

2013 UK Radioactive Waste Inventory:

Scope and Conventions



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The 2013 UK Radioactive Waste Inventory

Scope and Conventions

Report prepared for the Department of
Energy & Climate Change (DECC) and the
Nuclear Decommissioning Authority (NDA)
by Pöyry Energy Limited and Amec plc.

PREFACE

The 2013 United Kingdom Radioactive Waste & Materials Inventory (hereafter referred to as the 2013 Inventory) will provide comprehensive and up-to-date information on radioactive waste and materials as at 1 April 2013. It is part of an ongoing programme of research jointly conducted by the Department of Energy and Climate Change (DECC) and the Nuclear Decommissioning Authority (NDA).

DECC and NDA have commissioned the 2013 Inventory to provide information on the status of radioactive waste stocks (at 1 April 2013) and forecasts of future arisings in the United Kingdom. Additional information on radioactive materials which may become wastes is collated. Its aim is to provide data in an open and transparent manner for those interested in radioactive waste and material issues.

Information collected for the 2013 Inventory is presented in a series of reports, as listed below:

- High Level Summary
- Summary of Data for International Reporting
- Scope and Conventions
- Scenario for Future Radioactive Waste & Material Arisings
- Waste Quantities from All Sources
- Radioactive Waste Composition
- Radioactivity Content of Wastes
- Radioactive Wastes & Materials Not Reported in the 2013 UK Radioactive Waste Inventory.

All documents have been prepared on the basis of information supplied to the 2013 Inventory contractors, Pöyry Energy and Amec. This information was verified in accordance with arrangements established by Pöyry Energy and Amec.

This scope and conventions reporting output describes the sources and categories of radioactive waste, the scope of the 2013 Inventory and the terms and conventions used in reporting inventory data, and the data collection and processing procedures used. It also provides an overview of how radioactive wastes are managed in the UK.

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Feedback

You are invited to provide feedback to the NDA on the content, clarity and presentation of this report and the UK Radioactive Waste Inventory (i.e. the Inventory). Please do not hesitate to contact the NDA if you have any queries on the Inventory and radioactive waste issues. Such feedback and queries should be addressed to:

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1 INTRODUCTION

The 2013 Inventory provides the latest national record of information on radioactive wastes in the United Kingdom (UK). It has been compiled by Pöyry Energy, jointly funded by the Department of Energy and Climate Change (DECC) and the Nuclear Decommissioning Authority (NDA). Its publication is one facet of the continuing commitment of the Government and the organisations responsible for radioactive wastes to openness and transparency in matters relating to the management of these wastes.

The Inventory is updated periodically with the best available information. The impacts of changes in plant operating lifetimes, decommissioning programmes and waste management strategies are incorporated. The 2013 Inventory contains information on radioactive wastes in the UK that existed at 1 April 2013 and those that were projected to arise after that date. The Inventory includes information on the quantities, types and characteristics of wastes.

Forecasts of radioactive waste arisings in the UK are based on assumptions as to the nature and scale of future operations and activities. However, these forecasts, particularly in the longer term, may change for policy, commercial, technological or regulatory reasons, and current information may be subsequently refined.

Not all radioactive materials in the UK are classified as waste. Nuclear materials such as plutonium, uranium and spent nuclear fuel have potential value - uranium and plutonium can be used to make nuclear fuel, and spent nuclear fuel can be reprocessed to recover uranium and plutonium for reuse. However, this might change in the future if there was no further use for some or all of these materials. Information on UK civil nuclear materials and other potential radioactive waste is given in a separate reporting output.

Preparation of the 2013 Inventory has involved the compilation and assessment of detailed numerical and descriptive information for 1,326 waste streams. The data have been provided by the organisations that operate sites in the UK where there are radioactive wastes. The information provided has been checked for consistency and correct use of reporting conventions. Although no attempt has been made to validate the assumptions or quantities reported, which are those of the waste producers, explanations have been sought for significant changes compared with the previous (2010) Inventory.

Preparation of a UK Inventory of radioactive waste is driven by the commitment to openness and transparency and by two international obligations: the Euratom Community Directive on the Responsible and Safe Management of Spent Fuel and Radioactive Waste, and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

The Euratom Community Directive on the Responsible and Safe Management of Spent Fuel and Radioactive Waste requires Member States to include details of their spent fuel and radioactive waste inventories, and provide estimates for future arisings in their National Reports.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management came into force in June 2001 and requires each Contracting Party to submit a report on the measures taken to implement the obligations of the Convention. These national reports contain an inventory of radioactive waste that is held in storage, that has been disposed or that has resulted from past practices. The UK's fourth national report for the Convention was provided to the International Atomic Energy Agency (IAEA) in September 2011 [2].

The Inventory also provides a consistent reference source of information on radioactive wastes used by:

- UK Government Departments, Devolved Administrations and Agencies responsible for radioactive waste management policy and for regulation of waste management operations and disposal;
- NDA, a non-departmental public body with responsibilities for overseeing the decommissioning and clean up of the UK's public sector civil nuclear liabilities and, more recently, for developing, delivering and implementing programmes for interim storage and disposal of UK higher activity wastes;
- Those concerned with the planning, operation and performance of systems and facilities for the management of radioactive wastes in the UK;
- Other interested parties.

2 SOURCES OF RADIOACTIVE WASTE

Radioactive wastes are produced in the UK as a result of the generation of electricity in nuclear power stations and from the associated production and processing of the nuclear fuel, from the use of radioactive materials in industry, medicine and research, and from military nuclear programmes.

Radioactive wastes may contain naturally occurring radioactive materials, generally uranium, thorium and the products into which they decay, and radioactive materials arising from the activities of man. Most of the “man-made” radioactive materials result from the fission (splitting) of uranium atoms in nuclear reactors. They include fission products themselves (and their radioactive decay products), and activation products (and their radioactive decay products) produced in reactor internal and structural materials by the absorption of neutrons released during the fission process. Some of the radioactive materials used in medicine, industry and research, which can give rise to radioactive wastes, are produced in particle accelerators rather than nuclear reactors.

Figure 1 shows the sites of the major radioactive waste producers. Labels indicate the type or principal type of activity at a site, in terms of six areas covering all uses of radioactive materials in the UK. Many “small users” of radioactive materials such as hospitals and industrial, educational and research establishments produce small quantities of radioactive wastes; their sites are not shown. In the inventory these establishments are collectively referred to as *Minor Waste Producers*.

The major producers of radioactive wastes in the UK are the following organisations.

2.1 Nuclear Decommissioning Authority

The NDA does not produce radioactive waste, but has responsibility for overseeing continuing operations and the decommissioning and clean up at its 16 sites. It has established Site Licence Companies, which carry the licences to operate these sites:

- *Sellafield Ltd* operates Sellafield in Cumbria¹. Sellafield is home to the world’s first commercial nuclear power station – Calder Hall, which generated electricity from 1956 to 2003. Today the site is home to a wide range of operations including the decommissioning of redundant buildings associated with early defence work; spent fuel management including Magnox and Oxide fuel reprocessing; and the safe management and storage of nuclear waste.
- *Magnox Ltd* operates ten Magnox power station sites. Wylfa in Anglesey is the only operational power station; Berkeley in Gloucestershire; Bradwell in Essex; Dungeness A in Kent; Hinkley Point A in Somerset; Oldbury in South Gloucestershire, Sizewell A in Suffolk, Chapelcross in Dumfries and Galloway, Hunterston A in Ayrshire and Trawsfynydd in Gwynedd are no longer operational and are being decommissioned.
- *LLW Repository Ltd* operates the Low Level Waste Repository (LLWR) in Cumbria. The site has operated as a national disposal and storage facility for Low Level Waste since 1959.

¹ The transition of Sellafield Ltd’s activities at Capenhurst to Urenco was completed in November 2012. The Sellafield site now incorporates the historically separate licensed sites of Windscale and Calder Hall.

Figure 1: Major waste producers' sites



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

- *Dounreay Site Restoration Ltd (DSRL)* operates Dounreay in Caithness. The site was the UK centre for fast reactor research and development comprising three reactors, fuel reprocessing and various other fuel cycle facilities. The reactors and other facilities are no longer operational and are being decommissioned.
- *Research Sites Restoration Ltd (RSRL)* operates Harwell in Oxfordshire² and Winfrith in Dorset. These sites carried out nuclear research and development work. All facilities, including a number of research, experimental and prototype reactors, have closed down and have either already been decommissioned or are currently being decommissioned.
- *Springfield Fuels Ltd*³ operates Springfields near Preston in Lancashire. Nuclear fuel products are manufactured for the UK's nuclear power stations and for international customers. Natural uranium hexafluoride is supplied to Urenco and other organisations for enrichment.

2.2 EDF Energy

EDF Energy through its licence holder company EDF Energy Nuclear Generation Ltd operates Advanced Gas-cooled Reactor (AGR) power stations at seven sites: Dungeness B in Kent; Hartlepool in County Durham; Heysham 1 and 2 in Lancashire; Hinkley Point B in Somerset; Hunterston B in Ayrshire and Torness in East Lothian. The company also operates the Sizewell B Pressurised Water Reactor (PWR) power station at Sizewell in Suffolk.

2.3 Ministry of Defence

The Ministry of Defence (MoD) is a major user of radioactive materials in its naval nuclear propulsion and atomic weapons programmes, and in other activities. While the management of major MoD sites and facilities has been subject to a process of contractorisation or privatisation, MoD remains the legal owner of all defence wastes.

- *The Atomic Weapons Establishment (AWE)* at Aldermaston and Burghfield in Berkshire undertakes research and development, design, manufacturing, servicing and decommissioning of nuclear warheads.
- *Naval dockyards* at Devonport in Devon, the Clyde submarine base at Faslane near Helensburgh in Dunbartonshire and Rosyth near Dunfermline in Fife support the operation, refuelling, refitting and decommissioning of the nuclear submarine fleet. Development of nuclear propulsion systems is carried out at the Naval Reactor Test Establishment (NRTE) Vulcan at Dounreay. At Derby, Rolls-Royce Marine Power Operations Ltd (RRMPOL) develops and manufactures reactor cores and associated equipment for the nuclear submarine fleet. At Barrow in Cumbria, BAE Systems Marine Ltd (BAESM) builds, tests and commissions nuclear powered submarines.
- *Eskmeals Range* in Cumbria was used for test firing of depleted uranium projectiles.
- *The Joint Supply Chain Services* regional centre located at Donnington in Shropshire and HM Naval Base at Portsmouth in Hampshire store radioactive wastes.
- *The Defence Infrastructure Organisation* manages a major programme to assess and remediate contaminated ground at non-nuclear MoD sites in the UK.

² The Harwell site is owned by UKAEA Ltd and leased to the NDA.

³ On 1 April 2010 responsibility for the commercial fuel manufacturing business and Springfields Fuels Ltd was transferred from NDA to Westinghouse. NDA retains responsibility for the historic nuclear liabilities on the site.

2.4 United Kingdom Atomic Energy Authority

The United Kingdom Atomic Energy Authority (The Authority) manages the UK fusion research programme and operates the Joint European Torus (JET) on behalf of the European Fusion Development Agreement (EFDA) at Culham in Oxfordshire⁴.

2.5 GE Healthcare Ltd

GE Healthcare Ltd is a health science company providing products and services for use in healthcare and life science research. The company is a supplier of radioisotopes for medical, research and industrial uses. In the UK the company sites are The Grove Centre at Amersham in Buckinghamshire and The Maynard Centre at Cardiff. Historically the company also had facilities on UKAEA Ltd's site at Harwell in Oxfordshire, but operations ceased in 2012.

2.6 Urenco

Urenco⁵ is engaged in uranium enrichment and uranium management at Capenhurst in Cheshire. The site receives natural uranium hexafluoride from Springfields for U235 enrichment in gas centrifuge plants. Enriched uranium hexafluoride is returned to Springfields for conversion into uranium dioxide, which is used in the fabrication of nuclear fuel and intermediate products.

2.7 Imperial College

Imperial College has operated a small, low power research reactor, known as Consort, at Silwood Park, Ascot in Berkshire. The reactor provided teaching and research facilities, but is now shut down and is to be decommissioned.

⁴ Although the Culham site is currently owned and operated by United Kingdom Atomic Energy Authority, the NDA understands that the part of the site occupied by the JET facility will transfer to NDA ownership from the date when JET operation ceases.

⁵ Urenco took ownership and operation of NDA's site at Capenhurst in November 2012, where activities were previously carried out by Sellafield Ltd.

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 waste⁶. Radioactive wastes range from those from the nuclear industry containing high concentrations of radioactivity to general industrial and medical wastes that are only lightly contaminated with radioactivity.

In the UK radioactive wastes are classified in terms of the nature and quantity of radioactivity they contain and their heat-generating capacity, as High Level Wastes, Intermediate Level Wastes or Low Level Wastes.

High Level Wastes (HLW)

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.

Intermediate Level Wastes (ILW)

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

Low Level Wastes (LLW)

Wastes having a radioactive content not exceeding 4 GBq (gigabecquerels) per tonne of alpha, or 12 GBq per tonne of beta/gamma activity.

Very Low Level Waste (VLLW) is a sub-category of LLW that comprises [5]:

- 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 400kBq (kilobecquerels) of total activity, or single items containing less than 40kBq of total activity. There are additional limits for carbon-14 and tritium in wastes containing these radionuclides.
- High Volume VLLW (bulk disposals) – wastes with maximum concentrations of 4MBq (megabecquerels) per tonne of total activity that can be disposed of to appropriately permitted landfill sites. There is an additional limit for tritium in wastes containing this radionuclide.

The principal difference between the two VLLW categories is the need for controls on the total volumes of high volume VLLW being deposited at any one particular landfill site⁷. Low Volume VLLW is generated principally by so called "small users", while most High Volume VLLW (HVLLW) is produced at nuclear licensed sites.

⁶ The Environmental Permitting Regulations 2010 (as amended) apply in England and Wales, and the Radioactive Substances Act 1993 (as amended) and the associated Exemption Orders apply in Scotland and Northern Ireland. Guidance on the scope of and exemptions from UK legislation on radioactive wastes and radioactive materials is has been published by Government [6].

⁷ The Environment Agency has issued permits to the operators of certain landfill sites for the disposal of LLW with an activity of up to 200MBq per tonne [7].

4 SCOPE OF THE INVENTORY

The UK Inventory of radioactive wastes includes HLW, ILW and LLW, and some HVVLLW where there is reasonable certainty of the total waste arisings. This is illustrated in Table 1.

The 2013 Inventory also includes LLW held in Vaults 8 and 9 at the LLWR that is currently classed as stored, not disposed⁸.

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.

Excluded are small quantities of solid wastes with very low concentrations of radioactivity typically from hospitals, universities and the non-nuclear industry (small users) that can be disposed of with domestic refuse to landfill, either directly or after incineration.

Also excluded are naturally occurring radioactive materials (NORM), which accumulate as scale on pipework during the extraction of oil and gas. Because these scales have raised levels of radioactivity they are treated as radioactive waste.⁹

Table 1: Wastes reported in the inventory

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



Wastes included in 2013 Inventory

Note 1: Excludes low volumes of waste that can be disposed of by “controlled burial” at landfill sites.

Note 2: Includes HVVLLW from facilities decommissioning and site clean up at nuclear licensed sites. However some waste producers have chosen to report potentially contaminated ground with Radioactive Materials¹⁰ until there is more certainty on the volumes that might arise.

Note 3: 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. It is not mixed with controlled waste.

⁸ Most of the waste in Vault 8 and all of the waste in the trenches are classed as disposed under the terms of a permit granted by the Environment Agency, and so is not included in the 2013 Inventory.

⁹ 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

¹⁰ See the ‘Radioactive Materials’ reporting output.

The inventory covers radioactive wastes that existed on 1 April 2013 and those forecast to arise in the future. It gives, for each radioactive waste its:

- Name;
- Waste classification;
- Volume;
- Radioactivity concentration;
- Material composition;
- Current or planned treatment and packaging.

The inventory also gives the volumes of past and anticipated future LLW consigned to the LLWR.

5 CONVENTIONS

Radioactive wastes arise from diverse sources, and in a large number of different forms. A number of conventions have been adopted in order to collate and report information on the wastes in a consistent manner.

5.1 Waste stream identification

The fundamental designation used in the inventory is that of the waste stream. Waste streams are designated to summarise waste or a collection of waste items at a particular site, usually in a particular facility and/or from particular processes or operations. It 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 identifier. Historically the first character of the identifier indicated the custodian of the waste¹¹. However, with the recent reorganisation of the nuclear industry and transfer of custodianship at a number of sites, this is no longer the case.

In the 2013 Inventory 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 is EDF Energy)
02 (Waste stream; operational)

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 it arises, includes a /C suffix (e.g. 2D02/C).

A complete list of waste streams in the 2013 Inventory, and their identifiers, is given in the 'Waste Quantities from All Sources' reporting output. 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.

5.2 Waste classification

Every waste stream in the inventory is classified as HLW, ILW or LLW (see Section 3). The LLW classification includes waste streams that fall into the VLLW sub-category.

Some practices can result in an ILW stream becoming a LLW stream. A small number of ILW streams are being interim-stored to allow time for radioactive decay to take place. Some ILW streams may be decontaminated to allow classification as LLW, with the radioactivity concentrated in a much smaller volume of ILW. Some ILW Magnox fuel element debris is being dissolved using a chemical process that retains the radioactivity in a residue with the bulk liquid suitable for effluent discharge. In certain cases ILW when conditioning by the addition of grout can have a lower radioactivity concentration sufficient for the waste to be classified as LLW. Such waste streams are included as ILW, because convention is to classify existing waste according to its radioactivity at a reference time (for this inventory 1 April 2013)

¹¹ 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.

and to classify future wastes according to its radioactivity at the time it is forecast to arise. Those volumes of ILW that are expected to become LLW are given in the 'Waste Quantities from All Sources' reporting output.

Similarly, certain LLW may be decontaminated so that the bulk of the material is no longer classed as radioactive waste. Also, LLW consisting of combustible materials may be incinerated. In both cases residual LLW can be disposed of through conventional routes. Where these treatments are part of current waste management strategy, reduced estimates of LLW conditioned and packaged volumes are included in the 2013 Inventory.

Other waste streams have specific activities close to the upper limits for LLW. If waste streams cannot be classified definitively they may be designated ILW.

5.3 Operational and decommissioning wastes

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 arise during the normal day-to-day operations of a plant or facility, from its start-up to its final shutdown. They 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, ion exchange resins and sludges from the treatment of liquid effluents. Wastes from defuelling nuclear reactors, and wastes from Post-Operational Clean Out (POCO) activities that prepare a plant for decommissioning, are designated as operational wastes because they are of a similar nature to those that arise during operation. Future arisings of operational wastes can often be based on experience of past production rates.

Decommissioning wastes arise after shutdown of a facility, although the radioactivity already exists. They 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 processing radioactive material has started up, equipment and structures become radioactive, so decommissioning wastes are certain to arise no matter how long or short its operational life.

The precise timing of decommissioning and the procedures to be used may not yet be finalised, so waste volumes, and the timing of their arising, can be subject to greater uncertainty than for operational wastes. Processes such as Sellafield Ltd's decommissioning mandates, Magnox Ltd's SMART inventory reviews and DSRL's plant inventory walk-rounds are underpinning waste arisings estimates.

While the inventory contains separate waste streams for operational and decommissioning wastes, the information presented in this report does not distinguish between wastes from operation and decommissioning.

5.4 Reporting of waste volumes

The total volume of radioactive waste in the UK changes over time as further waste is generated and as existing wastes and new arisings are packaged for long-term storage and management.

Volumes are reported for wastes that existed on 1 April 2013 and for wastes that were forecast to be produced after this date (future arisings). Volumes are also reported for wastes once they have been packaged for long-term management. As packaging schemes are often still under development, particularly for decommissioning wastes, there is greater uncertainty in the resulting volumes.

5.4.1 Waste at 1 April 2013

Waste at 1 April 2013 comprises radioactive materials that had been declared as waste and were being held at this date. The volumes reported are those that the wastes occupied in tanks, vaults, silos, drums etc. in which they were contained.

Many of the wastes existed in either an untreated or partly treated state - some wastes are treated shortly after they arise to reduce volume and so minimise containment requirements; treatments include evaporation of liquid wastes and compaction of solid wastes.

Some wastes are being conditioned as they arise and other wastes have been retrieved from stores and conditioned. For these wastes, designated by the /C suffix in the stream identifier, the volume reported at 1 April 2013 is the conditioned volume. The addition of cement grout during waste conditioning increases volumes (see Section 5.4.4).

5.4.2 Future waste arisings

These are radioactive materials that waste producers forecast will be declared as waste at some specified time in the future. 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 volumes of future arisings reported reflect current waste management practices. So for most future arisings the volume reported is that for untreated or partly treated waste. There are a small number of waste streams where fresh arisings are being conditioned directly in suitable containers for long-term management. For these wastes, designated by the /C suffix in the stream identifier, the volume reported is the conditioned volume.

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

The volumes of future waste arisings are given for financial years April to March, not calendar years; although for medium and longer-term forecasts this distinction is unlikely to matter. For simplicity in presentation and discussion of waste volumes the financial year April 2013 to March 2014, for example, is referred to as '2013', and the period April 2013 to March 2014, for example, is referred to as '2013-2014'.

5.4.3 Packaged waste volume

Packaging is the loading of waste into a container for long-term management. In most but not all cases this involves conditioning. The packaged waste volume is the displacement volume of the container (see Figure 2). It represents a 'final' waste volume. Typically the packaged waste volume is between 20% and 50% greater than the conditioned waste volume, depending on the type of container. The number of packages is also reported in the inventory¹².

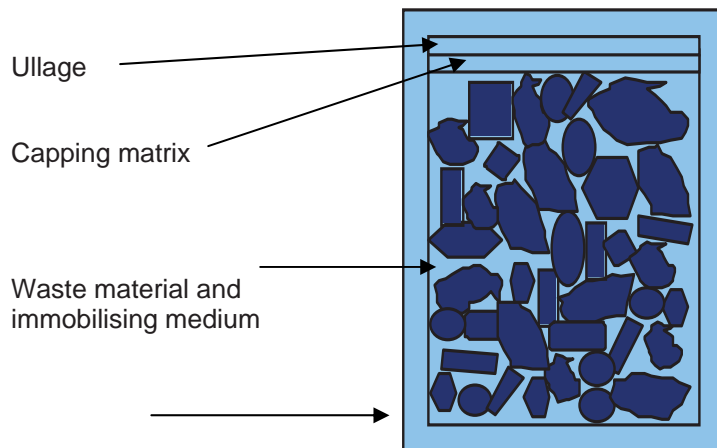
It is necessary to know packaged volumes and the corresponding numbers of packages as these determine the required capacity of storage and disposal facilities.

Waste that is recycled or incinerated does not appear in packaged volumes.

Most LLW for disposal at the LLWR is packaged in large mild steel International Organisation for Standardisation (ISO) freight containers, which have a nominal capacity of 15.6m³.

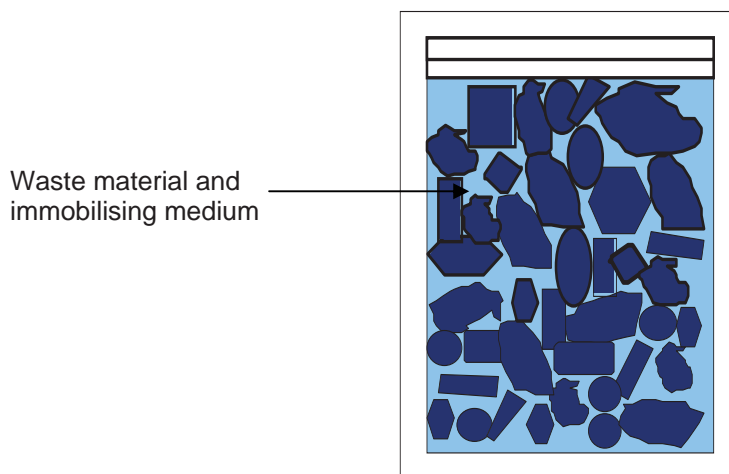
¹² For those streams where the waste producer has not specified the type of package, it has been assumed in calculations that operational and early stage decommissioning ILW would go into 500 litre drums, or for large waste items 4m ILW boxes (capacity 11m³); final stage decommissioning ILW into 4m boxes; and all LLW into half height ISO containers (nominal capacity 15.6m³). These assumptions are made in order that the total number of packages and total packaged volume can be reasonably estimated.

Figure 2: Illustration of packaged waste and conditioned waste volumes
Packaged waste volume (coloured area)



Note: Some packages do not contain any capping matrix or ullage

Conditioned waste volume (coloured area)



The UK Inventory does not compile data on any 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). Package numbers are not reported, but a nominal packaged volume is given that is the same as the reported volume.

Historically wastes that could not be disposed were stored, while plans for their long-term management were developed. Since the 1980s, facilities such as the Thermal Oxide Reprocessing Plant (Thorp) and the Fuel Handling Plant (FHP) at Sellafield have been designed and constructed along with purpose-built packaging plants to process wastes as they arise, and purpose-built stores to hold the waste packages.

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 historic 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 swarf from FHP and other minor waste streams, the Waste Packaging and Encapsulation Plant (WPEP) processes floc from the treatment of liquid effluents, the Wastes Encapsulation Plant (WEP) processes

wastes from 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. The Windscale Advanced Gas-cooled Reactor (WAGR) Packaging Plant immobilises operational and decommissioning wastes from the reactor in a cement matrix in large concrete boxes.

Other packaging plants are operating at Dounreay, Harwell and Trawsfynydd. The Dounreay Cementation Plant (DCP) immobilises Materials Testing Reactor (MTR) liquors 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. 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 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 Fuel Element Debris (FED) Retrieval & Processing Plant immobilise MAC and FED in cement within 3m³ 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 3m³ stainless steel drums.

5.4.4 Conditioned waste volume

Conditioning is immobilisation of radioactive waste in a suitable medium, such as a cement-based material, glass or polymer, to produce a solid and stable wastefrom within a container. Immobilising the waste reduces the hazard it presents compared with its untreated or partly treated form. The conditioned waste volume is the volume of the wastefrom (waste plus immobilising medium) within the container (i.e. the payload) (see Figure 2).¹³

Waste that is recycled or incinerated does not appear in conditioned volumes.

Waste held in Vaults 8 and 9 at the LLWR is conditioned by immobilising it in cement grout. Suitable waste is first supercompacted to minimise its volume, in facilities such as the Waste Monitoring and Compaction (WAMAC) plant at Sellafield. The WRACS facility at Dounreay supercompacts LLW from that site and from the adjacent Vulcan (MoD) site, and there is a supercompaction service on the Winfrith site.

A nominal conditioned volume is given for LLW and VLLW suitable for landfill disposal; this is the same as the reported volume.

Conditioned volumes are needed for the development of safety cases for waste disposal.

5.4.5 Rounding of numerical data

Individual waste stream volumes cover a wide range, from less than 1m³ to more than 1,000,000m³, and there are uncertainties in the volumes associated with the methods of measuring existing wastes and calculating future arisings. Therefore summed waste stream volumes are rounded to three significant figures, as any impression of undue arithmetic accuracy can be misleading.

Summed numbers of waste packages are also rounded to three significant figures, except for waste packages at 1 April 2013 where the actual numbers being held are reported.

Summed waste stream masses and activities are rounded to two significant figures.

Rounding errors affecting the last significant figure can occur if totals are compared with the sums of individual values within tables of data; this is purely an arithmetical effect and has no practical significance.

¹³ For those streams where the waste producer has not specified the volume of waste loaded into each container for conditioning, this volume is assumed to be equal to the payload of the container. This assumption is made in order that total conditioned volumes can be reasonably estimated.

6 DATA COLLECTION AND PROCESSING

6.1 Data compilation

Preparation of this inventory has involved the collation of detailed numerical and descriptive data for 1,326 radioactive waste streams produced in the UK. The number of waste streams is similar to the previous (2010) Inventory. Information on these wastes was gathered by requesting the data in a standard form for each waste stream [8]. Over 200 people across all waste producing sites were involved in providing the 2013 Inventory data.

6.2 Data assessment

The data provided have been checked by Pöyry Energy and Amec for consistency, completeness and technical accuracy, and the information compared with that in the 2010 Inventory to confirm changes and identify potential anomalies. Feedback was provided, as a result of which some revisions to data were made by waste producers. However, no attempt was made to validate the waste quantities reported, which are those of the waste producers.

6.3 The 2013 Inventory database

Following the completion of data assessment, the information for each waste stream was transferred into a database. This information was then processed to produce summary and detailed outputs for the 2013 Inventory reporting outputs. The waste producers have approved the publication of their data in the 2013 Inventory outputs.

7 RADIONUCLIDE PRODUCTION

7.1 Introduction

The term radionuclide is used to describe an atom or nucleus of an element that undergoes radioactive decay. There are about 2,300 known radionuclides, most of which are not naturally occurring. Several hundred of these are produced in nuclear reactors; many are of short half-life and so decay completely or to very low levels before they can appear in wastes.

The 2013 Inventory includes information on 112 radionuclides that have the potential to impact on the safe handling, transport, storage and disposal of radioactive waste generated in the UK [9]. Clearly, not all of these 112 radionuclides will exist in every waste stream.

Radionuclides are specified by the symbol of their chemical element and their atomic mass (for example Cl36 is the radioactive nuclide of chlorine with an atomic mass of 36). Some radionuclides exist in a metastable state: this is indicated by a suffix “m” or “n” (for example Ag110m).

The principal radioactive decay modes of radionuclides are:

- **Alpha**, which involves emission of an alpha particle;
- **Beta -**, which involves emission of a negative beta particle (electron);
- **Isomeric transition**, which involves the transition of a nuclide from one energy state to another accompanied by the emission of a gamma ray;
- **Electron capture / Beta +**, which involves the conversion of a proton into a neutron either by the proton capturing an orbital electron or emitting a positive beta particle (positron).

In general gamma ray, X-ray and Auger electron emission are associated with alpha, beta minus and electron capture / beta plus decay processes.

7.2 Production

The radionuclides in the wastes can be divided into three broad groups, according to the ways in which they are produced: *Fission products*, *Activation products* and *Actinides* (including their decay products).

7.2.1 Fission products

Fission products are produced from the fission (splitting) of heavy nuclei present in nuclear fuels. Fission products include those produced directly by the fission process or by the decay of fission fragments. The main source of fission products in both natural uranium and enriched uranium fuels is thermal-neutron binary fission of U235. This produces nuclides with mass numbers ranging from approximately 70 to 160, with peaks occurring at mass numbers around 95 (e.g. Sr90, Tc99) and 140 (e.g. Cs137, Ce144). A substantial fraction of fission products is also produced from fission of Pu239 produced from uranium during fuel irradiation in nuclear reactors. Fission products predominantly undergo beta/gamma decay.

Reprocessing of spent nuclear fuel separates the fission products from reusable uranium and plutonium, and results in a number of process waste streams that contain fission product contamination. In addition, where nuclides of the more volatile elements (e.g. iodine, caesium) have been released from the fuel while it is in the reactor or in store at the reactor site before being transported for reprocessing, these radionuclides will appear in reactor waste streams.

7.2.2 Activation products

Activation products arise from the neutron activation of stable isotopes of all masses. Reactions involving the absorption of a neutron followed by the emission of a gamma ray tend to produce the largest amounts of activation products. Since fission products mostly have atomic masses in the range 70 to 160, radionuclides outside this atomic mass range normally arise as activation products. Activation reactions will be the primary source of radionuclides in the mass range 70 to 160 when the fission product yield of the radionuclide is low. Examples of radionuclides that arise predominantly as activation products are: C14, Cl36, Co60, Ni63 and Nb94. Activation products predominantly undergo beta/gamma decay.

7.2.3 Actinides and their decay products

Actinides consist of actinium (atomic number 89) and the elements of higher atomic number. They include thorium, protactinium, uranium, neptunium, plutonium, americium and curium.

The actinides in the wastes are principally of two types: uranium and its decay products, and actinides of higher atomic number, such as plutonium, produced from uranium by neutron capture reactions during fuel irradiation in nuclear reactors. The higher actinides also undergo radioactive decay. In general, as the burn-up of the fuel is increased the total quantities of the higher actinides also increase. Actinides predominantly undergo alpha decay.

The reprocessing of spent nuclear fuel separates uranium and plutonium from the other actinides and fission products. Wastes arising from fuel reprocessing operations will contain varying quantities of these radionuclides.

8 RADIOACTIVE WASTE MANAGEMENT

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.

Current practice is that vitrified HLW 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.

Under the “Managing Radioactive Waste Safely” programme an independent Committee on Radioactive Waste Management (CoRWM) was appointed in 2003 to review the options for managing the UK’s legacy higher activity radioactive waste (HLW and ILW), and to recommend the best option that could provide a long-term solution. CoRWM reported in July 2006 with a package of recommendations including geological disposal, preceded by safe and secure interim storage [10]. The UK Government and Devolved Administrations for Wales and Northern Ireland accepted CoRWM’s recommendation as the way forward.

Following public consultation, the UK Government and Devolved Administrations for Wales and Northern Ireland published in June 2008 a White Paper “*Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal*” [11]. This set out the approach to siting a geological disposal facility based on voluntarism and partnership with local communities, coupled with the use of appropriate site screening and assessment criteria. It is also acknowledged that there should be a programme of ongoing research and development for which NDA will have primary responsibility.

The Scottish Government policy for higher activity waste is that long-term management should be in near-surface facilities [12]. 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.

Disposal routes for solid low activity radioactive wastes already exist in the UK. Most low activity waste had been sent to the LLWR in Cumbria or in certain cases to specific landfill sites.

However, a revised UK Low Level Waste policy was announced in March 2007 to address the diminishing capacity issue at the LLWR and set out a more flexible, sustainable approach for managing solid low level radioactive waste in the long-term [5]. NDA has published a UK-wide strategy for managing LLW from the nuclear industry [13]¹⁴.

Central to the UK-wide strategy for managing LLW from the nuclear industry is a more effective application of the waste hierarchy (non-creation of waste where practicable; minimisation where creation is unavoidable; re-use, recycling and recovery of energy in the form of heat from incineration of combustible waste; and, ultimately, disposal) and a move away from the past focus on disposal¹⁵. The strategy makes best use of existing disposal capacity, and the extent to which other waste management and disposal options might be employed to accommodate the wide range in the make-up and radioactivity of LLW.

¹⁴ Also, in December 2010 Government published a consultation document on a strategy for the management of solid low level radioactive waste from the non-nuclear industry in the UK.

¹⁵ 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.

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, since September 2009 certain suitable LLW has been processed in a metals recycling facility at Workington in Cumbria. This facility 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.

A new shallow, engineered LLW disposal facility is being constructed adjacent to the Dounreay site in Caithness. This will take wastes from decommissioning at Dounreay and the neighbouring Vulcan nuclear site. The facility is scheduled to operate from 2014 subject to regulatory consent.

In practice there is some LLW which, because of its radionuclide content or its physical/chemical properties, may have to be managed along with ILW. However this amounts to less than one per cent by volume of all LLW forecast from the operation and decommissioning of current nuclear plant in the UK.

The Office for Nuclear Regulation (ONR), an agency of the Health and Safety Executive (HSE), regulates the safety of nuclear installations in the UK. It does so through a system of licensing of nuclear sites. All nuclear installations as defined in the Nuclear Installations Act 1965 (as amended) (NIA65) require a licence from ONR and every activity, including the accumulation and storage of radioactive wastes, must be undertaken in accordance with the conditions ONR attaches to the licence. NIA65 does not apply to activities carried out directly by the MoD or the armed forces. However, regulation of such operations at MoD sites is to the same standards as at nuclear sites.

UK legislation covering the disposal of radioactive wastes from nuclear and non-nuclear sites – including the transfer of solid wastes for burial, incineration or storage elsewhere, as well as the discharge of liquid and gaseous wastes to the environment – comprises the Environmental Permitting Regulations 2010 (as amended) [4], which applies in England and Wales, and the Radioactive Substances Act 1993 (as amended) [3] and the associated Exemption Orders, which applies in Scotland and Northern Ireland. The regulatory bodies are the Environment Agency (EA) in England, the Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW) and the Environment and Heritage Service of the Department of Environment in Northern Ireland. For radioactive wastes arising on non-nuclear licenced sites, the environment agencies have regulatory responsibility for both accumulation and disposal.

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10 GLOSSARY

The glossary contains a list of specialised terms and abbreviations used in this reporting output.

AGR	Advanced Gas-cooled Reactor.
AWE	The Atomic Weapons Establishment. A Government owned, contractor-operated company concerned mainly with nuclear weapons technology. Located at Aldermaston, but with a smaller establishment at Burghfield.
BAESM	BAE Systems Marine Ltd.
CoRWM	The Committee on Radioactive Waste Management. An independent body set up by Government to recommend a strategy for the long-term management of higher activity radioactive wastes in the UK. The Committee reported in July 2006. CoRWM has been re-constituted with modified terms of reference and membership to scrutinize the Managing Radioactive Waste Safely (MRWS) programme and its implementation.
DCP	Dounreay Cementation Plant.
DECC	Department of Energy and Climate Change. The UK Government department responsible for all aspects of UK energy policy and for tackling global climate change on behalf of the UK.
DSRL	Dounreay Site Restoration Limited.
EA	Environment Agency.
EFDA	European Fusion Development Agreement.
FED	Fuel Element Debris.
FHP	Fuel Handling Plant
GBq	Gigabecquerel, one thousand million (10^9) Becquerels.
Government	A collective term for the central government bodies responsible for setting radioactive waste management policy within the UK. It includes the UK Government, the Scottish Government and the Devolved Administrations of Wales and Northern Ireland.
HLW	High Level Waste.
HSE	Health and Safety Executive.
HVLLW	High Volume Very Low Level Waste.
IAEA	
ILW	Intermediate Level Waste.
ISO	International Organisation for Standardisation.
JET	Joint European Torus.
kBq	Kilobecquerel, one thousand (10^3) Becquerels.
LLW	Low Level Waste.
LLWR	Low Level Waste Repository.

LWR	Light Water Reactor.
MAC	Miscellaneous Activated Component.
MBq	Megabecquerel, one million (10 ⁶) Becquerels.
MEP	Magnox Encapsulation Plant (at Sellafield).
MoD	Ministry of Defence.
MRWS	Managing Radioactive Wastes Safely. The programme was established by the UK Government and the devolved administrations for developing and implementing a policy for managing the UK's higher activity wastes in the long-term.
MTR	Materials Testing Reactor.
NDA	Nuclear Decommissioning Authority. A non-departmental public body set up by the Government in April 2005 with responsibility for the UK's public sector civil nuclear liabilities, and their subsequent management. In October 2006, the Government also gave the NDA the responsibility for developing and ensuring delivery and implementation of the programmes for interim storage and geological disposal of the UK's higher activity wastes. From March 2007, the NDA was also given responsibility for developing a UK wide strategy for managing the UK nuclear industry's Low Level Waste (LLW) and for securing disposal capacity for LLW generated by non-nuclear industry users.
NORM	Naturally Occurring Radioactive Materials.
NRW	Natural Resources Wales.
NRTE	Naval Reactor Test Establishment.
ONR	Office for Nuclear Regulation.
POCO	Post-Operational Clean Out
PWR	Pressurised Water Reactor.
RRMPOL	Rolls-Royce Marine Power Operations Ltd.
RSRL	Research Sites Restoration Limited.
SEPA	Scottish Environment Protection Agency.
SMART	The SMART inventory process involves re-estimating anticipated volumes using a combination of techniques including a visual walk-down of all active areas of plant with reactor staff, plus remote assessment of inaccessible areas. The operating experience of reactor staff has been particularly valuable in identifying contaminated plant and areas of potential contamination which could be decontaminated based upon past experience.
TILWSP	Transportable Intermediate Level Waste Solidification Plant.
Thorp	Thermal Oxide Reprocessing Plant.
UKAEA	United Kingdom Atomic Energy Authority.
VLLW	Very Low Level Waste.
WAGR	Windscale Advanced Gas-cooled Reactor (shut down in 1981).
WAMAC	Waste Monitoring and Compaction facility (at Sellafield site).
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).

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Electronic copies of this and other 2013 Inventory documents can be obtained from the NDA (see contact details below) or via the UK Radioactive Waste Inventory website www.nda.gov.uk/ukinventory

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Front cover images: left - waste packages at Dounreay, top - LLW vaults, bottom left - deplanting and demolition at Sizewell A, bottom right - demolition, making room for new facilities

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