



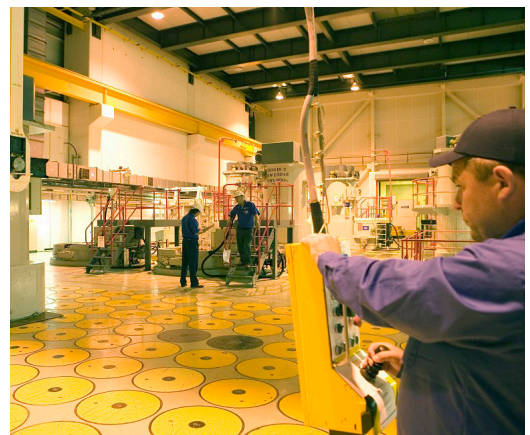
Department for
Business, Energy
& Industrial Strategy



Nuclear
Decommissioning
Authority

Radioactive Wastes in the UK:

Context and Methodology Report



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2016 UK RADIOACTIVE WASTE & MATERIALS INVENTORY: CONTEXT AND METHODOLOGY REPORT

**Report prepared for the Department for
Business, Energy & Industrial Strategy (BEIS) and the
Nuclear Decommissioning Authority (NDA)
by Pöyry Energy Limited and Amec Foster Wheeler plc.**

PREFACE

The 2016 United Kingdom Radioactive Waste & Materials Inventory (the 2016 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 2016 Inventory provides information on radioactive waste stocks (at 1 April 2016) and forecasts of future waste arisings. Information on radioactive materials that may be classed as waste in the future is also presented. The 2016 Inventory aims to provide data in an open and transparent manner for those interested in radioactive wastes and materials.

Information collected for the 2016 Inventory is presented in a suite of five reports:

- Summary Brochure
- Context and Methodology
- UK Radioactive Waste Inventory
- Radioactive Wastes and Materials Not Reported in the Waste Inventory
- Summary for International Reporting

All documents have been prepared using information supplied to the 2016 Inventory contractors, Pöyry Energy and Amec Foster Wheeler. This information was verified in accordance with arrangements established by Pöyry Energy and Amec Foster Wheeler in agreement with NDA.

This report provides information on the sources, categories and management of radioactive wastes in the UK. It also provides an overview of the process used to collect the Inventory data, describes the scope of the Inventory and the terms and conventions used in reporting Inventory data.

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Feedback

We welcome feedback on the content, clarity and presentation of the UK 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

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GLOSSARY

A ▶	AGR	Advanced Gas-cooled Reactor.
	Alpha activity	Radioactivity associated with the emission of alpha particles, which are positively charged particles comprising two <i>protons</i> and two <i>neutrons</i> .
B ▶	Beta/gamma activity	Radioactivity associated with the emission of beta particles and/or gamma radiation. A beta particle is emitted from a parent nucleus in beta decay with a corresponding neutrino. Beta ⁻ decay results in <i>electron</i> emission with an antineutrino and Beta ⁺ decay results in positron emission with a neutrino.
	Bq	Becquerel. The standard international unit of measurement of radioactivity, corresponding to one disintegration per second. A kilobecquerel is 1,000 Bq, a megabecquerel is 1,000,000 Bq and a gigabecquerel is 1,000,000,000 Bq.
	BEIS	The department for Business, Energy & Industrial Strategy. A ministerial department that brings together responsibilities for business, industrial strategy, science, innovation, energy, and climate change.
C ▶	C-14	An isotope of carbon having a radioactive half-life of about 5,730 years.
	Conditioning	The process used to prepare waste for long-term storage and/or disposal by converting it into a solid and stable form, e.g. by encapsulation in cement.
	Controlled burial	The authorised disposal of some <i>LLW</i> , arising principally in the non-nuclear sector, at suitable landfill sites that possess good containment characteristics.
D ▶	DCIC	Ductile cast iron container.
E ▶	Electron	Negatively charged fundamental particle in orbit about an atomic nucleus.
G ▶	GDF	Geological disposal facility. Deep underground facility for the 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 ▶	HAW	Higher Activity Waste. Waste unsuitable for near-surface disposal in current facilities. Comprises <i>HLW</i> , <i>ILW</i> and such <i>LLW</i> as cannot be disposed of at present.
	HLW	High Level Waste.
	HVLLW	High Volume Very Low Level Waste.
I ▶	IAEA	International Atomic Energy Agency.

	ILW	Intermediate Level Waste.
	ISO	International Organisation for Standardisation.
J ▶	JET	Joint European Torus – the internationally funded fusion project sited at Culham.
L ▶	LAW	Lower Activity Waste. Waste suitable for near-surface disposal in current facilities. Comprises <i>LLW</i> (apart from a small fraction that cannot be disposed of at present) and <i>VLLW</i> .
	LLW	Low Level Waste.
	LLWR	Low Level Waste Repository. The LLWR, south of Sellafield in Cumbria, has operated as a national disposal facility for <i>LLW</i> since 1959.
	LLW Repository Ltd	<i>NDA</i> Site Licence Company that manages the <i>LLWR</i> and oversees the National <i>LLW</i> Programme.
M ▶	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.
	MEP	Magnox Encapsulation Plant (at Sellafield).
	MOD	Ministry of Defence.
	MOX	Mixed Oxide. Refers to nuclear fuel consisting of uranium oxide and plutonium oxide for use in reactors.
N ▶	NDA	Nuclear Decommissioning Authority. A non-departmental public body responsible for overseeing the decommissioning and clean-up of 17 of the UK's civil public sector nuclear sites.
	Neutron	Subatomic neutral particle present in the atomic nucleus.
	NIF	National Inventory Forum. A body that provides support to contributors to the UK Inventory exercise. The NIF provides a forum for sharing best practice in the field of radioactive waste (and materials) inventory data compilation, management and communication.
	NORM	Naturally Occurring Radioactive Materials. These are materials that typically accumulate as scale on pipework during the extraction of oil and gas, and have raised levels of naturally occurring radioactivity.
P ▶	PCM	Plutonium Contaminated Material.
	Proton	Subatomic positively charged particle present in the atomic nucleus.
	PWR	Pressurised Water Reactor.
R ▶	R&D	Research and development.
	Raffinate	A solution resulting from a solvent extraction process. The term is applied to the aqueous solution of fission products (liquid <i>HLW</i>) remaining after the extraction of uranium and plutonium in the first stage of irradiated fuel reprocessing.

	RWM	Radioactive Waste Management Limited. A wholly-owned subsidiary of <i>NDA</i> that is responsible for implementing geological disposal of <i>HAW</i> in the UK.
T ▶	tHM	Tonnes of heavy metal. A unit of mass used to quantify uranium, plutonium and thorium including mixtures of these elements.
	Thorp	Thermal Oxide Reprocessing Plant (at Sellafield).
	TILWSP	Transportable Intermediate Level Waste Solidification Plant.
	Tritium	An isotope of hydrogen (H-3) having a radioactive half-life of about 12 years.
V ▶	VLLW	Very Low Level Waste.
W ▶	WEP	Wastes Encapsulation Plant (at Sellafield).
	WPEP	Waste Packaging and Encapsulation Plant (at Sellafield).
	WRACS	Waste Receipt Assay Characterisation and Supercompaction facility (at Dounreay).
	WTC	Waste Treatment Complex (at Sellafield).
	WVP	Waste Vitrification Plant (at Sellafield).

1 INTRODUCTION

1.1 The Inventory

The 2016 UK Radioactive Waste & Materials Inventory (the 2016 Inventory) provides the latest national record of information on radioactive wastes in the United Kingdom (UK). It has been compiled by the Department for Business, Energy and Industrial Strategy (BEIS) and the Nuclear Decommissioning Authority (NDA).

The UK Radioactive Waste & Materials Inventory is updated every three years. It is a snapshot of radioactive wastes and materials at a specific point in time, called the 'stock date'. The 2016 Inventory has a stock date of 1 April 2016.

The Inventory contains information about:

- Radioactive wastes that exist now;
- Radioactive wastes that will arise in the future; and
- Radioactive materials – these are substances not designated as waste now, but which might be in the future if no further use can be found for them.

The Inventory helps the UK to plan safe and efficient radioactive waste and materials management routes, with high standards of protection for people and the environment. The Inventory:

- Enables the UK to meet international reporting obligations;
- Informs policy and strategy development;
- Aids radioactive waste and material management planning; and
- Supports stakeholder engagement.

1.2 Users of the Inventory

The Inventory is used by a wide range of stakeholders, including:

- **Government Departments and Agencies** who develop policies and strategies for managing waste and who regulate nuclear operations;
- **Supply chain organisations** who process waste and need data to support the planning, operation and performance of their facilities;
- **Waste planners** who are responsible for ensuring that waste management facilities meet local and national needs;
- **Researchers and academics** who are developing innovative technologies and processes for managing radioactive waste; and
- **Members of the public** who would like to understand more about radioactive waste.

1.3 Inventory documents

The 2016 Inventory comprises five reports:

- **Summary Brochure** – gives a high level overview of radioactive waste in the UK, waste quantities and waste management;
- **Context and Methodology** – provides information on how the Inventory was produced, including the scope of the Inventory and the terms and conventions used in reporting Inventory data;
- **Radioactive Waste Inventory** – describes the volume, radioactivity and composition of radioactive waste in the UK;
- **Radioactive Wastes and Materials Not Reported in the Waste Inventory** – summarises information on UK civil nuclear materials and other radioactive substances that might have to be managed as waste in the future; and
- **Summary for International Reporting** – gives a summary of information to meet the UK's international reporting obligations in the field of radioactive waste.

As part of the commitment to openness, NDA has created a website dedicated to the Inventory, www.nda.gov.uk/ukinventory, where all 2016 Inventory reports can be found together with other information about radioactive waste.

1.4 This report

This '*Context and Methodology*' report provides information on the sources, categories and management of radioactive wastes in the UK. It also provides an overview of the process used to collect the Inventory data, describes the scope of the Inventory and the principal terms and conventions used in reporting Inventory data.

2 SOURCES OF RADIOACTIVE WASTE

2.1 Origin of 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 activation¹.

One important difference between contamination and activation is that contamination tends to occur on the surfaces of materials but activation also occurs within materials. A second important difference is that contamination can potentially occur wherever there are radioactive materials, but activation can only occur in the presence of a strong neutron (or proton) emitter.

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 decommissioned².

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. Radioactive waste continues to be produced where radioactive substances are used. Further information on how radioactive wastes come about can be found in the NDA report '*Understanding activities that produce radioactive wastes in the UK*', which can be found on NDA's website.

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; and
- Research and development (R&D) programmes.

Much of the waste is from older nuclear power stations, many of which are now shut down, and historical reprocessing and R&D programmes.

¹ 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).

² In general, the wastes that are produced in a nuclear power station or other facility during its operating lifetime are different in nature and radioactivity content from those wastes that remain after the facility is shut down. Operational wastes consist principally of organic materials such as cellulose and plastic, metals and various inorganic materials. Examples of operational wastes are redundant equipment, fuel element components, filters, change room wastes, and ion exchange resins and sludges from the treatment of liquid effluents. Decommissioning wastes consist mainly of building materials such as reinforced concrete, blockwork 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 wastes are certain to arise no matter how long or short its operational life.

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 [1, 2]. All 11 Magnox nuclear power stations have stopped producing electricity; they are now being decommissioned.

Reprocessing of spent nuclear fuel takes place at Sellafield in Cumbria, where Magnox and AGR spent fuel undergoes chemical processes to recover uranium and plutonium.

Nearly all of the waste from R&D into commercial nuclear energy 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

Sources outside the civil nuclear power industry that contribute to radioactive waste in the UK comprise:

- Defence activities;
- Research establishments; and
- 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 the Joint European Torus (JET) facility. The Rutherford Appleton Laboratory supports the work of a diverse research community using its neutron sources.

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).

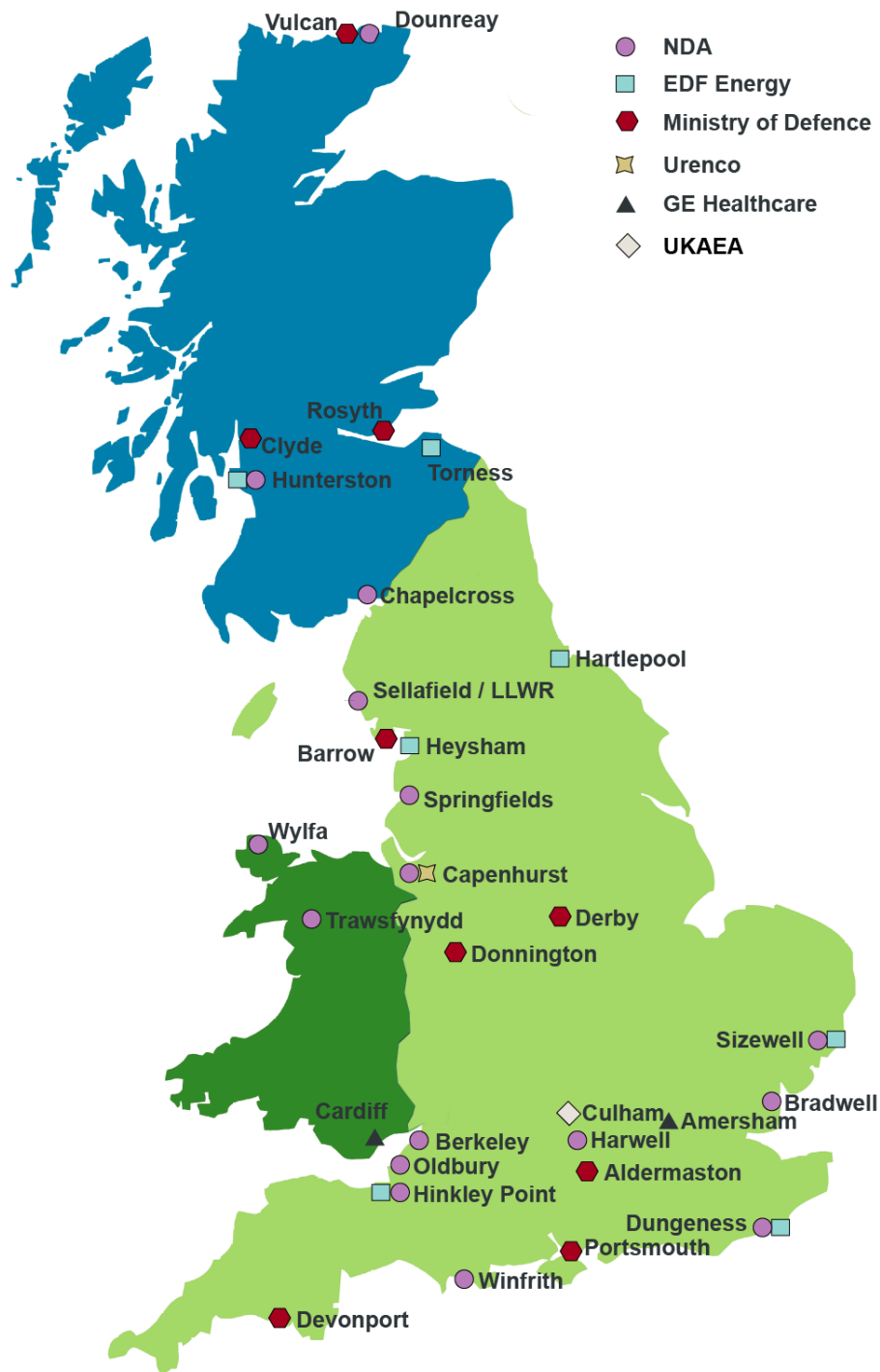
Some of the radioactive materials used in research, medicine and industry, which give rise to radioactive wastes, are produced in particle accelerators rather than in nuclear reactors.

2.2 Waste producers

Figure 1 shows the sites of the major radioactive waste producers in the UK.

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 Inventory these establishments and organisations are collectively referred to as '*Minor Waste Producers*'; their sites are not shown in Figure 1.

Figure 1: Major waste producers' sites

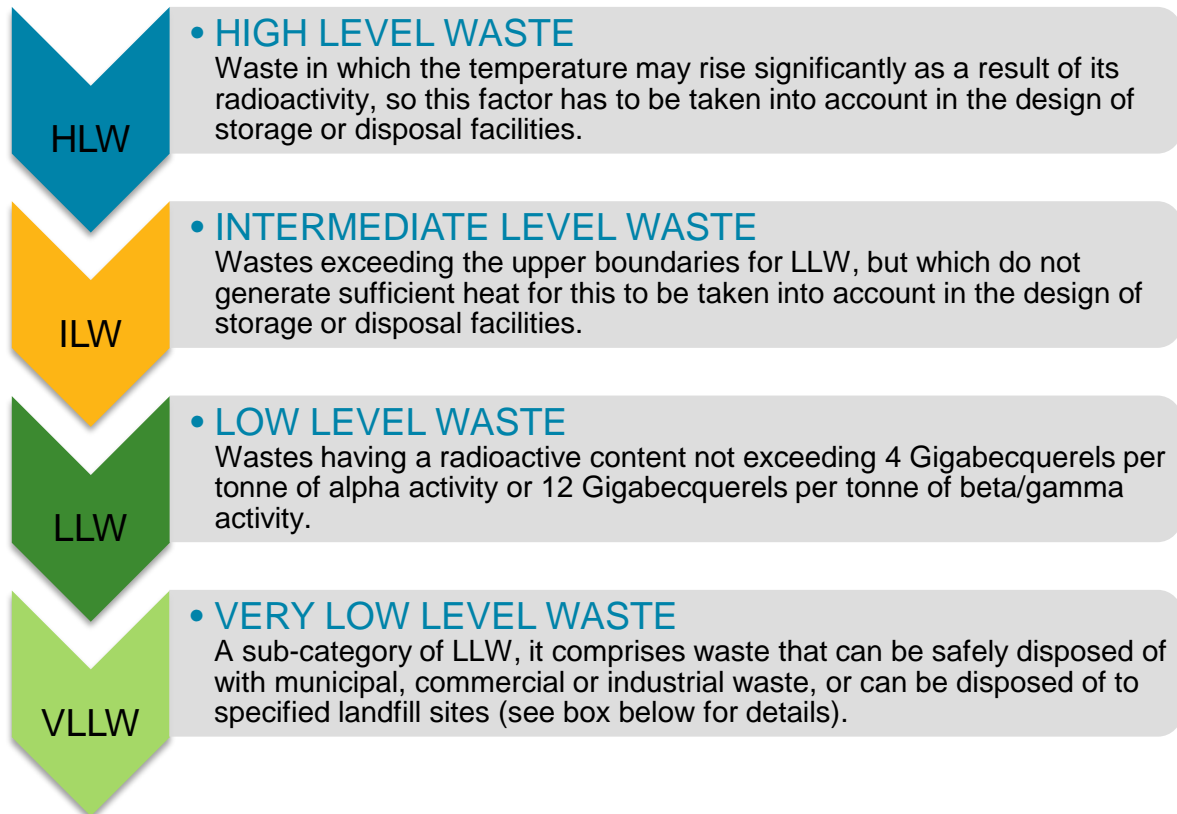


Note: There are no major waste producer sites in Northern Ireland.

3 CATEGORIES OF RADIOACTIVE WASTE

Material that has no further use, and is contaminated by, or incorporates, radioactivity above certain levels defined in UK legislation [3, 4] is known as radioactive waste. In the UK radioactive waste is classified according to how much radioactivity it contains and the heat that this radioactivity produces. Categories are High Level Waste (HLW), Intermediate Level Waste (ILW), Low Level Waste (LLW) and Very Low Level Waste (VLLW).

3.1 Definitions



Very Low Level Waste comprises:

- *High Volume VLLW (bulk disposals) – 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 ('dustbin loads') - wastes that can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste, each 0.1 cubic metre 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.*

The principal difference between the two categories of VLLW is the need for controls on the total radioactivity and volumes of High Volume VLLW that can be disposed of at any one particular landfill site³.

Radioactive wastes can also be categorised as:

³ The Environment Agency has issued permits to the operators of certain landfill sites for the disposal of LLW with an activity of up to 200 MBq per tonne.

- Higher Activity Waste (HAW) - comprising HLW, ILW and such LLW as cannot be disposed of at present; and
- Lower Activity Waste (LAW) - comprising LLW and VLLW.

4 RADIOACTIVE WASTE MANAGEMENT

The Inventory includes information on how wastes are currently being managed and any future plans, comprising:

- Conditioning and packaging of HAW; and
- Treatment, packaging and disposal of LAW.

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 The waste hierarchy

A central theme of UK radioactive waste management strategy is the waste hierarchy⁴ (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 at higher levels.



4.2 Lower Activity Waste (LAW)

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 [5]. 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.

The UK-wide strategy for managing LLW from the nuclear industry [6]⁵ has three themes:

- Application of the waste hierarchy (see above) and a move away from a historical focus on disposal;
- The best use of existing LLW management assets; and
- The need for new fit-for-purpose waste management routes.

NDA leads the implementation of the LLW strategy on behalf of Government through a National LLW Programme. LLW Repository Ltd leads the delivery of the National LLW Programme across the industry on behalf of NDA. The National LLW Programme delivers:

⁴ 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.

⁵ Government has also developed strategies for the management of LLW from the non-nuclear industry comprising of: 'Strategy for the Management of Solid Low Level Wastes from the Non-nuclear Industry: part 1 Anthropogenic Radionuclides', published in March 2012 and 'Strategy for the Management of Naturally Occurring Radioactive Material (NORM) Waste in the United Kingdom', published in July 2014. 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.

- The diversion of a significant quantity of LLW away from disposal to the LLWR;
- The development and use of alternate treatments (e.g. incineration, metal treatment) and disposal routes (e.g. authorised landfill sites); and
- Opportunities for improvement and the sharing of good practices.



Metal recycling

Further, waste characterisation may allow a lower categorisation to be made (e. g. LLW recategorised as VLLW). Improved segregation of waste materials can allow the diversion of metals for recycling and combustibles for incineration. For example, certain suitable LLW has been processed in a metals recycling facility at Workington in Cumbria, which uses size reduction and shot-blasting techniques to minimise quantities of LLW metal sent for disposal to the LLWR. The recovered material can be released back into the scrap metals market for a variety of uses. A small quantity of secondary waste is generated and consigned to the LLWR for disposal. A further example is that of the Berkeley power station boilers, which have been shipped to a specialist smelting plant in Sweden, with up to 95% of the metal being recycled into clean steel ingots for release into the market.

The LLWR disposal site remains a key strategic asset for the UK's management of LLW. Current disposals are made in an engineered facility with concrete-lined disposal vaults. At the LLWR, waste is grouted with cement in metal containers, and these are placed within the engineered 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.



Aerial view of the LLWR showing containers in disposal vaults

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.

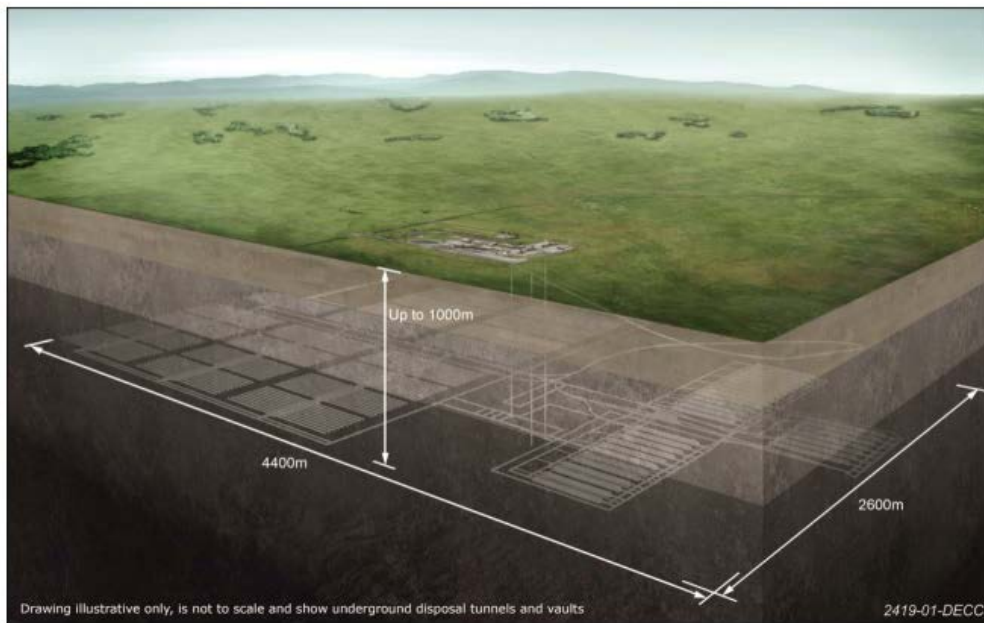
4.3 Higher Activity Waste (HAW)

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

Current practice is that vitrified HLW⁶ 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.

The long-term management policy of the UK Government and that of the Northern Ireland executive for HAW is eventual disposal in a deep geological facility, supported by ongoing research [7]. The Welsh Government has also decided to adopt a policy for geological disposal and continues to support the policy of voluntary engagement [8].

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 Geological Disposal Facility (GDF) is shown below.



Possible design for a Geological Disposal Facility

Radioactive Waste Management Ltd (RWM) is progressing with a programme of work to find a technically suitable site with a willing host community.

The Scottish Government has a different policy for its higher activity wastes; this is that long-term management should be in near-surface facilities [9]. Facilities should be located as near to the site where the waste is produced as possible and developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved.

Before a GDF or a near-surface disposal facility for Scottish HAW is available, the HAW inventory is being treated and packaged and placed into safe and secure interim storage facilities.

⁶ Vitrification is the process used at Sellafield to convert liquid HLW produced during spent fuel reprocessing into a borosilicate glass (see Section 4.4).

There are synergies between HAW policy and the LLW strategy (see Section 4.2) 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 ILW at the 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.

4.4 Packaging plants

There are a number of radioactive waste packaging plants operating in the UK. HLW is being conditioned and packaged at Sellafield in the Waste Vitrification Plant (WVP). Current arisings are being blended with historical holdings. The vitrification process converts the liquid waste into a borosilicate glass in 150-litre stainless steel canisters.

At Sellafield the Magnox Encapsulation Plant (MEP) processes Magnox fuel cladding swarf, the Waste Packaging and Encapsulation Plant (WPEP) processes floc from the treatment of liquid effluents, the Wastes Encapsulation Plant (WEP) processes wastes from the Thermal oxide reprocessing plant (Thorp), and the Waste Treatment Complex (WTC) processes plutonium contaminated materials. All these plants immobilise waste in a cement-based medium in 500-litre stainless steel drums.

Other packaging plants are operating at Dounreay, Harwell, Bradwell, Berkeley, Trawsfynydd and Sizewell B.

The Dounreay Cementation Plant (DCP) (see right) immobilises pretreated raffinate (liquid waste generated during past spent fuel reprocessing at Dounreay) in a cement matrix within 500-litre stainless steel drums, and the site Waste Receipt Assay Characterisation and Supercompaction (WRACS) facility processes and packages solid LLW.



Dounreay Cementation Plant

At Harwell, solid ILW is being retrieved from existing stores, monitored and inspected, and packaged in 500-litre stainless steel drums. The wastes will be immobilised in cement within the drums at a future date.

At Bradwell two conditioning plants using vacuum drying methods are conditioning ILW in robust shielded containers⁷. FAVORIT processes liquid/mobile waste forms from source to the container, while AVDS receives containers pre-filled with waste in a solid form and/or liquid form. There is a similar plant to AVDS at Berkeley where retrieved waste, currently Fuel Element Debris (FED), is being conditioned in robust shielded containers.

⁷ On the waste stream datasheets that waste producers have submitted, the 500 l robust shielded drum is sometimes referred to as a MOSAIK or a Type II ductile cast iron container (DCIC); the 3 m³ robust shielded box is sometimes referred to as a Type VI DCIC. The two are sometimes collectively referred to as DCICs.

At Trawsfynydd the Resin Solidification Plant immobilises ion exchange material in a polymer within Type 1803 drums, and the Miscellaneous Activated Components (MAC) Encapsulation Plant and FED Retrieval & Processing Plant immobilise MAC and FED in cement within 3 m³ stainless steel boxes. A mobile facility (Transportable Intermediate Level Waste Solidification Plant - TILWSP) is being used at the site to immobilise sludges in cement in 3 m³ stainless steel drums.

At Sizewell B a proprietary mobile resin processing plant is used for conditioning spent ion exchange resin prior to its placement into robust shielded storage casks. Conditioning involves dewatering of the resin followed by a final drying.

4.5 Radioactive materials management

UK Government policy is that spent nuclear fuel and nuclear materials management is a matter for the commercial judgment of its owners, subject to meeting the necessary regulatory requirements.

Spent fuel

Historically the UK's approach has been to reprocess spent nuclear fuel in order to recover the uranium and plutonium content. Plutonium recovery is no longer required for either civil or military purposes. However, some fuels continue to be reprocessed to support ongoing electricity generation and some because they are unsuitable for long-term storage.

An alternative approach to reprocessing of spent fuel is interim storage in purpose built ponds or dry stores pending a future decision on disposition. After the closure of Magnox and Thorp reprocessing plants at Sellafield, any remaining AGR and other spent oxide fuels will be stored. If spent fuel were subsequently declared as HAW it would be consigned to a geological disposal facility in line with UK Government policy.

Nuclear materials

The strategy for nuclear materials management in the UK is safe and secure storage pending development of cost-effective lifecycle solutions for their management in line with UK Government policy.

For plutonium the priority is to provide a solution that puts the vast majority of UK held plutonium beyond reach. This is because of the continuing and extensive safety and security arrangements needed for the storage of these materials alongside international non-proliferation objectives to reduce separated plutonium stocks worldwide. The Government's preferred long-term management option is to reuse the UK's civil plutonium stockpile as mixed oxide (MOX) fuel [10, 11].

Stocks of uranium have the potential to be re-used in nuclear fuel for generating electricity. Accordingly, uranium is held in safe and secure storage pending the development of disposition options. If it were decided that some of these materials have no future value they may need to be managed as waste.

5 OVERVIEW OF THE INVENTORY PROCESS

5.1 Introduction

Updating the Inventory is a major task which only happens every three years⁸. It involves engaging with waste producers and collecting information for over 1,300 radioactive wastes and more than 70 radioactive materials.

BEIS and NDA are responsible for appointing a suitable contractor for updating the Inventory.

In 2015, the NDA published a strategy paper on the *Management of Radioactive Waste & Materials Data* [12], which aims to clarify the NDA's strategic objective for inventory work, review current inventory management arrangements and assess whether further work is required to ensure that a robust, sustainable and optimised strategy is in place. The paper provides background information on the Inventory and on the issues encountered, and is available on NDA's website.

Figure 2 on the next page illustrates the process for compiling the 2016 Inventory. The stages are described in more detail in the following sections.

5.2 Develop plan

Before any data are collected, time is spent in developing and agreeing a plan, and the best way to work with sites and to record information. The National Inventory Forum (NIF) plays a central role in this process. The NIF brings together key stakeholders with an interest in the Inventory, including the NDA, BEIS, RWM, LLW Repository Ltd, data providers (inventory co-ordinators) and regulators.

Lessons learned from the previous exercise are taken on board, and recommendations are implemented where these are endorsed and are achievable. Any changes in inventory requirements are addressed.

A specification and outline programme of work are produced.

5.3 Data requirements

Information collected

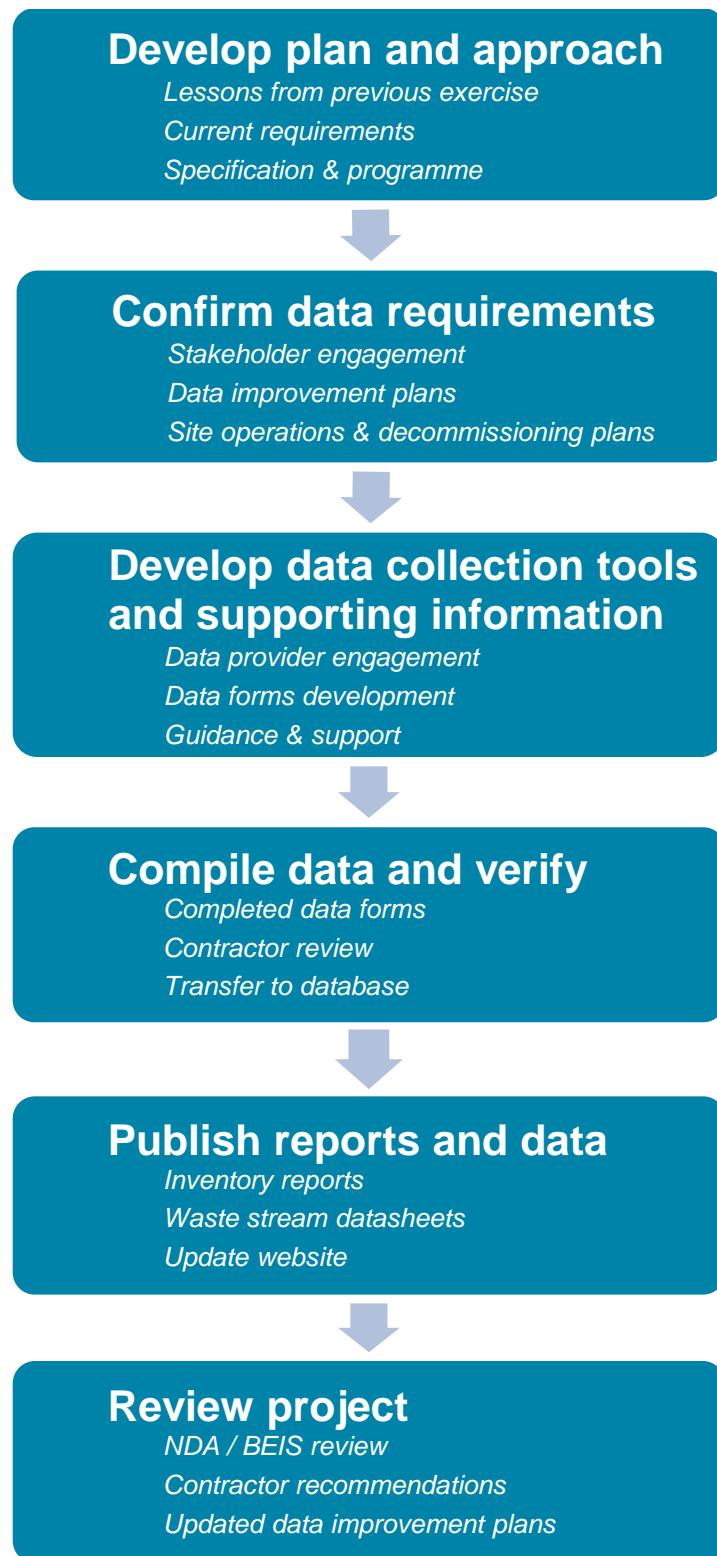
The Inventory provides a national record of information on radioactive wastes and radioactive materials. It is therefore important that this information continues to meet user requirements in helping to plan for safe and efficient radioactive waste and materials management.

A review of the information collected is carried out to:

- Validate Inventory data items by confirming an end user need;
- Ensure all international reporting requirements can be met; and
- Confirm data provider understanding.

⁸ Radioactive waste producers continually maintain their own inventories to support their ongoing site activities.

Figure 2: Overview of the 2016 Inventory process



Improvement plans

The Inventory has an important role in supporting waste management planning, strategy development and stakeholder engagement. It is therefore important that information contained within the Inventory is based on the best available data and that data providers are able to maintain a programme of continual inventory improvement. NDA maintains an Inventory data improvement plan for each data provider to help achieve this. The plan raises awareness of key areas for improvement and opportunities for eliminating data gaps, and for NDA Site Licence Companies (SLCs) feeds into existing improvement plans.

Scenario for future arisings

Each waste producer is responsible for estimating the future radioactive waste and material arisings at its sites. Forecasts are based on the nature, scale and timing of planned future operations and decommissioning activities, known as the 'baseline scenario'.

The baseline scenario for each site must be updated before we collect the inventory data. This ensures that we consider any changes to plans that may have been made for technical, commercial or policy reasons. We also need to be aware of new waste treatment and packaging plans.

The baseline scenarios are made at the 2016 Inventory stock date, 1 April 2016.⁹

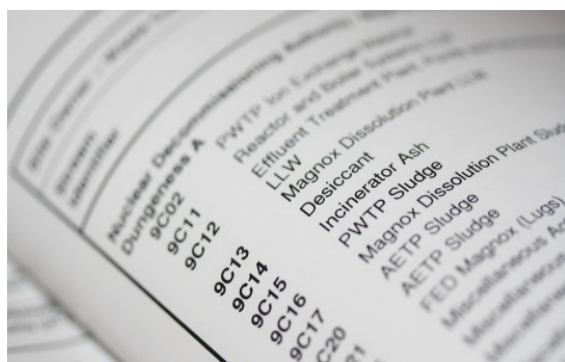
5.4 Data collection tools

Time is spent developing the data collection tools. As end users the data providers are involved in the process and encouraged to provide feedback.

A user guide for the tools is provided, and the previous 2013 Inventory data are preloaded for data providers to update.

Clear guidance and conventions are developed to help sites provide the right information and in a consistent form. The guidance must be updated to ensure that it's still relevant and takes into account any changes in radioactive waste management approaches since the last Inventory was produced.

5.5 Data compilation



A list of all wastes can be found in the '2016 UK Radioactive Waste Inventory' report

Preparing the 2016 Inventory has involved the collation of detailed numerical and descriptive data for each radioactive waste and material.

The waste producers may base their inventory submissions on data obtained from a number of sources - waste sampling, measurement and calculation. Where there are uncertainties, sites use the best available information to make reasonable data estimates. They may use data from surveys and historical evidence to support their assumptions.

Over 200 people across more than 30 UK sites were involved in compiling the 2016 Inventory

⁹ The 2016 Inventory includes no estimate of wastes and spent fuel from new nuclear power stations that may be constructed in the UK. While the UK Government has stated that it supports new nuclear power stations and some operators are planning new stations, it is not yet clear how many reactors and of what design might be constructed. No final investment decisions had been taken by the 2016 Inventory stock date.

data.

The waste producers are responsible for quality checking their data before submission. The inventory contractor then processes the data and carries out independent checking. Checking confirms that the data are consistent with the inventory data reporting conventions (see Section 7) and any changes from the previous inventory are explained. The Inventory contractor takes care to ensure that the waste producers are involved in verifying assumptions and responding to queries relating to specific wastes.

The data for each waste are transferred electronically into a database.

5.6 Reporting

Once all data have been collected and checked with sites, the Inventory database is 'frozen' to enable data analysis. The Inventory contractor then produces a suite of reports that are checked again by the waste producers, NDA and BEIS. Finally, the Inventory is ready for publication.

5.7 Review

After the Inventory is published, NDA works with all those involved to agree improvements for the next Inventory cycle. This includes improvements to the process itself (for example, the data collection tools) as well as identifying specific improvements to the data for particular wastes.

6 SCOPE OF THE INVENTORY

6.1 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 2016 Inventory.

Note 1: Some waste producers have chosen to report potential land contamination with radioactive materials 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 HVVLLW from facilities decommissioning and site clean-up at nuclear licensed sites. However some waste producers have chosen to report potential land contamination with radioactive materials 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 radioactivity 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 radioactivity typically from hospitals, universities and the non-nuclear industry (so-called 'small users') 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 radioactivity and are treated as radioactive waste; and¹⁰
- Estimates of waste and spent fuel from the future development of new nuclear power stations in the UK.

¹⁰ Most NORM waste has been discharged to sea. However Government is working to develop a long-term strategy for the management and disposal of wastes containing NORM. The Scottish Environment Protection Agency (SEPA) website provides information on the process of developing the UK strategy: http://www.sepa.org.uk/radioactive_substances/norm_strategy.aspx

The Inventory covers radioactive wastes that existed on 1 April 2016 and those forecast to arise in the future, and for each radioactive waste stream (see Section 7.1) gives its:

- Identification code;
- Name;
- Waste classification;
- Volume in stock at 1 April 2016;
- Volumes forecast in the future and the timing of these arisings;
- Physical and chemical composition;
- Radioactivity and radionuclide composition;
- Current or planned treatment and packaging; and
- 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.

The Inventory also gives the LLW volumes of past and forecast near-future disposals to the LLWR and the Dounreay LLW facility.

6.2 Radioactive materials

Radioactive materials are radioactive items that are not classed as waste now but may be in future if no further use can be found for them. As a result, we collect data about radioactive materials separately.

We compile information on irradiated and unirradiated fuels, and on nuclear materials (plutonium, uranium and thorium).

Excluded are nuclear materials outside safeguards. The UK Safeguards Office defines non-safeguarded nuclear material as “nuclear material that is excluded from the accountancy and safeguards requirements for reasons of national security and/or defence purposes” [13]¹¹. Also excluded are small quantities of nuclear materials with very low concentrations of radioactivity typically from research establishments, universities and the non-nuclear industry.

Information covers radioactive materials that existed on 1 April 2016 and those forecast to arise in the future. We collect information about the type and quantity of radioactive materials that exist in operational reactors and stores. We also collect estimates of future arisings of radioactive materials.

¹¹ Nuclear licensed sites used solely for defence purposes are not subject to safeguards requirements. Nevertheless, it is Ministry of Defence (MOD) policy to have nuclear materials accountancy standards and management arrangements that are, so far as reasonably practicable, at least as good as those required by safeguards legislation. Civil nuclear licensed sites that handle nuclear materials excluded from safeguards for reasons of national security/defence requirements are expected to comply with the MOD requirements.

7 INVENTORY DATA REPORTING CONVENTIONS

We collate a large amount of information in producing the Inventory. As radioactive wastes arise from diverse sources and in a large number of different forms, we have adopted certain conventions in order to compile and report this information in a consistent manner.

Similar conventions are used in compiling information for radioactive materials, although there are far fewer forms of material and less information is collated.

7.1 Waste stream identification

The fundamental designation used in the Inventory is that of the waste stream. Waste streams include waste or a collection of waste items at a particular site, usually in a particular facility and/or from particular processes or operations. A waste stream is often distinguishable by its radionuclide content and in many cases also by its physical and chemical characteristics.

Each waste stream in the Inventory is allocated a unique identification code. Historically the first character of the identifier indicated the custodian of the waste¹². However, with the recent reorganisation of the nuclear industry and transfer of custodianship at a number of sites, this is no longer the case.

The first two characters uniquely identify the site (and hence its custodian), and are followed by a two- or three- digit number. Numbers in the range 01 to 99 identify operational wastes, and a three-digit number identifies decommissioning wastes.

For example:

Waste stream 3K02	3K (site = Hartlepool; custodian = EDF Energy) 02 (operational waste)
--------------------------	--

In some cases the two- or three-digit number may be supplemented by decimals (e.g. 2D96.1 or 2D87.2.3).

A waste stream that has been conditioned in a suitable container for long-term management, or is being conditioned directly as it arises, includes a /C suffix in the identification code (e.g. 2D38/C).

A complete list of waste streams in the 2016 Inventory, and their identifiers, is given in the report '2016 UK Radioactive Waste Inventory'. Numbers are not sequential because over previous inventories some waste streams have been amalgamated, others split up and renumbered. Some LLW streams have been disposed and so are no longer reported.

7.2 Reporting of wastes at category boundaries

The Inventory categorises each waste stream as HLW, ILW, LLW or VLLW (see Section 3 for definitions of the waste categories) and indicates whether it is expected to be managed as HAW through geological disposal (or long-term storage in the case of Scottish policy wastes) or as LAW through near-surface disposal or suitable alternative management routes in accordance with the waste hierarchy.

At the boundaries between the ILW and LLW categories there are a number of LLW streams where geological disposal may be more appropriate and some ILW streams, particularly

¹² The custodian is the licensee of the site where the waste is currently stored or will arise. The custodian has all responsibilities for the safe and environmental compliant management of the waste. For a very small number of waste streams, some of the waste has been generated at another site.

those containing short-lived radionuclides, where a more appropriate management route could be in a near-surface environment.

Where current or planned waste management practices, including future treatment, will result in all or part of an existing ILW stream being managed at some point in the future as LLW, an ILW categorisation is reported in the Inventory and information is provided on how the waste is treated and its disposal route. The volume of ILW that is expected to be managed as LLW is given in the report '*2016 UK Radioactive Waste Inventory*'.

Similarly, certain LLW may be treated (e.g. by decontamination, incineration, metal melting) such that the bulk of the material is no longer classed as radioactive waste, and residual radioactivity managed through conventional disposal routes. Where these treatments are part of current waste management strategy, they lead to reduced estimates of packaged volumes requiring longer-term management.

7.3 Site contamination

The Inventory includes wastes associated with radioactively contaminated land and subsurface structures:

- Radioactive land contamination (e.g. soil) if it is excavated (e.g. for treatment or to access another subsurface structure, such as a pipeline); and
- Buildings and structures that are beneath the surface and radioactively contaminated above out-of-scope levels (e.g. reactor basements, below ground ponds and radioactive effluent pipelines) that will be excavated and disposed of ex situ or that will be disposed of in situ.

Radioactive land contamination is not considered to be waste if there is no intention to excavate it (i.e. to leave it in situ). Radioactive land contamination may be managed in-situ pending better future characterisation and decisions about its longer-term management. Such material, as well as subsurface structures, may be given separately in the report '*Radioactive wastes and materials not reported*', where there is significant uncertainty over the management route and/or waste amounts.

7.4 Reporting of volume

The Inventory presents radioactive waste volumes in three different ways to satisfy user needs:

- Reported volume;
- Conditioned volume; and
- Packaged volume (the number of packages is also given).

The following sections explain what these volumes represent and why they are quantified.

Reported volume

For wastes that exist at the Inventory stock date of 1 April 2016 the reported volume is the volume they take up. It is the volume the wastes occupy inside the tanks, vaults, silos and drums in which they are contained. Most wastes are in an untreated or partly treated form, while some have already been processed or conditioned for disposal or longer-term storage.

For wastes that will arise in the future, the reported volume is the volume that waste producers forecast will be generated. Most of the radioactivity already exists (for example in reactor structures), but will only arise as waste during the decommissioning of nuclear

facilities and site clean-up. Other radioactive waste - that from future planned operations - has yet to be produced.

In general the reported volumes of future arisings reflect current individual waste stream management practices. Hence where new waste is being conditioned directly it arises, the reported volume is also the conditioned volume.

The volumes of future waste arisings are given for financial years April to March. For simplicity in presentation and discussion of waste volumes the financial year April 2016 to March 2017, for example, is referred to as '2016', and the period April 2016 to March 2020, for example, is referred to as '2016-2019'.

A reliable inventory of existing waste stocks and forecast future arisings is required for planning waste handling, storage, transport and the capacity of waste processing facilities.

Conditioned volume

To package wastes for safe long-term management through storage or disposal, it is often necessary to mix the waste with an 'immobilising medium', to create a solid, stable wasteform. The immobilising medium may be a cement-based material, glass or polymer. This 'conditioning' helps to reduce the hazards posed by the waste. The conditioned volume is the volume of the 'wasteform' (waste plus immobilising medium; also called the 'container payload') within the package (see Figure 3)¹³.

Before being immobilised suitable waste may be treated in a way that changes its volume (e.g. compaction). This is accounted for in the conditioned volume.

Waste that is treated to remove its radioactivity so that it is out-of-scope, or waste that is incinerated, does not appear in conditioned volumes.

Where wastes are not conditioned in disposal packages, a nominal conditioned volume is given in the Inventory that is equal to the container payload.

Conditioned volume is used in the development of safety cases for waste storage and disposal facilities.

Packaged volume

Waste is placed into packages for long-term management. In most cases this involves conditioning. The packaged volume is the total volume taken up by the waste, the immobilising medium and the waste container (see Figure 3). Typically the packaged volume is between 20% and 50% greater than the conditioned volume, depending on the type of container. The number of waste packages is also given in the Inventory¹⁴.

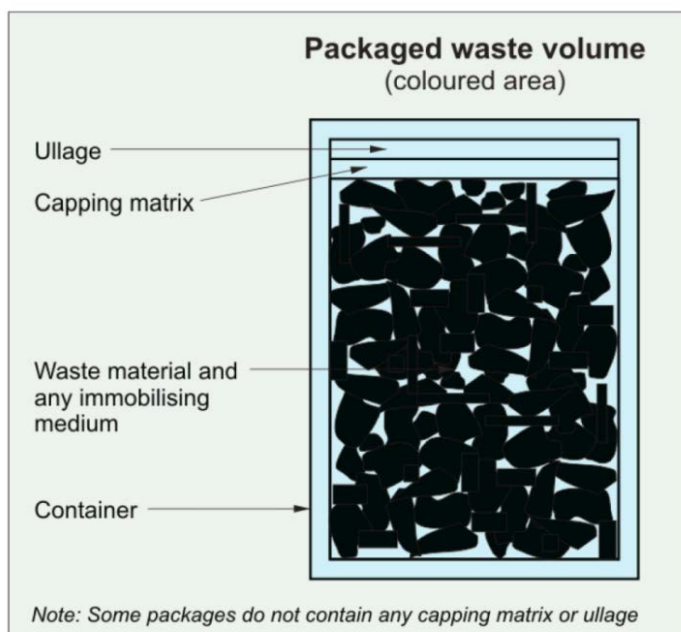


Figure 3: Illustration of packaged volume

The packaged volume represents the final waste volume, and this together with the number of packages is important information

ified the volume of waste loaded into each e payload of the container. This assumption estimated.

ie type of package, it has been assumed in would go into 500-litre drums, or for large ssioning ILW into 4m boxes; and all LLW into nptions are made in order that the total ' estimated.

used to plan the size of new disposal and long-term storage facilities.

Waste that is treated to remove its radioactivity so that it is out-of-scope or waste that is incinerated does not appear in packaged volumes.

The conditioned volume applies to the volume of waste material and immobilising medium and excludes any capping matrix, ullage and container volume.

No data are compiled on packaging that may be associated with LLW and VLLW suitable for landfill disposal (such lightly contaminated waste does not require the same degree of engineered protection provided by the LLWR and the Dounreay LLW facility). Package numbers are not reported, but a nominal packaged volume is given that is the same as the reported volume.

Volume uncertainty

Inventory waste volumes are estimates based on the best information available to waste producers at the stock date. There may be difficulties or impracticalities in accurately measuring or calculating waste volumes; for example how much sludge is held in a storage tank or how much radioactive structural concrete will result from decommissioning a building. Understanding the uncertainties in waste volumes is important in supporting effective waste management planning.

Uncertainty in reported volumes in the 2016 Inventory is quantified by lower and upper factors for stocks and forecast future arisings. In general uncertainties are lower for waste stocks and near-term future arisings, and higher for longer-term arisings particularly those from facility decommissioning and site clean-up.

Overall the uncertainties in conditioned volumes and packaged volumes are expected to be higher than for reported volumes as packaging schemes are often still under development, particularly for decommissioning wastes.

The Inventory does not record uncertainties in the quantities of nuclear materials, but in general these are very low. Detailed records are kept of all nuclear materials that are received and processed at nuclear sites; these records are the basis for nuclear materials accountancy. International safeguards inspectors from the European Commission and the International Atomic Energy Agency (IAEA) regularly monitor how civil nuclear materials are handled and accounted for. This verification provides an overview of the systems that keep track of civil nuclear material and the records of the quantities involved.

7.5 Reporting of radioactive material masses

The masses of radioactive materials that exist at the stock date of 1 April 2016 and in forecast future arisings are compiled. Masses are reported as tonnes of heavy metal (tHM).

7.6 Physical and chemical composition of wastes

Information is collected on the physical items that make up the waste and the metal, organic and inorganic components, and any hazardous substances and non-hazardous pollutants.

Waste groups

Radioactive wastes arise in a variety of chemical and physical forms. 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 that include conditioning and packaging solutions appropriate for their properties.

Hence waste streams in the Inventory have been divided into broad waste groups to inform the development of strategies for managing these wastes. These groups are listed in Table 2. They are based on those used in the document ‘An Overview of NDA Higher Activity Wastes’ [14], but extended to include all waste streams in the Inventory.

Most 2016 Inventory waste streams can be assigned to a single waste group, although some streams contain wastes that fall into more than one group.

Table 2: Designated waste groups

• Activated metals	• Floccs	• Mixed wastes ⁽¹⁾
• Activated other materials	• Fuel cladding & miscellaneous wastes	• Oils and other fluids
• Asbestos and other insulation materials	• Fuel element debris	• Organic ion exchange materials
• Concrete & rubble	• Fuels & uranium residues	• Plutonium contaminated material (PCM)
• Conditioned waste	• HLW	• Raffinate
• Contaminated metals	• Graphite	• Sludges
• Contaminated other materials	• Inorganic ion exchange material	• Soil
• Desiccant & catalysts	• Miscellaneous contaminated materials	• Uranium and thorium contaminated material

(1) Comprises a mix of activated and contaminated materials.

7.7 Radioactivity and radionuclide composition of wastes

Information is collected on the average concentrations of radionuclides and total radioactivity in waste, and on the uncertainty in these values.

Radioactivity

Radioactivity is the spontaneous splitting of unstable atomic nuclides, which may be naturally occurring or man-made, with release of energy through emission of one or more sub-atomic particles and/or radiation. Unstable nuclides are known as radionuclides (also called radioisotopes), and the transformation process is known as radioactive decay. Each radionuclide has a unique half-life, which is the time required for one half of the atoms to decay. Half-lives vary enormously, from a fraction of a second to billions of years¹⁵.

¹⁵ To find out more about the origin and types of radioactivity you can refer to a recent report published by NDA: ‘Understanding activities that produce radioactive wastes in the UK’ [16].

Radionuclides

Atomic nuclei are distinguished by their mass and atomic number. Several hundred different radionuclides are produced in nuclear reactors; many are of short radioactive half-life and so decay completely or to very low levels before they can appear in wastes. Radionuclides are specified by the symbol of their chemical element and their atomic mass (e.g. chlorine-36 is the radioactive nuclide of chlorine with an atomic mass of 36). Some radionuclides exist in a metastable state¹⁶: this is indicated by a suffix 'm' or 'n' (e.g. silver-110m).

The 2016 Inventory includes information on 114 radionuclides that have the potential to impact on the safe handling, transport, storage and disposal of radioactive waste generated in the UK [15]¹⁷. Not all of these 114 radionuclides will exist in every waste stream.

Radioactivity uncertainty

The Inventory quantifies uncertainty in reported average radionuclide activity concentrations by using a double letter band (e.g. BC). The first letter indicates the limit on the upper (+) side and the second letter indicates the limit on the lower (-) side. These limiting values approximate to the 5% and 95% levels on the cumulative distributions of activity (i.e. there is a 5% probability of the specific activity being less than the lower limit, and a 95% probability of the activity being less than the upper limit)¹⁸. The uncertainty bands are shown in Table 3. Upper and lower estimates for radioactivity are derived by using these factors with the reported average activity concentrations.

Table 3 Radionuclide specific activity uncertainty bands

Band (Upper & Lower)	Uncertainty factor
A	1.5
B	3
C	10
D	100

¹⁶ A metastable state is a higher energy state. Some radionuclides can exist in more than one energy state, with different radioactive properties.

¹⁷ Two radionuclides (Na-22 and Al-26) have added to the 112 identified in Reference [15].

¹⁸ With only four uncertainty bands available, the bands reported are those that give limiting values on the cumulative distribution that are no greater than the 5% level and no less than the 95% level.

8 REFERENCES

- [1] Department for Business, Energy & Industrial Strategy, "Digest of United Kingdom Energy Statistics 2016," July 2016.
- [2] Department for Business, Energy & Industrial Strategy, "Energy Trends 2016," December 2016.
- [3] "Radioactive Substances Act 1993 (as amended)," 27 May 1993.
- [4] "Environmental Permitting (England and Wales) Regulations 2010 (as amended). Statutory Instrument," 10 March 2010..
- [5] Department for Environment, Food and Rural Affairs, "Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom," March 2007.
- [6] Department of Energy & Climate Change, "UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry," February 2016.
- [7] Department of Energy & Climate Change, "Implementing Geological Disposal: A Framework for the long-term management of higher activity waste," URN14D/235, 2014.
- [8] Welsh Government, "Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste," 2015.
- [9] The Scottish Government, "Scotland's Higher Activity Radioactive Waste Policy 2011," January 2011.
- [10] Department of Energy & Climate Change, "Management of the UK's plutonium stocks. A consultation response on the long-term management of UK-owned separated civil plutonium," URN 11D/819, December 2011.
- [11] Department of Energy & Climate Change, "Management of the UK's plutonium stocks. A consultation response on the proposed justification process for the reuse of plutonium," URN 13D/091, May 2011.
- [12] Nuclear Decommissioning Authority, "Management of Radioactive Waste & Materials Inventory Data – Research & Strategic Case (Gate 0)," June 2015.
- [13] UK safeguards Office, "Guidance on International Safeguards and Nuclear Material Accountancy at Nuclear sites in the UK," 2010 Edition, Revision 1.
- [14] Nuclear Decommissioning Authority, "An Overview of NDA Higher Activity Waste," Ref. 23366104, November 2015.
- [15] UK Nirex Limited, "The Identification of Radionuclides Relevant to Long-Term Waste Management in the United Kingdom," Nirex Report N/105, November 2004.
- [16] Nuclear Decommissioning Authority, "Understanding activities that produce radioactive waste in the UK," Ref. 23527545, 2015.

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Electronic copies of this and other 2016 Inventory documents can be obtained from the NDA (see contact details below) or via the UK Radioactive Waste Inventory website

<http://ukinventory.nda.gov.uk>

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

T +44 (0) 1925 802077

enquiries@nda.gov.uk

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