figure 12 illustrates the origin of radioactivity in ILW at 1 April 2019.

Figure 11: Proportions of radioactivity by waste category at 1 April 2019



The major contributor is ILW from spent fuel reprocessing at Sellafield, where radioactivity is present in fuel cladding and process wastes. The AGR and PWR power stations are the other major source of radioactivity. Most of this radioactivity is generated as activation products in fuel element and reactor core components that have been subjected to neutron irradiation.

Figure 12 Proportions of radioactivity by waste origin in ILW at 1 April 2019



Most LLW is held in interim storage on the site of arising for a short period only before being consigned for disposal, recycled or diverted for metal treatment or incineration, so the origin of the waste at any one date is subject to change. VLLW is similarly managed.

10 WASTE COMPOSITION

Key facts:

- Radioactive wastes arise in a variety of chemical and physical forms.
- HLW is processed into a glass waste form.
- ILW comprises a number of different forms, with graphite and PCM making up ~42% by volume.
- LLW is ~75% by volume miscellaneous contaminated materials and concrete & rubble.
- VLLW comprises almost 90% by volume concrete & rubble.
- The total mass of all wastes at 1 April 2019 and for future arisings is 5,100,000 tonnes.

In the UK, radioactive materials are used for a wide range of purposes, including nuclear power generation and a variety of medical, industrial and research activities. The radioactive wastes that are produced from these activities take many different forms and have varying physical, chemical and radiological properties. Waste can range from large solid items that are relatively inert to chemically reactive sludges and liquids.

These different forms of waste may need separate management arrangements. This could include particular conditioning and packaging solutions appropriate for their properties. To facilitate an explanation of the forms of waste that are generated, and how these forms are to be processed and stored, they are assigned to 24 different waste groups (see the *2019 UK Radioactive Waste Detailed Data* report for a list of the waste groups).

Subsections 10.1-10.3 below describe the composition of ILW, LLW and VLLW in terms of the volumes of these waste groups. HLW has its own single waste group because all HLW is managed the same way; HLW is vitrified, meaning that it is processed into a glass waste form.

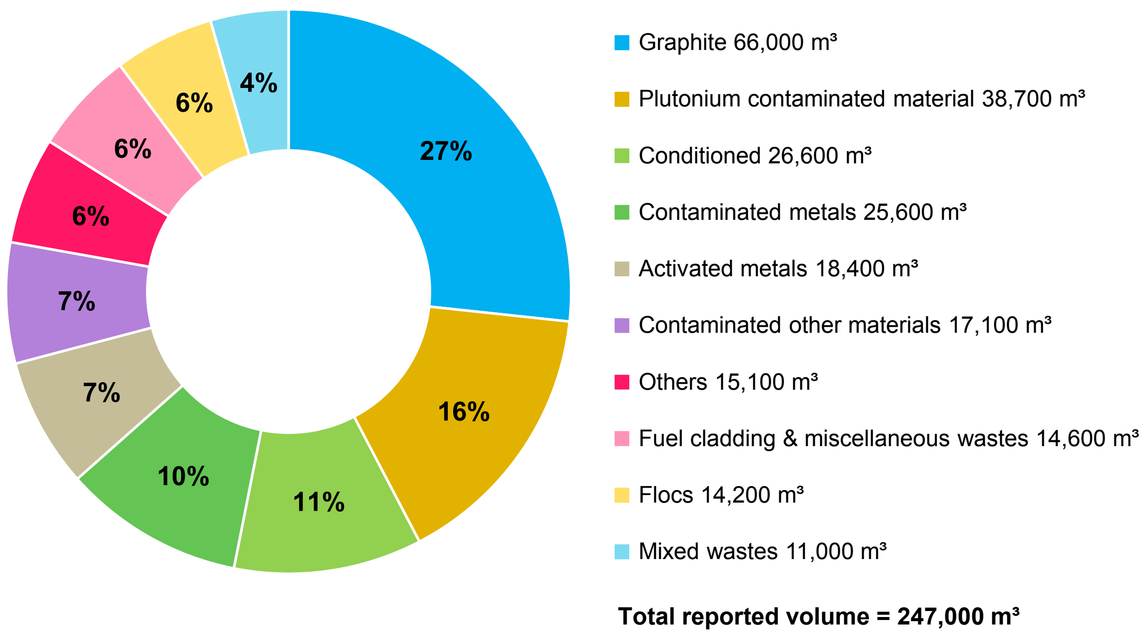
Section 10.4 gives a separate breakdown of the wastes in terms of their component material masses (metal, organic and inorganic species).

The mass of conditioned HLW at 1 April 2019 was 2,400 tonnes. A further 1,600 tonnes of liquid waste remained to be conditioned. Once all waste at 1 April 2019 and projected future arisings of liquid waste and contaminated scrap items are conditioned the total mass will be about 3,200 tonnes. This mass does not include HLW that will be exported.

10.1 Intermediate Level Waste

Figure 13 illustrates the waste groups that make up the total reported volume of ILW.

Figure 13: Composition of ILW by waste group



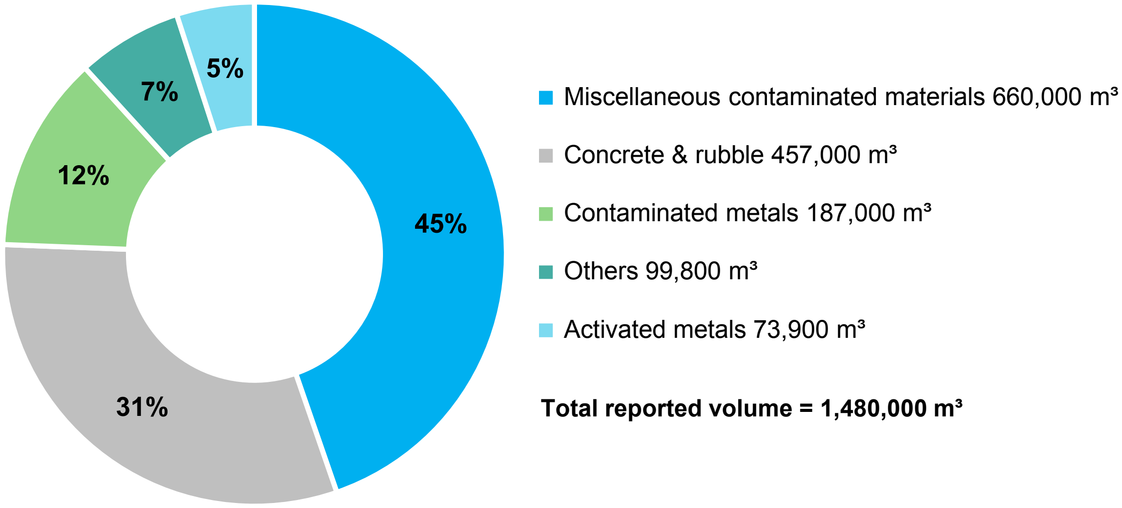
The two largest waste groups – graphite and plutonium contaminated material (PCM) – account for over 42% of the total ILW reported volume. Most graphite is associated with Magnox and AGR cores and will arise during final stage decommissioning of the reactors. PCM is mainly from spent fuel reprocessing and future facilities decommissioning at Sellafield as well as plutonium plant decommissioning at Aldermaston.

Two other waste groups – conditioned and contaminated metals - each contribute more than 10% of the total ILW reported volume. Conditioned includes all conditioned wastes in the inventory, most comprising waste in a cement-based matrix. The majority (78%) of conditioned waste is at Sellafield, including fuel cladding (Magnox, AGR and LWR), PCM and flocculant. The majority of contaminated metals arise from plant decommissioning at Sellafield.

10.2 Low Level Waste

Figure 14 illustrates the waste groups that make up the total reported volume of LLW.

Figure 14: Composition of LLW by waste group

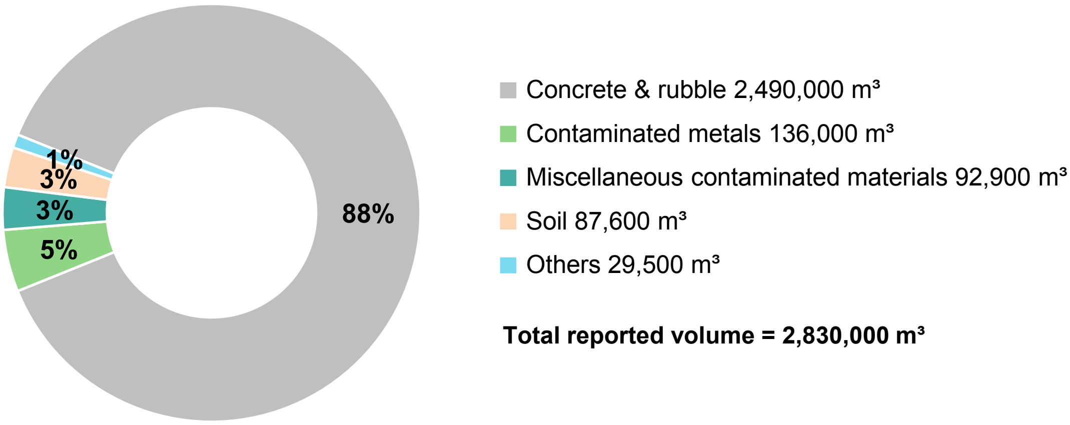


Two waste groups - miscellaneous contaminated materials and concrete & rubble – account for about 75% of the total LLW reported volume. Miscellaneous contaminated materials are mainly from routine operations, demolition and excavation projects at Sellafield and the decommissioning of uranium processing and fabrication facilities at Springfields. Concrete and rubble arises mostly from the decommissioning of Magnox reactors, while most contaminated metals are from decommissioning and arise across the inventory.

10.3 Very Low Level Waste

Figure 15 illustrates the waste groups that make up the total reported volume of VLLW.

Figure 15: Composition of VLLW



Almost 90% of VLLW is comprised of concrete & rubble, with smaller quantities of contaminated metals, miscellaneous contaminated materials and soil. Most VLLW is from the decommissioning of reprocessing and associated plants, waste storage and treatment plants, and site service facilities at Sellafield. Sellafield's best estimate, albeit based on limited decommissioning experience, is that about 70% of this waste may be exempt from regulatory control.

10.4 Waste component masses

Table 9 gives the total masses of material components in HLW, ILW, LLW and VLLW. This includes wastes at 1 April 2019 that had already been conditioned as well as future arisings that are reported as conditioned waste.

Table 9: Mass of materials by waste category

Material	Mass (tonnes)			
	HLW	ILW	LLW	VLLW
Metals:				
Stainless steel	1.9	28,000	150,000	8.2
Other steel	-	32,000	370,000	1,100
Iron	-	3,200	37,000	4,300
Magnox/magnesium	-	6,500	130	0.11
Aluminium	-	1,900	19,000	8.1
Zircaloy/zirconium	-	1,300	240	0.11
Copper & alloys	-	300	13,000	440
Nickel & alloys	21	88	1,100	-
Uranium	-	1,000	970	55.0
Other metals	-	1,400	41,000	140,000
Organics:				
Cellulosics	-	1,200	68,000	41,000
Plastics	-	4,600	89,000	830
Rubbers	-	1,100	16,000	210
Ion exchange resins	-	430	200	-
Hydrocarbons	-	46	8,100	1,100
Other organics	-	370	31,000	19,000
Inorganics:				
Asbestos	-	66	22,000	28,000
Cementitious materials	-	64,000	780,000	2,100,000
Graphite	-	82,000	15,000	-
Sand, glass & ceramics	2,700	1,200	20,000	150
Ion exchange materials	-	3,200	74	-
Brick, stone & rubble	-	1,100	77,000	430,000
Sludges, flocculants & liquids	490	31,000	12,000	2.4
Other inorganics	-	1,200	340	27,000
Soil	-	150	92,000	140,000
Unspecified materials(1)	0	8,700	12,000	220
TOTAL	**3,200**	**280,000**	**1,900,000**	**2,900,000**

(1) *Includes wastes for which no material breakdown or a partial breakdown is reported.*

The breakdown includes only the major contributors to radioactive waste mass; there are many other minor components present in the wastes. For waste streams where characterisation data are uncertain, waste producers may have reported no material composition or only a partial composition (the unspecified materials mass is shown in the table).

11 UNCERTAINTY IN THE INVENTORY

Key facts:

- The greatest uncertainties are in radioactivities on the upper side of current best estimate values.
- Currently a small number of waste streams make a large contribution to uncertainty in volumes and radioactivities, and so can be targeted as priorities for data improvement.
- Uncertainties will reduce in the future as decommissioning experience feeds into improved inventory estimates and waste is packaged for long-term management.
- Nuclear new build will impact on future inventories.

There are a number of reasons why there is uncertainty in UK Inventory data:

- Much waste is in situ (e.g. activated reactor structures) and hasn't been fully characterised
- Waste producers' plans for their future activities, including plant operating lifetimes, can change
- Waste management strategy can change
- New waste treatment solutions and packaging technologies may be developed.

There is the highest level of confidence in the volumes, material composition and activity of waste streams that have already been packaged for long-term management, because they have been well characterised. The greatest uncertainties rest with future arisings of waste, particularly from facilities decommissioning and site clean-up where past operational experience is less relevant and future strategies may not yet be confirmed. As decommissioning projects progress through initial scoping studies, detailed planning and then implementation, and as land contamination surveys are extended and refined, waste volumes can be estimated with greater certainty.

Legacy waste streams generated many years ago may lack detailed contemporary records. As these waste streams are retrieved from storage and characterised the uncertainties on the amounts and compositions are greatly reduced.

Consequently waste estimates can change from one inventory to the next (section 13 provides a comparison of the 2019 Inventory with the previous 2016 Inventory). Furthermore, the NDA maintains an inventory Data Improvement Plan for each waste producer to support a programme of continual UK Inventory improvement.

11.1 Volumes

The 2019 Inventory includes information on the confidence levels in reported waste stream volumes. Where lower and upper uncertainties on the reported best estimate volumes can be quantified, waste producers have provided appropriate factors. These data have been used to calculate lower and upper waste volume estimates for each waste category (see Table 10).

Table 10: Estimated uncertainties in reported volumes for each waste category [(1)]

Waste category	Best estimate (m^3)	Lower estimate (m^3)	Upper estimate (m^3)
HLW	1,390	1,240	1,550
ILW	247,000	192,000	384,000
LLW	1,480,000	990,000	2,500,000
VLLW	2,830,000	1,000,000	4,140,000
Total	**4,560,000**	**2,190,000**	**7,030,000**

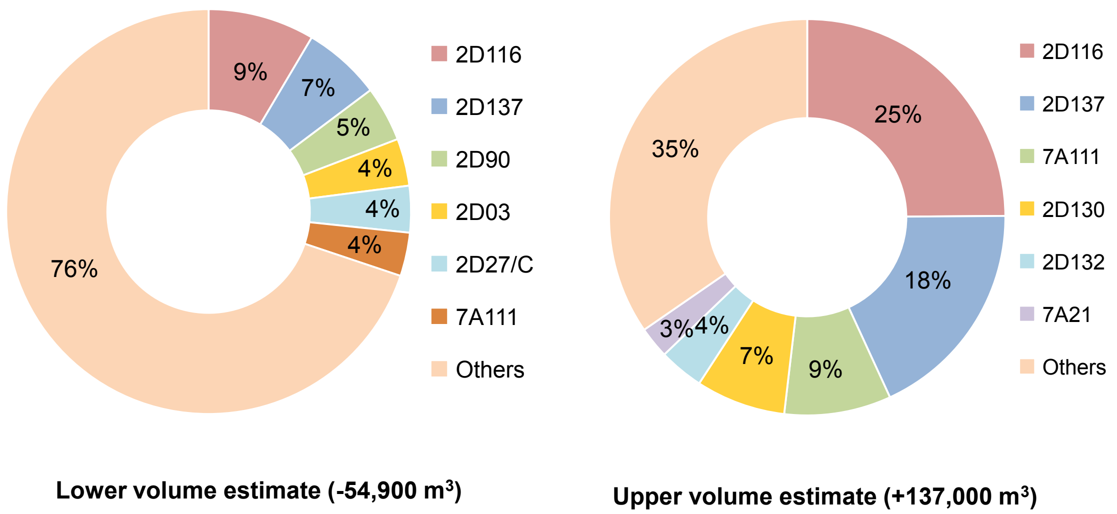
(1) The 2019 Inventory includes numerical lower and upper volume uncertainty factors on the best estimate volumes for waste streams covering more than 99% of the total reported waste volume.

The uncertainties in the HLW volume are relatively small, as spent fuel reprocessing schedules and the HAL vitrification process are well defined.

For ILW the calculated lower volume estimate is 54,900 m^3 (22%) less than the best estimate volume, while the calculated upper volume estimate is 137,000 m^3 (55%) more than the best estimate volume.

A large percentage of the uncertainties in the ILW volume can be attributed to a small number of waste streams. The major contributors are shown in Figure 16. (A list of waste streams is given in the *2019 UK Radioactive Waste Detailed Data* report). They comprise operational PCM arisings and plant decommissioning wastes at Sellafield (2D streams) and operational PCM arisings and plutonium plant decommissioning waste at AWE Aldermaston (7A streams). Volume uncertainties for the major contributing streams are higher on the upper side.

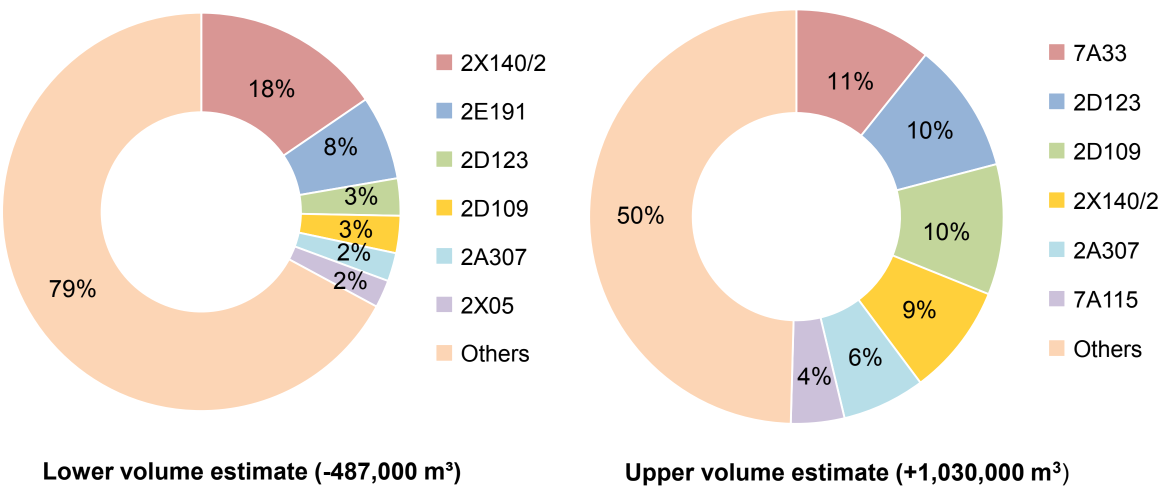
Figure 16: Waste stream percentage contribution to the change in reported best estimate volume associated with lower and upper volume uncertainty for ILW



For LLW the calculated lower volume estimate is 487,000 m^3 (33%) less than the best estimate volume, while the calculated upper volume estimate is 1,030,000 m^3 (70%) more than the best estimate volume.

A large percentage of the uncertainties in the LLW volume can be attributed to a small number of waste streams. The major contributors are shown in Figure 17. They include plant decommissioning wastes and miscellaneous wastes contaminated by aerial discharges at Sellafield (2D and 2X streams), decommissioning waste at Springfields (2E), plutonium plant decommissioning waste and radioactive contaminated land at AWE Aldermaston (7A) and concrete decommissioning waste at Calder Hall (2A). Volume uncertainties for the major contributing streams are higher on the upper side.

Figure 17: Waste stream percentage contribution to the change in reported best estimate volume associated with lower and upper volume uncertainty for LLW



Most VLLW reported in the Inventory is generated from future decommissioning projects at Sellafield. The best estimate of Sellafield VLLW volume is 2,700,000 m^3, but there is a large uncertainty in the potential arisings. Improved inventory assessments have refined the likely lower and upper bounds to be 1,000,000 m^3 and 4,000,000 m^3. Also, Sellafield has stated its current best estimate volume, based on limited decommissioning experience, is that approximately 70% of the waste may be exempt from regulatory control.

Strategies for site end states can differ; hence some sites might generate much more VLLW from land remediation work than others.

Radioactive land contamination and radioactively contaminated subsurface structures at certain sites have not been included in the Radioactive Waste Inventory where clean-up plans have not been confirmed and there is significant uncertainty over the management route and the waste quantities. Volume estimates can be found in the *2019 UK Material Inventory* report. As land contamination surveys are extended and refined, and there is more certainty on management routes, waste volumes can be determined with increasing confidence.

11.2 Radioactivities

The 2019 Inventory includes information on the confidence levels in waste stream radioactivities and radionuclide concentrations. These data have been used to calculate lower and upper waste radioactivity estimates at the stock date of 1 April 2019 and decayed radioactivities at 2200 for each waste category (see Table 11).

Table 11: Estimated uncertainties in total radioactivity for each waste category

Waste type	At 1.4.2019 (TBq)			At 1.4.2200 (TBq)		
	Best estimate	Lower estimate	Upper estimate	Best estimate	Lower estimate	Upper estimate
HLW	80,000,000	53,000,000	120,000,000	1,500,000	970,000	2,200,000
ILW	4,100,000	1,200,000	110,000,000	460,000	110,000	13,000,000
LLW	32	7.2	230	89	11	1,800
VLLW	0.09	0.002	0.95	14	0.33	130
Total	**84,000,000**	**54,000,000**	**230,000,000**	**1,900,000**	**1,100,000**	**15,000,000**

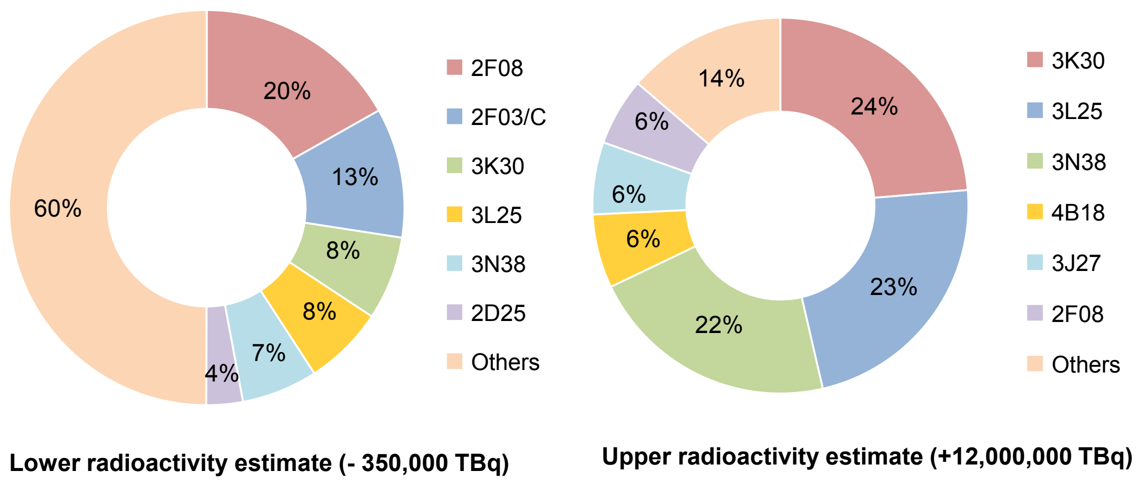
The uncertainties on radioactivity are greater than those on volume because there are greater uncertainties associated with the sampling, measurement and calculation processes.

The uncertainties in the HLW radioactivity are relatively small, as HAL and the vitrified product are well characterised.

For ILW the calculated lower radioactivity estimate at 2200 is 350,000 TBq (76%) less than the best estimate radioactivity, while the upper radioactivity estimate is over 12,000,000 TBq (2,600%) more than the best estimate radioactivity.

A large percentage of the uncertainties in the ILW radioactivity can be attributed to a small number of waste streams. The major contributors are shown in Figure 18. They are fuel cladding wastes at Sellafield (2D & 2F streams) and AGR activated components and fuel component debris. The radioactivities of the AGR streams are based on theoretical estimates and have associated lower and upper uncertainty factors of 0.01 and 100.

Figure 18: Waste stream percentage contribution to the change in reported best estimate activity associated with lower and upper activity uncertainty for ILW at 2200

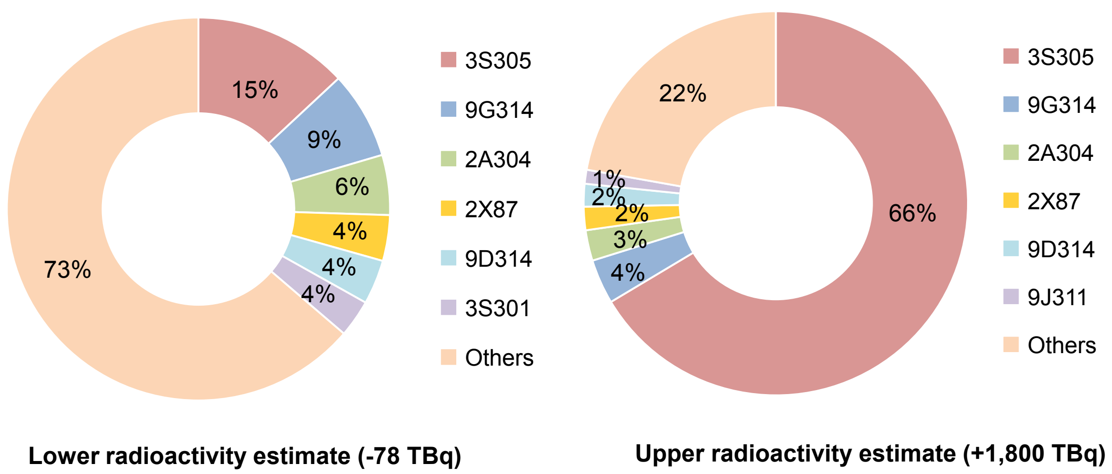


The radioactivities of LLW and VLLW are small in comparison to HLW and ILW. Uncertainties are relatively high because the majority of radioactivity is from plant decommissioning wastes, but their impact on total radioactivity in the 2019 Inventory is negligible.

For LLW the calculated lower radioactivity estimate at 2200 is 78 TBq (88%) less than the best estimate radioactivity, while the upper radioactivity estimate is about 1,800 TBq (2,000%) more than the best estimate radioactivity.

A large percentage of the uncertainties in LLW radioactivity can be attributed to a small number of waste streams, as illustrated in Figure 19. They are mostly made up of decommissioning wastes from the Sizewell B PWR (3S streams) and Magnox power stations (2A, 9G, 9D & 9J streams).

Figure 19: Waste stream percentage contribution to the change in reported best estimate activity associated with lower and upper activity uncertainty for LLW at 2200



The uncertainties in the VLLW radioactivity are dominated by the waste arisings from future decommissioning projects at Sellafield, where the lower and upper uncertainty factors are 0.1 and 100.

Retrieval of decanner section from legacy pond, Sellafield

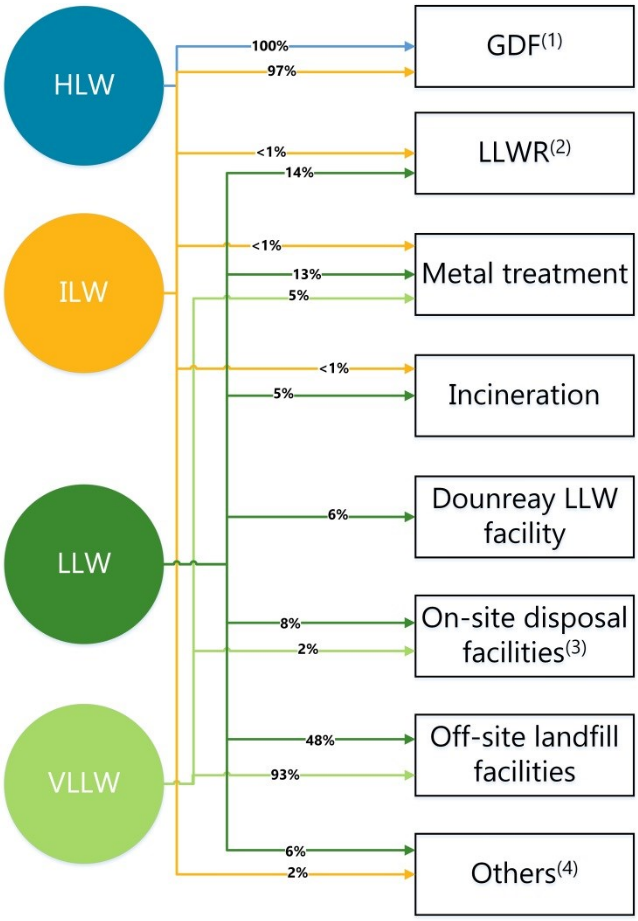
12 WASTE DISPOSALS

Key facts:

- More LLW is being diverted away from the LLWR where annual disposals are at historical lows.
- Disposals are being made to the Dounreay LLW facility from decommissioning at the site.

The UK Inventory compiles data on waste producers' waste disposal plans. Disposal routes for HLW, ILW, LLW and VLLW in the 2019 Inventory are illustrated in Figure 20. All HLW and nearly all ILW will be disposed to a GDF. Small fractions of ILW are to be diverted using LLWR's waste services framework for metal treatment, incineration or disposal at the LLWR. Most LLW is forecast to be diverted away from the LLWR for incineration, metal treatment or authorised landfill disposal.

Figure 20: Projected disposal routes for radioactive wastes in the 2019 Inventory (% of reported volumes)



(1) The Scottish Government policy is that long-term management of higher activity wastes should be in near-surface facilities.

(2) All ILW projected for disposal to the LLWR will have decayed to LLW by the time of its disposal.

(3) On-site disposal facilities comprise the Calder Landfill Extension Segregated Area (CLESA) facility at Sellafield.

(4) Others' comprises recycling/reuse, material expected to be 'out of scope' once recharacterised and wastes for which no disposal route is given in the 2019 Inventory.

There is greater certainty in how lower activity wastes (LAW) will be managed in the near term.

Figure 21 shows the disposal routes for LLW forecast to arise over the next six years (2019-2024 inclusive). Only about 11% of the reported volume is expected to be disposed of at the LLWR. All other LLW is expected to be disposed of at the Dounreay LLW facility or be diverted away from the LLWR, with the majority routed to appropriately permitted landfill sites, or for metal treatment or incineration. All VLLW in this period is expected to be disposed of at appropriately permitted landfill sites or sent for metal treatment.

A small volume of ILW (1,810 m^3) forecast to arise over the next six years is expected to diverted as LAW using LLWR's waste services framework. The majority of this waste (1,170 m^3) is expected to be disposed of at the LLWR.

Figure 21: Projected routing of LLW arising in the period 2019-2024

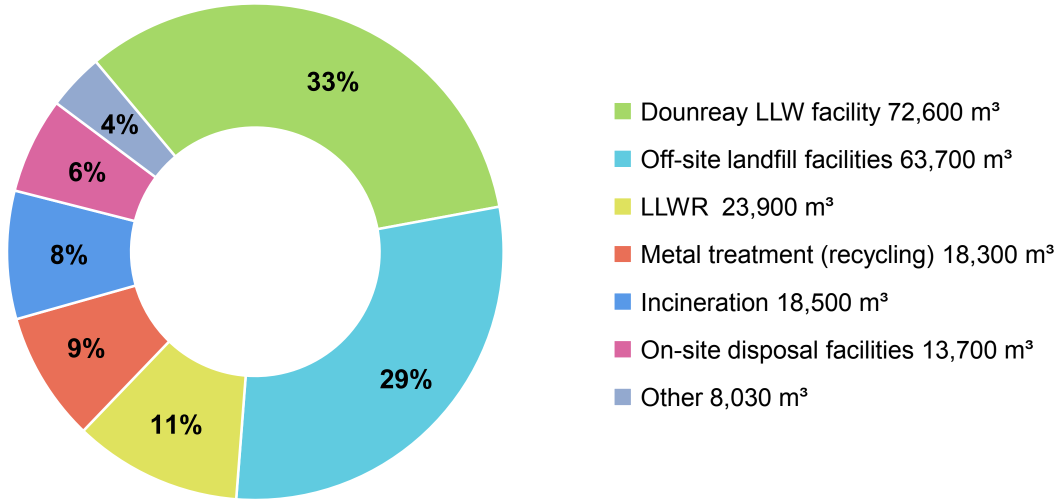


Table 13 provides an analysis of projected disposal routes for LLW and VLLW in the 2019 inventory, comprising stocks at 1 April 2019 and all forecast future arisings. The arisings are projected far into the future and so have high uncertainties associated with them. The table shows that about half of all LLW by volume is expected to be disposed of at off-site landfill facilities, with less than 15% expected to be disposed of at the LLWR.

The 2019 Inventory data show that increasing amounts of LLW are expected to be diverted for landfill disposal, on-site disposal or metal treatment compared with previous inventories. Also, more waste is expected to be out of scope of regulatory control when it arises. In the 2016 Inventory over half of all LLW was forecast to be disposed of at the LLWR and only 18% at off-site landfill facilities.

Most VLLW is consigned for disposal at suitably authorised and permitted landfill sites, with smaller amounts disposed at on-site landfill facilities or sent for metal treatment or incineration. The proportions are similar to those reported in the 2016 Inventory.

Table 13: Projected routing of LLW and VLLW - wastes at 1 April 2019 and estimated for future arisings

Expected waste route	LLW		VLLW	
	Reported volume (m^3)	Reported volume (%)	Reported volume (m^3)	Reported volume (%)
LLWR	214,000	14.5	-	-
Off-site landfill facilities	706,000[(1)]	47.8	2,640,000	93.1
On-site disposal facilities[(2)]	122,000	8.3	54,300	1.9
Dounreay LLW facility	89,000	6.0	-	-
Metal treatment	190,000	12.9	141,000	5.0
Incineration	68,300	4.6	579	0.02
Recycled / reused	11,000[(3)]	0.7	-	-
Out-of-scope[(4)]	60,700[(5)]	4.1	-	-
Unconfirmed	15,700	1.1	-	-
Total	**1,480,000**	**100**	**2,830,000**	**100**

(1) About 310,000 m^3 is concrete from final stage decommissioning of Magnox reactors and 238,000 m^3 of mixed LLW/VLLW at Springfields.

(2) Comprises the Calder Landfill Extension Segregated Area (CLESA) facility at Sellafield.

(3) Includes 9,860 m^3 of mixed LLW/VLLW at Springfields.

(4) Following treatment or characterisation, waste is expected to contain activity below regulatory levels.

(5) Includes 54,900 m^3 from Miscellaneous Wastes Contaminated by Aerial Discharges at Sellafield.

Consignments to the LLWR over the past ten years have totalled about 41,000 m^3 (see Table 14). Annual consignment volumes have reduced, driven primarily by application of the waste hierarchy, and by diversion of significant volumes of LLW and the development and use of alternative treatment and disposal routes.

Table 14: Consignments to the LLWR 2009 to present

Year[(1)]	Total volume (m^3)[(2)]	Year[(1)]	Total volume (m^3)[(2)]
2009	6,190	2014	3,650
2010	5,700	2015	3,320
2011	6,070	2016	3,350
2012	5,000	2017	1,810
2013	4,170	2018	1,720

(1) For period 1 April to 31 March.

(2) Volume is for waste and its primary containment and represents volumes of waste received with the intent for disposal.

At 1 April 2019 disposed waste containers in vaults at the LLWR occupied approximately 233,000 m^3.

Consignments to the Dounreay LLW facility started in 2015. Total disposals to date are given in Table 15.

Table 15: Consignments to Dounreay LLW facility 2015 to present

Year(1)	Total volume (m^3)(2)
2015	2,050
2016	1,900
2017	643
2018	0
2019(3)	78

(1) For period 1 January to 31 December.
(2) Volume is for packaged waste.
(3) Up to 31 March 2019.

Table 16 gives a projection of total waste consignments to the LLWR and Dounreay disposal vaults over the next few years. The values are packaged volumes for waste streams that are identified in the 2019 Inventory as expected to be consigned to the LLWR or for disposal at Dounreay.

Table 16: Projected future consignments to disposal facilities

Year(1)	Total packaged volume (m^3)(2)	
	LLWR	Dounreay LLW facility(3)
2019	4,410	20,500
2020	4,290	19,100
2021	3,850	17,600
2022	3,880	16,500
2023	2,880	16,400
2024	2,990	16,100

(1) For period 1 April to 31 March.
(2) Volume is the packaged volume and reflects the effect of both waste compaction and containerisation.
(3) Provisional volumes.

13 COMPARISON WITH THE 2016 INVENTORY

Key facts:

- A number of waste streams show changes in volume as inventories have been updated.
- Package numbers have increased as progress continues in conditioning HLW and ILW for long-term management.
- Stocks of LLW have decreased by almost 10% since the 2016 Inventory due to disposals.
- The forecast total LLW packaged volume has decreased by 20% since the 2016 Inventory due to changes in the routing of LLW for disposal, with more waste being diverted from the LLWR to incineration and metal treatment.

This section summarises the changes in the 2019 Inventory compared with the previous 2016 Inventory.

Information about radioactive wastes may change from one inventory to the next due to a range of technical, commercial or policy reasons:

- **Understanding of the waste streams has improved.** Some radioactive waste streams generated many years ago lack detailed contemporary records, but as these waste streams (often referred to as legacy wastes) are characterised a better understanding of amounts and compositions are gained.
- **The waste stream category has changed.** Opportunities may arise to optimise the waste lifecycle where waste streams are close to the boundary between categories; for example, decay storage or decontamination of ILW to LLW or of LLW to VLLW.
- **The strategy for managing wastes has been updated.** This may be due to more sustainable and cost-effective techniques being used such as new treatment, packaging and disposal options.
- **Operational activities have affected the amount of waste.** Volumes of waste recorded may change as waste continues to be generated, treated, conditioned and packaged.
- **Forecasts of future amounts have been updated.** Given the many decades over which arisings are projected, there are inevitable changes in future estimates, and assumptions underpinning the forecasts and plant operating lifetimes are updated.

13.1 Reported volumes

Stocks

Table 18 gives the changes in the reported volumes of waste stocks compared with the 2016 Inventory.

Table 18: Changes in stocks reported volume between the 2019 and 2016 Inventories

Waste category	Reported volume (m^3)		Change	
	2016 Inventory	2019 Inventory	(m^3)	(%)
HLW[1]	1,960	2,150	+188	+9.6
ILW	99,000	102,000	+3,000	+3.0
LLW	30,100	27,400	-2,770	-9.2
VLLW	935	1,040	+108	+11.6
Total	**132,000**	**133,000**	**+528**	**+0.4**

(1) For HLW the reported volume is for conditioned waste.

The principal reasons for changes are:

- For HLW, increases in liquid waste from Magnox and oxide fuel reprocessing and in conditioned waste from continuing vitrification
- For ILW, an increase in conditioned wastes with progress in waste packaging.
- For LLW, the decrease indicates that more waste has been consigned for treatment and disposal.

Total

Table 19 gives the changes in total projected reported volumes compared with the 2016 Inventory.

Table 19: Changes in total reported volume between the 2019 and 2016 Inventories

Waste category	Reported volume (m^3)		Change	
	2016 Inventory	2019 Inventory	(m^3)	(%)
HLW	1,150	1,390	+243	+21.2
ILW	290,000	247,000	-43,100	-14.8
LLW	1,350,000	1,480,000	+130,000	+9.7
VLLW	2,860,000	2,830,000	-25,300	-0.9
Total	**4,490,000**	**4,560,000**	**+62,400**	**+1.4**

The principal reasons for changes are:

- For HLW, a residue of liquid waste from liquor heels in the Highly Active Storage Tanks (HASTs) not previously reported.
- For ILW, a re-assessment of PCM from future decommissioning projects at Sellafield.
- For LLW, a reassessment of future arisings across the Sellafield site and a re-evaluation of general waste arisings at Springfields intended for disposal to the Clifton Marsh landfill site.

13.2 Packaged volumes and package numbers

While most wastes in stock at 1 April 2019 are in an untreated or partly treated state, increasing amounts of legacy wastes are being retrieved from stores and packaged for long-term management. Progress in the packaging of wastes, as indicated by the accumulation in the numbers of waste packages over time, is illustrated in Table 20.

Table 20: Numbers of waste packages accumulated (1)

Date	HLW	ILW	LLW(2)	Total
At 1.4.2001	2,281	21,654	23	**23,958**
At 1.4.2004	3,037	31,557	123	**34,717**
At 1.4.2007	4,319	40,797	8,527	**53,643**
At 1.4.2010	5,108	47,662	1,288	**54,058**
At 1.4.2013	5,626	55,326	2,549	**63,501**
At 1.4.2016	5,781	60,407	648	**66,836**
At 1.4.2019(3)	6,101	67,307	1,324	**75,694**

(4) The table gives the numbers of packages accumulated at various Inventory reference dates. As VLLW can be disposed to appropriately permitted landfill sites no package numbers are collated for this waste category in the Inventory.

(5) LLW package numbers exclude those in short-term storage before consignment for disposal. Packages at 1.4.2007, 1.4.2010 and 1.4.2013 include those held in vaults at the LLWR and which had not been classed as disposed under existing environmental permits. Most of the packages reported at 1.4.2007 were subsequently classed as disposed.

(6) At 1.4.2019 HLW packages were at Sellafield, ILW packages were at Sellafield, Dounreay, Harwell, Chapelcross, Berkeley, Bradwell, Oldbury, Trawsfynydd and Hunterston A, and LLW packages were mostly at Dounreay and Winfrith.

Table 21 gives the changes in total projected packaged volumes compared with the 2016 Inventory.

Table 21: Changes in total packaged volume between the 2019 and 2016 Inventories

Waste category	Packaged volume (m^3)		Change	
	2016 Inventory	2019 Inventory	(m^3)	(%)
HLW	1,500	1,500	+2.8	+0.2
ILW	449,000	499,000	+49,400	+11.0
LLW	1,600,000	1,280,000	-321,000	-20.1
VLLW	2,720,000	2,690,000	-27,300	-1.0
Total	**4,770,000**	**4,470,000**	**-299,000**	**-6.3**

The principal reasons for changes are:

- For ILW, revised packaging assumptions for Sellafield decommissioning wastes.
- For LLW, changes in the routing of waste streams for disposal with more waste being diverted from the LLWR to incineration and metal treatment.

Table 22 gives the changes in the total projected numbers of packages compared with the 2016 Inventory.

Table 22: Changes in total number of packages between the 2019 and 2016 Inventories

Waste category	Number of packages		Change	
	2016 Inventory	2019 Inventory	(number)	(%)
HLW	7,650	7,660	+14	+0.2
ILW	229,000	292,000	+62,700	+27.4
LLW	71,600	22,300	-49,300	-68.8
VLLW(1)	-	-	-	-
Total	**308,000**	**322,000**	**+13,400**	**+4.3**

(1) As VLLW can be disposed to appropriately permitted landfill sites no package numbers are collated for this waste category in the Inventory.

For LLW, the much larger decrease in package numbers than in packaged volume is because more waste is being diverted to appropriately permitted landfill sites (the Inventory does not compile data on packages numbers disposed to landfill).

13.3 Radioactivities

Table 22 gives the changes in total radioactivities at 1 April 2200 compared with the 2016 Inventory.

Table 22: Changes in radioactivity between the 2019 and 2016 Inventories

Waste category	Total radioactivity at 2200 (TBq)		Change	
	2016 Inventory	2019 Inventory	(TBq)	(%)
HLW	1,200,000	1,500,000	+260,000	+21.6
ILW	410,000	460,000	+44,000	+11.0
LLW	72	89	+17	+23.0
VLLW	13	14	+0.49	+3.8
Total	**1,600,000**	**1,900,000**	**+300,000**	**+18.8**

The changes in radioactivities are largely the result of increased waste arisings and additional radionuclide data for waste streams where they were previously not estimated.

14 WASTES FROM OVERSEAS MATERIALS

Key facts:

- Waste from reprocessing overseas spent fuel is returned to the country of origin.
- About 1,780 canisters of vitrified HLW and smaller quantities of other wastes will be exported.

A proportion of the waste from the Thorp and Magnox reprocessing plants at Sellafield results from reprocessing overseas spent fuel. All reprocessing contracts with overseas customers signed since 1976 include a provision to return packaged wastes or their equivalent (by internationally agreed substitution arrangements) back to the country of origin.

Government policy is that wastes resulting from the reprocessing of overseas spent fuel should be returned to the country of origin, and HLW should be returned as soon as practicable after vitrification. The policy allows “waste substitution” arrangements that ensure broad environmental neutrality for the UK. Waste substitution is the process whereby an additional amount of HLW from reprocessing would be returned, which is smaller in volume but equivalent in radiological terms to customers’ ILW and LLW from reprocessing that would otherwise be returned.

Exports of vitrified HLW started in January 2010 and are planned to be completed by around 2025. In total about 1,780 canisters of vitrified HLW (about 267 m^3) are planned for export, and this volume assumes that substitution arrangements are implemented.

Future arisings of HLW reported in the Inventory are net of exports to overseas reprocessing customers, so that the total volume/number of containers reported represents only the HLW that is a UK liability.

During the 1990s materials test reactor fuel was reprocessed at Dounreay for customers in Belgium, Germany, the Netherlands and Australia. The contracts and regulatory authorisations required that the radioactive wastes produced be returned to the countries of origin within 25 years of reprocessing. The contracts are backed by inter-governmental letters. A total of 123 containers of cemented waste were returned to Belgium between 2012 and 2014. In 2012 the Scottish and UK governments agreed in principle to allow waste substitution and those arrangements are currently at various stages of implementation.

Shipment of vitrified HLW from Sellafield to Japan

GLOSSARY

	~	About.
A	**AGR**	Advanced Gas-cooled Reactor.
	AWE	AWE develops nuclear warheads for the UK's deterrent at Aldermaston and Burghfield in Berkshire.
B	**Becquerel (Bq)**	The standard international unit of measurement of radioactivity – corresponding to one disintegration per second (see also kBq, MBq and TBq).
	BEIS	The Department for Business, Energy & Industrial Strategy is a ministerial department that brings together responsibilities for business, industrial strategy, science, innovation, energy, and climate change.
	Beta/gamma activity	Radioactivity associated with the emission of beta particles and/or gamma radiation.
C	**C&M**	Care and Maintenance.
	Capping material	Cement or other substance forming inactive cover over conditioned waste in a container.
	Clifton Marsh	Landfill site (near Preston).
	Conditioned volume	The volume of waste after conditioning, consisting of the waste material and encapsulating matrix.
	Conditioned waste	Radioactive waste that has undergone conditioning.
	Conditioning	The process used to prepare waste for long-term storage and/or disposal by converting it into a solid and stable form. The conditioning material may be cement, glass or polymer.
	Controlled burial	The authorised disposal of some LLW, arising principally in the non-nuclear sector, at suitable landfill sites that possess good containment characteristics.
D	**Decommissioning waste**	Wastes arising after shutdown of a facility associated with the use or handling of radioactive materials. They can consist of plant or equipment, building debris and material from the clean-up of surrounding ground.
	Disposal	The emplacement of waste in a suitable facility without intent to retrieve it.
E	**Enriched uranium**	Uranium where the U235 isotope content is above the naturally occurring 0.72% by mass.
	Enrichment	The process of increasing the abundance of fissionable atoms in natural uranium.
F	**FED**	Fuel Element Debris.
	Fission	Spontaneous or induced fragmentation of heavy atoms into two (occasionally three) lighter atoms, accompanied by the release of neutrons and radiation.
	Fission products	Atoms, often radioactive, resulting from nuclear fission.
	Flocculant	A product of flocculation, a process of coagulation by the use of reagents.
	Fuel cladding	The metal casing around the fuel.
	Fusion	A nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy.
G	**GE Healthcare Ltd**	A company that provides products and services for use in healthcare and life science research. This includes radioisotopes for medical and research users.
	GDF	Geological Disposal Facility. Deep underground facility for disposal of higher activity wastes.

	Government	A collective term for the central government bodies responsible for setting radioactive waste management policy within the UK. It comprises the UK Government, the Scottish Government and the devolved administrations of Wales and Northern Ireland.
H ▸	**HAL**	Highly Active Liquor.
	HAW	Higher Activity Waste.
	HLW	High Level Waste.
	HVVLLW	High Volume Very Low Level Waste.
I ▸	**ILW**	Intermediate Level Waste.
	ISO	International Organisation for Standardisation.
J ▸	**JET**	Joint European Torus - the internationally funded fusion project sited at Culham.
K ▸	**kBq**	Kilobecquerel (equal to 1,000 Becquerels).
L ▸	**LAW**	Lower Activity Waste.
	LLW	Low Level Waste.
	LLWR	Low Level Waste Repository. The LLWR in Cumbria has operated as a national disposal facility for LLW since 1959.
	LWR	Light Water Reactor.
M ▸	**m^3**	Cubic metres – a measure of volume.
	Magnox	An alloy of magnesium used for fuel element cladding in natural uranium fuelled gas-cooled power reactors, and a generic name for this type of reactor.
	MBGWS	Miscellaneous Beta Gamma Waste Store (at Sellafield).
	MBq	Megabecquerel (equal to 1,000,000 Becquerels).
	MEP	Magnox Encapsulation Plant (at Sellafield).
	MOD	Ministry of Defence.
N ▸	**NDA**	Nuclear Decommissioning Authority. A non-departmental public body responsible for overseeing the decommissioning and cleanup of 17 of the UK's civil public sector nuclear sites.
	NIF	National Inventory Forum. A body that brings together key radioactive waste inventory stakeholders, including the NDA, BEIS, RWM, LLW Repository Ltd, waste producers and regulators.
	Nuclear fuel	Fuel used in a nuclear reactor. Most fuel is made of uranium metal or oxide, and produces heat when the uranium atoms split into smaller fragments.
O ▸	**Operational waste**	Wastes arising from the day-to-day operations of a facility or site.
P ▸	**Packaged volume**	The volume of waste after packaging, consisting of waste material, any encapsulating matrix, any capping grout and ullage, and the container.
	Packaged waste	Radioactive waste that has undergone packaging.
	Packaging	The loading of waste into a container for long-term storage and/or disposal.
	PCM	Plutonium Contaminated Material.
	Plutonium	A radioactive element created in nuclear reactors. It can be separated from spent nuclear fuel by reprocessing. Plutonium is used as a nuclear fuel, in nuclear weapons and as a power source.
	POCO	Post Operational Clean Out. Activity after final shutdown that prepares a plant for decommissioning.
	PWR	Pressurised Water Reactor.
R ▸	**R&D**	Research & Development.
	Radioactivity	A property possessed by some atoms that split spontaneously, with release of energy through emission of a sub-atomic particle and/or radiation.

	Reprocessing	The chemical extraction of reusable uranium and plutonium from waste materials in spent nuclear fuel.
S	**SDP**	Submarine Dismantling Project.
	Small users	Organisations that use radioactive materials and create radioactive waste that are not part of the nuclear sector licensed under the Nuclear Installations Act 1965 (as amended), including hospitals, universities and industrial undertakings.
	Storage	The emplacement of waste in a suitable facility with the intent to retrieve it at a later date.
	Supercompaction	The reduction in bulk volume by the application of high external force (1,000-2,000 tonnes). It differs from routine compaction in that the original container (metal drum or box) is compacted along with its contents.
T	**TBq**	Terabecquerel (equal to 1,000,000,000,000 Becquerels).
	Thorp	Thermal Oxide Reprocessing Plant (at Sellafield).
	Treatment	A process that changes the state or form of radioactive waste to facilitate its future management.
	Tritium	An isotope of hydrogen (H-3) having a radioactive half-life of about 12 years.
	tU	Tonnes of Uranium – a measure of mass.
U	**Ullage**	The space remaining within a container above the conditioned waste matrix and any capping material.
	United Kingdom Atomic Energy Authority	A public body that manages the UK fusion research programme and operates the Joint European Torus (JET).
	Uranium	A radioactive element that occurs in nature. Uranium is used for nuclear fuel and in nuclear weapons.
V	**Vitrification**	The process of converting materials into a glass or glass-like form. Vitrification is the process used to convert liquid HLW into a borosilicate glass.
	VLLW	Very Low Level Waste.
	Vulcan	The Naval Reactor Test Establishment (NRTE), located adjacent to the Dounreay site on the north coast of Scotland.
W	**Waste package**	A container and its content of conditioned radioactive waste.
	WVP	Waste Vitrification Plant (at Sellafield).
Z	**Zircaloy**	An alloy of zirconium used for the cladding of nuclear fuel – particularly in water reactors.