Analyse, inform and activate

Analyseren, informeren, en activeren

Stichting Laka: Documentatie- en onderzoekscentrum kernenergie

De Laka-bibliotheek

Dit is een pdf van één van de publicaties in de bibliotheek van Stichting Laka, het in Amsterdam gevestigde documentatie- en onderzoekscentrum kernenergie.

Laka heeft een bibliotheek met ongeveer 8000 boeken (waarvan een gedeelte dus ook als pdf), duizenden kranten- en tijdschriften-artikelen, honderden tijdschriftentitels, posters, video's en ander beeldmateriaal. Laka digitaliseert (oude) tijdschriften en boeken uit de internationale antikernenergie-beweging.

De catalogus van de Laka-bibliotheek staat op onze site. De collectie bevat een grote verzameling gedigitaliseerde tijdschriften uit de Nederlandse antikernenergie-beweging en een verzameling video's.

Laka speelt met oa. haar informatie-voorziening een belangrijke rol in de Nederlandse anti-kernenergiebeweging.

The Laka-library

This is a PDF from one of the publications from the library of the Laka Foundation; the Amsterdam-based documentation and research centre on nuclear energy.

The Laka library consists of about 8,000 books (of which a part is available as PDF), thousands of newspaper clippings, hundreds of magazines, posters, video's and other material.
Laka digitizes books and magazines from the international movement against nuclear power.

The catalogue of the Laka-library can be found at our website. The collection also contains a large number of digitized magazines from the Dutch anti-nuclear power movement and a video-section.

Laka plays with, amongst others things, its information services, an important role in the Dutch anti-nuclear movement.

Appreciate our work? Feel free to make a small donation. Thank you.

www.laka.org | info@laka.org | Ketelhuisplein 43, 1054 RD Amsterdam | 020-6168294

1207-INT-6-1
Version 1.3

Integrated Project Team on Uranium: Phase 2

[Task INT-6]

Review of UK and Overseas Depleted, Natural and Low Enriched Uranium Management

S. Doudou and E.J. Harvey
(Galson Sciences Ltd)

19 May 2014

Galson
SCIENCES LTD

5 Grosvenor House, Melton Road, Oakham, Rutland LE15 6AX, UK
Tel: +44 (1572) 770649   Fax: +44 (1572) 770650   www.galson-sciences.co.uk

Conditions of publication

Bibliography

If you would like to see other reports available from Radioactive Waste Management Limited and the NDA, a complete listing can be viewed at our website www.nda.gov.uk, or please write to our Communications department at the address below.

Feedback

Readers are invited to provide feedback to the Radioactive Waste Management Limited on the contents, clarity and presentation of this report and on the means of improving the range of reports published. Feedback should be addressed to:

Head of Stakeholder Engagement and Communications
Radioactive Waste Management Limited
Building 587
Curie Avenue
Harwell Oxford
Didcot
OX11 0RH
UK

email rwmdfeedback@nda.gov.uk

Integrated Project Team on Uranium: Phase 2

[Task INT-6]

Review of UK and Overseas Depleted, Natural and Low Enriched Uranium Management

Report History

This document has been prepared by Galson Sciences Ltd for RWMD under the terms of NDA Purchase Order RWM005724.

Version 1, Draft 1 (dated 28 September 2012) was produced under Phase 1 of the uranium IPT, to inform development of the Phase 2 programme.

Version 1, Draft 2 (dated 16 July 2013) incorporated a description of UK DNLEU management practices, and addressed comments on Version 1, Draft 1 from Ciara Walsh and Matthew Wellstead and from the US Department of Energy and the Japan Atomic Energy Agency.

Version 1 addressed comments from the French waste management organisation ANDRA and URENCO UK on Version 1, Draft 2, and has been reviewed by Matt Wellstead at RWMD.

Version 1.1 (dated 28 March 2014) updated the inventory information in the UK section to be consistent with RWMD's Derived Inventory, and has been reviewed by Martin James and Matt Wellstead at RWMD.

Version 1.2 (dated 1 April 2014) responded to comments made by Martin James (of RWMD) on Version 1.1.

Version 1.3 responds to comments made by Danny Fox and Paul Gregson of NDA on Version 1.2.

Review of UK and Overseas Depleted, Natural and Low Enriched Uranium Management					
Report No.:	Date:	Principal Author: S. Doudou (ASSIST)	Principal Reviewer: D.A. Galson (ASSIST)	Principal Reviewer: M. Wellstead (RWMD)	Approved by: M. Wellstead (RWMD)
1207-INT-6-1 Version 1.3	19 May 2014	Sign: .... Date: 19/5/14	Sign: .... Date: 19/5/14	Sign: M. Wellstead .... Date: 20/05/14	Sign: M. Wellstead .... Date: 20/05/14

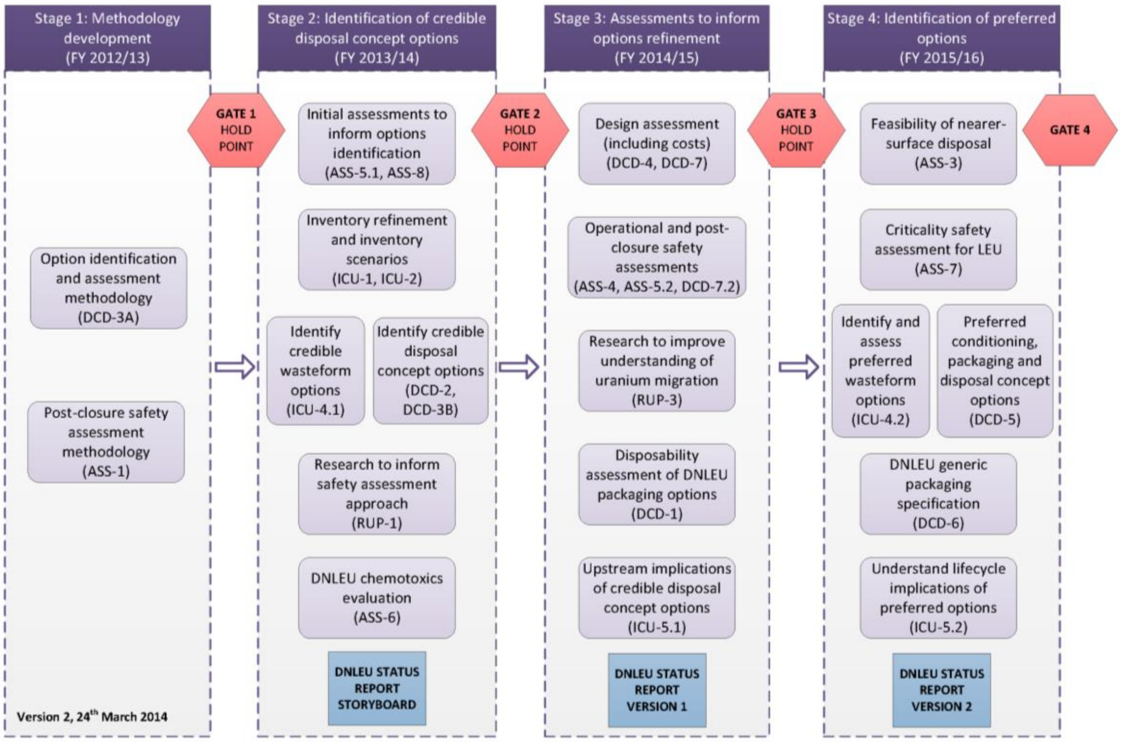
Preface

An Integrated Project Team (IPT) comprising Nuclear Decommissioning Authority (NDA) – Radioactive Waste Management Directorate (RWMD) staff and members of the contractor base has been formed to work collaboratively on the topic of depleted, natural and low-enriched uranium (DNLEU). This is referred to as the "uranium IPT". The project focuses on the disposability and associated full lifecycle implications of managing the UK inventory of DNLEU through geological disposal.

- Phase 1 (August 2012 to March 2013) involved planning and prioritising a programme of work to address knowledge gaps and advance understanding. This led to development of a Roadmap for Phase 2.[1]
- Phase 2 (January 2013 to March 2016) involves implementing Roadmap activities, including review, integration and communication of the work.

A staged approach is being followed for Phase 2, as illustrated in the figure below, so that the work programme can be informed by initial activities and be revised as work proceeds. Phase 2 includes a number of technical integration activities not shown in the figure, such as integration workshops, meetings with regulators, and an international review of DNLEU management practices.

This report is one of a suite of documents being published as part of the Phase 2 activities of the uranium IPT.



(Task reference numbers are provided in parentheses.)

[1] NDA, 2013. Geological Disposal: Integrated Project Team on Uranium: Phase 2 Planning Report – Volume 1 Roadmap, NDA Technical Note No. 19641861.

Executive Summary

An Integrated Project Team (IPT) comprising Nuclear Decommissioning Authority (NDA) Radioactive Waste Management Directorate (RWMD) staff and members of the supporting contractor base has been formed, to work collaboratively on the topic of depleted, natural and low-enriched uranium (DNLEU), focusing on the disposability and associated full lifecycle implications of managing the UK inventory of these materials through geological disposal (the "uranium IPT").

This document reports the outcomes of an international review of DNLEU management practices. The review collates information on current and planned activities in the UK and overseas, in order to inform work undertaken elsewhere by the uranium IPT.

Worldwide DNLEU stocks arise mainly from uranium enrichment operations for nuclear fuel, with significant quantities also arising from reprocessing spent nuclear fuel (RepU), particularly in France and the UK. Russia, the US and France hold by far the largest stocks of depleted uranium (DU). DNLEU stocks held by these countries significantly exceed UK stocks.

In most countries, including the UK, France, Russia, Japan and South Korea, DNLEU is considered to be a potential (or current) resource, and it is held in storage with this in mind. Some countries, notably France, reuse RepU within fuel rods for nuclear power plants, either as conventional uranium oxide (UOX) fuel, or within mixed-oxide (MOX) fuel.

Approaches to package DNLEU for storage are similar across different countries. Depleted uranium hexafluoride (UF_6) is typically stored in steel cylinders, as in the UK. Triuranium octoxide (U_3O_8) is regarded as the preferred chemical form for long-term storage and/or disposal in most countries. In the UK, deconverted U_3O_8 will be stored in DV-70 containers, as is also done in France, Germany, and the Netherlands.

Transport of DNLEU stocks in a variety of chemical forms (including UF_6, liquid uranyl nitrate, U_3O_8 and uranium trioxide (UO_3) powders) is routinely undertaken in many countries. The materials are usually classified as Low Specific Activity (LSA) and industrial packages (IP) are used for their transport.

The US is the only country that currently regards at least some DNLEU as a waste. The regulator classifies it as low-level waste (LLW), and regulatory policy provides for disposal of DNLEU in near-surface facilities. However, to date only relatively small quantities have been disposed of in this way at the existing sites.

Japan has examined the possibility of near-surface disposal of some uranium-bearing wastes of low activity concentration in a trench-type facility.

Germany is the only country that has assessed the performance of a geological disposal facility (GDF) for significant quantities of DU (in a salt dome at Gorleben). Some consideration has been given in US research projects to alternative (beneficial)

uses of DU in a GDF. However, overall, there is relatively little transferable experience from overseas that is specifically relevant to geological disposal concept development for DNLEU in the UK.

Contents

Review of UK and Overseas Depleted, Natural and Low Enriched Uranium Management

1 Introduction

1.1 Background to the Uranium IPT

An Integrated Project Team (IPT) comprising Nuclear Decommissioning Authority (NDA) Radioactive Waste Management Directorate (RWMD) staff and members of the supporting contractor base has been formed, to work collaboratively on the topic of depleted, natural and low-enriched uranium (DNLEU), focusing on the disposability and associated full lifecycle implications of managing the UK inventory of these materials through geological disposal (the "uranium IPT").

The work of the uranium IPT is being carried out in two phases:

- Phase 1 (August 2012 to March 2013) established the strategic framework for the project, and involved collating current understanding to identify knowledge gaps and uncertainties relating to DNLEU disposal, with a view to planning and prioritising a programme of work to address these knowledge gaps and advance understanding. Phase 1 is now complete and a roadmap for Phase 2 has been produced (NDA, 2013).
- Phase 2 (January 2013 to March 2016) involves implementing the programme of technical work developed during Phase 1 and providing ongoing technical integration and stakeholder engagement.

In the UK, DNLEU is not currently classified as waste; it is considered to be a zero-value asset radioactive material. If it were to be declared as radioactive waste, then as part of the UK's baseline inventory for higher activity wastes, it may need to be disposed of in a geological disposal facility (GDF).

The Phase 2 work programme is organised into five technical work areas, each comprising a set of tasks designed to challenge the reference assumptions on which RWMD's 2010 generic Disposal System Safety Case (DSSC) was based (NDA, 2010), and to inform wider NDA decision-making concerning the future management options for the UK inventory of DNLEU.

In Phase 1, a scoping review of overseas DNLEU management practices was conducted with the aim of informing Phase 2 activities. The review has been updated and finalised early in Phase 2.

1.2 Objectives of this Report

The objectives of this review are:

- To collate information on the current status of activities in the UK and other countries relating to DNLEU management in order to set the context for work undertaken by the uranium IPT.

- To identify relevant experience from which RWMD can draw in developing approaches for the possible geological disposal of DNLEU in the UK.

1.3 Scope and Approach

DNLEU stocks from the civil nuclear industry mainly arise from either uranium enrichment activities or from reprocessing spent fuel to recover uranium. In the former case, the product, often referred to as “tails”, is typically depleted uranium (DU), which has a lower U-235 content than natural uranium (typically lower than 0.72% by mass). In the latter case, the U-235 content of the product (often referred to as “RepU”) can vary, such that the material is classified as any of DU, natural uranium (NU) or low-enriched uranium (LEU). LEU is defined as uranium enriched in U-235 to less than 20% by mass, depending on factors such as the original enrichment level of the fuel and the irradiation regime in the reactor. **Figure 1** describes the different routes from which DU, RepU and uranium tailings can be generated in the nuclear fuel cycle. Consistent with the scope of the uranium IPT, this review does not consider management practices for highly-enriched uranium (defined as uranium with a U-235 content of more than 20% by mass).

This document summarises current practices for DNLEU management in various countries that own significant quantities of such materials, including the UK, France, the US, Russia, Japan, South Korea, the Netherlands and Germany, based on publicly available information. These management practices are often quite complex, particularly in countries where multiple enrichment and/or reprocessing plants are in operation, and which store DNLEU stocks at a number of different sites. This review does not attempt to present a comprehensive description of every aspect of DNLEU management but, rather, it aims to summarise management practices at a high level, with a view to identifying aspects of other national approaches that are likely to be of interest to RWMD.

Available information has been tabulated systematically in datasheets using a common format, so that specific information can be readily identified and so that practices between countries are easily comparable. The format includes information on the following topics:

- The DNLEU inventory.
- The organisations holding the material.
- Current chemical form(s) and storage approach.
- Long-term management strategy.

- Plans for conversion to other chemical form(s).

For France and the US, sections on Transport, Regulations and Disposal are also included. For the US, a section on Research is added and for Japan and the UK, a section on Disposal is included.

As well as using publicly available information, national waste management organisations (WMOs) were contacted to review drafts of the respective national datasheets.

1.4 Structure of this Report

The remainder of this report has the following structure:

- Sections 2 to 7 summarise DNLEU management practices in the UK, France, the US, Russia, Japan and South Korea respectively.
- Section 8 discusses national DNLEU management practices in Germany and the Netherlands, where URENCO is responsible for most DNLEU stocks, as in the UK.
- Section 9 discusses key themes identified in the review.
- Section 10 contains a list of references.

2 DNLEU Management in the UK

DNLEU Inventory

DNLEU has been produced in association with the thermal reactor fuel cycle in the UK since the birth of the nuclear industry in the 1940s.

The UK Radioactive Waste Inventory (UKRWI) contains information on quantities of radioactive waste and other materials such as DNLEU that could, possibly, come to be regarded as wastes and that might need to be disposed of in the future. The UKRWI is updated every three years. RWMD considers the materials in the UKRWI that might require geological disposal, and converts the data on these into a Derived Inventory that contains additional detail needed to develop plans for their long-term management. The Derived Inventory currently contains two estimates: a Baseline Inventory and an Upper Inventory that considers potential defence wastes and wastes arising from a potential future programme of new nuclear power stations.

UKRWI estimates of the Baseline Inventory (stocks plus arisings) of UK-owned DNLEU from civil nuclear operations have varied in the range 160,000 – 180,000 tU (tonnes of uranium) over the period 2007-2013 (Defra & NDA, 2008; DECC & NDA, 2011; 2014). These estimates exclude foreign-owned and defence DNLEU, which are expected to be less than 10% each of the Baseline Inventory.

The most recent version of RWMD's Derived Inventory is based on figures in the 2010 UKRWI. Table 1 summarises information on the quantity and location of DNLEU materials in the UK based on information in RWMD's 2010 Derived Inventory (Pöyry Energy Limited, 2011) and references therein, and the uranium IPT roadmap (NDA, 2013). The estimates are in the form of data on the total mass of DNLEU by material type that might eventually need to be disposed of to a UK GDF, should the materials be declared as waste. Note that the Derived Inventory will be updated later in 2014.

The biggest uncertainty in the inventory estimate is that associated with the largest component, the depleted uranium hexafluoride (UF_6) tails owned by URENCO UK (UUK) and, in particular, the likely amount of future arisings. Future arisings will be influenced to a great extent by commercial factors associated with UUK's enrichment services, including any nuclear new build fuel requirements. In recent discussions with RWMD, UUK has indicated that it expects its future operations at Capenhurst to generate approximately 5,000 tU per annum of depleted UF_6 tails, which suggests that the total future stockpile could be very large.

Figure 1 (page 8) is a simplified diagram for the UK thermal fuel cycle, showing the movements of different uranic materials in different chemical forms between the main reactors, reprocessing plants, etc.

Table 1: Ownership, source, location and total estimated mass of various kinds of UK-owned DNLEU from civil nuclear operations.

Data on quantities from Pöyry Energy Limited (2011) and reference therein. UK-owned materials only; a relatively small quantity of foreign-owned materials is currently in the UK awaiting return to its owners (in some cases following further processing). Also, there is a relatively small amount of MOD-owned DNLEU at various sites.

Material	Owner	Original source	Current location	Total mass (tU)
Depleted UF_6 tails	UUK NDA	Residue from enrichment of uranium for fuel manufacture	Capenhurst	131,500
Magnox Depleted Uranium (MDU)	NDA	Sellafield – reprocessing of spent fuel from Magnox reactors	Capenhurst	39,000
Thermal Oxide Reprocessing Plant (THORP) Product Uranium (TPU)	NDA EDF Energy	Sellafield – reprocessing of spent fuel from AGR reactors in THORP	Sellafield	5,500
Miscellaneous LEU	NDA	Residues and scraps from uranium purification, conversion and fuel fabrication; plus small amounts from UK fast reactor research activities	Dounreay Sellafield Springfields Capenhurst Harwell Winfrith	2,000
Natural uranium	NDA	Produced for Magnox fuel		2,000
Total				**180,000**

Organisations Holding the Material

URENCO UK, NDA and EDF Energy are responsible for current stocks of civil DNLEU material in the UK as shown in Table 1. The Ministry of Defence (MoD) is responsible for some defence DNLEU stocks (not shown in Table 1).

Current Chemical Form(s) and Storage Approach

The majority of DU material in the UK is in the form of UF_6 from enrichment activities at Capenhurst. These stocks are stored largely in Type 48 cylinders, although almost half of NDA-owned material is stored in older design 0236 cylinders. The fuel cycle starts when natural, unirradiated uranium arrives at the Springfields nuclear site from overseas in the form of uranium ore concentrate (UOC). At Springfields, UOC used to be purified and converted mainly into two chemical forms: uranium metal and UF_6. The uranium metal was used to fabricate fuel for the Windscale Piles and later for the UK fleet of Magnox reactors. UOC purification and conversion, uranium metal production, and Magnox fuel fabrication have now ceased at Springfields. The site continues to produce UF_6 from pure, natural, unirradiated uranium trioxide (UO_3). UF_6 produced at Springfields is sent to

Capenhurst and to URENCO's Dutch and German sites for enrichment. There are also occasional shipments of UF_6 from Springfields to AREVA in France. Some of the enriched UF_6 from UUK's operations at Capenhurst is returned to Springfields for fuel fabrication, but most of UUK's output goes to fuel fabrication sites other than Springfields. The resulting depleted UF_6 tails are retained in storage at Capenhurst regardless of the end customer. If this material is declared a waste, then URENCO will own the liability, recognising that URENCO is currently part-owned by the UK Government.

Spent fuel from Magnox reactors and Advanced Gas-cooled Reactors (AGRs) is transported to Sellafield for reprocessing. Magnox fuel is reprocessed in the Magnox reprocessing plant and AGR fuel is reprocessed in the Thermal Oxide Reprocessing Plant (THORP). THORP also reprocesses spent fuel from foreign Light Water Reactors, but not from Sizewell B, where the spent fuel is retained in storage on-site. The uranium product of spent fuel reprocessing at Sellafield is in the form of UO_3 powder. The product from the Magnox fuel reprocessing plant is known as Magnox depleted uranium (MDU) and that from THORP is known as THORP product uranium (TPU). Up until the early to mid-1990s, some MDU was reconverted at Springfields into UF_6. This was sent to Capenhurst for re-enrichment. The resulting depleted UF_6 tails were retained in storage at Capenhurst, whereas the enriched UF_6 was returned to Springfields, where it was converted into UO_2 and used to fabricate AGR fuel. All MDU is now stored at Capenhurst. Plans to reconvert and recycle TPU at Springfields have never come to fruition, and the UK-owned material is stored at Sellafield.

The MDU is stored in 200-litre mild steel drums, some of which have been overpacked into larger steel drums. Some MDU is stored in 210-litre stainless steel drums. 50-litre stainless steel drums with a clamped lid are used for storage of TPU material. When first produced, MDU and TPU are free-flowing powders. However, with prolonged storage in contact with air, the material can absorb water to form a hydrate. This can cause the surface layers of the powder to agglomerate into hard mass (NDA, 2013).

The miscellaneous DNLEU part of the inventory (Table 1) includes some LEU material. This component is heterogeneous and relatively small quantities are held in a variety of chemical/physical forms at a range of sites. The major constituents are UF_4 material stored in drums at Capenhurst and uranium metal billets stored in drums at Springfields and Capenhurst.

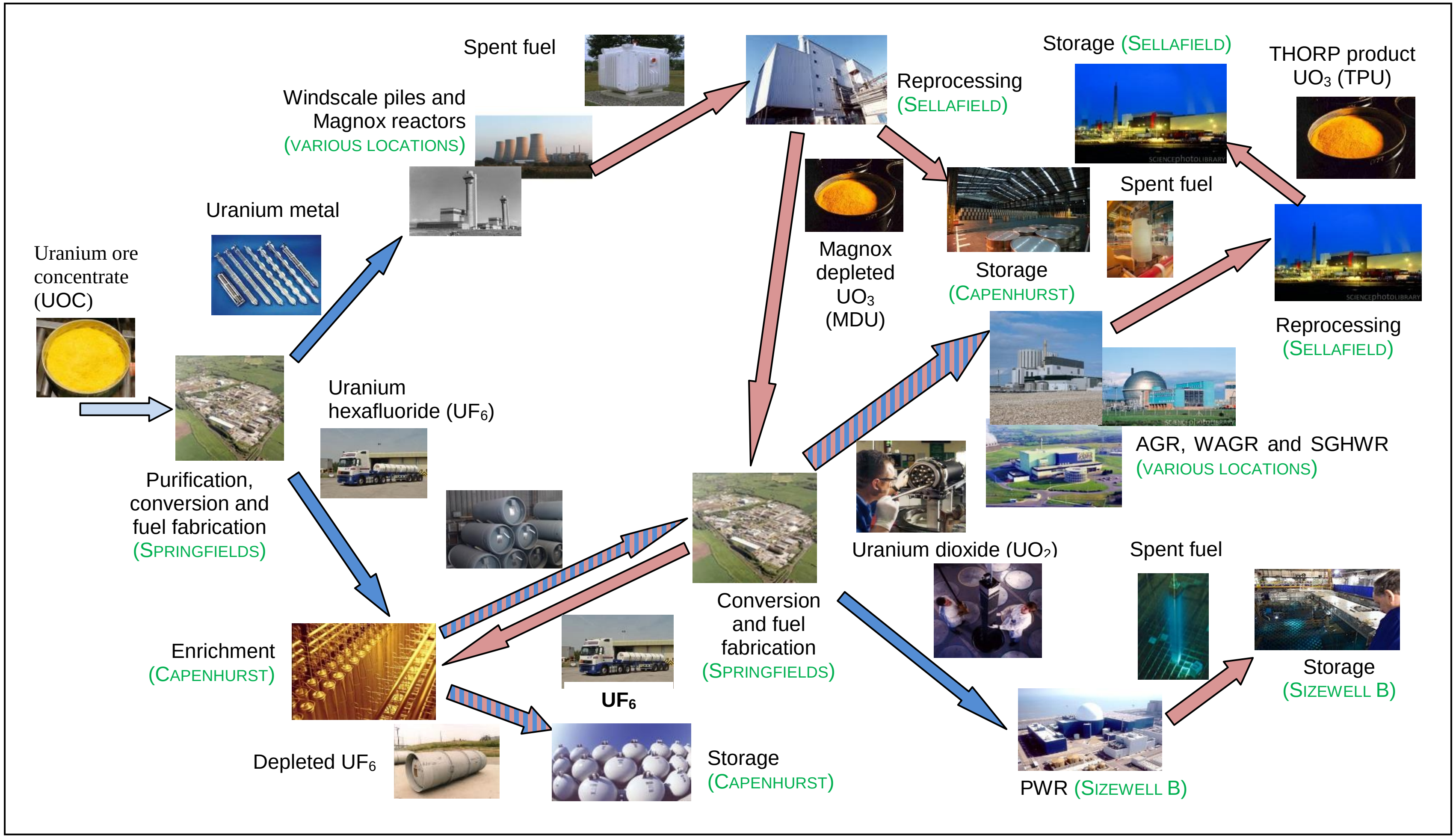
Long-Term Management Strategy

In the UK, DNLEU is not currently classified as waste; it is considered to be a zero-value asset radioactive material. If it were to be declared as radioactive waste, then as part of the UK's baseline inventory for higher activity wastes, it may be disposed of in a GDF. The future management of UK DNLEU is subject to ongoing strategic decision-making.

Plans for Conversion to Other Chemical Form(s)
URENCO is currently constructing a new facility at Capenhurst known as the Tails Management Facility (TMF). The TMF is owned and will be operated by a URENCO subsidiary, URENCO ChemPlants (UCP), and will be used to treat both URENCO-owned and NDA-owned depleted UF_6 tails. The TMF will comprise a deconversion plant to deconvert depleted UF_6 tails to triuranium octoxide (U_3O_8), a uranium oxide storage facility, and a UF_6 cylinder wash, cylinder store, and uranic residue recovery facility. The uranium oxide store will be owned by UUK and managed by UCP. UCP will provide a processing service to UUK, its sister European sites, and the NDA. The current owners of the depleted UF_6 tails will retain ownership of the uranium material after deconversion and during storage. The U_3O_8 product will be placed in DV-70 containers for storage.

Figure 1: Simplified diagram of the UK thermal reactor fuel cycle (NDA, 2013)

Blue arrows show the movements of unirradiated uranic materials and red arrows represent irradiated uranic materials. Striped arrows indicate the transfer of both unirradiated and irradiated uranic materials. Site locations are shown in parentheses using capitals and green text.



Transport

Transport of DNLEU material has been carried out safely for many years in the UK. MDU in the form of UO_3 powder in mild or stainless steel drums has been transported from Sellafield to Capenhurst for storage. UOC, which is similar in terms of activity to the deconverted U_3O_8 product, has also been imported from overseas since operations at Springfields and Capenhurst began. A detailed study for transport of DNLEU materials in the UK and in other countries has been carried out in a separate task as part of Phase 2 of the uranium IPT (ASSIST, 2014). Table 2 gives a summary of UK transport practices for the main components of the DNLEU inventory.

Table 2: UK DNLEU inventory components and associated transport practices (ASSIST, 2014).

Inventory component	Chemical form	Level of enrichment	Presence of contamination	Activity	Transport package
DU tails from TMF (including URENCO and NDA stocks)	U_3O_8	<0.7% U-235	Low – natural levels	LSA-I	Yet to be decided
MDU	UO_3	<0.7% U-235	Yes (mainly fission products and transuranics)	LSA-II	IP-2 (mild or stainless steel drums in ISO freight containers)
TPU	UO_3	Variable, some of which is more than 1 % U-235	Yes (mainly other uranium isotopes)	LSA-II	IP-2 (stainless steel drums in ISO freight containers)

Disposal

DNLEU is not considered as waste in the UK. The uranium IPT has been formed to work on the topic of DNLEU, focusing on the disposability and associated full lifecycle implications of managing the UK inventory of these materials through geological disposal if they were declared a waste in the future. The objectives of the uranium IPT are to:

- Develop RWMD's plans for managing DNLEU through geological disposal, should these materials be declared as a waste in the future, and inform wider strategic decision-making on UK DNLEU management.
- Evaluate the lifecycle implications of conditioning, packaging and disposal concepts developed for DNLEU, by exploring a range of possible options, building on previous work.
- Challenge current assumptions relating to the reference disposal concept for DNLEU set out in RWMD's 2010 generic DSSC (NDA, 2010).
- Include consideration of potential opportunities for beneficial re-use of DNLEU in a GDF.
- Incorporate opportunities for engagement with internal and external stakeholders, including RWMD and contractor IPT members, wider RWMD staff and management, wider NDA, regulators, DNLEU owners, and the wider technically interested community.

3 DNLEU Management in France

DNLEU Inventory

As of 2010, DU stocks in France were about 271,000 tHM (tonnes of Heavy Metal) (ANDRA, 2012). These stocks arose from the EURODIF (an AREVA subsidiary) gaseous diffusion plant on the Tricastin site in the south of France, which has been in operation since 1979. This plant was renamed Georges Besse plant in 1988 and ceased enrichment activities in June 2012. A new enrichment plant, the Georges Besse II plant at the same site, which uses the centrifugation technique for enrichment, began commercial operations in 2011. DU stocks are forecast to reach about 345,000 tHM in 2020 and 454,000 tHM by 2030 (ANDRA, 2012).

The amount of natural uranium was estimated at about 16,000 tHM in 2010. This is expected to rise to 25,000 tHM by 2020 and 28,000 tHM by 2030 (ANDRA, 2012).

The quantity of uranium separated during reprocessing (RepU) was just over 24,000 tHM in 2010 (ANDRA, 2012). This has arisen from reprocessing activities at the Marcoule and La Hague sites. The projected future inventory of RepU is estimated to be 40,000 tHM by 2020 and 40,000 tHM by 2030 (i.e. no change).

Organisations Holding the Material

AREVA NC, formerly the Compagnie générale des matières nucléaires (COGEMA), and EURODIF are currently responsible for the DU stocks in France.

EDF is responsible for management of the largest share of French stocks of RepU.

Current Chemical Form(s) and Storage Approach

About 75% of the DU is in the form of a U_3O_8 black powder, which is stored in 3 m^3 painted mild steel boxes, the so-called DV-70 containers, stocked in warehouses (based on figures from 2001) (OECD NEA & IAEA, 2001). The rest of the DU (~ 25%) is stored as UF_6, in 48-inch containers in open-air yards. The typical isotopic composition of DU in France is 0.002% U-234, 0.20-0.30% U-235, and no U-232 or U-236 isotopes.

The RepU is initially obtained in the form of liquid uranyl nitrate hexahydrate (UNH) [$UO_2(NO_3)_2.6H_2O$], with a concentration of <400g U/l (IAEA, 2007)), primarily via the PUREX process. Some RepU is stored in this form, but the majority is generally transported to the Pierrelatte site and converted to other chemical forms, either for long-term storage (as U_3O_8 in 220 litre steel drums), for use in mixed oxide (MOX) fuel (UO_2), or for re-enrichment and fabrication of new fuel rods (UF_6) (IAEA, 2007). U_3O_8 is the preferred chemical form for RepU that is not intended for immediate recycling.

Long-Term Management Strategy

In France, DU in the form UF_6 is deemed unsuitable for long-term storage because it can react with water vapour to produce hazardous chemicals such as hydrofluoric acid gas (HF). As a result, UF_6 is deconverted into a more stable form of uranium oxide (U_3O_8). This form of uranium can be compacted so that storage of this material in DV-70 containers occupies smaller volumes, with a reduced accessible surface area. The 3 m^3 steel containers of U_3O_8 are stored on the Tricastin site in the south of France and are also being transported by rail to a new storage site, Bessines, in central France. These containers are stacked on three levels in modular sheds. Each modular shed is designed with anti-seismic features, a surface area of 2,600 m^2, and can store up to 2,200 containers (OECD NEA & IAEA, 2001). The U_3O_8 will be stored until required, as it is not classified as a waste.

DU and RepU are considered as reusable materials. They can be:

- Used in MOX fuels (this represents a stream of about one hundred tons per year).
- Enriched to the level of natural uranium.
- Used in potential future 4th generation reactors.

Significant quantities of RepU have already been re-enriched and recycled into new fuel rods, and four French reactor units are now specifically fuelled with RepU, with more than twenty other nuclear power plant units using RepU within MOX fuel (IAEA, 2007). The portion of the French RepU that is recycled has so far been sent to Russia for re-enrichment and the enriched product is sent back to France for fuel fabrication. The new Georges Besse II plant in Tricastin may be used to re-enrich RepU in France (PNGMDR, 2009).

Plans for Conversion to Other Chemical Form(s)

AREVA NC is currently deconverting UF_6 stocks to the more stable U_3O_8 form for long-term storage. The deconversion process is performed at a slightly higher rate than tails production in order to minimise the amount of potentially hazardous UF_6 held in storage facilities.

Transport

DNLEU material in different forms is routinely transported in France. RepU in the form of UNH is transported from the reprocessing plant in La Hague and from interim storage at Marcoule to the Pierrelatte site for conversion into U_3O_8 (or other chemical forms) (IAEA, 2009a). The resulting U_3O_8 has been transported to other sites in France, or to facilities in Russia, for conversion into UF_6 and recycling. The transport of U_3O_8 drums with less than 1% U-235 content does not pose any specific problem (IAEA, 2009a). DU in the form U_3O_8 is also transported from the Pierrelatte facility to the Bessines storage site by rail in DV-70 containers. A more detailed study of DNLEU transport practices in France and in other countries has

been carried out as part of the uranium IPT Phase 2 work (ASSIST, 2014).
Regulations
The 2006 law on radioactive waste management (law no. 2006-739 of 28 June 2006, Article 5 available at (JORF, 2006)) states: • "A radioactive material shall include any radioactive substance that is intended for further use, after treatment, if need be." • "Radioactive waste shall include any radioactive substance for which no further use is prescribed or considered." • "Ultimate radioactive waste shall include any radioactive waste for which no further processing is possible under current technical and economic conditions, notably by extracting their recoverable fraction or by reducing their polluting or hazardous character." Reuse of radioactive materials depends on the continued pursuit of nuclear power programmes in France and/or abroad. Owing to uncertainties in predicting future policies, the study of possible management options for these materials, if they are to be considered as waste, is prescribed by the French Government to all owners of reusable radioactive materials (PNGMDR, 2009).
Disposal
Due to the potential value of DU stocks, France does not currently have a disposal option for this material (OECD NEA & IAEA, 2001). Consistent with Government requirements (PNGMDR, 2009), owners of reusable radioactive materials have conducted studies on possible management routes in case these materials would be considered as waste in the future.

4 DNLEU Management in the US

DNLEU Inventory
In 2011, the United States Department of Energy (USDOE) estimated the US DU stocks at about 510,000 metric tons of uranium (MTU) in the form of UF_6 (USDOE, 2013). This would equate to about 750,000 tonnes of depleted UF_6. As of 31 December 2012, USDOE has an inventory of 5,234 MTU of US-origin natural uranium (NU) as UF_6 and 7,700 MTU of Russian-origin NU. There is also a small inventory of off-spec DNLEU that amounts to ~1,300 MTU (USDOE, 2013). The US suspended reprocessing activities in 1977 due to proliferation concerns and, therefore, only limited RepU stocks exist (IAEA, 2009a; OECD NEA & IAEA, 2012). About 620 tonnes of uranium were recovered from spent fuel reprocessing by Nuclear Fuel Services at the West Valley Demonstration Plant between 1966 and 1972 (USDOE, 1999).
Organisation Holding the Material
USDOE stocks of DU originated from the operation of three gaseous diffusion plants built during the 1940s and 1950s, one of which was closed in 1985. The two remaining plants have been operated by the United States Enrichment Corporation (USEC) since 1993. In 2001, USEC ceased enrichment activities at the Piketon plant (Portsmouth, Ohio) and consolidated operations at the Paducah (Kentucky) plant. In 2011, USEC de-leased the Piketon site back to the USDOE. Today, the Piketon site hosts the American Centrifuge Demonstration Facility and construction has begun on the future American Centrifuge Plant (USEC, 2013a). The Paducah plant (USEC, 2013b) is currently being shut down by USEC. USDOE and USEC are the responsible organisations for the current DU stocks. URENCO's National Enrichment Facility (NEF) in Eunice, New Mexico, is now operational and generating tails stocks. These stocks are currently small, but will increase with time.
Current Chemical Form(s) and Storage Approach
DU in the US is stored mostly in the UF_6 form (USEPA, 2006), in 48-inch-diameter cylinders stacked horizontally in two layers and in open-air yards (see Figure 2). The way in which these cylinders were arranged, coupled with the advanced age of some of them, has resulted in an environmental and safety hazard (OECD NEA & IAEA, 2001) due to possible external corrosion from contact with water or ageing of paint. This requires control and maintenance to avoid any potential risks that may arise owing to the hazardous nature of UF_6. The UF_6 cylinders are currently stored at the Paducah site in Kentucky and the Portsmouth site in Ohio. About 5,000 UF_6 cylinders have previously been transferred from the East Tennessee Technology Park (ETTP) to the Portsmouth site. The image in Figure 2 is of the Paducah (Kentucky) site.

Figure 2: UF_6 cylinders at the Paducah gaseous diffusion plant in Kentucky (Haire & Spencer, 2005).

Small quantities of DU are stored in forms other than UF_6. These include UO_3, uranium metal, UF_4, and oxide forms other than UO_3 (ANL & USDOE, 2013a).

Long-Term Management Strategy

Over the last 50 years, large quantities of UF_6 have been produced from enrichment activities in the US. Little of the UF_6 has been converted into other forms. However, the USDOE started a programme in 2000 calling for proposals to design and operate deconversion facilities for UF_6. These facilities will convert the USDOE's inventory of UF_6 to a more stable uranium oxide form (primarily depleted U_3O_8) acceptable for transportation, beneficial use/reuse, and/or disposal (OECD NEA & IAEA, 2001). In late 2010, Babcock & Wilcox conversion services (BWCS) won a five-year operating contract for DU conversion facilities in Paducah, Kentucky and Piketon, Ohio. BWCS assumed the management and operation of the facilities in March 2011.

Environmental Impact Statements (EISs) (USDOE, 2004a, 2004b) have been prepared for the construction and operation of the UF_6 deconversion facilities in Paducah and Piketon. In these EISs, it was considered that the uranium oxide deconversion product would be transported and disposed of at the EnergySolutions Clive, Utah facility or the Nevada National Security Site (NNSS) facility. USDOE has intended to identify disposal locations at the sites in its Records of Decision (RODs). Pursuant to the National Environmental Policy Act (NEPA), a Supplemental Analysis (SA) was prepared (USDOE, 2007) by the USDOE to determine whether the RODs can be modified to include a decision on the disposal locations or whether the USDOE must supplement the existing EISs or create new ones. It was concluded that no supplemental or new EISs are required. The draft SA was placed on hold in 2009 and the USDOE is evaluating options to update its disposal alternatives (e.g., to recognise the recently opened Waste Control Specialists in Andrews, Texas, and the update to the EnergySolutions performance assessment for the Clive, Utah LLW disposal site).

About 114,000 MTU of the USDOE inventory of 510,000 MTU of depleted UF_6 is believed to have potential economic value for re-enrichment to NU levels or higher, should circumstances arise that make these options attractive (USDOE, 2013). This proportion of the DU inventory includes uranium tails with assays of more than 0.34% uranium-235. It is planned that this high-assay depleted UF_6 will be processed through the deconversion plant last. This will allow time to consider the potential sale or transfer of this material should it prove commercially viable (USDOE, 2013).

Plans for Conversion to Other Chemical Form(s)

740,000 metric tons of UF_6 will be deconverted at the BWCS facilities at Piketon and Paducah to a stable chemical form (U_3O_8) for reuse, storage or disposal. The U_3O_8 form is considered by the US Nuclear Regulatory Commission (USNRC) to be the preferred choice, because of its very slow reaction with water and non-pyrophoric nature compared to other possible forms of DU such as UF_6, UO_2 or UF_4 (Croff *et al*., 2000).

In the period October 2011 – September 2012, 6,170 Metric Tons of depleted UF_6 were processed at the two plants compared to 6,218 Metric Tons in the period October 2012 – March 2013.

Transport

Regulations for shipping UF_6 cylinders in the US require the cylinders to be designed, fabricated, inspected, tested and marked according to the version of American National Standards Institute (ANSI) N14.1 "Packaging of Uranium Hexafluoride for Transport". Example requirements include: (a) cylinders must be filled to less than 62% of the volumetric capacity, (b) the pressure in the cylinders must be less than 14.8 psia (101.3 kPa), and (c) cylinders must be free of cracks, excessive distortion, bent or broken valves or plugs, and broken or torn stiffening rings or skirts, and must not have shell thicknesses that have decreased below a specified minimum value. Cylinders not meeting these requirements are referred to as substandard or nonconforming (ANL & USDOE, 2013b). Any cylinders considered to be nonconforming cannot be transported without some type of prior preparation, such as placement of the nonconforming cylinder in an overpack, or transfer of the UF_6 to a conforming cylinder (ANL & USDOE, 2013b). DU material in other forms has been transported between different sites in the US. A detailed study of DNLEU transport practices in the US and in other countries has been carried out as part of the uranium IPT Phase 2 work (ASSIST, 2014).

Regulations

In general, USDOE waste is not classified until the time of disposal, in accordance with USDOE order 435.1. In 2005, the USNRC recommended that DU be classified as Class A LLW – the least hazardous type of LLW (USNRC, 2005). The

Commission decided to continue with this classification in 2009, but with a requirement that the federal regulations for LLW disposal (at 10 CFR part 61) be amended to require a site-specific analysis for the disposal of wastes not foreseen at the time the regulations were initially promulgated in 1982 (USNRC, 2008). These wastes include the large quantities of DU stocks held in the US. Revised drafts of the rule-making language for 10 CFR part 61 were produced by the USNRC for consultation and comment, the latest of which was circulated for comment in December 2012. Among the changes is a proposal to revise the existing site-specific analysis for protection of the general population to include a 10,000-year compliance period, as outlined in the accompanying regulatory basis for the proposed revisions (USNRC, 2012).

Disposal

Drums containing depleted UO_3 wastes have been disposed of at the LLW disposal facility at the NNSS in Nevada and at the EnergySolutions (previously, Envirocare) Clive facility in Utah (Gillas & Berg, 2009).

In assessing suitability for near-surface disposal with other LLW, the following amendments will be considered in the US, as part of the suggested changes to 10 CFR part 61:

- Conduct of site-specific performance analyses to permit the development of criteria for waste acceptance.
- The existing site-specific analysis for protection of the general population will include a 10,000-year compliance period.
- A new site-specific analysis will be required for the protection of inadvertent intruders that would include a 10,000-year compliance period and a dose limit.

A performance assessment model was developed in 2011 for disposal of DU at the Clive facility (EnergySolutions, 2011). The specific performance objectives require (Black *et al.*, 2012):

- Assessment of annual individual radiation dose over a 10,000-year performance period.
- Qualitative analysis of effects at the time of maximum dose.
- Estimation of groundwater concentrations within a 500-year compliance period.
- Assessment of site stability in the long term.

The first draft of the performance assessment has been submitted to the State of Utah for review. The results of this preliminary analysis indicate that doses are very low for site-specific receptors for the 10,000-year compliance period. The DU waste is assumed to be buried beneath zones exposed by erosion. Groundwater concentrations of DU waste constituents do not exceed groundwater protection limits over the 500-year compliance period (Black *et al.*, 2012).

Research

Since a final decision on the specific location for disposal of large quantities of DU has not yet been made, research has gone into investigating potential benefits of using DU as a fill in waste packages and in a geologic repository and other disposal alternatives (Forsberg, 1997, 2000; Haire & Spencer, 2005).

Some applications of DU in a geologic repository are depicted in the left side of the schematic in Figure 3 below. Although studies have indicated some potential benefits to use of DU in geological disposal, its use has not been seriously considered in the US. As mentioned above, DU is classified as LLW and therefore geological disposal of this material is not being considered.

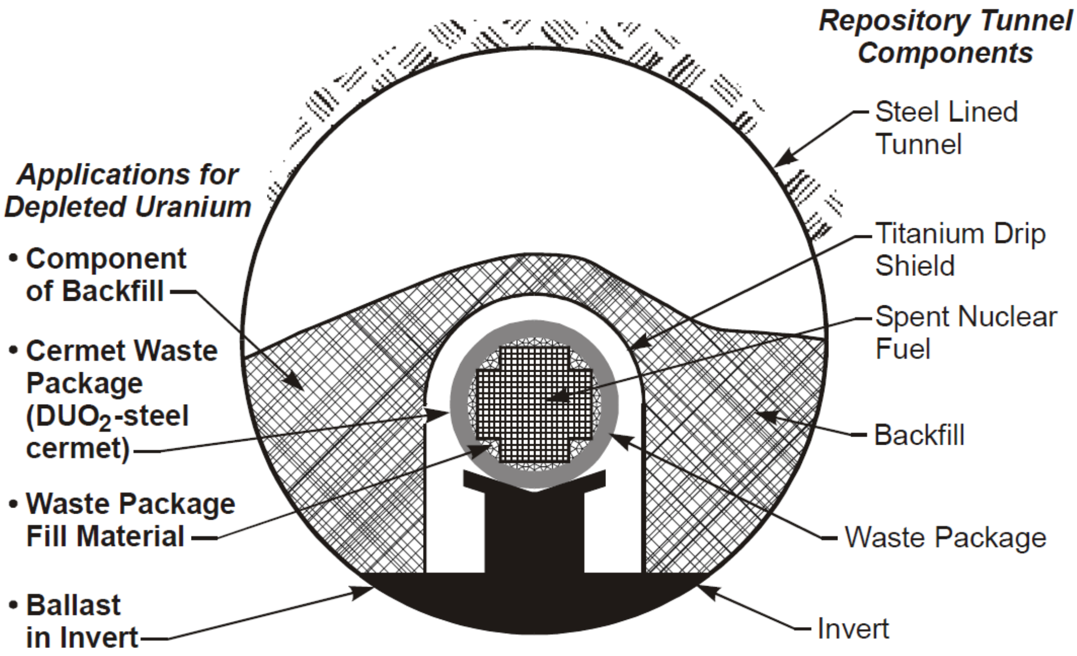


Figure 3: Potential DU applications in a GDF (Haire & Spencer, 2005).

5 DNLEU Management in Russia

DNLEU Inventory

Russia operated four gaseous diffusion enrichment plants which are now closed and have been replaced by centrifuge enrichment plants since the early 1950s. By the end of 2005, the total amount of uranium tails in Russia was 545,000 tonnes (OECD NEA, 2007).

There is a very limited stock of RepU in Russia since all the reprocessed uranium from the reprocessing plant at Mayak is recycled into the RBMKs (light-water graphite-moderated nuclear reactors) (IAEA, 2009a).

Some of Russia's DU inventory consists of "super-tails" from re-enrichment of other countries' DU sent by URENCO and EURODIF. The re-enriched uranium (up to natural uranium level) is sent back to the country of origin, but the secondary tails remain in Russia. These super-tails are then re-enriched further to obtain more natural-equivalent uranium or slightly enriched uranium for use in downblending of surplus highly enriched weapons-grade uranium into reactor-grade uranium (Diehl, 2004).

Organisation Holding the Material

The Russian Federal Atomic Energy Agency (Rosatom) is currently responsible for managing DU stocks in Russia.

Current Chemical Form(s) and Storage Approach

As of 2001, most uranium tails in Russia (~ 98%) are stored in the form of UF_6 in steel containers in open-air yards, with the remainder as oxides, metal and calcium diuranate (CaU_2O_7) (OECD NEA & IAEA, 2001). The UF_6 containers are controlled and maintained to ensure acceptable performance.

Long-Term Management Strategy

Russia considers the use of DU to make MOX and fast reactor fuel as the main application of DU stocks. Other proposed uses are as feed for the production of HF, as radiation protection shields, as heavy metal for flywheels, and for the production of special sorbents (OECD NEA & IAEA, 2001).

Rosatom has started a programme to define the strategy for the storage and management of UF_6 stocks (OECD NEA & IAEA, 2001).

Plans for Conversion to Other Chemical Form(s)

Conversion processes have been considered in Russia to convert some of the UF_6 into more stable uranium oxides. Plasma and low-temperature hydrolysis processes that convert UF_6 to U_3O_8 and UO_2 have been developed (OECD NEA & IAEA, 2001). The first deconversion project in Russia was put into operation in December 2009 by the Electrochemical Plant (ECP) company; the deconversion process is based on that used by AREVA at Pierrelatte in France. This plant converts UF_6 into uranium oxides for long-term storage and yields HF as a by-product.

Russia has also developed a process to convert UF_6 to UF_4, and plans to implement this technology in a new plant at the Angarsk Electrolysis Chemical Complex in the Irkutsk region. The plant was due to be commissioned in 2012. The advantage of UF_4 over UF_6 is that UF_4 has a low solubility and reacts very slowly with moisture at ambient temperatures.

6 DNLEU Management in Japan

DNLEU Inventory
Japan Atomic Energy Agency (JAEA, former JNC) and Japan Nuclear Fuel Limited (JNFL) operate centrifuge enrichment plants that produced a total of 10,000 tonnes of DU by 2001 (OECD NEA & IAEA, 2001). The RepU from the Tokai Reprocessing Plant (TRP) was estimated at 890 tonnes in 2004 (IAEA, 2007). However, until recently Japan's spent nuclear fuel reprocessing was largely undertaken by BNFL (now Sellafield Ltd) and AREVA NC in Europe, with the vitrified high-level waste returned to Japan for disposal. The total RepU from AREVA NC and BNFL reached 2,840 and 2,330 tonnes, respectively, by the end of March 2004 (IAEA, 2007). Currently, JNFL is commencing operation of its own commercial reprocessing plant, as spent nuclear fuel shipments to Europe ceased in 2001. This new plant at Rokkasho Mura in the Aomori Prefecture has a nominal capacity of 800 tonnes per year (IAEA, 2007).
Organisation Holding the Material
JAEA and JNFL are currently responsible for managing DU and RepU stocks in Japan.
Current Chemical Form(s) and Storage Approach
The DU is held in the form of UF_6 in 30-inch and 48-inch containers (OECD NEA & IAEA, 2001). The RepU from the TRP is in the form of UO_3 powder. The UO_3 material is packed and stored in drums (IAEA, 2009a).
Long-Term Management Strategy
DU stocks in Japan are considered a potential future resource for use in fast breeder reactors if they come into existence. Other potential uses of DU material considered include (OECD NEA & IAEA, 2001): • Use as shielding material for spent fuel casks, owing to the ability of uranium and uranium hydride to shield against gamma and neutron rays. • Use as a hydrogen storage alloy that can be employed for energy storage systems. • Use as a magnetic material in controlled areas to replace rare-earth magnets. • Use in a redox flow cell for electric power storage.
Plans for Conversion to Other Chemical Form(s)
JAEA is considering deconversion of DU stocks to U_3O_8 for long-term storage (OECD NEA & IAEA, 2001).

Disposal
A recent research article examined near-surface disposal (trench type) for LLW in Japan, including uranium-bearing wastes of low activity concentration (Amazawa *et al.*, 2012). The article includes consideration of radionuclide release and land use scenarios. At present, the volume and activity inventory of the uranium-bearing wastes to be disposed of in the trench type facility are not completely defined. Disposal concepts for uranium-bearing wastes of higher activity concentration will be addressed in future studies.

7 DNLEU Management in South Korea

DNLEU Inventory
South Korea has DU stocks from enrichment activities carried out by the US and France on its behalf. South Korea has no enrichment facilities and the DU stocks are held by the Korea Atomic Energy Research Institute (KAERI). DU stocks as of 2000 were about 200 tonnes (OECD NEA & IAEA, 2001).
Organisation Holding the Material
KAERI is currently responsible for managing DU stocks in South Korea.
Current Chemical Form(s) and Storage Approach
DU stocks in South Korea include about 185 tonnes in the form of UF_6, 10 tonnes as UF_4, and 4 tonnes as uranium metal (OECD NEA & IAEA, 2001).
Long-Term Management Strategy
KAERI has imported 17 cylinders of UF_6 from the US (OECD NEA & IAEA, 2001). South Korea considers DU a potential future energy resource through re-enrichment to produce new nuclear fuel. It is also considering alternative uses of DU for: • Shielding of radioactive material. • Liquid metal cooling of nuclear reactor fuel.
Plans for Conversion to Other Chemical Form(s)
South Korea has facilities to convert UF_6 to UF_4 and DU metal. UF_4 was used for R&D activities to develop containers for shielding radioactive material. Some of the UF_4 was reduced further to produce DU metal, which can be used for radiation shielding as well as for other nuclear fuel technologies (OECD NEA & IAEA, 2001).

8 DNLEU Management in the Netherlands and Germany

DU stocks exist in many other countries, but of particular interest to the UK are Germany and the Netherlands. The uranium enrichment company URENCO currently holds stocks of DU from enrichment operations in the UK, Germany and the Netherlands. The estimated inventories of DU in Germany and the Netherlands were 4,500 tonnes and 6,500 tonnes, respectively, at the end of 2005 (OECD NEA, 2007). Current estimates for URENCO stocks on site are 3,800 tU in Germany and 3,900 tU in the Netherlands. However, this does not include U_3O_8 returned from deconversion in France or material stored in France pending either deconversion or return. This will add a significant amount to the inventory.

URENCO Limited is composed of several subsidiary companies as shown in the organogram in Figure 4. The main enrichment part of the company in Europe is owned one third each by the British and Dutch governments and one sixth each by the German companies RWE and E.ON. The owners have recently agreed to pursue the sale of their stakes in URENCO (UK Government 2013).

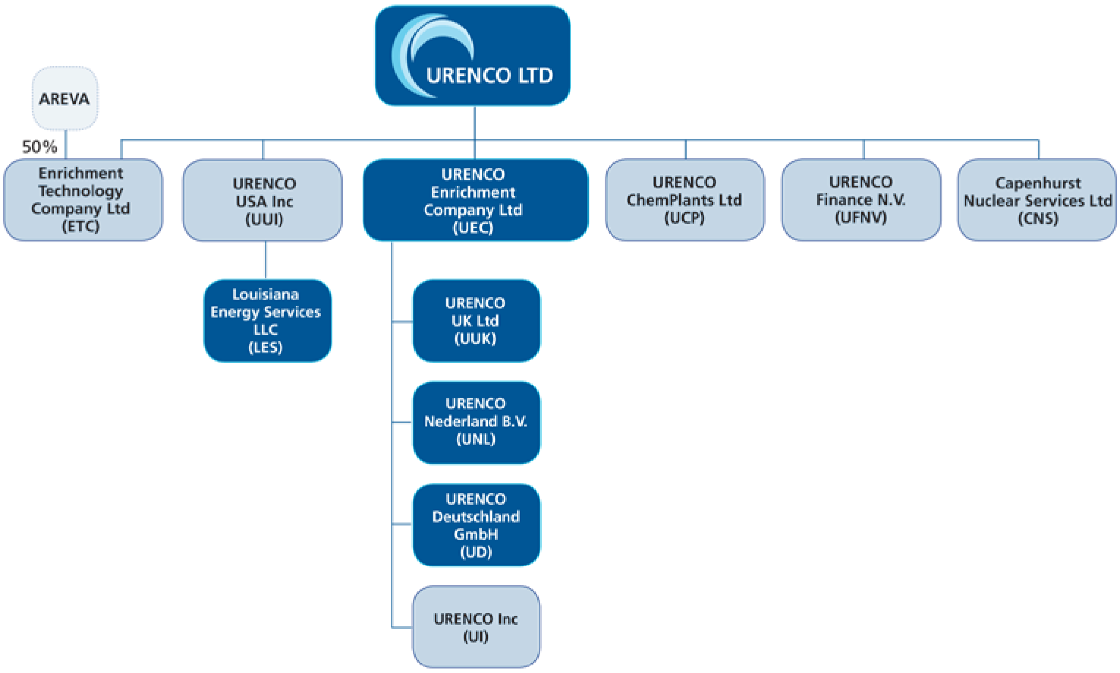


Figure 4: URENCO Limited company structure.

In the Netherlands, URENCO produces UF_6 tails from uranium enrichment activities at its site in Almelo. The tails material is initially stored in 48Y cylinders on site prior to transfer to a processing site for deconversion into U_3O_8. The tails material currently goes to Pierrelatte in France, but will in the future go to the URENCO-owned TMF in the UK. The converted product is sent back to the Netherlands for storage by COVRA, the Central Organisation for Radioactive Waste. The U_3O_8 is stored in 3 m^3 containers (DV-70s) in custom-built modular storage buildings. A building with a storage capacity of 650 containers became operational in 2004 and two other buildings were made available in 2008 (VROM, 2008). These buildings make up the DU storage building (VOG). An extension to the DU store is planned (VOG2) (COVRA, 2012). By the end of 2012, 2,519 DV-70 containers were stored at the COVRA site (IAEA, 2009b). A decision is yet to be made as to whether DU will be reused or disposed.

URENCO also produces tails material at its enrichment plant at Gronau in Germany. As with the Netherlands, the tails material is initially stored on site prior to transfer for deconversion at Pierrelatte and at the Capenhurst TMF in the future. The processed U_3O_8 will be returned to Germany in DV-70s for long-term storage. A new storage building for uranium oxide will be completed by 2014 and it will have the capacity to store about 60,000 tonnes of U_3O_8.

In Germany, DU is currently considered a resource for further enrichment and not as waste (Möller, 2007). However, if the DU stocks were to be classified as a waste in the future, then a disposal option would be necessary. For disposal at Konrad, a GDF for non-heat-generating radioactive waste, the amount of uranium is limited by the existing license, which does not allow large amounts of DU to be disposed of (Möller, 2007). The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) has conducted a preliminary safety assessment (VSG – Vorläufige Sicherheitsanalyse Gorleben) for possible disposal of 35,000 m^3 of DU at the Gorleben facility, a proposed GDF mainly for heat-generating waste (GRS, 2011). It should be noted that Gorleben is no longer considered a default choice for a GDF in Germany, with a new siting process for a GDF to be started in the near future.

9 Discussion and Conclusions

This section discusses some of the key themes identified in this review of overseas DNLEU management practices, with a view to highlighting issues likely to be of particular relevance to RWMD, and for planning work to be carried out by the uranium IPT.

Worldwide DNLEU stocks arise mainly from enrichment operations, with significant quantities also arising from reprocessing activities, particularly in France and the UK. France, Russia and the US hold by far the largest stocks of DU. DNLEU stocks held by these countries significantly exceed UK stocks. Germany also holds significant stocks of DU, with other countries having relatively small inventories.

In many countries, including the UK, France, Russia, Japan and South Korea, DNLEU is considered to be a potential (or current) resource, and is held in storage with this in mind. Some countries, notably France, but also Belgium, Germany, India, the Netherlands, Sweden and Switzerland, reuse RepU within fuel for nuclear power plants, either as conventional uranium oxide fuel, or within mixed oxide fuel. The lower the burn-up of fuel in a reactor is, the easier it is to re-use the RepU. The trend for many years has been towards higher enriched fuel and higher burn ups; hence it is historic stocks that have most potential for re-use.

The US is the only country that currently regards at least some DNLEU as a waste. The regulator classifies it as LLW, and regulatory policy provides for disposal of DNLEU in near-surface facilities. However, to date only relatively small quantities have been disposed of in this way at the existing sites.

Japan has examined the possibility of near-surface disposal of some uranium-bearing wastes of low activity concentration in a trench-type facility.

Germany is the only country that has assessed the performance of a GDF for significant quantities of DU (in a salt dome at Gorleben). Some consideration has been given in US research projects to alternative (beneficial) uses of DU in a GDF. However, overall, there is relatively little transferable experience from overseas that is specifically relevant to geological disposal concept development for DNLEU in the UK.

In addition, several disposability issues relating to DNLEU have been identified, including:

- The presence of fine particulate matter. This presence of loose material (unconditioned) needs to be considered in safety assessments, and could be particularly important in the case of an accident during emplacement operations in a GDF (e.g. canister drop leading to rupture).

- Sorbed/associated contaminants such as HF. The potential presence of chemotoxic contaminants needs to be considered in safety assessments.

- Potential pyrophoricity. This issue needs to be considered in assessments of transport and operational safety, and is strongly dependent on chemical form.
- Radioactivity levels arising from short-lived contaminants in DNLEU. Typically safety assessments focus on the primary uranium components (and daughter products) of DNLEU. However, some DNLEU, particularly that derived from reprocessing operations, has been contaminated with a range of other radionuclides. It is important to understand the extent of any such contaminants and their potential impacts on transport, operational and post-closure safety.

Some of these issues are strongly dependent on the chemical form of DNLEU under consideration.

U_3O_8 is generally regarded as the preferred chemical form for long-term storage, where no immediate use has been identified, and for disposal. Other chemical forms such as UO_3, UF_4, UO_2 and uranium metal have also been considered suitable for disposal, but in some cases, with reduced confidence in their disposability and in their ability to comply with waste acceptance criteria for specific disposal sites (e.g. in the US).

DU tails or RepU stored as U_3O_8 can be converted back to UF_6 for re-enrichment and/or reuse via the same processes used for preparing fuel from uranium ore. Some countries, such as the US and Russia, store most of their DNLEU as UF_6, but in most cases (including the US and the UK), steps are being taken to deconvert this material into the less reactive form U_3O_8 (and to recover associated resources, such as HF). UF_6 is not generally considered to be a suitable chemical form for disposal, although some parties have argued otherwise (Laverov *et al*., 2010).

Approaches to package DNLEU for storage are similar across different countries. UF_6 is typically stored in steel cylinders. In the UK, deconverted U_3O_8 will be stored in DV-70 containers, as is also done in France, Germany, and the Netherlands.

Transport of DNLEU stocks in a variety of chemical forms (including UF_6, liquid uranyl nitrate, U_3O_8 and UO_3 powders) is routinely undertaken in many countries.

10 References

Amazawa, H., Sakai, A., Nakata, H., Hara, H., Kurosawa, R., Yamamoto, M., Kawata, Y. and Sakamoto, Y. (2012). Conceptual Design of Near Surface Disposal Facilities Of Radioactive Wastes Generated from Research, Industrial and Medical Facilities. JAEA-Technology 2012-031. (In Japanese).

ANDRA (2012). National Inventory of Radioactive Materials and Waste.

ANL & USDOE (2013a). http://web.ead.anl.gov/uranium/faq/mgmt/faq23.cfm (accessed on: 10/09/2013).

ANL & USDOE (2013b). http://web.ead.anl.gov/uranium/mgmtuses/transport/index.cfm (accessed on: 10/09/2013).

ASSIST (2014). Doudou, S., Harvey, E.J., Freer, A.R. and Hutchinson, D.L. Transport Safety Review and Scoping Study. 1207-ASS-8-1 Version 1.2, April 2014.

Black, P., Tauxe, J., Perona, R., Lee, R., Catlett, K., Balshi, M., Fitzgerald, M., McDermott, G., Shrum, D., McCandless, S., Sobocinski, R. and Rogers, V. (2012). Advancing Performance Assessment for Disposal of Depleted Uranium at Clive Utah – 12493. WM2012 Conference, February26 – March 1, 2012, Phoenix, Arizona, USA.

COVRA (2012). Jaarrapport 2012. Annual report 2012.

Croff, A.G., Hightower, J.R., Lee, D.W., Michaels, G.E., Ranek, N.L. and Trabalka, J.R. (2000). Assessment of Preferred Depleted Uranium Disposal Forms. ORNL/TM-2000/161.

DECC & NDA (2014). Radioactive wastes and materials not reported in the 2013 UK Radioactive Waste Inventory. DECC Report URN 14D043 and NDA Report NDA/ST/STY(14)0013, Prepared by Pöyry Energy Limited and AMEC plc, February 2014.

DECC & NDA (2011). Radioactive materials not reported in the 2010 UK Radioactive Waste Inventory. DECC Report URN 10D/988 and NDA Report NDA/ST/STY(11)/0007, Prepared by Pöyry Energy Limited, February 2011.

Defra & NDA (2008). Radioactive materials not reported in the 2007 UK Radioactive Waste Inventory. Defra Report DEFRA/RAS/08.005 and NDA Report NDA/RWMD/007, Prepared by Pöyry Energy Limited, March 2008.

Diehl, P. (2004). Re-enrichment of West European Depleted Uranium Tails in Russia.
EnergySolutions. (2011). Utah Low-Level Radioactive Waste Disposal License – Condition 35 (RML UT2300249) Compliance Report. EnergySolutions, Salt Lake City, UT, 1 June 2011.

Forsberg, C.W. (1997). Long-Term Criticality Control in Radioactive Waste Disposal Facilities Using Depleted Uranium. Oak Ridge National Laboratory. CONF-970926-3.

Forsberg, C.W. (2000). Effect of Depleted-Uranium Dioxide Particulate fill on Spent-Nuclear-Fuel Nuclear Technology, Vol. 131, pages 337-353.

Gillas, D.L. and Berg, J. (2009). Packaging and Transportation of Depleted Uranium for Disposition from The Savannah River Site. WM’ 09 Conference, March 2009, Phoenix, AZ.

GRS (2011). Abfallspezifikation und Mengengerüst, Basis Ausstieg aus der Kernenergienutzung (Juli 2011), Bericht zum Arbeitspaket 3, Vorläufige Sicherheitsanalyse für den Standort Gorleben.

Haire, M.J. and Spencer, B.B. (2005). Depleted Uranium Disposition Option: Beneficial Disposal in a High-Level-Waste Geologic Repository. Oak Ridge National Laboratory (Presentation).

IAEA (2007). Management of Reprocessed Uranium: Current Status and Future Prospects. IAEA TECDOC 1529.

IAEA (2009a). Use of Reprocessed Uranium: Challenges and Options. Report No. NF-T-4.4.

IAEA (2009b). Peer Review of the Radioactive Waste Management Activities of COVRA, Netherlands.

JORF (Official Journal of the French Republic) (2006)._LOI n° 2006-739 du 28 juin 2006 de programme relative à la gestion durable des matières et déchets radioactifs (1) – Article 5.

Laverov, N.P., Velichkin, V.I., Yudintsev, S.V. and Tagirov, B.R. (2010). Geological conditions of safe long-term storage and disposal of depleted uranium hexafluoride. Geology of Ore Deposits. Volume 52, Number 4.

Möller, K.D. (2007). Challenges Dealing with Depleted Uranium in Germany: Reuse or Disposal. ICEM2007-7294, pages 85-88.

NDA (2010). Geological Disposal: An overview of the generic Disposal System Safety Case. NDA Report no. NDA/RWMD/010.

NDA (2013). Geological Disposal: Integrated Project Team on Uranium: Phase 2 Planning Report Volume 1 – Roadmap, 1207b-4a, Version 1, LL 185444101, March 2013.

OECD NEA (2007). Management of Recyclable Fissile and Fertile Materials. NEA No. 6107.

OECD NEA & IAEA (2001). Management of Depleted Uranium.

OECD NEA & IAEA (2012). Uranium 2011: Resources, Production and Demand. NEA No. 7059.

Pöyry Energy Limited (2011). An explanation of the differences between the 2007 Derived Inventory and equivalent wastes and materials in the 2010 UK Radioactive Waste Inventory. Contractor Report to NDA Reference 390761/23, July 2011.

PNGMDR (2009). French National Plan for the Management of Radioactive Materials and Waste (PNGMDR) 2010-2012. Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, Autorité de Sûreté Nucléaire.

UK Government (2013). https://www.gov.uk/government/news/government-to-proceed-with-urenco-sale-to-realise-value-for-the-taxpayer (accessed on 16/07/2013).

USDOE (1999). Plutonium and Uranium Recovery from Spent Fuel Reprocessing by Nuclear Fuel Services at West Valley, New York from 1966 to 1972.

USDOE (2004a). Final Environmental Impact Statement for Construction and Operation of a Depleted Uranium Hexafluoride Conversion Facility at the Paducah, Kentucky, Site, DOE/EIS-0359.

USDOE (2004b). Final Environmental Impact Statement for Construction and Operation of a Depleted Uranium Hexafluoride Conversion Facility at the Portsmouth, Ohio, Site, DOE/EIS-0360.

USDOE (2007). Draft Supplement Analysis (AS) for Location(s) to Dispose of Depleted Uranium Oxide Conversion Product Generated from DOE's Inventory of Depleted Uranium Hexafluoride, (HEXAFLUORIDE, (DOE/EIS-0359-SA1 AND DOE/EIS-0360-SA1).

USDOE (2013). Excess Uranium Inventory Management Plan. Report to Congress, July 2013.

USEC (2013a). http://www.usec.com/gaseous-diffusion/portsmouth-gdp (accessed on 10/09/2013).

USEC (2013b). http://www.usec.com/gaseous-diffusion/paducah-gdp (accessed on 10/09/2013).

USEPA (2006). Depleted Uranium Technical Brief. EPA-402-R-06-011.

USNRC (2005). http://www.nrc.gov/reading-rm/doc-collections/commission/orders/2005/2005-05cli.pdf (accessed on: 10/09/2013).

USNRC (2008). http://www.nrc.gov/reading-rm/doc-collections/commission/srm/2008/2008-0147srm.pdf (accessed on: 10/09/2013).

USNRC (2012). Regulatory Basis for Proposed Revisions to Low-Level Waste Disposal Requirements (10 CFR Part 61).

VROM (Ministry of Housing, Spatial Planning and the Environment of the Netherlands) (2008). National report on the joint convention on the safety of spent fuel management and on the safety of radioactive waste management.