Nuclear Decommissioning Authority

DEPARTMENT OF ENERGY & CLIMATE CHANGE

Radioactive Materials Not Reported in the 2010 UK Radioactive Waste Inventory

URN 10D/988
NDA/ST/STY(11)/0007
February 2011

Radioactive Materials Not Reported in the 2010 UK Radioactive Waste Inventory

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

PREFACE

The Department of Energy & Climate Change (DECC)[1] and the Nuclear Decommissioning Authority (NDA) have commissioned the 2010 UK Radioactive Waste Inventory (2010 Inventory) to provide information on the status of radioactive waste at 1 April 2010 and forecasts of future arisings in the UK. Its aim is to provide comprehensive and up-to-date data in an open and transparent manner for those interested in radioactive waste issues. It is part of an ongoing programme of research jointly conducted by DECC and NDA.

This report provides a summary of radioactive materials not reported in the 2010 UK Radioactive Waste Inventory. This includes nuclear materials not currently deemed to be waste (spent fuel, uranium and plutonium), and some potentially radioactively contaminated ground not included in the 2010 UK Radioactive Waste Inventory.

This report has been prepared on the basis of information supplied to Pöyry Energy, the principal contractor for the production of the 2010 UK Radioactive Waste Inventory. This information was verified in accordance with arrangements established by Pöyry Energy.

The information given in this report represents the best available knowledge at the time of compilation of the 2010 Inventory based upon the processes, strategies and assumptions that were applicable at that time. Revision of the predictions, particularly of the long-term forecasts, may be necessary as plans change and estimates are refined.

2010 Inventory documents

Information collected for producing the 2010 UK Radioactive Waste Inventory is presented in a series of reports, as listed below.

- A summary of the 2010 UK Radioactive Waste Inventory;
- The main report for the 2010 UK Radioactive Waste Inventory;
- A summary of Information for International Reporting;
- A review of the processes contributing to radioactive wastes in the UK (the report published in 2008 has not been updated);
- Information on other radioactive substances that may require long-term management as radioactive waste in the UK is presented in a separate report (this document).

These reports are available in both printed and electronic format.

The 2010 Inventory documents can be obtained from the NDA (see contact details opposite) or via the UK Radioactive Waste Inventory website www.nda.gov.uk/ukinventory.

Conditions of Publication

[1] The results of this work will be used in the formulation of Government policy, but views expressed in this report do not necessarily represent Government policy.

ISBN 978-1-905985-22-7

Feedback & Queries

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:

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

Tel: 01925 802077

foi@nda.gov.uk

NDA Document Library

If you would like to see other reports available from NDA, a complete listing can be viewed at our website www.nda.gov.uk, or please contact the NDA at the address provided above.

CONTENTS

1 INTRODUCTION

Radioactive material is defined in the Radioactive Substances Act 1993 [1] and the Exemption Order on Substances of Low Activity [2] as a substance falling within either or both of the following descriptions:

- A naturally-occurring substance containing an element (actinium, lead, polonium, protactinium, radium, radon, thorium or uranium) present at an activity level that is greater than a specified level;
- Any substances which are not naturally occurring, whose radioactivity is wholly or partly due to nuclear fission, neutron bombardment or ionising radiation.

Material that has no further use, and is contaminated by, or incorporates, radioactivity above certain levels defined in legislation is known as radioactive waste [1]. As one of the pioneers of nuclear technology, the UK has accumulated a substantial legacy of radioactive waste from a variety of different civil and defence-related nuclear programmes. Some of this waste is already in storage, but most of it still forms part of existing facilities, and will only become waste over the next century or so as these plants are shut down, decommissioned and cleaned up.

An inventory of radioactive waste in the UK is compiled periodically by the Department of Energy & Climate Change (DECC) and the Nuclear Decommissioning Authority (NDA) to meet the UK's international reporting obligations, to provide up-to-date information for waste management policy development, and for the regulation and planning of waste treatment, storage and long-term management.

The 2010 UK Radioactive Waste Inventory is the latest public record of information on the sources, quantities and properties of radioactive waste in the UK at 1 April 2010 and predicted to arise after that date based on assumptions as to the nature and scale of future operations and activities [3].

As well as waste, past and existing nuclear programmes have produced an accumulation of radioactive materials such as spent (i.e. used) nuclear fuel, uranium and plutonium that are not currently classified as waste. In most cases this is because they have potential value. Spent fuel can be reprocessed to separate uranium and plutonium, which in turn can be used to manufacture fresh fuel. However, if it were decided at some point in the future, on the basis of economics, or environmental and safety issues, that these materials had no further use, they may need to be managed as wastes.

Government[1] recognises that policy for managing radioactive materials should be as comprehensive and forward looking as possible, and that the UK waste management strategy should include a clear idea of which radioactive materials might come forward as waste. Consequently the UK Government's "Managing Radioactive Waste Safely" (MRWS) programme for developing and implementing a policy for managing the UK's higher activity wastes in the long-term is also considering radioactive materials not currently classified as wastes.

The independent Committee on Radioactive Waste Management (CoRWM) was appointed to oversee the review of long-term waste management options and recommend a strategy to Government. CoRWM reported in 2006 with a package of recommendations including geological disposal preceded by safe and secure interim storage, along with a programme of ongoing research and development [4]. The UK Government and Devolved Administrations for Wales and Northern Ireland accepted CoRWM's recommendation as the way forward.

[1] The use of "Government" in this report refers collectively to the UK Government and the devolved administrations for Scotland, Wales and Northern Ireland.

1 Introduction

Following public consultation, in June 2008 the UK Government and Devolved Administrations for Wales and Northern Ireland published a White Paper *"Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal"* [5] setting out detailed policy and plans for the long-term management of higher activity wastes. The White Paper was accompanied by a call for communities to express an interest in discussing with the Government the possibility of hosting a geological disposal facility.

The White Paper identified an inventory that included both higher activity wastes and some radioactive materials - spent fuel, uranium and plutonium.

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

Civil nuclear facilities are subject to the UK's safeguards agreements with international bodies - the International Atomic Energy Authority (IAEA) and the European Atomic Energy Community (Euratom) - and to the safeguards provisions of the Euratom treaty. These are designed to detect diversion of material into clandestine weapons programmes, and involve accounting for material and submitting to international inspection. All civil plutonium and highly enriched uranium in the UK (whether separated or in spent fuel) is stored safely and securely under relevant national and international regulations including inspection by international safeguards authorities.

Government has obligations under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management to report in these areas. The UK's third national report for the Convention was provided to the IAEA in May 2008 [6]. This report contains an inventory of spent nuclear fuel in storage, as well as volumes of radioactive waste in storage and projected in future arisings.

Government also publishes annual figures for the UK's stocks of civil plutonium and uranium, and in accordance with its commitment under the "Guidelines for the Management of Plutonium" provides figures to the IAEA. The latest figures are for 31 December 2009 [7].

The principal purposes of this report are to bring together in the public domain information required for the UK to meet its international reporting obligations in respect of civil nuclear materials, and as part of the UK Radioactive Waste Inventory process to provide a comprehensive inventory of UK radioactive substances that might have to be managed as waste at some time in the future. Nuclear materials from defence programmes are excluded for reasons of national security. Also excluded are small quantities of nuclear materials with very low concentrations of radioactivity typically from research establishments, universities and the non-nuclear industry (so-called 'small users').

The inclusion of nuclear materials within the UK Radioactive Waste Inventory allows development of management strategies and the planning of systems and facilities for managing radioactive wastes for the UK, as well as allowing it to be used as a basis for open and transparent discussions within the MRWS programme.

The structure of the remainder of this report is as follows. Chapter 2 describes the materials included in this report. Chapter 3 presents material quantities in storage and projected to arise in the future. Annex 1 presents the assumptions used in reporting nuclear material quantities. Annex 2 presents some detailed information about potentially contaminated ground and miscellaneous wastes and materials. Annex 3 provides a glossary of terms and abbreviations.

2.1 INTRODUCTION

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

- Civil nuclear materials that are not currently deemed to be waste. This category comprises irradiated fuel, unirradiated fuel, uranium, plutonium and thorium.
- Land that is potentially contaminated and miscellaneous materials some of which are deemed to be waste. There is often considerable uncertainty in the quantities that might arise, and as a consequence some waste producers have chosen to report volume estimates here rather than in the 2010 UK Radioactive Waste Inventory [3].

Nuclear materials from defence programmes[1] or from 'small users' are not included in the UK Inventory.

2.2 IRRADIATED 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 termed spent fuel. Spent fuel still contains large amounts of uranium (and some plutonium), which can be separated out through reprocessing and used to make new fuel. It is because of the potential value of the uranium and plutonium that it contains that most spent fuel is not classified as radioactive waste.

Currently, civil UK nuclear fuels are used in Magnox reactor, Advanced Gas-cooled Reactor (AGR) and Pressurised Water Reactor (PWR) power stations. Typically the spent fuel is made up of 96% unreacted uranium, 1% plutonium and 3% waste products, although the precise composition depends on the type of reactor and the amount of power produced by the fuel.

Spent Magnox and AGR fuel is stored at the station for a short cooling period before transfer to Sellafield in Cumbria. Magnox spent fuel and a proportion of AGR fuel is reprocessed at Sellafield. The remaining spent AGR fuel is held at Sellafield. Spent PWR fuel from Sizewell is currently stored at the station. Some spent Light Water Reactor (LWR) fuel from overseas is also held and reprocessed at Sellafield[2].

Until 1996 there was also spent fuel reprocessing at Dounreay in Caithness in support of the UK fast breeder reactor programme and overseas customers, but on a much smaller scale than at Sellafield. Some spent fuel remains in storage at the site.

Other spent fuels have arisen from research, experimental and prototype reactors. Spent fuel from the Windscale Advanced Gas-cooled Reactor (WAGR) and the Steam Generating Heavy Water Reactor (SGHWR) is stored at Sellafield pending reprocessing.

Small quantities of relatively low irradiation spent fuel that are not planned to be reprocessed have already been designated as waste and are reported in the 2010 UK Radioactive Waste Inventory. These comprise spent fuels from the Windscale Piles, Graphite Low Energy Experimental Pile (GLEEP), Dragon and Zenith reactors, plus small quantities of mainly prototype commercial fuels.

[1] Information about nuclear materials can be found in the Ministry of Defence 1998 Strategic Waste Review [8].
[2] The UK has contracts with other countries to reprocess their spent fuel. All contracts signed since 1976 provide for the return of recovered uranium and plutonium and associated waste to the country of origin.

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 research fuels.

2.4 PLUTONIUM

Plutonium is a radioactive element that does not occur in nature. Plutonium is created in nuclear reactors as a result of 'burning' (i.e. 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 in purpose built facilities within high integrity containers at reprocessing sites as plutonium oxide powder.

Plutonium is a potentially valuable energy source. The original intention of recovering plutonium was to reuse the material in a future fast breeder reactor programme. It was believed in the 1950s and 1960s that a closed nuclear fuel cycle was the most desirable option for future energy supply in light of the scarcity of uranium at the time. Fast breeder reactors make more efficient use of nuclear materials – effectively generating more fuel than they consume. The UK fast breeder reactor programme was cancelled in the early 1990s as the forecast uranium supply shortage did not occur, therefore closing this option for the use of recovered plutonium.

However, plutonium can be used as a component of mixed oxide (MOX) fuel – a mixture of uranium and plutonium. Some countries are using MOX fuel in their reactors, but MOX fuel (and hence UK owned plutonium) is not currently used in UK reactors[3].

2.5 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 imported into the UK 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 U-235 content of about 0.72% by mass. Natural uranium is used in its metallic form in Magnox reactor fuel[4].

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

[3] MOX fuel that is delivered to overseas reactors only contains plutonium that the overseas customer owns.
[4] Latterly some Magnox fuel has been slightly enriched (<1% U-235) to offset the effects of reactor ageing.

High-enriched uranium (HEU) Uranium enriched in U-235 to 20% or more by mass. HEU is used in the manufacture of specialist nuclear fuels (e.g. for research reactors). In the past it has also been recovered by the reprocessing of these fuels.

Depleted uranium (DU) Uranium with U-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.

In the UK, fuel for civil nuclear reactors is manufactured at Springfields in Lancashire. Yellowcake is first converted through chemical processing into uranium tetrafluoride (UF_4). The next process stage depends on the type of fuel to be manufactured. AGR fuel is fabricated from low enriched (UO_2). Here UF_4 is first converted to UF_6, which is enriched at Capenhurst in Cheshire. The enriched UF_6 is then converted to UO_2 at Springfields, which in turn is formed into ceramic pellets. For Magnox reactor fuel UF_4 was converted to uranium metal: the manufacture of the fuel has now ceased.

Uranium recovered from the reprocessing of spent fuel can be re-enriched and re-utilised in new nuclear fuel. Some reprocessed uranium from the Magnox programme has in the past been used to manufacture new AGR fuel. Depleted uranium UF_6 can be enriched to provide feed stock for new fuel. Depleted uranium can also be mixed with plutonium to make MOX fuel.

Radiation shielding applications and limited other industrial applications make use of specific properties of uranium.

2.6 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 has already been designated as waste and is reported in the 2010 UK Radioactive Waste Inventory.

Non-nuclear industrial uses of thorium are in illuminants, electron emitters, ceramics and glass, catalysts and specialist alloys.

2.7 CONTAMINATED GROUND

Ground and building foundations of some nuclear sites may become contaminated with low concentrations of radioactivity as a result of lifetime site operations. The removal of contaminated foundations and the remediation of contaminated ground will generate radioactive wastes. These wastes comprise principally soil and concrete/rubble, and most will arise during the final stage of site decommissioning and clean up.

There is greater uncertainty in the future arisings of waste from the remediation of contaminated ground than in facility dismantling and demolition wastes. This is particularly the case for radioactive wastes at the lower end of the activity range referred to as Very

Low Level Waste (VLLW). Estimation of volumes of these wastes can be somewhat speculative due to uncertainty about regulatory requirements and disposal routes, lack of definition of site decommissioning and clean up plans, and that much characterisation work might remain to be carried out and that this work may indicate that remediation is not required. Furthermore the benefit of decontamination operations that might allow waste volume to be below the lower threshold level for radioactive waste must be considered against the cost and dose detriment.

At some non-nuclear defence sites low level radioactive contamination may be present as a result of the historic production, maintenance, storage and disposal of luminised instruments. The peak period for luminising was from the 1930s to the 1970s. The luminising paint used originally contained radium, though more recently promethium and tritium were used. The Ministry of Defence has a continuing programme of land quality assessment.

Some contaminated ground is reported as radioactive waste in the 2010 UK Radioactive Waste Inventory [3]. However because of the uncertainties described above, some waste producers have chosen to report potentially contaminated ground in this report until contamination surveys are extended and refined, and there is more certainty on volumes.

2.8 MISCELLANEOUS WASTE AND MATERIALS

2.8.1 Miscellaneous wastes and materials

There is a limited number of radioactive wastes for which no final treatment, packaging or disposal route has yet been identified, and which are not sufficiently well characterised to be reported in the 2010 UK Radioactive Waste Inventory. These wastes are included in this report.

2.8.2 Waste generated from planned future facilities

This comprises radioactive wastes that might arise from the operation of new facilities that are anticipated to be required for facilitating implementation of planned waste treatment, decommissioning and site clearance programmes. These wastes arise from the treatment of existing wastes, and so no ‘new’ radioactivity will be generated.

Plans for these future waste retrieval, treatment and packaging plants are not yet fully developed. Consequently, robust estimates of these secondary waste arisings are not yet available, and so the wastes are reported here rather than in the 2010 UK Radioactive Waste Inventory.

Waste generated from planned future facilities excludes radioactive wastes associated with any new programmes for further nuclear power stations, fuel manufacturing and spent fuel reprocessing in the UK.

3.1 INTRODUCTION

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 in the future.

Quantities of nuclear materials (nuclear fuel, plutonium and uranium) are given as masses expressed as tonnes of heavy metal (tHM). Quantities of waste that may arise from the remediation of radioactively contaminated ground, and the miscellaneous wastes and materials, are given as volumes expressed as cubic metres.

Annex 1 sets out the assumptions used in reporting radioactive materials in the UK. Annex 2 provides more details on potentially contaminated ground, and miscellaneous wastes and materials.

3.2 IRRADIATED FUEL

The UK's current stock of irradiated fuel consists mainly of Magnox, AGR and PWR fuels, but also includes smaller stocks of various irradiated experimental and research fuels. The UK also holds stocks of foreign owned LWR fuel awaiting reprocessing[1].

Table 3.1 gives the masses of UK owned irradiated fuel at 1 April 2010 and estimated in future arisings. The total mass of irradiated fuel at 1 April 2010 was about 9,900tHM, with estimated future arisings of about 2,800tHM. The figures for irradiated fuel at 1 April 2010 exclude about 680tHM of overseas owned LWR fuel at Sellafield, and 0.7tHM of overseas owned spent fuel at Dounreay.

It is planned that the stocks of Magnox, SGHWR fuels and other spent fuels at Sellafield, as well as DFR breeder material currently stored at Dounreay, will be reprocessed (apart from a small quantity that is unsuitable). It is also planned that future arisings of spent Magnox fuel will be reprocessed. A proportion of the fuel produced over the lifetime of the AGR stations will be reprocessed. It is assumed that about 3,100tHM of spent AGR fuel will remain in long-term storage. Actual quantities of fuel to be reprocessed and/or stored are subject to contractual arrangements to be agreed between NDA and its customers.

The Sizewell B PWR station is expected to generate about 1,000tHM spent fuel over its 40-year operating lifetime. It is currently assumed that this fuel will be held in long-term storage.

3.3 UNIRRADIATED FUEL

Table 3.2 gives the masses of UK owned unirradiated fuel in the UK. The total mass of unirradiated fuel at 1 April 2010 is estimated to be about 520tHM. This excludes 1.2tHM of overseas owned unirradiated fuel in storage at Dounreay. There will be future arisings of UK power reactor fuels to meet the fuelling requirements for projected reactor lifetimes, but these are not estimated.

[1] The UK has contracts with other countries to reprocess their spent fuel. All contracts signed since 1976 provide for the return of recovered uranium and plutonium and associated waste to the country of origin.

Table 3.1: UK owned irradiated fuel Mass in stocks and estimated for future arisings (tHM)

Location	Description	Stock at 1 April 2010 (1)		Estimated future arisings
		In reactor	In storage	
Sellafield	Magnox fuel		420	- (2)
	AGR fuel		2,900	- (3)
	SGHWR fuel		120	0
	WAGR fuel		28	0
	Other fuels		330 (4)	0
Dounreay	DFR breeder fuel	44		
	PFR		10	
	Other fuels		<1	0
Magnox power stations	Magnox fuel	3,600	290	260 (5)
AGR & PWR power stations	AGR & PWR fuel (6)	~1,700	~480	~2,500
Others	Various		~14 (7)	0

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

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

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

(4) Excludes ~10tHM of uranic residues declared as waste and reported in the 2010 UK Radioactive Waste Inventory.

(5) Based on station operating lifetimes reported in the 2010 UK Radioactive Waste Inventory.

(6) From data provided by EDF Energy and from best available public domain information.

(7) Comprises mainly low irradiated fuels - Zero Energy Breeder Reactor Assembly (ZEBRA) fuel as plutonium and natural uranium oxide plates on loan to Cadarache in France, and other fuels at Harwell and Winfrith.

Table 3.2: UK owned unirradiated fuel Mass in stocks (tHM)

Location	Description	Stock at 1 April 2010
Sellafield	MOX fuel	3.4
Dounreay	Various	~20 (1)
All UK sites	Magnox fuel	270 (2)
All UK sites	AGR fuel	~200 (3)
All UK sites	PWR fuel	~30 (3)

(1) Includes PFR, plutonium and thorium fuels.

(2) Slightly more fuel has been manufactured to meet the current operating lifetimes of Magnox reactors than is forecast to be irradiated in these reactors. The estimated future arisings of spent Magnox fuel are 260tHM (See Table 3.1).

(3) Nominal figure available in the public domain corresponding to the approximate annual fuel usage.

3.4 PLUTONIUM

Table 3.3 gives the total masses of UK owned separated plutonium at the end of 2009. Separated plutonium is held mainly as plutonium dioxide from the reprocessing of Magnox and oxide fuel at Sellafield, with a small amount in other forms and fuel residues.

Table 3.3: UK owned separated plutonium Mass in stocks (tHM)

Location	Description	Stock at 31 December 2009 (1)
All UK sites	PuO_2	~84

(1) Latest figure published by the UK Government [7] at the time of compilation of the 2010 Inventory.

There are currently about 84tHM of separated plutonium in stock. This excludes material from the reprocessing of overseas spent LWR fuel.

Forecast future arisings of UK owned plutonium from reprocessing spent fuel at Sellafield are about 29tHM.

In total about 34tHM of plutonium are forecast from reprocessing overseas spent LWR fuel.

3.5 URANIUM

Table 3.4 gives the total masses of UK owned DNLEU (Depleted, Natural and Low Enriched Uranium) and HEU from all sources.

Table 3.4: UK owned uranium Mass in stocks (tHM)

Location	Description	Stock at 1 April 2010
All UK sites	DNLEU	~80,000 (1)
All UK sites	HEU	1.3

(1) The latest figure published by the Government [7] is ~100,000tHM. This is greater than the figure reported here because it includes DNLEU present in irradiated fuels as well as foreign owned uranium, both of which are reported separately in the 2010 Inventory (see Table 3.1 and text below).

There are about 80,000tHM DNLEU in stock. This excludes about 11,000tHM of overseas owned material. The major components of UK owned uranium stocks 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 other sites.

Future arisings of DNLEU are estimated at about 100,000tHM. This figure assumes the continuation of uranium enrichment operations up to 2030 and the reprocessing scenario reported in the 2010 UK Radioactive Waste Inventory. It excludes approximately 2,600tHM of foreign owned DNLEU that is estimated to arise in the future. The majority of anticipated future arisings are depleted uranium from enrichment operations.

The total of stocks and estimated future arisings is 20,000tHM more than reported in the 2007 UK Radioactive Waste Inventory principally because depleted material is no longer exported for deconversion.

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 are currently about 1.3tHM of HEU in stock. This material comprises residues from reprocessing and fuel fabrication. No further arisings are expected.

3.6 THORIUM

Table 3.5 gives the total mass of UK owned thorium at 1 April 2010. There are no reported future arisings.

Table 3.5: UK owned thorium Mass in stocks (tHM)

Location	Description	Stock at 1 April 2010
All UK sites	Thorium metal	~11

Thorium metal was previously reported in the UK Radioactive Waste Inventory, but this material may now be recovered for reuse. Thorium associated with spent Dragon reactor fuel is deemed to be waste and is reported in the 2010 UK Radioactive Waste Inventory.

3.7 CONTAMINATED GROUND

The total reported volume of potentially contaminated ground is about 13,000,000m^3. This is made up of soil (about 98%) and building foundations (about 2%). Much of the waste, about 90%, is potentially contaminated VLLW soil from site clearance at Sellafield. Much of this soil may ultimately not require remediation (see Annex 2 for further information). Due to regulatory requirements contaminated soil at Sellafield is reported as an existing stock although remediation is not expected until the period 2090-2100.

A total of about 150,000m^3 of contaminated ground waste is reported in the 2010 UK Radioactive Waste Inventory.

3.8 MISCELLANEOUS WASTE AND MATERIALS

Miscellaneous wastes that are not yet well characterised and materials that might be recategorised as waste at Sellafield and Capenhurst are reported (see Annex 2). Estimated waste stocks and future arisings are 570m^3 and 52,000m^3 respectively. The major streams in term of volume are hydrogen fluoride from uranium hexafluoride deconversion and contaminated uranic residues.

New facilities are planned at Sellafield to facilitate implementation of the waste treatment, decommissioning and site clean-up programmes. Wastes that might arise from the

operation of these facilities are reported (see Annex 2). Some broad volume estimates have been made.

4 REFERENCES

1 *Radioactive Substances Act 199*3.

2 *The Radioactive Substances (Substances of Low Activity) Exemption Order 1986.*

3 *The 2010 UK Radioactive Waste Inventory - Main Report.* URN 10D/985, NDA/ST/STY(11)0004. February 2011.

4 Committee on Radioactive Waste Management*. Managing Our Radioactive Waste Safely: CoRWM's Recommendations to Government.* CoRWM Document No. 700, July 2006.

5 *Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal.* Cm 7387, June 2008.

6 HSE. *The United Kingdom's Third 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,* May 2008.

7 HSE. *Annual Civil Plutonium and Uranium Figures as of 31 December 2009.* www.hse.gov.uk/nuclear/safeguards/civilplut09.htm.

8 MoD. *Strategic Defence Review 1998*.

ANNEX 1 ASSUMPTIONS USED FOR REPORTING CIVIL NUCLEAR MATERIALS

All assumptions listed below are in line with those used in compiling data for the 2010 UK Radioactive Waste Inventory. These assumptions represent the planning positions at 1 April 2010 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 or are changed for commercial, policy or funding reasons, or if improved data become available.

Since the 1 April 2010 there have been developments in the forward plans at a number of sites. This means that certain assumptions used in preparing data for the 2010 Inventory have already been revised or are being reviewed, and there will be or are likely to be some changes to waste and material estimates. Revisions can affect either or both the quantity and timing of future arisings.

Generic assumptions

- Plutonium, uranium and irradiated nuclear fuel from UK civil nuclear power stations have potential value as they can be reused for manufacturing fresh nuclear fuel. These materials are not currently classified as waste.
- Small quantities of relatively low irradiation spent fuel that are not planned to be reprocessed have already been designated as waste and are reported in the 2010 UK Radioactive Waste Inventory (i.e. excluded from this report).
- Most irradiated fuel arising from UK reactors has been or will be reprocessed (see assumptions below). To report this irradiated fuel, as well as plutonium and uranium that has or will be produced by reprocessing the fuel, would result in double counting of nuclear materials. In addition some materials recovered from these (reprocessing) operations have been reused to manufacture fresh fuel. To prevent double counting, the radioactive materials inventory includes quantities of plutonium, uranium and spent fuel that were held in the UK at 1 April 2010; and future arisings of irradiated fuel. The estimated quantities of plutonium and uranium that will be produced by future fuel reprocessing are given for information.
- The radioactive materials inventory reports UK 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 Ministry of Defence or ‘small users’ i.e. universities and research establishments.
- The 2010 UK Radioactive Waste Inventory includes radioactive waste that is expected to be produced when all the UK spent fuel that is planned to be reprocessed has been reprocessed - see assumptions below.
- Volumes of contaminated ground reported in the radioactive materials inventory are in-situ volumes of potentially radioactively contaminated ground and foundations that are not sufficiently well characterised for inclusion in the 2010 UK Radioactive Waste Inventory. Radioactive wastes anticipated from radioactively contaminated ground and foundations where there is more certainty in the quantities that might be produced are reported in the 2010 UK Radioactive Waste Inventory.

Irradiated fuel arisings

- In addition to the spent fuel already generated from the nine shut-down power stations in the UK, irradiated fuel will arise from the operations and final defuelling of the following nuclear power stations:

Table A1.1: Operational nuclear power stations in the UK

Station	Planned shutdown date[1]
Magnox:	
Oldbury	2011
Wylfa	2011
AGR:	
Hinkley Point B	2016
Hunterston B	2016
Hartlepool	2014
Heysham 1	2014
Dungeness B	2018
Heysham 2	2023
Torness	2023
PWR:	
Sizewell B	2035

Note: Arisings from new nuclear power stations are not included in this report.

- No new nuclear power stations are assumed to be constructed in the UK[2].
- UK has contracts with other countries for reprocessing some of their spent nuclear fuel.

Irradiated fuel management

- Nuclear fuel manufacturing in the UK is assumed to continue until 2030.
- The following spent fuel that has been produced or is forecast to arise from UK reactors is assumed to be reprocessed at Sellafield:
  - 55,000tHM from Magnox reactors, of which about 51,000tHM had been reprocessed by 1 April 2010;

[1] Since the 2010 UK Radioactive Waste Inventory data were compiled, NDA has announced it is engaging with nuclear regulators and Government to secure a short-term life extension for Oldbury, subject to business and safety case approval. In October 2010 it was announced that Wylfa Power Station will continue operating for up to two additional years beyond December 2010. Extended generation will be subject to safety case approval. In December 2010 EDF Energy announced operational life extensions for Heysham 1 and Hartlepool of 5 years to 2019.

[2] While the UK Government has stated that it supports new nuclear power stations and some operators are planning new stations, it is not yet clear how many reactors and of what design might be constructed.

  - 5,500tHM from AGRs, of which about 2,500tHM had been reprocessed by 1 April 2010;
  - 28tHM from WAGR;
  - 120tHM from SGHWR;
  - About 44tHM from DFR;
  - Small amount of Post Irradiation Examination (PIE) type materials.
- 4,400tHM of foreign owned LWR spent fuel is assumed to be reprocessed in the UK.
- The following spent fuel that has been produced or is forecast to arise from UK reactors is assumed to be held in long-term storage in the UK (i.e. there are no current plans for reprocessing these fuels)[3].
  - 3,100tHM from AGRs;
  - 1,049tHM from PWR.

Separated uranium and plutonium arisings & management

- Separated uranium and plutonium is assumed to arise in the UK from the reprocessing activities listed above. Magnox fuel reprocessing is assumed to be complete by 2016; other spent fuel reprocessing by 2021.
- All UK owned separated uranium and plutonium is assumed to be held in long-term storage in the UK.

[3] Although plutonium, uranium and spent fuel are not classified as waste, these materials are considered in the Government's "Managing Radioactive Waste Safely" programme for developing and implementing a policy for managing the UK's higher activity wastes in the long-term.

ANNEX 2 CONTAMINATED GROUND WASTE AND MISCELLANEOUS WASTE AND MATERIAL STREAMS

This annex presents volumes of potentially contaminated ground wastes and miscellaneous material streams that are deemed or may be deemed to be waste. These are not in the 2010 UK Radioactive Waste Inventory because the waste producers have chosen to include them in this report until there is more certainty in the quantities that might be produced.

Table A2.1 lists potentially contaminated ground waste (soil plus building foundations) streams at Sellafield, Capenhurst, Springfields and Aldermaston. Other UK sites with anticipated contaminated ground waste have reported volumes in the 2010 UK Radioactive Waste Inventory. Also contaminated ground at Aldermaston for which there is more certainty on volume is reported in the 2010 UK Radioactive Waste Inventory.

The volumes given for Sellafield in Table A2.1 represent the best estimate of ground volumes affected by contamination in the various waste categories. They are, by necessity, estimates but are based on the most recent characterisation data and understanding of the site. They are subject to constant review as knowledge of the site improves. It is not envisaged that, on the basis of an overall balance between risk and benefit, all of this material will be excavated for management as waste. In particular, for the most lightly contaminated material within the HVVLLW category the optimum management plan may be some form of in-situ treatment. This may apply to approximately five million cubic metres out of the total quoted for Sellafield in Table A2.1, based on the current analysis. Excavation and remediation of appropriate Sellafield wastes is currently expected to take place in the period 2090-2100. However, the soil streams are considered to be an existing stock, rather than a future arising, as the Nuclear Installations Inspectorate (NII) requires that these materials are adequately and safely managed throughout the lifetime of the site.

At Springfields the stock volume is based on results from test boreholes carried out over the past three years. Further investigation work through 2010/11 will give clearer information on potential future arisings.

At Aldermaston about 110,000m^3 of land associated with process buildings have been identified as having the potential to be contaminated. Further investigations will be carried out after building decommissioning.

Table A2.1: Potentially contaminated ground Volume at 1 April 2010 and estimated for future arisings (m^3)

Site	Stream identifier	Stream description	Stock at 1 April 2010	Future arisings
Sellafield	2D150	Contaminated Soil ILW	1,600	0
	2D151	Contaminated Soil LLW	1,060,000	0
	2D152	Contaminated Foundations ILW	0	2,200
	2D153	Contaminated Foundations LLW	0	33,000
	2D154	Contaminated Soil from Site Clearance - HVVLLW	11,800,000	0
	2D155	Contaminated Foundations from Site Clearance - HVVLLW	0	200,000
Capenhurst	2B104	Contaminated Land - LLW	0	860
	2B105	Contaminated Land - HVVLLW	0	6,000
Springfields	-	Radioactive Contaminated Land	4,000	<30,000 (1)
Aldermaston	7A33	Radioactive Contaminated Land	0	~110,000
All sites		**Total**	**12,900,000**	**<382,000**

(1) Volumes are uncertain, but will be established during ongoing contaminated ground projects.

Table A2.2 lists miscellaneous waste and material streams at Sellafield and Capenhurst. These include wastes that are not yet sufficiently well characterised to be reported in the 2010 UK Radioactive Waste Inventory and materials that are not yet classified as wastes but may be at some time in the future.

Table A2.2: Miscellaneous waste and materials Volume at 1 April 2010 and estimated for future arisings (m^3)

Site	Stream Identifier	Stream description	Stock at 1 April 2010	Future arisings
Sellafield	2D64	Magnox interfacial crud - ILW	<10	10
	2D97	Miscellaneous Trench Silt ILW/LLW	43	0
	2F28	Interfacial Crud ILW/LLW	0.12	~1
	2Y60	Miscellaneous Minor Wastes - ILW	~~40	~~10
	2Y61	Lead - ILW	~~0	~~50
	2Y62	Oils and Solvents - ILW	~~1	~~90
	2Y63	Metallic Wastes: Plant and Equipment - ILW	~~180	~~260
	2Y64	Sludges, Resins and Flocs - ILW	~~50	~~80
	2Y65	Miscellaneous Minor Wastes - LLW	~~130	~~100
	2Y66	Lead - LLW	0	~~100
	2Y67	Oils and Solvents - LLW	~~0.4	0
	2Y68	Metallic Wastes: Plant and Equipment - LLW	~~100	~~310
	2Y69	Sludges, Resins and Flocs - LLW	~~1	~~20
Capenhurst	2B13	Technetium Contaminated Uranic Residues	6.4	~16,000
	2B14	Uranic Residues	8.6	0
	2B18	HF from Hex Deconversion	0	~30,000
	2B19	Solid Waste from Hex Cylinder Decommissioning	3.8	~220
	2B110	Stores Decommissioning - HVVLLW	0	~4,500
All sites		**Total**	**~~570**	**~~52,000**

Table A2.3 lists radioactive wastes that might arise from the operation of new facilities at Sellafield anticipated for facilitating implementation of planned waste treatment, decommissioning and site clean up programmes and for which indicative volumes are available. As programmes are confirmed, estimates for such wastes will become more robust and will be reported appropriately.

Table A2.3: Miscellaneous wastes – new build on the Sellafield site Volume estimated for future arisings (m^3)

Stream Identifier	Stream description	Future arisings
2Y22	Future Local Effluent Treatment Plants – ILW	~120
2Y26	Future LLW Treatment Plants - LLW	~11,000
2Y27	ILW Rework Plant including Mobile Grouting - ILW	~150
2Y28	ILW Rework Plant including Mobile Grouting - LLW	~300

ANNEX 3 GLOSSARY OF TERMS AND ABBREVIATIONS

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

~	Approximately.
~~	Very approximately.
AGR	Advanced Gas-cooled Reactor.
CoRWM	The Committee on Radioactive Waste Management.
Contaminated ground	Contaminated ground is defined as ground, soil, water and, potentially, underground structural materials such as building foundations which have been impacted by radioactive and/or chemical substances from past or present operations (including authorised discharges and disposals), and for which the level of the radioactive or chemical substance is above natural background.
DECC	Department of Energy & Climate Change. The UK Government department which, with the Scottish Government and the environment departments of Wales and Northern Ireland, sets policy for UK radioactive waste management.
Depleted uranium	Uranium where the uranium-235 isotope content is below the naturally occurring 0.72% by mass.
DFR	Dounreay Fast Reactor.
DNLEU	Depleted, Natural and Low Enriched Uranium.
Dragon	Experimental high temperature reactor project sited at Winfrith and funded by the Organisation for Economic Cooperation and Development (shut down in 1976).
DU	Depleted Uranium.
Enriched uranium	Uranium where the uranium-235 isotope content is above the naturally occurring 0.72% by mass.
Enrichment	The process of increasing the abundance of fissionable atoms in natural uranium.
Euratom	European Atomic Energy Community.
GLEEP	Graphite Low Energy Experimental Pile. Low energy, 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 includes the UK Government, the Scottish Government and the Devolved Administrations of Wales and Northern Ireland.
HEU	Highly Enriched Uranium. Uranium where the uranium-235 isotope content is 20% by mass or more.
HF	Hydrogen Fluoride.
HVVLLW	High Volume Very Low Level Waste
IAEA	International Atomic Energy Agency.
ILW	Intermediate Level Waste
Irradiated fuel	Fuel that is being or has been used to power nuclear reactors.

LEU	Low Enriched Uranium. Uranium enriched in U-235 to less than 20% by mass.
LLW	Low Level Waste
LWR	Light Water Reactor.
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.
MOX	Mixed Oxide. Refers to nuclear fuel consisting of uranium oxide and plutonium oxide for use in reactors.
MRWS	Managing Radioactive Wastes Safely.
NDA	Nuclear Decommissioning Authority. A 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.
NU	Natural Uranium.
Nuclear fuel	Fuel used in a nuclear reactor. Most fuel is made of uranium, and produces heat when the uranium atoms split into smaller fragments.
PFR	Prototype Fast Reactor (at Dounreay site).
Plutonium	A radioactive element created in nuclear reactors. It can be separated from nuclear fuel by reprocessing. Plutonium is used as a nuclear fuel, in nuclear weapons and as a power source for space probes.
Pu	Plutonium.
PWR	Pressurised Water Reactor.
Reprocessing	The chemical extraction of reusable uranium and plutonium from waste materials in spent nuclear fuel.
SGHWR	Steam Generating Heavy Water Reactor (at Winfrith site). Shut down in 1990.
Spent fuel	Fuel that has been used in nuclear reactors that is no longer capable of efficient fission due to the loss of fissile material.
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.
U-235	Uranium-235 is the main fissile isotope of uranium. Natural Uranium typically contains 0.72% by weight of U-235.

Uranium	A radioactive element that occurs in nature. Uranium is used for nuclear fuel and in nuclear weapons.
Unirradiated fuel	Fuel that has not yet been used to power nuclear reactors.
VLLW	Very Low Level Waste.
WAGR	Windscale Advanced Gas-cooled Reactor (shut down in 1981).
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.
Zenith reactor	A research reactor at Winfrith that has been decommissioned.

URN 10D/988
NDA/ST/STY (11) 0007
February 2011

Certificate No. 4002929

Certificate No. 4002929/A

Further copies of this and other 2010 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**

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

T +44 (0) 1925 802077

foi@nda.gov.uk

ISBN: 978-1-905985-22-7

Front cover images: top left - Redundant facilities being demolished at Dounreay in 2007, top right - Asbestos removal at Chapelcross, bottom left - Trawsfynydd ILW store, bottom right - ILW storage at Winfrith.

04/03 300