# NUCLEAR WASTE MANAGEMENT IN THE UK

# GROWING VOLUMES AND NO SOLUTIONS

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## 1. Overview

The UK was one of the earliest developers of nuclear technology. This was initially for the purpose of producing nuclear weapons, and the site at Sellafield (formerly Windscale) in North West England was used to develop the 'Windscale piles' for the production of plutonium for weapons. This was followed by the development of dual-use reactors, which were used both for plutonium production for weapons as well as electricity generation. [1]

The UK has been through three distinct phases in development of power reactors. The first was the development of the Magnox design, based on the dual-use reactors. They used natural uranium and were graphite-moderated and cooled by carbon dioxide. All are now closed. A second phase was also based on gas-graphite reactors, the Advanced Gas Cooled Reactors (AGRs) now using enriched uranium.[2] A third, truncated phase involved importing pressurized water reactors (PWR) and one was completed in 1997. After a long gap, Hinkley Point C, a European Pressurized Water Reactor (EPR) of similar design to the earlier PWR, is now under construction. That a further five large new nuclear stations might be built are open to question, as developers have stopped work, citing financial problems.[3]

"Care and maintenance" (a UK. term)[4] is the status where all buildings have been removed from the reactor site except for the reactor building, pond structures and ILW stores. These remaining facilities are then weather-proofed. It is expected that they will be dismantled after around 80 years. Only one Magnox station has yet reached care and maintenance status and the others are expected to do so by 2029.[5]

The UK has a very wide range of other nuclear structures. Besides facilities for producing nuclear weapons, these include two fast breeder reactors, several prototype reactors, and many other research facilities. The UK has never mined or milled any uranium, but it has plants for all other stages of the nuclear fuel chain. This includes conversion, enrichment and fabricating nuclear fuel, as well as reprocessing spent fuel to separate out plutonium and uranium. The UK has operated two large reprocessing plants at Sellafield. One is called B205 which is designed to reprocess metallic fuel from Magnox reactors, opened in 1962 and due to close in 2020. The other is a Thermal Oxide Reprocessing Plant (THORP), opened in 1994 and closed in 2018.[6] THORP has reprocessed significant quantities of foreign fuel, notably from Japan and Germany, but its main activity was always reprocessing of UK-owned fuel from the AGRs. The U.K. also has an operating dry

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1 R.F. Pocock,Nuclear Power: its development in the United Kingdom, Unwin, 1977

2 Gordon MacKerron and Mike Sadnicki, "UK nuclear privatisation and public sector liabilities" STEEP special Report No. 4, November 1995 pp. 42-44.

3 The Guardian, "Hitachi scraps £16bn. nuclear power station in Wales" 17 January 2019, see www.theguardiancom/environment/uk-nuclear-plant-hitacho-wylfa-anglesey, accessed 5 April 2019

4 See Nuclear Decommissioning Authority (NDA), Business Plan 1 April 2018 to 31 March 2021, March 2018, p. 9.

5 NDA 2018, op. cit. p.9 and p.30.

6 NDA, "End of reprocessing at THORP signals new era for Sellafield" see www.gov.uk/news/end-of-reprocessing-at-thorp-signals-new-era-for-sellafield, 16 November 2018, accessed 5 April 2019

fuel store at Sizewell and LLW disposal sites at Drigg, near Sellafield and at Dounreay in Scotland.

The Sellafield site is especially complex and hosts hundreds of disused buildings and stores. Much work remains to be done before all the wastes there can even be characterized, let alone managed safely.[7] Like most other countries the UK plans to use Deep Geological Disposal (DGD) to dispose of ILW and HLW but has made little progress to date. Scotland's policy is different from that of the rest of the UK, and envisages near-surface disposal of all wastes within its borders.[8]

## 2. Waste classification system

The UK waste classification system is close to the IAEA system (as outlined in Chapter 2). The main categories are as follows:[9]

- Very low level wastes (VLLW), defined as wastes that of low enough levels of radioactivity to be predominantly disposed to licensed landfill sites.
- Low level wastes (LLW) defined as wastes at low levels of activity but which still need to be managed in engineered shallow repositories,
- Intermediate level wastes (ILW) which contain activity above the upper limit for LLW but are not heat-generating
- High level wastes (HLW), produced from reprocessing spent fuel, which are heat-generating as well as highly radioactive.

UK policy does not define separated plutonium, spent fuel, and depleted or reprocessed uranium as wastes, and so these are not included in the official waste inventory. This decision is officially rationalized on the grounds that all these materials might be used in fabricating nuclear fuel in the future. However, such uses are far from certain, and even if all are used in fuel fabrication, they would lead to further waste streams and these do not appear in the official UK waste inventory.

## 3. Quantities of waste

The UK Government publishes a waste inventory every three years. All the data below comes from the most recent inventory, which records waste volumes and activity as at 1 April 2016.[10] Among the features of the inventory are:

- There is a very large number of waste streams identified—some 1,300 in total. These streams are divided into 24 waste groups.
- A high proportion of all wastes are in 'raw' (in U.K. terms 'reported') form. These are wastes that are not yet conditioned or packaged—of the 24 waste 'groups' only one is described as 'conditioned waste'. While the

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[7] National Audit Office (NAO), "The Nuclear Decommissioning Authority: progress wirth reducing risk". HC 1126, June 20 2018, pp. 32-35.

[8] Natural Scotland/Scottish Government, "Scotland's higher activityradioactive waste policy, Edinburgh, 2011

[9] Department of Business Energy and Industrial Strategy(BEIS)/NDA, "Radioactive wastes in the UK: UK radioactive waste inventory report", 31 March 2017, see https://ukinventory.nda.gov.uk, accessed 5 April 2019

[10] Reference 9

proportion of wastes in this raw form has not been disclosed it seems probable that it is well over half of total volumes.

- The majority of wastes by volume will arise in a future time span that goes out to the year 2125. A high proportion of anticipated future volumetric arisings of ILW (62 percent) and LLW (84 percent) are expected to derive from decommissioning of power plants and Sellafield facilities.
- Liquid and gaseous discharges are not included in the inventory, which therefore consists essentially of different forms of solids.
- While VLLW and LLW are dominant in terms of volumes, they are a very small proportion of all the radioactivity contained in the wastes. As of 2016, the total activity in VLLW and LLW was well under 0.00003 percent of the total. ILW (around 5 percent) and especially HLW (around 95 percent) represented the dominant shares of radioactivity contained in the UK wastes.
- Most of the wastes by activity levels (58 percent) are concentrated at Sellafield (only 0.03 percent was at military sites).
- Foreign-owned wastes are not included in the UK inventory.[11]

Because the UK will not have an operational DGD facility for decades to come, successive U.K. inventories show that the volumes and activity of higher activity wastes continue to accumulate and require ever-growing interim storage facilities.

The table below shows the volumes and mass of nuclear wastes in storage. The HLW arises entirely as a by-product of reprocessing and is currently stored at Sellafield. This waste is initially in the form of highly active nitric acid (Highly Active Liquor or HAL), which undergoes an evaporation process before it is vitrified into glass blocks inside stainless steel canisters.

ILW is much more diverse and also lacks a current disposal route, and so also must be stored. About 74 percent by volume of ILW is at Sellafield. Nearly all the rest is at power stations. When packaging occurs, it can be in cement (inside steel or concrete containers) or immobilized in polymer inside mild steel containers. LLW and VLLW are routinely disposed and so the volumes currently awaiting disposal are small.

[11] There have been several substitution agreements in recent years between relevant Governments (of the UK., and owners of wastes held in the UK). They specify that the foreign owners of wastes held in the U.K will receive back the same amount of radioactivity as that contained in the original spent fuel, but in the form of vitrified high level waste, rather than the much larger volumes of HLW, ILW and LLW actually produced by the reprocessing of their spent fuel.

| Nuclear waste | Type of storage | Storage Site | Quantity stored |
|---|---|---|---|
| SNF | Interim storage (wet) | Storage pools at NPPs[12] | 3,549 t HM |
| | Interim storage (wet) | Sellafield | 4,151 t HM |
| HLW | Interim storage | Sellafield | 1,960 $m^3$ |
| ILW | Interim storage | Sellafield, Aldermaston, Dounreay, Harwell, NPPs | 99,000 $m^3$ |
| LLW | Interim storage | Sellafield, Capenhurst, Dounreay | 30,100 $m^3$ |
| | Disposed waste | Closed (in 2005) near-surface repository at Dounreay | 33,600 $m^3$ [13] |
| | Disposed waste | New near-surface repository at Dounreay | 3,130 $m^3$ |
| | Disposed waste | Near-surface repository LLWR[14] at Drigg | 905,000 $m^3$ [15] |
| VLLW | Interim storage | | 935 $m^3$ |
| | Dump sites | | no data |

Table 1: Existing Waste Volumes in the United Kingdom

Source: own compilation based on BEIS/NDA(2017). See footnote 9

The significance of ILW and especially HLW derive from their high levels of radioactivity relative to LLW and VLLW. HLW contains by far the bulk of activity levels in the UK inventory, much of which will reduce over the next century as a result of radioactive decay.

*Other radioactive materials not classified as wastes*

Definitions of what is and is not waste vary by country and over time. At present in the UK, uranium, separated plutonium and spent fuel are not classified as waste because plutonium and uranium might be used as ingredients of future nuclear fuel. The UK holding of stocks of separated plutonium will amount to 140 tons at

[12] NPPs = Nuclear Power Plants
[13] Data from (Neumann 2010, 56).
[14] LLWR = Low Level Waste Repository
[15] Data from (Neumann 2010, 56).

the end of reprocessing in 2020, of which 23 tons will be foreign-owned. This is the world's largest stockpile of civil separated[16]

Overall, plutonium, spent fuel and uranium will, once finally classified as waste, add very significantly both to the activity (spent fuel and plutonium) and volume (uranium) of UK nuclear wastes - a high probability that current policy ignores.

### 1.4 Waste management policies and facilities

The UK produced military wastes from the 1940s and civilian wastes from the 1950s. LLW was always disposed via shallow burial. Serious policy for other wastes was for many years solely a commitment to reprocessing all spent fuel. Reprocessing was based on the conviction that the plutonium would initially be needed for weapons and then later that it would be needed to fuel fast breeder reactors. This latter rationale evaporated and in 1994 fast reactor development was abandoned,[17] though reprocessing continued.

Policy for higher activity wastes was neglected until the 1970s when an influential report from the Royal Commission on Environmental Pollution[18] recommended that new nuclear power should not be developed until credible waste management routes were demonstrated. This led to explicit plans for deep geological disposal of ILW and, implicitly if later in time, HLW. Attempts to achieve this all failed due to local resistance at proposed sites.

An independent Committee on Radioactive Waste Management (CoRWM) reported in 2006 in favor of DGD for all higher activity wastes.[19] It also suggested robust interim storage and a new voluntary process in which local communities would be invited to negotiate terms under which they would accept development of DGD. Government chose to endorse this general approach in 2008[20] and pursued one serious (but failed) attempt to get buy-in from communities around Sellafield to agree to host a DGD. Government is engaged, as of early 2019, in a second process designed to find a willing host community for DGD.[21]

The UK's Department of Business Energy and Industrial Strategy (BEIS) is in charge of nuclear waste policy.  Closure of the Magnox stations and the poor and deteriorating state of Sellafield made it clear by the early 2000s that a more coherent policy and higher expenditure were needed to manage wastes in the short- and medium-term. The 2004 Energy Act provided the foundation for the

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[16] NDA, "Progress on plutonium conditioning, storage and disposal" 29 March 2019, p. 5, see https://assets.publishing.service.go.uk/government/uploads/systyem/uploads/attachment_data/file/791036/Progress_on_Pltonium.pdf accessed 5 April 2019

[17] International Panel on Fissile Materials, "Plutonium separation in nuclear power programs" 1 September 2015, p. 99.

[18] Royal Commisssion on Environmental Pollution, "Nuclear power and the environment" 6th report of the Royal Commission on Environmental Pollution, Cm 6618, 1976

[19] Committee on Radioactive Waste Management, "Managing our radioactive waste safely: CoRWM's recommendations to Government" Doc 700, November 2006, Chapter 14

[20] Defra, BERR and the devolved administrations of Wales and Northern Ireland "Managing our radioactive waste safely: a framework for implementing geological disposal" June 2008, especially chapter 2

[21] World Nuclear News, "UK relaunches repository site selection process" 20 December 2018, see www.world-nuclear-news.org/Articles/UK-relaunches-repository-site-selection-process

setting up of the Nuclear Decommissioning Authority (NDA) in 2005.[22] Its purpose is to deliver the decommissioning and clean-up of all publicly-owned nuclear sites and also to undertake the long-term management of resultant wastes. It is the first time that an institution has been developed in the UK with the primary purpose of nuclear waste management.

The NDA recognized that Sellafield was the most problematic site, containing a huge range of ex-military and ex-civilian buildings and wastes. Sellafield contains four so-called Legacy Ponds and Silos, all representing major hazards, as well as being home to virtually all UK spent fuel, much of which has been reprocessed there. This means that cleaning up Sellafield is the highest priority for the NDA.[23]

The NDA attempted to innovate in managing the nuclear sites, which it now owns. In particular, it has held competitions to appoint 'Parent Body Organisations' (PBOs) to oversee, for specified periods, the work of the site license companies at each site. These competitive processes were designed to incentivize cost reductions and bring in wider international expertise. However, the model has not worked well and the NDA is taking direct management responsibility for the two largest segments of the UK decommissioning and waste management task: Sellafield and the Magnox sites.[24]

## 5. Costs and financing

The total costs of managing all of the UK's wastes are very high. NDA provides estimates for the future costs of public sector 'legacy' wastes. This legacy covers wastes which have either arisen in the past or are unavoidable in the future (mainly because of the need to decommission many nuclear structures). As of 2006, the NDA estimated the undiscounted future costs of its task to amount to £53 bn. [needs US $ equivalents]By 2018 this had escalated to an estimate of £121 bn. of which costs at Sellafield, where escalation has been concentrated, were an expected £91 bn. NDA now puts an uncertainty range on their central estimate of £99–225 bn.[25] Expenditures are expected until around 2025.

The U.K. has a poor historic record in financing waste. Only for very brief periods has it set up small segregated funds for public sector wastes and these were all abandoned. Currently, there are three different systems of finance:

- The main system is an annual Government grant-in-aid. It finances the NDA and is supplemented by income that the NDA receives from services it provides, such as managing spent fuel via reprocessing, and long-term spent fuel storage. In 2017/18 this commercial income totaled £1.2 bn., most of which was for spent fuel services.[26] The UK Government grant amounted to £2.1 bn. making the total spent in 2017/18 around £3.3 bn. 60% of this was spent at Sellafield. Total annual NDA expenditure has been around £3 bn. for several years. In future, commercial income from spent

[22] Energy Act 2004, see https://www.legislation.gov.uk/id/ukpga/2004/20/pdfs/ukpga_20020020_en.pdf
[23] NAO, op. cit. part 2
[24] Nuclear matters, "Magnox becomes NDA subsidiary", 4 July 2018, see www.nuclearmatters.co.uk/2018/07/magnox-becomes-nda-subsidiary
[25] NDA,"Annual Report and Accounts 2017 t0 2018, 12 July Financial Summary (unpaginated),
[26] NDA, reference 25, Nuclear Provision (unpaginated)

fuel services will fall steeply, because of the closure of all reprocessing by 2020.

- The second finance system is the Nuclear Liabilities Fund (NLF), an independent trust, which currently amounts to £9.26 bn.[27] It is used for the decommissioning and waste liabilities of AGR reactors (excluding ongoing payments to the NDA for spent AGR fuel). These are all owned by EDF Energy. The fund is expected to cover the discounted value of EDFE liabilities. Qualifying expenditure has to be approved by the NLF. Because the AGRs are still operating, expenditure from the NLF has so far been limited, primarily for a dry spent fuel store at Sizewell.
- The third system is a planned Funded Decommissioning Plan which will apply to new reactors. Reactor owners are to develop this Plan, which then is subject to Government approval. It covers all future liabilities and is designed to ensure that owners of reactors bear the full costs of decommissioning and waste management.[28] Included in these arrangements will be a system in which a waste transfer price will be set in future, at which point, after reactor shutdowns, owners will pay Government to take title to wastes. The intention is to ensure that this price will be high enough to more than cover all subsequent waste management costs.

## 6. Summary

The UK has a legacy of over 1,200 waste streams, and a policy history of largely neglecting the active management of decommissioning and wastes until the setting up of the Nuclear Decommissioning Authority in 2005. Most wastes will arise in the course of more than 100 years in the future.

The required expenditure to manage these wastes is extremely high and the task very challenging. The great bulk of future expenditure on waste management will come from annual public expenditure and is expected to exceed £120 bn. Spent fuel, separated plutonium and uranium are not considered as wastes in the UK and this means that actual waste volumes are higher than official estimates. However, in keeping with other countries, policy for higher activity wastes is to use Deep Geological Disposal, but progress has been slow, and no repository is likely to be available before, at best, 2040.

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[27] Nuclear Liabilities Fund, "Protecting the future: Annual Report and Accounts 2017-2018", p. 14

[28] Energy Act 2008 "Funded decommissioning programme guidance for new nuclear power stations" December 2011, Part 2b.