Department for
Business, Energy
& Industrial Strategy

2022 UK Radioactive Material Inventory

2022 UK RADIOACTIVE MATERIAL INVENTORY

Report prepared for the Department for Business, Energy and Industrial Strategy (BEIS) and the Nuclear Decommissioning Authority (NDA)
by Jacobs UK Ltd and AFRY Solutions UK Ltd

PREFACE

The 2022 United Kingdom Radioactive Waste and Materials Inventory (the 2022 Inventory) provides detailed information on radioactive wastes and materials in the United Kingdom (UK). It is produced by the Department for Business, Energy and Industrial Strategy (BEIS) and the Nuclear Decommissioning Authority (NDA).

The 2022 Inventory provides information on radioactive waste stocks (at 1 April 2022) and forecasts of future waste arisings. Information on radioactive materials that may be classed as waste in the future is also presented. The 2022 Inventory aims to provide data in an open and transparent manner for those interested in radioactive wastes and materials.

Information collected for the 2022 Inventory is presented in a suite of four reports:

- 2022 UK Radioactive Waste Inventory
- 2022 UK Radioactive Material Inventory
- 2022 UK Radioactive Waste Detailed Data
- 2022 Summary of UK Radioactive Waste and Material Inventory for International Reporting.

All documents have been prepared using information supplied to the 2022 Inventory contractors, Jacobs and AFRY by the radioactive waste producers and custodians. This information was verified in accordance with arrangements established by Jacobs and AFRY in agreement with NDA.

This report provides a summary of radioactive wastes and materials not reported in the 2022 UK Radioactive Waste Inventory. This includes nuclear materials not currently designated to be waste (some spent fuels, uranium and plutonium). It also includes potential radioactively contaminated land and other materials that are not yet sufficiently well characterised to be included in the UK Radioactive Waste Inventory.

Conditions of Publication

Feedback

We welcome feedback on the content, clarity and presentation of the 2022 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:

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Uranium hexafluoride cylinders at Capenhurst

1 INTRODUCTION

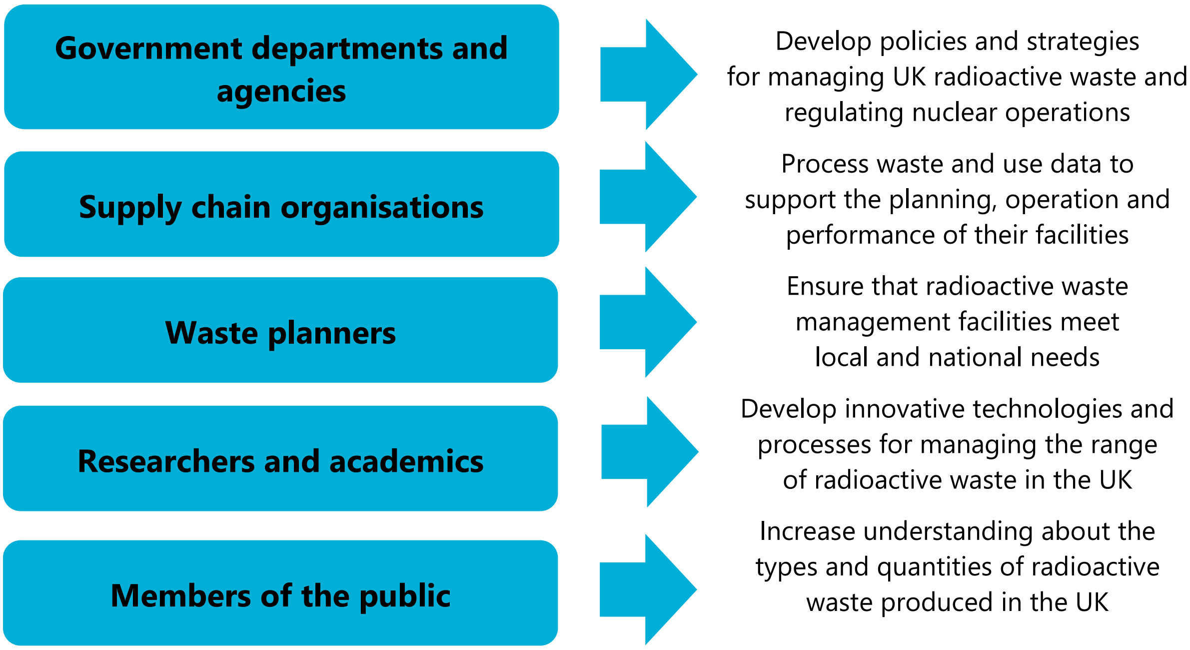
1.1 The Inventory

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

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

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

The inventory is used by a wide range of stakeholders:



The 2022 UK Radioactive Waste and Materials Inventory (the 2022 Inventory) is the latest public record on the sources, quantities and properties of radioactive waste and materials in the UK at 1 April 2022 and predicted to arise after that date.

1.2 Inventory documents

The 2022 Inventory comprises four reports:

Department for Business, Energy & Industrial Strategy

2022 UK Radioactive Waste Inventory

Radioactive Waste Inventory

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

Department for Business, Energy & Industrial Strategy

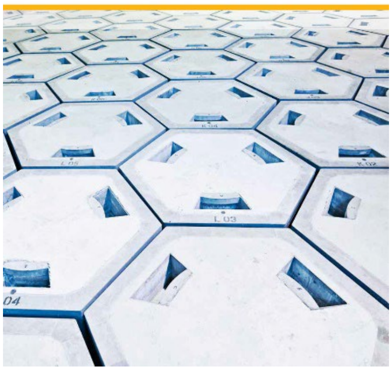
2022 UK Radioactive Material Inventory

Radioactive Material Inventory

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

Department for Business, Energy & Industrial Strategy

2022 UK Radioactive Waste Detailed Data



Waste Detailed Data

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

Department for Business, Energy & Industrial Strategy

2022 Summary of UK Radioactive Waste and Material Inventory for International Reporting

Summary for International Reporting

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

#As part of the commitment to openness, NDA has created a website dedicated to the Inventory, www.nda.gov.uk/ukinventory. All of the 2022 Inventory reports can be found together with other information about radioactive waste at this location.

1.3 This report

This report brings together information about civil nuclear materials in the UK and other radioactive substances that are not currently classed as waste but might have to be managed as waste in the future.

The inventory includes radioactive materials that existed on 1 April 2022 and those forecast to arise in the future. Information is collected about the type and quantity of radioactive materials that exist in operational reactors and stores. Also collected are estimates of future arisings of radioactive materials.

This report also includes land contamination (e.g. radioactively contaminated soil) that might arise as waste and radioactively contaminated subsurface structures (e.g. building foundations), where significant uncertainty over the management route and/or the waste quantities currently prevents inclusion in the UK Radioactive Waste Inventory.

UK defence activities produce irradiated fuel, plutonium and uranium, but these are not included in this report.

AGR fuel flask in Fuel Handling Plant, Sellafield

2 RADIOACTIVE MATERIALS

UK legislation[1,2,3] defines radioactive material as a substance containing either one or more naturally-occurring or man-made radionuclides at concentrations exceeding those specified in the legislation.

Through past and current nuclear programmes, the UK has accumulated radioactive materials such as spent (i.e. used) nuclear fuel, uranium and plutonium. These materials are not currently designated as radioactive waste by their owners. If it were decided at some point in the future that these materials had no further use, they would need to be managed as wastes.

There are two categories of radioactive material included in this report:

- **Civil nuclear materials and spent fuel** that are not currently designated to be waste. This category comprises uranium, thorium, plutonium, unirradiated and irradiated fuels.
- **Land that is potentially contaminated with radioactivity** but is yet to be fully characterised, and therefore has considerable uncertainty in the quantities that may arise. As a consequence these provisional volume estimates are not reported in the 2022 UK Radioactive Waste Inventory.

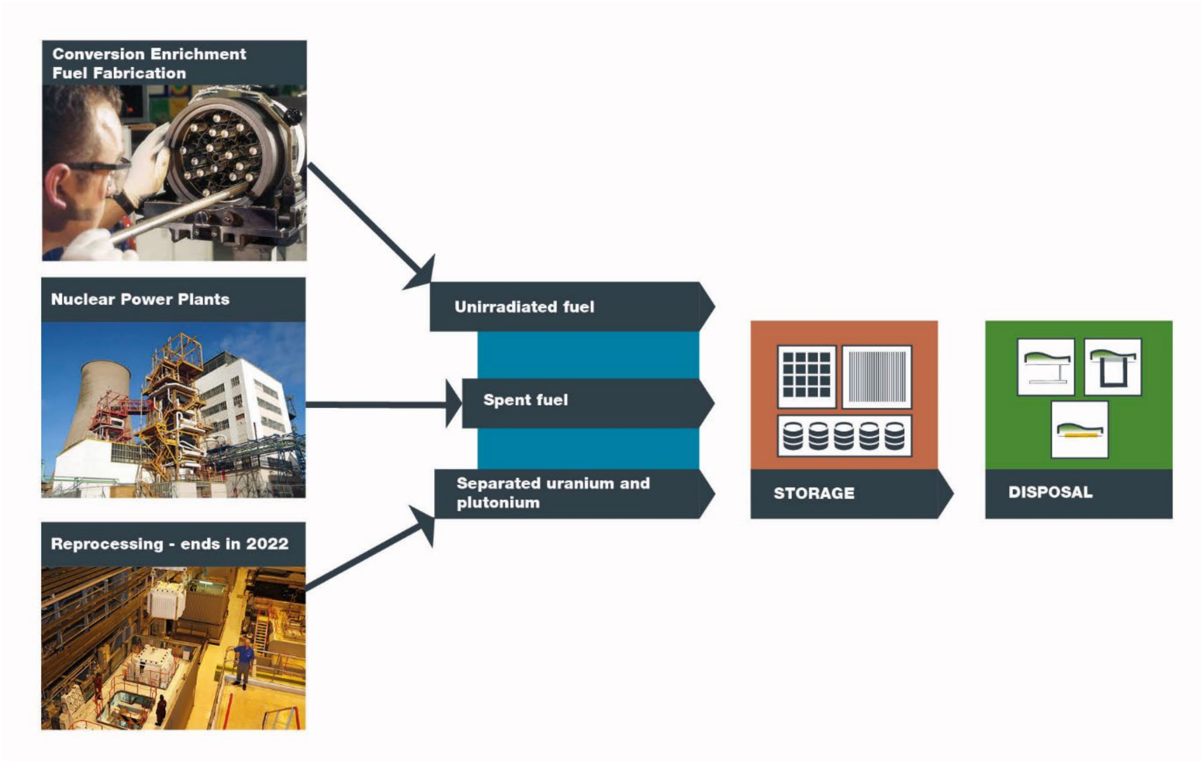
Excluded are nuclear materials outside safeguards. The UK Safeguards Office defines non-safeguarded nuclear material as "*nuclear material that is excluded from the accountancy and safeguards requirements for reasons of national security and/or defence purposes*". Nuclear licensed sites used solely for 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. Also excluded are small quantities of nuclear materials with very low concentrations of activity, typically from research establishments, universities and the non-nuclear industry.

[1] *Radioactive Substances Act 1993 (as amended), 27 May 1993.*
[2] *Environmental Permitting (England and Wales) Regulations 2016 (as amended). Statutory Instrument, 11 December 2016.*
[3] *Environmental Authorisations (Scotland) Regulations 2018.*

The diagram below illustrates the sequence of activities for processing uranium and manufacturing nuclear fuel to generate electricity by nuclear power. It also includes activities to manage depleted uranium hexafluoride from the uranium enrichment process (storage and deconversion) and spent nuclear fuel (reprocessing and storage).

Spent fuel reprocessing in the UK ended in 2022.

Information on the use of nuclear materials and nuclear fuels in the UK is given on the following pages.



2.1 Uranium

Uranium is a naturally occurring radioactive element that is the raw material used for making fuel for nuclear reactors. Uranium ore is processed to concentrate the uranium content, which is exported from mines as triuranium octoxide (U_3O_8) – commonly referred to as yellowcake. This product is then further processed to produce uranium in a physical and chemical form suitable for fabricating into nuclear fuels.

There are different types (or grades) of uranium:

Natural Uranium (NU)

Uranium in nature has a uranium-235 content of about 0.72% mole fraction. Natural uranium was used in its metallic form in Magnox reactor fuel[4].

Highly Enriched Uranium (HEU)

Uranium enriched in uranium-235 to 20% or more by mass. HEU is used in the manufacture of specialist nuclear fuels. In the past it has also been recovered by reprocessing these fuels.

Low Enriched Uranium (LEU)

Uranium enriched in uranium-235 to less than 20% by mass. LEU as uranium dioxide (UO_2) is used in the manufacture of Advanced Gas Reactor (AGR) and Pressurised Water Reactor (PWR) fuels. Power reactor fuels have a typical initial uranium-235 content of between 3 and 5% by mass. LEU (with reduced uranium-235 content) is also a product of reprocessing these fuels. This recycled uranium is stored as uranium trioxide (UO_3).

Depleted Uranium (DU)

Uranium with uranium-235 content less than in natural uranium. DU is a by-product of the uranium enrichment process used in the manufacture of nuclear fuels for AGR and PWR power stations. This is currently stored as uranium hexafluoride (UF_6). DU is also a product of reprocessing spent Magnox reactor fuel. This is stored as UO_3. DU is a component of Mixed Oxide (MOX) fuel.

To manufacture fuel for current UK civil nuclear reactors, yellowcake is first converted through chemical processing into uranium hexafluoride UF_6, which is enriched to LEU. The enriched UF_6 is then converted to UO_2 and formed into ceramic pellets which are fabricated into fuel pins and assemblies. In the UK, enrichment is carried out at Capenhurst in Cheshire and enriched oxide fuel is fabricated at Springfields in Lancashire.

Uranium recovered from the reprocessing of spent fuel can be re-enriched and re-utilised in new nuclear fuel. In the past, some reprocessed uranium from the Magnox programme was used to manufacture new AGR fuel. Depleted UF_6 can be enriched to provide feed stock for new fuel. Depleted uranium can also be mixed with plutonium to make MOX fuel. MOX fuel is not currently used or manufactured in the UK.

2.2 Thorium

Thorium is a naturally occurring radioactive element that can be mined, extracted and processed to make fuel for nuclear reactors. In the UK only experimental reactors have used thorium-based fuels. The Dragon high temperature helium-cooled reactor at Winfrith, which operated from 1964 to 1975, used a mix of uranium and thorium fuels. Dragon reactor fuel and unused reactor grade thorium

[4] *Some Magnox fuel was slightly enriched (<1% uranium-235) to offset the effects of reactor ageing.*

metal bars have been designated as waste, and are reported in the 2022 UK Radioactive Waste Inventory.

2.3 Unirradiated fuel

Unirradiated fuel is nuclear fuel that has not yet been used to power nuclear reactors. It includes fuel at fabrication plants awaiting shipment and fuel at nuclear power stations awaiting loading into reactors. There are also small quantities of surplus unirradiated research fuels.

Assembling an AGR fuel element at Springfields

2.4 Spent fuel

Irradiated fuel is nuclear fuel that is being or has been used to power nuclear reactors. When it has reached the end of its life and is no longer capable of efficient fission, it is known as 'spent fuel'. Typically, the spent fuel is made up of 96% unreacted uranium, 1% plutonium and 3% waste products. The precise composition depends on the type of reactor and the amount of power produced by the fuel.

There are three main types of nuclear power reactor that have operated in the UK (Magnox, AGR and PWR), and spent fuel from each is handled differently.

Magnox	Spent fuel from shutdown Magnox reactors was reprocessed until July 2022. The remaining spent fuel will be stored at Sellafield pending decisions about its future disposal.
AGR	Reprocessing of spent fuel from AGRs was completed in November 2018. The remaining and future spent fuel from the seven AGR stations will be stored at Sellafield pending decisions about its future disposal.
PWR	Spent fuel from the Sizewell B PWR is stored at the station pending decisions about its future disposal.

AGR spent fuel flasks at Sellafield

Irradiated fuel has also arisen from the various test and prototype reactors, both large and small, that have operated in the UK. These include the Prototype Fast Reactor (PFR) and Dounreay Fast Reactor (DFR) at Dounreay, DIDO and PLUTO at Harwell, Windscale Advanced Gas Cooled Reactor (WAGR) at Windscale and Steam Generating Heavy Water Reactor (SGHWR) at Winfrith. All of these research reactors, and their associated facilities, are shut down and being decommissioned or have already been decommissioned. Much of the spent fuel from these research reactors has been reprocessed, and the remaining fuel will be stored pending decisions about its future disposal.

New nuclear power stations built in the UK will also produce spent fuel however, it is not yet clear how many reactors in total will be constructed. The uncertainty in the volume and type of spent fuel that may be generated means it would not be appropriate to include in this report. An assumed new build programme is accounted for in Nuclear Waste Services’ (NWS) Environmental Safety Case for the Low Level Waste Repository (LLWR) and the Inventory for Geological Disposal.

Small quantities of relatively low irradiation spent fuel have already been designated as waste and are reported in the 2022 UK Radioactive Waste Inventory. These comprise spent fuels from the Graphite Low Energy Experimental Pile (GLEEP), the Dragon and Zero Energy Nitrogen Heated Thermal (ZENITH) reactors. It also includes small quantities of Windscale Pile fuel and prototype commercial fuels.

2.5 Plutonium

Plutonium is a radioactive element that does not occur in nature. It is created in nuclear reactors as a result of irradiating the uranium in nuclear fuel. It is contained within spent nuclear fuel when it is removed from the reactor, but can be extracted by reprocessing the fuel. Separated plutonium is stored as plutonium oxide powder within high integrity containers in purpose-built facilities.

However, plutonium can be used as a component of MOX fuel – a mixture of uranium and plutonium (see section 3.1). Some countries are using MOX fuel in their reactors, but MOX fuel (and hence UK-owned plutonium) is not currently used in UK reactors.

Plutonium store at Sellafield

2.6 Radioactive land contamination

Land (e.g. soil) and building structures that are beneath the surface may become contaminated as a result of lifetime site operations. Land contamination that is in situ is not considered to be waste. It only becomes waste if it is excavated (e.g. for treatment or to access another subsurface structure). Much of the land contamination at nuclear sites is being managed in situ at present and may never require excavation.

Radioactively contaminated subsurface structures become waste when they no longer have a purpose. It is also dependent on whether they are disposed of in situ or excavated and disposed of ex situ. Examples are reactor basements, below ground ponds and radioactive effluent pipelines.

There can be significant uncertainty in the quantities of waste from the clean-up of land contamination and radioactively contaminated structures. This is particularly the case for radioactive wastes at the lower end of the activity range referred to as Very Low Level Waste (VLLW). Because of these uncertainties it is likely that the estimated waste volumes from land contamination in the UK Radioactive Waste Inventory will change.

Where clean-up plans have been confirmed, the waste resulting from radioactive land contamination and radioactively contaminated subsurface structures is reported in the 2022 UK Radioactive Waste Inventory. However, some waste producers have chosen to include information in the 2022 UK Radioactive Material Inventory (this report) until site characterisation has been completed and the optimal management or disposal route has been identified.

Clearing land at Oldbury

Aerial view of Capenhurst

3 MATERIALS MANAGEMENT

3.1 Management policy

Government recognises that its policy for managing radioactive materials in the long term should be as comprehensive and forward looking as possible. The UK waste management strategy should include a clear idea of those radioactive materials that might later be declared as waste. The UK Government in its framework for the long-term management of higher activity waste is also considering radioactive materials not currently classified as wastes[5].

Spent fuel

Historically the UK's approach has been to reprocess spent nuclear fuel in order to recover the uranium and plutonium content. However, the UK ceased reprocessing in 2022. All remaining and future spent fuel arising from nuclear power stations in the UK will be stored pending a future decision on whether to declare them as waste for disposal in a Geological Disposal Facility (GDF).

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[6].

For plutonium the priority is to provide a solution that puts the UK's civil plutonium beyond reach. This is because continued, indefinite, long-term storage leaves a burden of security risks and proliferation sensitivities for future generations to manage.

In 2011 the UK Government set out its preferred policy for the long-term management of civil separated plutonium. This was that it should be reused in the form of MOX fuel[7,8]. At that time the Government believed that there was sufficient information to set out a direction, but not to implement a MOX programme. Since then, the Government has been working closely with the NDA to develop, assess and ultimately to implement approaches to put the inventory of separated civil plutonium beyond reach. As a proportion of the inventory cannot be reused, both reuse as new nuclear fuel and immobilisation are being considered. In 2019 NDA published progress on plutonium consolidation, storage and disposition options outlining potential solutions[9].

Uranium has the potential to be reused in nuclear fuel for generating electricity, subject to the availability of the appropriate power stations and supporting infrastructure. Uranium stocks are held in safe and secure storage on fuel manufacture, enrichment and historic reprocessing sites 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.

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[5] *The UK Government policy (and that of the Northern Ireland executive) for higher activity waste is geological disposal, preceded by safe and secure interim storage and supported by ongoing research. The Welsh Government has also decided to adopt a policy for geological disposal and continues to support the policy of voluntary engagement. The Scottish Government has a different policy for its higher activity waste. Long-term management should be in near-surface facilities. Spent nuclear fuel, plutonium, uranium or other such radioactive fuels and materials are not covered by this policy.*

[6] *Nuclear Decommissioning Authority, "Strategy Effective from March 2021", March 2021.*

[7] *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.*

[8] *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.*

[9] *Nuclear Decommissioning Authority, "Progress on Plutonium Consolidation, Storage and Disposition", March 2019.*

Radioactive land contamination

'Guidance on Requirements for Release of Nuclear Sites from Radioactive Substances Regulation (GRR)', July 2018, from the environmental regulators directs nuclear operators to review their approach to site-wide waste management, to ensure the delivery of an optimised site end state. This may involve options for the in situ disposal of existing subsurface structures and the on-site disposal of associated above-ground parts.

3.2 Nuclear safeguards

Nuclear safeguards are measures to verify that countries abide by their commitments to use nuclear material for declared peaceful purposes.

Civil nuclear facilities are subject to the UK's safeguards agreements with the International Atomic Energy Agency (IAEA). They are also subject to the safeguards provisions of the UK-Euratom Nuclear Cooperation Agreement (NCA). These are designed to detect diversion of nuclear material into clandestine weapons programmes, and involve accounting for nuclear material and submitting to international inspection.

3.3 Government reporting

Government has reporting obligations under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. The UK's 7th national report for the Convention was provided in October 2020[10]. The national report contains an inventory of spent nuclear fuel in storage, as well as volumes of radioactive waste in storage and projected in future arisings. National reports are subject to a process of peer review by the Contracting Parties and are updated every three years.

Government also publishes annual figures for the UK's stocks of civil plutonium and uranium. In accordance with its commitment under the "Guidelines for the Management of Plutonium", the UK also provides these figures to the IAEA. The latest figures are for 31 December 2020[11].

[10] *Department for Business, Energy & Industrial Strategy, "The United Kingdom's Seventh National Report on Compliance with the Obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management," October 2020.*

[11] *Office for Nuclear Regulation https://www.onr.org.uk/safeguards/civilplut20.htm*

4 MATERIAL QUANTITIES

Key facts:

- UK-owned uranium stock is ~ 110,000 tHM
- UK-owned plutonium stock is ~113 tHM
- UK-owned spent fuel in reactor and in storage is ~6,000 tHM
- Reprocessing of spent fuel at Sellafield ended in July 2022

This chapter presents summary information on the quantities of radioactive materials in the UK. The information has been provided by the NDA and those organisations that operate sites in the UK where radioactive materials are stored and forecast to arise.

Quantities of nuclear materials (uranium, thorium, plutonium, and spent and unirradiated nuclear fuels) are given as masses expressed as tonnes of heavy metal (tHM). Quantities of radioactive land contamination and radioactively contaminated subsurface structures are given as volumes expressed as cubic metres.

The Appendix sets out the assumptions used in reporting radioactive materials in the 2022 Inventory.

4.1 Uranium

Table 1 gives the total masses of UK-owned DNLEU (Depleted, Natural and Low Enriched Uranium) and HEU at 1 April 2022.

**Table 1: UK-owned uranium
Mass in stocks (tHM)**

Location	Description	Stock at 1 April 2022
All UK sites	DNLEU	~110,000 (1)
All UK sites	HEU	<1

(1) The latest figure published by the Office for Nuclear Regulation (ONR) is 120,000 tHM at 31 December 2020. This is greater than the figure reported here because it includes DNLEU present in spent fuels as well as foreign-owned uranium, both of which are reported separately in the 2022 Inventory (see Table 5 and text below). The radioactive materials inventory does not include nuclear materials owned by the MOD.

There are about 110,000 tHM of DNLEU in stock. The major components are depleted uranium from enrichment in the form of UF_6, and from reprocessing of Magnox fuel in the form of UO_3. DNLEU stocks are held at Capenhurst, Springfields, Sellafield and Dounreay. Table 1 excludes about 9,300 tHM of overseas-owned material.

Future arisings of UK-owned DNLEU are estimated at about 88,000 tHM. This figure assumes enrichment operations continuing over the next twenty years, and the spent fuel management scenario as described in the Appendix.

In addition approximately 94,000 tHM of foreign-owned UF_6 are forecast for enrichment at Capenhurst. Future enrichment may utilise either existing uranium stocks or new uranium depending on the economics. Hence, there is uncertainty in the total quantities of DNLEU that will be produced.

There is currently less than 1 tHM of HEU in stock. This material comprises residues from reprocessing and fuel fabrication. No further arisings are expected.

4.2 Thorium

Table 2 gives the total mass of UK-owned thorium at 1 April 2022. There are no reported future arisings.

**Table 2: UK-owned thorium
Mass in stocks (tHM)**

Location	Description	Stock at 1 April 2022
Springfields	ThO_2	~0.2

4.3 Plutonium

Table 3 gives the total masses of UK-owned separated plutonium at 1 April 2022. Separated plutonium is held mainly as plutonium dioxide (PuO_2) from the reprocessing of Magnox and oxide fuel at Sellafield, with a small amount in other forms and fuel residues. Reprocessing finished in July 2022. Plutonium will continue to arise for another 1-2 years as production is completed and post operational clean out (POCO) is undertaken.

**Table 3: UK-owned separated plutonium
Mass in stocks (tHM)**

Location	Description	Stock at 1 April 2022
All UK sites	PuO_2	~113

There are currently about 113 tHM of UK-owned separated plutonium in stock.

Existing stocks of plutonium from reprocessing overseas spent Light Water Reactor (LWR) fuel are about 24 tHM[12] with about 4 tHM in unirradiated MOX fuel or semi-fabricated and unfinished products.

4.4 Unirradiated fuel

Table 4 gives the masses of UK-owned unirradiated fuel in the UK. The total mass of unirradiated fuel at 1 April 2022 is estimated to be about 110 tHM. There will be future arisings of UK power reactor fuels to meet the fuelling requirements for projected reactor lifetimes, but these are not estimated.

[12] *The UK Government has stated that overseas owners of plutonium stored in the UK could have that plutonium managed in line with UK plutonium, subject to commercial terms that are acceptable to the UK Government. In addition, subject to compliance with inter-governmental agreements and acceptable commercial arrangements, the UK is prepared to take ownership of overseas plutonium stored in the UK as a result of which it would be treated in the same way as UK-owned plutonium. In the long term, this approach will help to simplify the implementation of the government's plutonium management policy by reducing uncertainty for both the UK and the overseas owners.*

Table 4: **UK-owned unirradiated fuel**
Mass in stocks (tHM)

Location	Description	Stock at 1 April 2022
Sellafield	Various (1)	~19
Dounreay	Various (2)	~0.2
All UK sites	AGR fuel	~50
All UK sites	PWR fuel	~40
Total		**~110**

(1) Includes unirradiated uranium metal, uranium oxide and MOX fuels.

(2) Includes unirradiated PFR, MOX and carbide fuels.

4.5 Spent fuel

The UK's current stock of spent fuel consists mainly of Magnox, AGR and PWR fuels. It also includes smaller stocks of various spent experimental and research fuels.

Table 5 gives the masses of UK-owned spent fuel at 1 April 2022 and estimated in future arisings. The total mass of spent fuel at 1 April 2022 was about 6,000 tHM, with estimated future arisings of about 2,400 tHM[13]. The figures for spent fuel at 1 April 2022 exclude about 0.7 tHM of overseas-owned spent fuel at Dounreay.

Reprocessing of spent AGR fuel came to an end in November 2018; existing stocks and future arisings produced over the planned lifetimes of the AGR stations will remain in long-term storage.

Spent fuel from shutdown Magnox reactors was reprocessed until July 2022. The remaining spent fuel will be stored at Sellafield pending decisions about its future disposal.

The Sizewell B PWR station is expected to generate about 1,020 tHM spent fuel over its 40-year operating lifetime. It is currently assumed that this fuel will be held in long-term storage.

13 Spent fuel from new build reactors (including Hinkley Point C) is not included in estimate.

Table 5: UK-owned spent fuel
Mass in stocks and estimated for future arisings (tHM)

Location	Description	Stock at 1 April 2022 (1)		Estimated future arisings
		In reactor	In storage	
Sellafield	Magnox fuel	-	289	-
	AGR fuel	-	~2,500	- (2)
	SGHWR fuel	-	68	-
	WAGR fuel	-	21	-
	Other fuels (3)	-	~795	-
Dounreay	DFR breeder fuel	~7.39	~2.3	-
	PFR	-	10	-
	Other fuels	-	<1	-
AGR power stations	AGR fuel	~1,520	~110	~390
PWR power station	PWR fuel	~90	~640	~290
Total		**~1,600**	**~4,400**	**~770**

(1) Fuel 'In reactor' is that in reactor cores; fuel 'In storage' has been removed from reactor cores to storage facilities.

(2) See AGR power stations for future transfers of spent fuel to Sellafield.

(3) Includes miscellaneous fuels (~720 tHM), overseas origin Light Water Reactor (LWR) fuels from Thorp programme transferred to UK ownership (~69 tHM) and DFR breeder fuel transferred from Dounreay (~1.5 tHM).

4.6 Miscellaneous materials

There are a number of uranic residues at Capenhurst from uranium enrichment operations. Table 6 includes a list of streams and quantities. These materials continue to be processed off-site to recover the uranium content. Any radioactive waste from this activity is being disposed of by the processing site and is included in the 2022 Inventory.

Table 6: Miscellaneous materials
Mass at 1 April 2022 and estimated future arisings (tHM)

Site	Stream identifier	Stream description	Stock at 1 April 2022	Future arisings
Capenhurst	8A14	Uranic residues	13.5 (1)	0
	M8A1011	Chemical adsorber trap residues (CATR)	29	106
	M8A1012	Citric sludge	0.26	4.4
	M8A1013	Degreaser sludge	0.14	5.0
	M8A1014	Effluents	3.2	38

Site	Stream identifier	Stream description	Stock at 1 April 2022	Future arisings
	M8A1015	Uranic residues	0.92	0.8
	M8A1018	Chemical tap material	0	0.36

(1) Volume (m³) of material.

4.7 Contaminated land volumes

Table 7 gives volume estimates for potential radioactive land contamination and radioactively contaminated subsurface structures. Included are materials at Sellafield, Springfields, Aldermaston, the LLWR and various MOD sites.

The estimated volume of radioactive land contamination is about 6,100,000 m³. Most of this is High Volume VLLW (HVVLLW) and LLW contaminated soil at Sellafield. Much of the radioactively contaminated soil on site can be managed in situ and will not require excavation and treatment as waste.

The estimate of radioactively contaminated subsurface structures is about 235,000 m³. Most of this comprises building foundations at Sellafield.

The volumes given for Sellafield in Table 7 represent the best estimate of land affected by radioactive contamination in the various waste categories. They are estimates based on the most recent characterisation data and understanding of the site. They are subject to constant review as knowledge of the site improves. The Sellafield strategy is to manage land contamination in situ in the short-term. In the longer-term access to the contamination will be possible when extensive decommissioning takes place. It is not envisaged that, on the basis of an overall balance between risk and benefit, all contaminated material will be excavated. In particular, for the most lightly contaminated material within the HVVLLW category the optimum plan may be in situ management.

At Springfields the stock volume is based on site investigations and the results of soil samples collected from boreholes.

At Aldermaston a methodology for estimating volumes of radiologically contaminated soil waste has been developed. Verification of the volumes can only be achieved once further characterisation is undertaken as facilities approach the final stages of decommissioning and demolition. This is due to the majority of the forecast volume being associated with below ground structures.

Table 7: Potential radioactive land contamination and radioactively contaminated subsurface structures

Site	Stream identifier	Stream description	Estimated volume (m³) (1)
Sellafield	2D150	Contaminated Soil	1,610
	2D151	Contaminated Soil LLW	2,560,000
	2D152	Contaminated Foundations ILW (2)	2,160
	2D153	Contaminated Foundations LLW (2)	32,900

Site	Stream identifier	Stream description	Estimated volume (m^3) (1)
	2D154	Contaminated Soil from Site Clearance - HVVLLW	3,490,000
	2D155	Contaminated Foundations from Site Clearance – HVVLLW (2)	200,000
Springfields	2E5000	Radioactive Contaminated Land	<32,500 (3)
Aldermaston	7A5000	Radioactive Contaminated Land	~3,390
Various (MOD)	7S5000	Contaminated soil, ash and rubble	350 (4)
LLWR	2N101	Vault Profiling Material from PCM Facilities VLLW	20,900
	2N102	Contaminated Land VLLW	3,710
All sites		**Total**	**6,350,000**

(1) Volumes are currently being managed in situ under existing regulatory requirements for the management of contaminated land and groundwater on nuclear sites. Some of this material may never arise as waste. The optimum management plan may be some form of in situ disposal, particularly for the most lightly contaminated material.

(2) Some of this material may be suitable for beneficial reuse or the optimum management plan may be some form of in situ disposal.

(3) Volumes are uncertain, but will be established during ongoing land contamination projects.

(4) Based on estimates from various MOD sites with known radiological contamination which may require disposal. There is a possibility that future land quality assessments may result in additional volumes.

The Defence Infrastructure Organisation (DIO) is responsible for managing the MOD Estate. This includes a major programme to assess and remediate contaminated ground at MOD sites in the UK.

At the LLWR the estimate of land contamination is based on non-targeted ground investigation and therefore has high uncertainty.

At all sites further site investigation work will give clearer information on potential volumes.

The 2022 UK Radioactive Waste Inventory itself includes about 140,000 m^3 of contaminated soil and spoil from radioactive land contamination. This is principally at Sellafield, Dounreay, Harwell, Capenhurst and Magnox reactor sites. It also includes radioactively contaminated subsurface structures as a component of site decommissioning waste streams.

APPENDIX ASSUMPTIONS USED FOR REPORTING CIVIL NUCLEAR MATERIALS

All assumptions listed below are in line with those used in compiling data for the 2022 Inventory. These assumptions represent the planning positions at 1 April 2022 of the organisations that operate sites where radioactive waste and materials are generated or held. Projections may need to be amended as plans and arrangements are developed. Alternatively these could be changed for commercial, policy or funding reasons, or if improved data become available.

A1. Generic assumptions

- Plutonium, uranium and spent nuclear fuel from UK civil nuclear power stations have potential value as they can be reused for manufacturing fresh nuclear fuel, subject to the availability of the appropriate power stations and supporting infrastructure. These materials are not currently classified as waste.
- Small quantities of relatively low irradiation spent fuel have already been designated as waste. These are reported in the 2022 UK Radioactive Waste Inventory (i.e. excluded from this report).
- The radioactive materials inventory reports UK-owned materials. Quantities of overseas-owned materials currently held in the UK are given for information.
- The radioactive materials inventory does not include nuclear materials owned by the MOD or 'small users' (i.e. universities and research establishments).
- Land contamination is managed in situ under existing regulatory requirements. Some of this material may never arise as waste. Volume estimates are based on the most recent characterisation data and understanding of the site. The estimates are subject to change as knowledge of the site improves. Where land remediation work or other actions will generate waste this is reported in the 2022 UK Radioactive Waste Inventory.
- Radioactively contaminated subsurface structures are likely to be difficult to characterise. The structures reported here are those not sufficiently well characterised to be included in the 2022 UK Radioactive Waste Inventory.

A2. Spent fuel

- In addition to the spent fuel already generated, spent fuel will arise from the operations and final defuelling of the following nuclear power stations:

Table A1: Operating nuclear power stations in the UK

Station	Planned shutdown date
AGR:	
Hinkley Point B	2022 (1)

Station	Planned shutdown date
Hartlepool	2024
Heysham 1	2024
Heysham 2	2028
Torness	2028
PWR:	
Sizewell B	2035

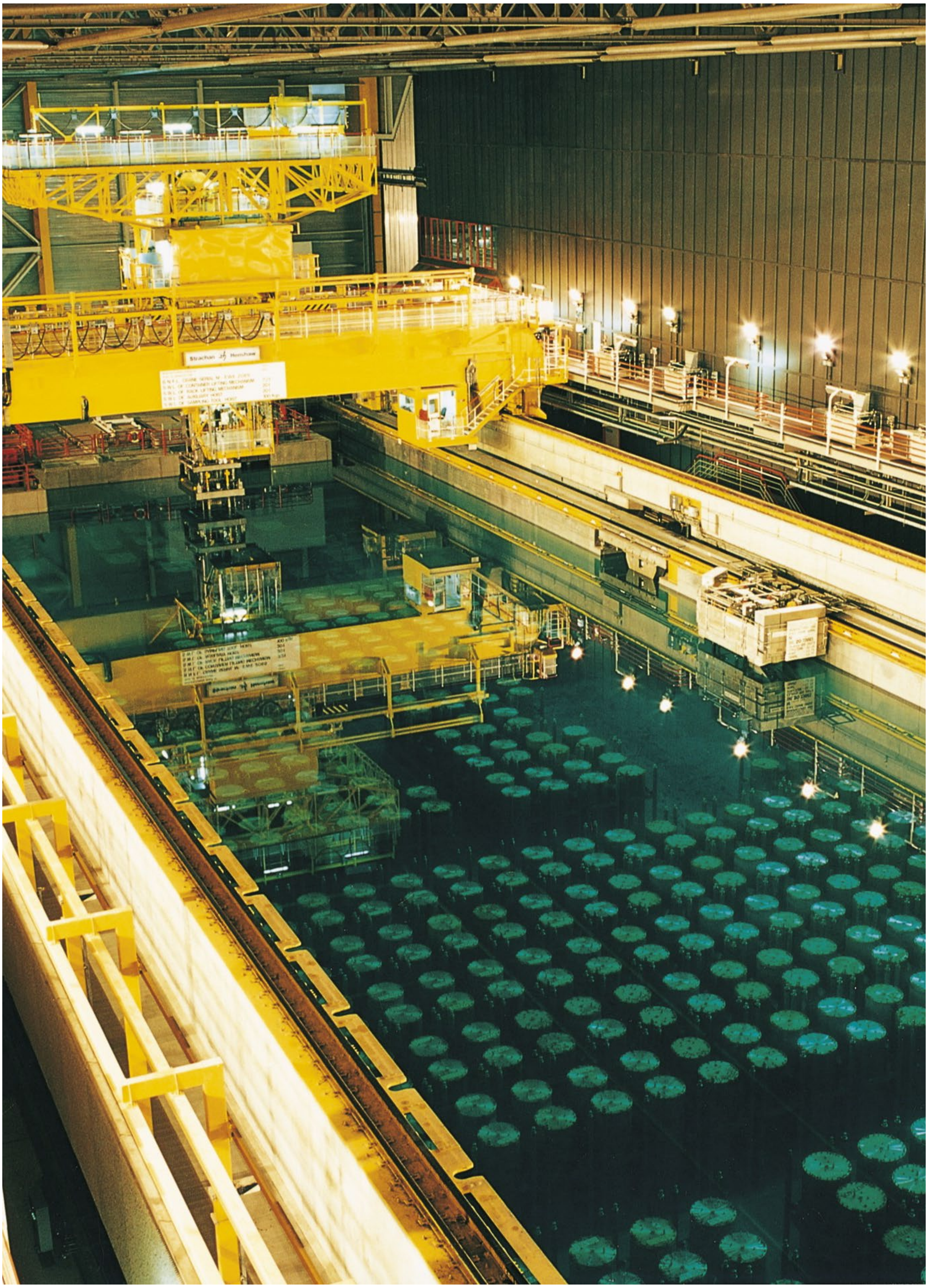
(1) Hinkley Point B ceased generating in August 2022.

- This report does not include spent fuel from new nuclear power stations being (or intended to be) built in the UK. However, an assumed new build programme is accounted for in the environmental safety cases for the LLWR and the generic design for a GDF.
- Nuclear fuel manufacturing in the UK is assumed to continue until 2028.
- The following quantities of spent fuel that have been produced or are forecast to arise from UK reactors will be held in long-term storage in the UK[14]:
    - ~290 tHM from Magnox reactors
    - ~4,500 tHM from AGRs
    - ~1,015 tHM from the Sizewell B PWR
    - Small quantities of other fuels, including some SGHWR and WAGR fuel.

A3. Separated uranium and plutonium

- Separated uranium and plutonium is assumed to arise in the UK from reprocessing activities.
- All UK-owned separated uranium and plutonium is assumed to be held in long-term storage in the UK.

[14] *Although plutonium, uranium and spent fuel are not classified as waste, these materials are considered in the inventory for disposal in the Government's 'Implementing Geological Disposal – Working with Communities', an updated framework for long-term management of higher activity radioactive waste.*



Spent AGR fuel storage at Sellafield

GLOSSARY

	~	About.
	<	Less than.
A ▸	**AGR**	Advanced Gas-cooled Reactor.
B ▸	**BEIS**	The Department for Business, Energy & Industrial Strategy is a ministerial department that brings together responsibilities for business, industrial strategy, science, innovation, energy, and climate change.
C ▸	**CATR**	Chemical Adsorber Trap esidues.
D ▸	**Depleted uranium (DU)**	Uranium where the U235 isotope content is below the naturally occurring 0.72% by mass.
	DFR	Dounreay Fast Reactor (shut down in 1977).
	DIO	The Defence Infrastructure Organisation (DIO) is responsible for managing the MOD Estate.
	DNLEU	Depleted, Natural and Low Enriched Uranium.
	Dragon	Experimental high temperature reactor project (at Winfrith; shut down in 1976).
E ▸	**Enriched uranium**	Uranium where the U235 isotope content is above the naturally occurring 0.72% mole fraction.
	Enrichment	The process of increasing the abundance of fissionable atoms in natural uranium.
	Euratom	European Atomic Energy Community.
	Ex situ	'Off the site' (in the context of waste disposal).
F ▸	**Fission**	Spontaneous or induced fragmentation of heavy atoms into two (occasionally three) lighter atoms, accompanied by the release of neutrons and radiation.
	Fission products	Atoms, often radioactive, resulting from nuclear fission.
G ▸	**GDF**	Geological Disposal Facility. Deep underground facility for disposal of higher activity wastes.
	GLEEP	Graphite Low Energy Experimental Pile. Graphite reactor at Harwell site (shut down in 1990).
	Government	A collective term for the central government bodies responsible for setting radioactive waste management policy within the UK. It comprises the UK Government, and the devolved administrations of Scotland, Wales and Northern Ireland.
H ▸	**HEU**	Highly Enriched Uranium. Uranium where the U235 isotope content is 20% by mass or more.
	HVVLLW	High Volume Very Low Level Waste.
I ▸	**IAEA**	International Atomic Energy Agency.
	ILW	Intermediate Level Waste.
	In situ	'On the site' (in the context of waste disposal).

L ▸	**LEU**	Low Enriched Uranium. Uranium enriched in uranium-235 to less than 20% by mass.
	LLW	Low Level Waste.
	LLWR	Low Level Waste Repository. The LLWR, south of Sellafield in Cumbria, has operated as a national disposal facility for LLW since 1959.
	LWR	Light Water Reactor.
M ▸	**Magnox**	An alloy of magnesium used for fuel element cladding in natural uranium fuelled gas-cooled power reactors. Also a generic name for this type of reactor.
	MOD	Ministry of Defence.
	MOX	Mixed Oxide. Refers to nuclear fuel consisting of uranium oxide and plutonium oxide.
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.
	NCA	Nuclear Cooperation's Agreement.
	NU	Natural Uranium.
	Nuclear fuel	Fuel used in a nuclear reactor. Most fuel is made of uranium metal or oxide, and produces heat when the uranium atoms split into smaller fragments.
	NWS	Nuclear Waste Services. The organisation formed from the LLW Repository Ltd , Radioactive Waste Management and the Nuclear Decommissioning Authority group's Integrated Waste Management Programme.
O ▸	**ONR**	Office for Nuclear Regulation (an agency of the Health and Safety Executive).
P ▸	**PFR**	Prototype Fast Reactor (at Dounreay site; shut down in 1994).
	Plutonium	A radioactive element created in nuclear reactors. It can be separated from spent nuclear fuel by reprocessing. Plutonium is used as a nuclear fuel, in nuclear weapons and as a power source.
	Pu	Plutonium.
	PuO_2	Plutonium dioxide.
	PWR	Pressurised Water Reactor.
R ▸	**Radioactive waste**	Waste that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body.
	Radionuclide	A general term for an unstable nuclide that emits ionising radiation (e.g. cobalt-60).
	Reprocessing	The chemical extraction of reusable uranium and plutonium from waste materials in spent nuclear fuel.
S ▸	**SGHWR**	Steam Generating Heavy Water Reactor (at Winfrith site; shut down in 1990).
	Spent fuel	Fuel that has been used (i.e. irradiated) in nuclear reactors that is no longer capable of efficient fission due to the loss of fissile material.

T ▸	**tHM**	Tonnes of heavy metal. A unit of mass used to quantify uranium, plutonium and thorium including mixtures of these elements.
	Thorium	Thorium is a naturally occurring radioactive element that can be mined, extracted and processed to make fuel for certain reactors.
	Thorp	Thermal Oxide Reprocessing Plant (at Sellafield).
U ▸	**UF_6**	Uranium hexafluoride.
	U_3O_8	Triuranium octoxide.
	UO_2	Uranium dioxide.
	UO_3	Uranium trioxide.
	Uranium	A radioactive element that occurs in nature. Uranium is used for nuclear fuel and in nuclear weapons.
	Uranium-235	The main fissile isotope of uranium. Natural uranium typically contains 0.72% by weight of U235.
	Unirradiated fuel	Fuel that has not yet been used to power nuclear reactors.
V ▸	**VLLW**	Very Low Level Waste.
W ▸	**WAGR**	Windscale Advanced Gas-cooled Reactor (at Sellafield; shut down in 1981).
Y ▸	**Yellowcake**	Yellowcake is concentrated uranium oxide, obtained through the milling of uranium ore. Yellow cake typically consists of 70-90% U_3O_8 with the remainder consisting of UO_2 and UO_3.
Z ▸	**ZENITH**	Zero Energy Nitrogen Heated Thermal reactor. A research reactor at Winfrith that has been decommissioned.