Nuclear Decommissioning Authority

Integrated Waste Management

NDA Higher Activity Waste Strategy

May 2016

Contents

Executive Summary

The UK has been producing and managing radioactive waste for many decades. A major part of the Nuclear Decommissioning Authority (NDA) role to decommission civil nuclear sites is enabled through the management of legacy waste. Often these legacy wastes were managed in a way that would not meet today's standards. The challenges posed in the management of legacy wastes serve as a pertinent reminder of the need to manage waste in a responsible manner to ensure it is safe now and throughout the waste lifecycle. The aim now is to convert wastes to a passively safe and disposable form in a timely manner, reducing the burden on future generations.

The term Higher Activity Waste (HAW) refers to all radioactive material that has no further use that falls into the following categories: High Level Waste (HLW), Intermediate Level Waste (ILW) and the relatively small volume of Low Level Waste (LLW) that is not deemed suitable for disposal at the LLWR or the LLW facility at Dounreay. Our strategy involves converting the HAW within the NDA estate into a form that can be safely stored and managed.

HAW cannot be simply retrieved and directly disposed of. Waste management requires a series of lifecycle steps through which it is important to consider the waste hierarchy: pursuing opportunities for waste minimisation, reuse and recycling, before undertaking treatment, packaging and storage. The waste must then be stored safely pending future transport and then final disposal, when a disposal facility is available.

The NDA's HAW strategy ***is to convert the HAW inventory into a form that can be safely and securely stored for many decades. At the appropriate time the stored waste in England and Wales will be transported to and disposed of in a geological disposal facility (GDF) and the NDA will continue to work with Scottish government to implement its policy for the long-term management of HAW at its sites in Scotland.***

The NDA recognises that there are well established plans in place for the management of HAW across the estate and the HAW strategy is to progress these plans (the 'reference strategy') while at the same time seeking to identify and promote good practice, give guidance and leadership in key strategic areas and pursue opportunities to make overall improvements. The HAW strategy aims to foster the benefits of improved efficiency for the management of HAW across the NDA estate while supporting the technical challenges in implementing the reference strategy. The strategic imperatives can be broadly described as:

- application of the waste hierarchy
- development of alternative waste management routes
- making best use of existing and future planned assets

We recognise that the near-term waste management plans can often be well established making it more difficult and less beneficial to change course. The main opportunities to introduce strategic change to bring significant benefit occur in the longer term where planning is at an early stage and less mature. We also recognise that our Site Licence Companies (SLCs) are the strategy implementers and have the primary responsibility for ensuring safety, security and environmental performance at their sites at all times.

The desired outcome of HAW strategy is that waste is well managed by SLCs, in a manner that supports operational and decommissioning needs. This means greater focus on all aspects of the waste lifecycle and includes strategic evaluation to consider whether waste is better managed by sites working independently or by them sharing assets and capabilities. It is important to recognise that the NDA HAW Strategy applies to HAW within the NDA estate and is delivered under contract by the SLCs, such that the NDA is the strategic authority and client. Although this strategy is for the NDA-owned HAW we work with other owners of HAW to encourage good practice and knowledge transfer across the whole of the industry.

This strategy recognises that within the UK there are policy differences regarding the long-term management of HAW in England and Wales to those in Scotland. The NDA works with the relevant governments to provide management solutions that are consistent with these different policies. The UK policy on the long-term management of HAW recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. To support this UK policy and the Scottish government policy position of near-surface management of HAW we will explore a range of disposal options together with RWM and our SLCs.

Current UK policy classifies radioactive waste into categories depending on the nature and quantity of radioactivity they contain and whether they generate heat or not. The NDA (with support from the nuclear site regulators) advocates an approach where wastes are managed based on their best means of disposal rather than what waste category they fall into. The NDA is now moving towards a single radioactive waste strategy for its estate that will need to demonstrate how it will support all relevant policies in the UK. Our radioactive waste strategy will not replace the use of existing waste categories (e.g. ILW, LLW). It will also need to take into account the nature of wastes (radiological, chemical and physical properties) and the most appropriate waste management route while recognising the challenges posed by waste classification boundaries. Considerable stakeholder engagement will be required as the strategy develops over the next few years.

1. Introduction

1.1 Background

Nuclear site operations and successful site decommissioning and remediation depend on the availability of a robust, sustainable waste management infrastructure. Effective waste management is an essential requirement for the delivery of our mission and is a significant part of our programme [1].

The UK has been producing and managing radioactive waste for many decades. A major part of the NDA's role to decommission civil nuclear sites is enabled through the management of legacy waste. Often these legacy wastes were managed in a way that would not meet today's standards. The challenges posed in the management of legacy wastes serve as a pertinent reminder of the need to manage waste in a responsible manner to ensure it is safe now and throughout the waste lifecycle. The aim is now to convert all wastes to a passively safe and disposable form in a timely manner, reducing the burden on future generations.

The term HAW refers to all radioactive material that has no further use that falls into the following categories: HLW, ILW and a relatively small volume of LLW that is not deemed suitable for disposal at the LLWR or the LLW facility at Dounreay. Our strategy is to convert the HAW within the NDA estate into a form that can be safely stored and managed. The NDA also identifies and pursues opportunities to manage the HAW in ways that deliver benefits by improving safety, efficiency or value. The NDA has recently published an overview of the NDA's HAW which describes the waste in greater detail [2]. The total lifetime packaged volume of the NDA's HAW is 404,000 m^3 (~87% of all UK HAW). About 75% of all the NDA's HAW is from the Sellafield site and about 20% from the Magnox sites.

HAW cannot simply be retrieved and directly disposed of. HAW management requires a series of lifecycle steps (see Figure 1) through which it is important to consider the waste hierarchy: pursuing opportunities for waste minimisation, reuse and recycling before undertaking treatment, packaging and storage. The waste must be stored safely pending future transport to a suitable disposal facility when it becomes available. The waste management steps are undertaken within an environment of regulation, policy and contract whereby a number of different organisations have different roles to fulfil. The NDA is the management organisation and the owner of the nuclear liability. Through the SLCs we implement retrieval, treatment, conditioning and interim storage to support decommissioning of the UK's civil nuclear estate. The NDA's wholly-owned subsidiary Radioactive Waste Management Ltd (RWM) is responsible for implementing a GDF for HAW, a Nationally Significant Infrastructure Project[1]; as well as providing engagement to help waste producers in the development of waste management solutions.

[1] The Planning Act 2008 (subsequently amended by the Localism Act 2011) introduced a development consent process for Nationally Significant Infrastructure Projects (NSIPs). NSIPs are usually large scale developments (relating to energy, transport, water, or waste) which require "development consent". A Development Consent Order (DCO) automatically removes the need to obtain several separate consents, including planning permission and is designed to be a much quicker process than applying for these separately.

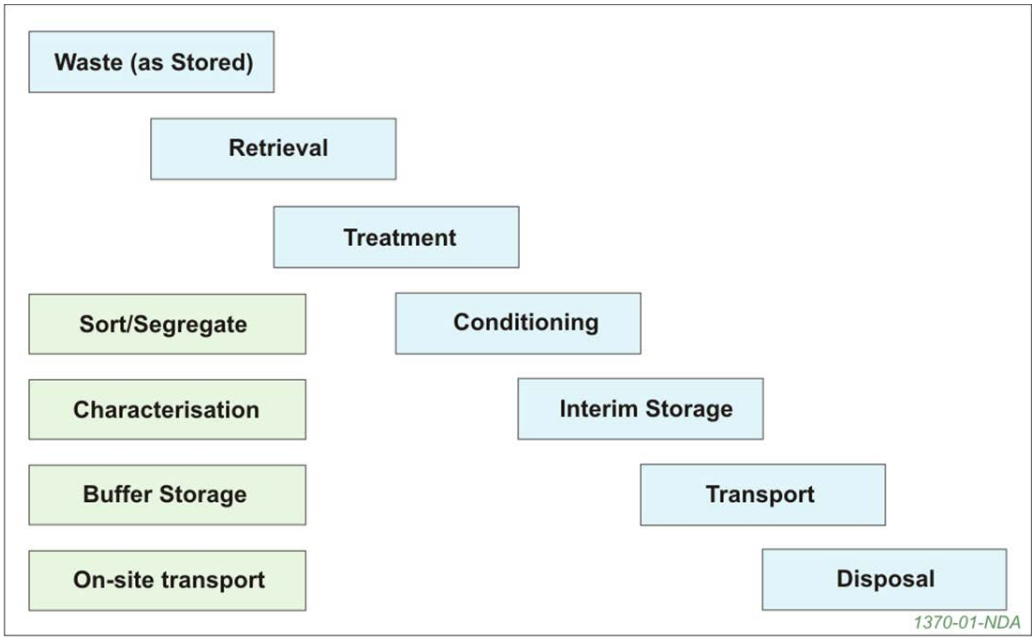


FIGURE 1 WASTE MANAGEMENT LIFECYCLE STEPS

The focus of recent years has tended to deliver waste management solutions that support ongoing site operations. This approach can be effective but is unlikely to be efficient or optimal overall because consideration of operational drivers alone may not address the requirements of subsequent waste management steps including eventual disposal.

The desired outcome of HAW strategy is that waste is well managed by our SLCs, in a manner that supports operational and decommissioning needs. This means greater focus on all aspects of the waste lifecycle and includes strategic evaluation to consider whether waste is better managed by sites working independently or by them sharing assets and capabilities. It is important to recognise that the NDA HAW strategy applies to HAW within the NDA estate and is delivered under contract by the SLCs, such that the NDA is the Strategic Authority and Client. SLCs carry the primary responsibility for safe, secure and environmentally responsible operation of their site(s) (See Appendix 3).

The nuclear industry has seen significant changes to improve the management of LLW under the remit of the National Waste Programme. There has been greater application of the waste hierarchy and waste producers are working together, and with the supply chain to deliver more optimised waste management practices. This change was driven by the UK Nuclear Industry LLW strategy first published in 2010 [3]. The UK LLW strategy was reviewed and the update was published in early 2016 [4]. To deliver similar improvements in HAW management the NDA has developed this HAW strategy as a first important step towards the delivery of a single Radioactive Waste Strategy that will support further integration of waste management across the NDA estate.

The NDA's HAW strategy ***is to convert the HAW inventory into a form that can be safely and securely stored for many decades. At the appropriate time the stored waste in England and Wales will be transported to and disposed of in a geological disposal facility and the NDA will continue to work with Scottish government to implement its policy for the long-term management of HAW at its sites in Scotland.***

The NDA recognises that there are well established plans in place for management of HAW across the estate and the HAW strategy is to progress these baseline plans (referred to as the 'reference strategy') while at the same time seeking to identify and promote good practice, give guidance and leadership in key strategic areas and pursue opportunities to make overall improvements. The HAW strategy aims to foster the benefits of improved efficiency for the management of HAW across the NDA estate while supporting the technical challenges in implementing the reference strategy. We recognise that the near-term waste management plans can often be well established making it more difficult and less beneficial to change course. The main opportunities to introduce strategic change to bring significant benefit occur in the longer term where planning is at an early stage and less mature. We also recognise that SLCs are the strategy implementers and have the primary responsibility for ensuring safety at their sites at all times.

Current UK policy classifies radioactive waste into categories depending on their radioactive concentration and whether they generate heat or not. The NDA (with support from the nuclear site regulators) advocates an approach where wastes are managed based on their best means of disposal rather than what waste category they fall into. The NDA is now moving towards a single radioactive waste strategy for its estate that will need to demonstrate how it will support all relevant policies in the UK. Our radioactive waste strategy will not replace the use of existing waste categories (e.g. ILW, LLW). It will also need to take into account the nature of wastes (radiological, chemical and physical properties) and the most appropriate waste management route while recognising the challenges posed by waste classification boundaries. Considerable stakeholder engagement will be required as the strategy develops over the next few years.

1.2 Summary of HAW inventory

The current HAW inventory lifecycle arisings are dominated by ILW in terms of volume and HLW in terms of radioactivity. ILW is the most complex area due to the range of chemical, physical and radiological characteristics of wastes to be managed, as well as the timescales to be considered, *i.e.* from legacy programmes to future reactor decommissioning. The main focus of the NDA HAW strategy is the lifecycle management of ILW as this area provides the greatest current technical challenge for the NDA.

As the NDA sites exist in England, Scotland and Wales, the NDA needs to be cognisant of the relevant UK and devolved administration policies and the implications they have on waste management activities for components of the waste inventory. For example, England will need to manage the majority of the inventory in relation to both volume and radioactivity and a sustained programme of waste management will be required from now until site remediation whereas in Wales the current HAW inventory by volume is mostly associated with reactor decommissioning during Magnox final site clearance, which is currently planned to take place towards the end of the century. The majority of the ILW inventory to be managed in Scotland will be as a consequence of Magnox and Advanced Gas-cooled Reactor (AGR) reactor dismantling, and the remainder of the inventory is dominated by the management of arisings from decommissioning the Dounreay site.

While implementing geological disposal in England and Wales (through RWM), the NDA continues to support Scottish government in developing the options for the long-term management of HAW, specifically in relation to robust storage arrangements and near-surface disposal.

Although the NDA HAW strategy is only applicable to the HAW within the NDA estate, this is by far the majority of the total amount of HAW arising across the whole of the UK including 100% of the HLW inventory. Figure 2 provides a breakdown of the current status of HAW packaging (left) and an overview of the percentage of total packaged volume of UK HAW inventory by waste producer (right).

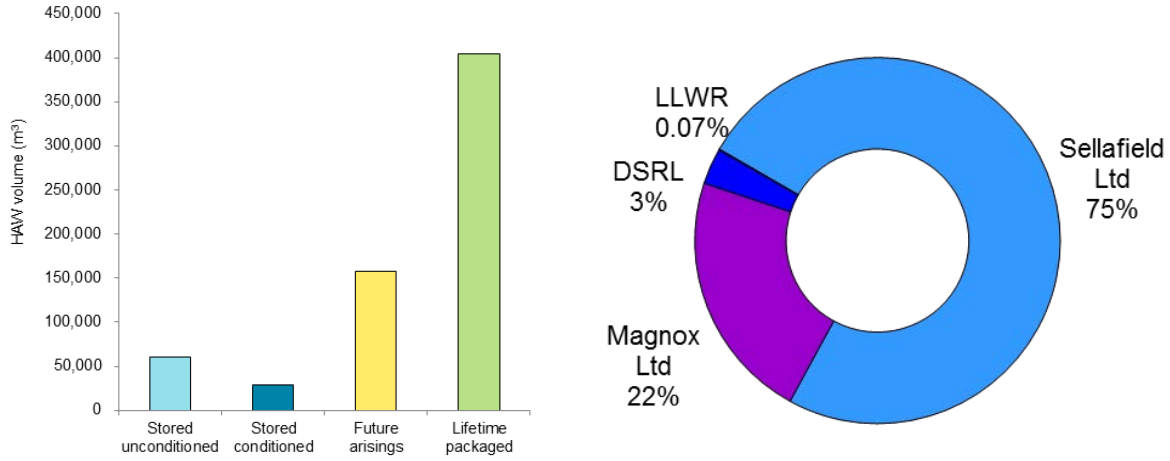


FIGURE 2 OVERVIEW OF THE ANTICIPATED HAW ARISINGS (LEFT) AND TOTAL PACKAGED VOLUME OF HAW INVENTORY BY WASTE PRODUCER (RIGHT) [2]

The HAW inventory managed by the NDA can be divided into four main types of waste, as described below. The waste types correspond to 'topic strands' which enable the NDA strategy to address the HAW inventory in a manageable way, reflecting some of the significant differences between the wastes. These topic strands have been used as a framework for strategy development and moving forward, we will review this approach as we prepare the radioactive waste strategy.

Wet ILW/potentially mobile wastes

Within this topic strand wet ILW is defined as potentially mobile material that is stored currently in aqueous conditions or dry materials that are potentially mobile or friable. Typical wet ILW streams include the following:

- Magnox sludges
- Fuel debris
- Ion-exchange resins
- Desiccants
- Sand
- Corrosion and degradation products

- PCM
- Raffinates

These materials are often heterogeneous waste streams stored in historical facilities that in some circumstances require urgent attention due to time-critical risks in terms of materials retrieval and engineering containment, in particular legacy wastes on the Sellafield site.

The strategic drivers for the management of raw wet ILW are centred on the need to immobilise these waste forms to reduce hazard. For some wastes it may be necessary to adopt a multi-stage process to achieve a final disposable product. A number of issues can be identified for these types of waste which should be given appropriate consideration, including:

- Taking steps to ensure the production of disposable packages
- Prompt containerisation of wastes with time-critical risks
- The potential for deferred final conditioning of waste packages
- Ensuring consideration of long term package performance
- Managing the reactive component of wastes (e.g. aluminium, Magnox, and uranium)
- Planning for the management of out of specification waste packages
- Considering potential the NDA estate wide opportunities

Operational wastes that are already conditioned for final disposal and in storage, which contain reactive metals, will be closely monitored under this topic strand, e.g. Magnox encapsulation plant product drums at Sellafield.

Solid ILW

Solid ILW arisings are mostly generated as a result of decommissioning activities. Typical solid ILW streams include the following:

- Concrete/rubble
- Activated steel
- Lead
- Sources
- Miscellaneous beta-gamma waste

Sorting and segregation of these wastes can range from generally straight-forward to significantly challenging depending on the mixtures of material and storage conditions. This is especially true where solid waste is being retrieved from wet environments and sludge needs to be separated. Solid ILW in its raw form is relatively immobile and these wastes are also generally easier to characterise and easier to package for interim storage and eventual disposal than wet ILW.

There are significant volumes of solid ILW at the lower end of the ILW radioactive spectrum (i.e. close to 12GBq/tonne beta gamma and 4GBq/tonne alpha). While current plans identify solid ILW from England and Wales being disposed of in a GDF, for these wastes it is important to consider the application of a risk-based approach to waste management, including the investigation of nearer-surface disposal options, with a focus on reactor decommissioning wastes. Disposal of the waste in a near-surface environment must be

justified using safety arguments that satisfy the environmental safety case of the disposal facility.

Graphite

Within the UK there are large quantities of irradiated graphite present in AGR, Magnox and test/prototype reactors. There is approximately 60,000 tonnes of graphite on Magnox sites alone. The present baseline strategy is to defer reactor dismantling for a number of decades followed by decommissioning and conditioning of the waste into disposable forms. Waste will then be exported to a GDF for England and Wales or placed under long-term management in near-surface facilities in Scotland.

Alternative waste treatment solutions could substantially reduce the volume of graphitic wastes that are currently planned to go to a GDF. At the present time work on developing these alternatives into practicable engineering solutions is not a high priority and there is sufficient time to revisit the options in the future. However, the NDA is investigating the optimum timing and sequencing of Magnox reactor dismantling, which could lead to a revised decommissioning strategy and a possible change in associated waste management plans.

Under the current plans for reactor care and maintenance the majority of the graphite will arise as a result of reactor decommissioning at the NDA and EdF sites, although graphite wastes also arise on sites in the form of operational wastes. Graphitic operational wastes are usually in the form of intact or fragmented reactor sleeves, struts, dowels or boats and have been stored in a number of facilities, *e.g.* solid waste vaults or silos. Operational graphite wastes may also be associated with irradiated steel items.

The major graphite streams covered by this strategy include:

- Magnox reactor graphite
- Windscale pile graphite
- Graphite fuel element debris at Hunterston A and Berkeley
- AGR graphite sleeves stored at Sellafield

It is also recognised that other smaller volume graphite waste streams will need to be dealt with, *e.g.* Dounreay reactor graphite.

As already discussed, the bulk of the graphite under current reactor dismantling plans will arise from 2070 onwards and it is important to ensure that current opportunities for learning and for the development of practical waste treatment and management of wastes are considered and applied where relevant, e.g. graphite from the Windscale pile and research reactors. Scottish policy is a key consideration when determining the preferred timing for reactor dismantling and subsequent management of graphite.

High Level Waste

In the UK, the only HLW that exists is that which is managed at Sellafield through vitrification of highly active liquors (HAL). The reference strategy for vitrification of HAL is nearing completion and therefore the NDA HAW strategy proposes no changes to the current treatment baseline, but will continue to investigate opportunities for subsequent storage, transport and disposal stages. The NDA HAW strategy covers the relevant HLW areas, namely:

- UK owned HLW including interim storage and disposal
- Overseas owned HLW
- HLW waste substitution of overseas owned ILW

1.3 Government policies

Government radioactive waste management policy is supported by a regulatory framework that aims to ensure that the wastes are safely and appropriately managed in ways that pose no unacceptable risks to people and the environment.

The Council Directive 2011/70/EURATOM requires European Union (EU) member states to have national programmes that ensure the safe management of spent nuclear fuel (SNF) and radioactive waste from civilian activities both now and in the future[2]. The Directive also requires member states to submit progress reports on the implementation of the national programme every three years. The national programme [5] has been developed and is expected to remain largely unchanged, with updates expected once every three years.

For HAW, the long-term management policy of the UK government is to package and hold wastes in secure interim storage until they can be transferred to a GDF. The White Paper on Implementing Geological Disposal sets out the UK government's framework for managing HAW in the long term through geological disposal recognising that a GDF will be '*implemented alongside ongoing interim storage and supporting research*' [6]. The current planning assumption is that a GDF would be available to receive HAW from around 2040 and HLW and SF in 2075.

As described in Section 3.6, the UK policy position recognises that some radioactive materials not currently classified as waste, including spent nuclear fuel, uranium and plutonium, may be managed as HAW if it is decided at some future time they are of no further use.

The Welsh government has participated in the Managing Radioactive Waste Safely (MRWS) programme since its inception in 2001 and consulted on their policy for the long term management of HAW in 2015. The Welsh government has decided to adopt a policy for geological disposal for the long term management of HAW [7]. Although the Welsh government has adopted a policy for geological disposal for HAW, this does not mean that a geological disposal facility (GDF) will necessarily be sited in Wales. The Welsh government continues to support the policy of voluntary engagement where potential host communities are able to seek discussions, without prior commitment, about potentially hosting a GDF. The Welsh government considers that a GDF can only be built in Wales if a community is willing to host it.

The Scottish government published its policy on HAW in January 2011 [8]. The policy is for long-term management in near-surface facilities. Paragraph 1.19 of the policy states that: *'……Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how*

[2] The Directive does not apply to authorised releases (discharges) of radioactive waste to the environment or to radioactive waste that is produced by onshore extractive industries, which falls within the scope of Directive 2006/21 /EC.

waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements.'

The Scottish government policy addresses disposal solutions, long-term storage and baseline improvement initiatives such as waste processing and storage consolidation opportunities.

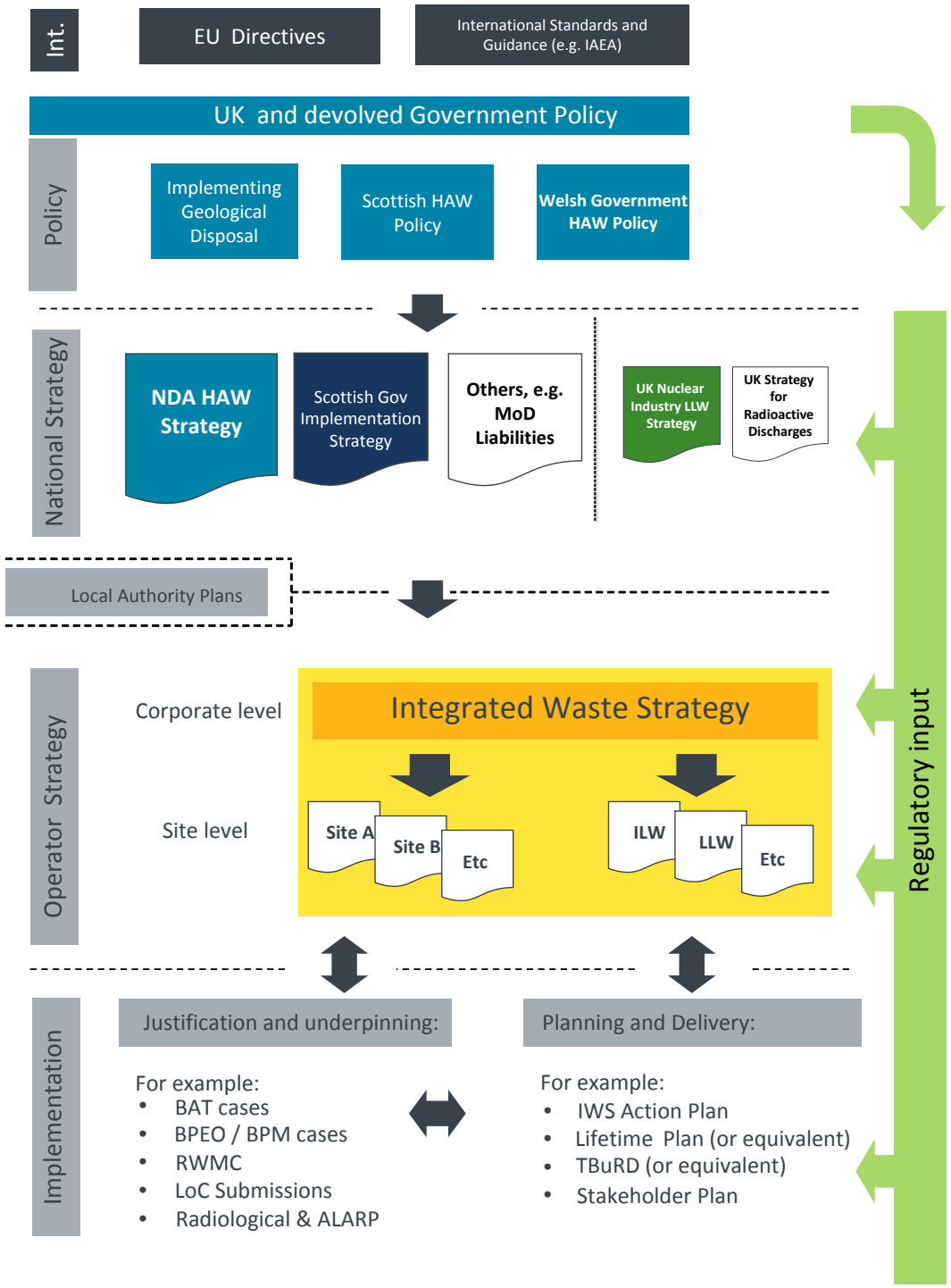


FIGURE 3 INTEGRATED WASTE MANAGEMENT STRATEGY AND IMPLEMENTATION

2. HAW Management Lifecycle

2.1 The lifecycle approach to HAW management

The waste management lifecycle includes a series of steps, throughout which it is important to consider the application of the waste hierarchy: pursuing opportunities for waste minimisation, reuse and recycling, before undertaking an appropriate waste treatment to enable packaging for the subsequent storage, transport and final disposal in accordance with government policy. The waste hierarchy is a central theme of the NDA HAW strategy (see Figure 4 below). The waste hierarchy provides a framework for waste management decision making throughout the lifecycle and enables an effective balance of priorities.

FIGURE 4 SUMMARY OF THE WASTE HIERARCHY

HAW currently exists in different states at different stages in the waste management lifecycle from generation through to interim storage. The following sections describe the typical waste lifecycle steps including ultimate disposal. It is recognised that there are often site specific or wastestream specific factors that can affect each of these steps. The generic steps described here are retrievals, treatment and conditioning, packaging, storage and disposal. The NDA promotes early planning and preparation, timely characterisation and sorting and segregation in the development of waste management.

It should be noted that transport of HAW is a particularly significant enabling step within the waste management lifecycle. The safe and secure movement of waste requires significant planning and specialised reusable transport containers. This is addressed within the Transport and Logistics strategic theme of the NDA Strategy [1].

HAW retrievals, treatment and conditioning

Retrieval is the act of extracting and transferring the unconditioned waste from its storage or origin location. The term 'unconditioned' refers to raw waste that has been freshly generated or is a legacy of past operations that requires further processing to produce a disposable form. Retrieved waste could be transferred directly into containers or transferred into a treatment facility to undergo some form of processing. Retrievals can involve significant technology deployment, and may also necessitate a degree of pretreatment, for example the mobilisation, homogenisation and transfer of HAW sludges or size reduction of metal and concrete structures and components. From a strategic perspective, the NDA believes its SLCs are best placed to make the tactical decisions about the best retrieval approach to take, in full consideration of waste specific and site specific factors.

Pretreatment can be undertaken as an enabling activity for subsequent waste management steps and such activities typically include sorting, segregation, decontamination or chemical adjustment. Treatment changes the characteristics of the waste while conditioning changes the form of the waste such that the resulting product can be safely handled, transported stored and if necessary disposed of. These processes can be used to create waste packages that are passively safe. Where possible, the volume of waste can be reduced to minimise the number of waste packages. For solid wastes this may be by compaction or mechanical size reduction and for liquid wastes by evaporation or dewatering. In most cases wastes are also mixed with encapsulating materials such as cement to give a solid and immobile wasteform and also to make them more suitable for disposal. This encapsulation process is called 'conditioning'. While conditioning typically refers to waste being processed and immobilised in a suitable medium to give a solid and stable wasteform, it is noted that both the container and the wasteform have a role to play in the durability of waste packages. Robust, thick-walled containers can sometimes be used to achieve a stable waste package without waste being immobilised within a matrix. In this sense containerisation is sometimes referred to as a form of conditioning.

The NDA continues to investigate treatment options through the HAW Treatment Framework [9], looking to develop strategic guidance in key areas and actively pursuing opportunities to develop alternative treatment technologies and capabilities. This is aimed at providing a broad range of treatment options for waste owners to consider, as well as improving the long term performance of wastes that present more challenges due to, for example, their chemical reactivity.

HAW packaging

HAW packaging refers to the process of loading waste into a container that is suitable for handling, long-term storage, transport and potentially for disposal. There are three general types of package used in HAW packaging:

- For some ILW of lower activity and LLW managed as ILW, sufficient radiation shielding can be provided by concrete boxes or concrete-lined steel boxes. These are known as '*shielded*' waste packages. They can be handled using normal industrial warehousing methods ('*contact-handled*') and can usually be transported without the need for overpacking.
- Higher activity ILW often requires greater radiation shielding than can reasonably be afforded by a container alone. Therefore, it is generally packaged in thin-walled steel drums and boxes that provide physical containment but limited radiation shielding. These are known as '*unshielded*' packages. They will require transport in a shielded container and will need to be managed using remote-handling techniques.

- Thick-walled waste containers can be used to provide both radiation shielding and physical containment. These robust, shielded waste packages are potentially capable of being stored, transported and disposed of without the need for remote handling techniques or overpacking.

Note that some of the LLW that must be managed as HAW may be suitable for packaging in thin-walled containers that do not provide substantial shielding and are still able to be contact-handled due to the low level of radioactivity.

SLCs are responsible for providing solutions for waste packaging including the selection of the container. However, the NDA is working with RWM to ensure appropriate strategic guidance on the selection and use of container types. This will provide better information for SLC's in the development of their plans for the retrieval, treatment and packaging of their waste ensuring more efficient use of resources and raising awareness of all possible packaging options.

The packaging of HLW is a well-established process with an advanced programme which is set to continue in the same way until vitrification is complete. The HLW vitrified waste product is contained within a thin walled canister developed for storage. These canisters have not been designed specifically for disposal and are currently assumed to require additional packaging before they can be considered suitable for disposal.

HAW storage

Waste storage is an essential component of the HAW management lifecycle providing a safe and secure environment for waste packages and ensuring they remain in an appropriate condition while awaiting final disposal. An interim store for packaged HAW is a robust engineered facility with a design life of typically 100 years that is resistant to foreseeable incidents such as seismic events and severe weather. Furthermore, an interim store system should provide protection for waste packages from potential external corrosion caused by ambient conditions including atmospheric salts, temperature and humidity levels which could have a long-term impact on the integrity of the package.

The storage system effectively provides containment for the prevention of releases of radioactivity to the outside environment. The system is typically made up of a number of barriers as listed below:

- the wasteform itself, which acts as the primary barrier
- the container is a secondary barrier
- shielding (either of the package directly to varying degree or of the store structure)
- the external store structure which provides environmental control and physical security

From a waste management perspective the balance of these engineered barriers is normally focussed on the wasteform, then the container and finally, the store. The store itself should be given limited credit for control of the risk and hazard, because it represents the final barrier between the waste and the environment. The store's primary functions are as a barrier, to ensure appropriate environmental conditions for the packages and to provide security.

Monitoring and inspection of waste packages is a key measure of the performance of these multi-barriers. Understanding how packages are evolving with time is important for managing waste packages over the long time periods required for safe storage.

A robust system of storage arrangements will be more resilient to any changes in timescales for available disposal routes and it minimises the risks that packages will require rework at

the end of the storage period. In line with UK and Scottish policies and CoRWM recommendations, the NDA will ensure that its strategy allows for the safe and secure storage of HAW for a period of at least 100 years. The NDA's 2009 UK Radioactive Higher Activity Waste Storage Review also recognised the importance of an integrated approach to HAW storage.

As the UK's nuclear clean-up mission progresses, more and more packaged HAW will be held within interim storage facilities reflecting the current status of the waste retrievals, waste processing and indeed, the disposal programmes. Hence, the packaged HAW is of high intrinsic value in terms of environmental, safety and security benefit and cost and programme investment. Therefore it is highly appropriate that the industry takes the right precautions in managing the storage system and ensuring the waste packages remain in good condition to minimise the potential need for future rework.

The NDA has delivered industry guidance on the storage of packaged HAW. The Guidance was published in November 2012 and was developed by representatives from all the NDA's SLCs with packaged HAW, RWM (formerly RWMD), EdF Energy, MOD, AWE and supply chain organisations through the NDA's Direct Research Portfolio. The regulators and CoRWM observed the development of the Guidance and attended workshops. RWM, on behalf of the NDA, intend to update and re-issue this guidance during financial year 2016/17.

HAW disposal

Disposal is the emplacement of waste in a suitable facility without intent to retrieve it. The UK government continues to pursue its policy aim of a long-term sustainable solution for the disposal of HAW in a GDF, a vital final piece in the decommissioning programme. In July 2014 UK government published a White Paper that details the renewed process for siting a GDF [6]. In 2011 the Scottish government published its policy for safely managing its higher activity waste [8]. The policy is that the long-term management of HAW in Scotland should be in near-surface facilities.

RWM is a wholly-owned subsidiary of the NDA with responsibility for delivering a geological disposal facility in support of the UK government's programme. RWM carries out preparatory work to plan for geological disposal and this work is described as generic as no sites have yet been identified. RWM also supports the development of waste management solutions through the provision of advice to waste producers regarding the disposability of HAW and waste management options.

HAW disposal is the final activity associated with the NDA's ultimate aim of reducing its overall liability to zero or as close to zero as possible. When this aim is met, the NDA's annual spend will be as low as possible on HAW management but this is likely to be more than a century away. The aim will be achieved through developing a GDF, with an acceptable safety case, to provide a permanent disposal solution for HAW. Geological disposal of HAW is the planning assumption for all HAW in England and Wales noting that alternative disposal options may be possible for certain HAW streams.

A GDF will be designed so that natural barriers (the geology) and man-made barriers (the waste package and the underground engineered vaults and tunnels) together maximise the retention of radioactivity over the long timescales required to allow for radioactive decay of the wastes. The concept is based on isolation and containment provided by multiple barriers as shown in Figure 5.

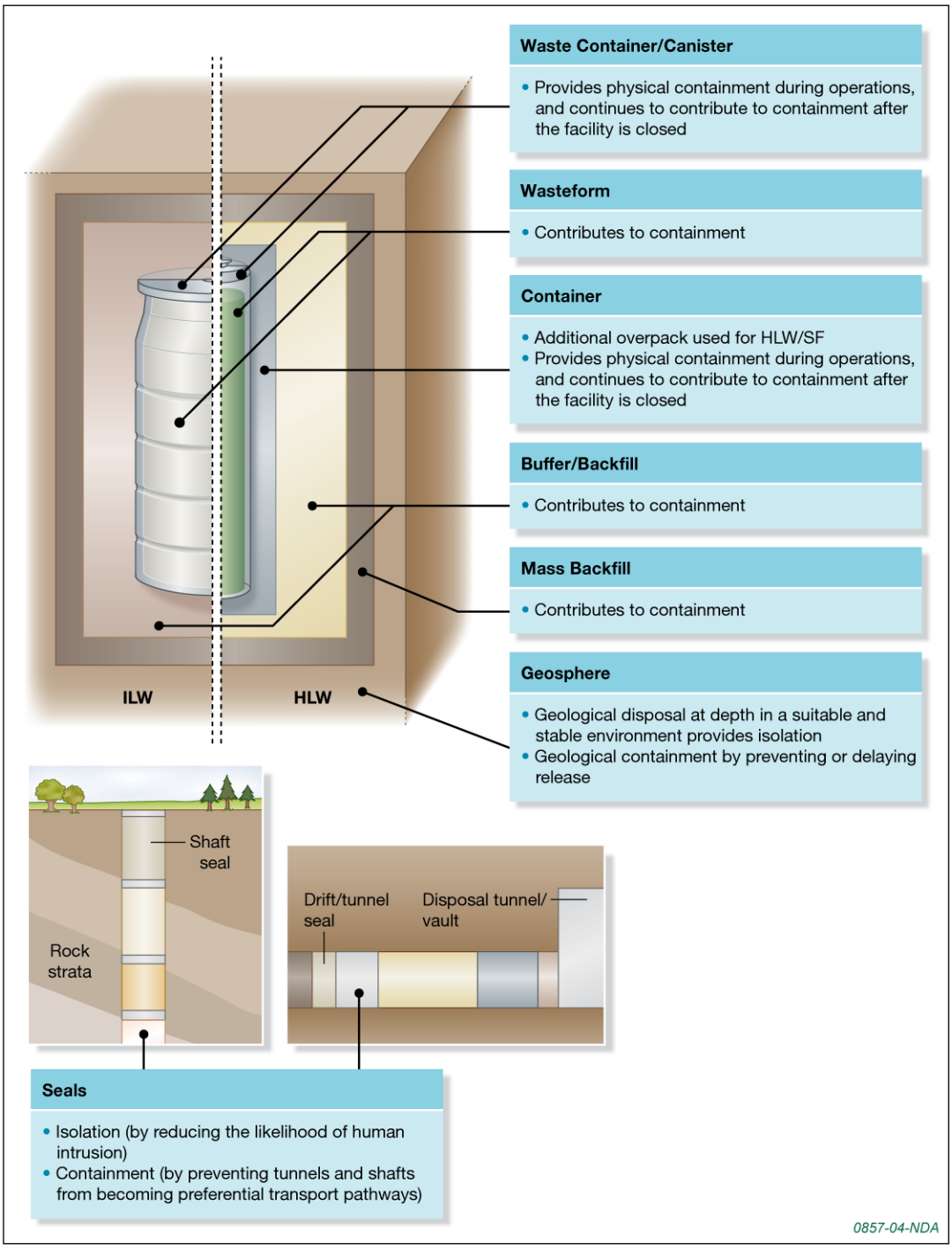


FIGURE 5 THE MULTI-BARRIER CONCEPT FOR WASTE DISPOSAL

The detailed layout and design of a GDF will depend on the waste inventory and the specific geological characteristics of the site. The diagram in Figure 6 illustrates one possible concept for a GDF.

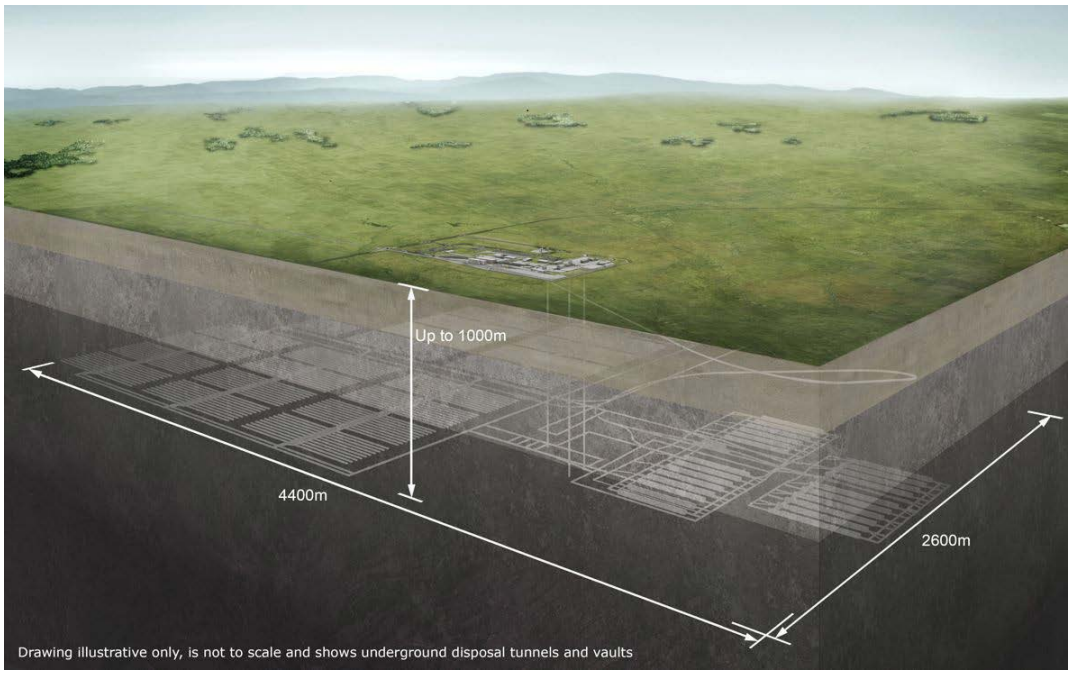


FIGURE 6 ILLUSTRATION OF A CONCEPTUAL GEOLOGICAL DISPOSAL FACILITY

The NDA has published its strategic position on the disposal of graphite wastes where it has been established that there is currently no compelling case for change and the current baseline of GDF disposal for wastes arising in England and Wales remains the preferred position [10]. However, the NDA will explore in more detail alternative management options for wastes at the ILW/LLW boundary including opportunities for HAW disposal to near-surface facilities, *e.g.* in support of integrated radioactive waste management, ILW treatment to allow for near-surface management and sentencing of LLW to a GDF when it challenges the LLWR Conditions for Acceptance or Environmental Safety Case.

The UK policy for the long-term management of HAW recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. To support this policy position and Scottish government's policy position of near-surface management of HAW we will explore a range of disposal options together with RWM and our SLCs. We expect to have a leading role in determining credible options for the disposal of HAW in the near-surface environment where we will work with other waste owners and secure expert support from RWM and our SLCs including LLWR. We will report our proposed options to the Department for Energy and Climate Change (DECC), Scottish government and the regulators. As the work progresses we will engage with stakeholders to ensure any issues are highlighted and addressed.

2.2 Lifecycle steps and integration opportunities

Planning for the management of HAW early and ideally before the waste is generated, taking into account the lifecycle stages and applying the waste hierarchy gives the greatest potential for developing an optimal approach. In the early stages of the waste hierarchy process it would be preferable to seek waste avoidance possibilities, opportunities for waste recategorisation and/or investment in treatment and packaging innovations that could reduce waste volumes by significant margins. However, the NDA is managing civil nuclear sites

where major programmes are at different stages of the lifecycle. Since the April 2011 NDA Strategy, there has been greater recognition of management opportunities at the boundary between ILW and LLW and the need to explore ways to manage these wastes more effectively. Figure 7 summarises the lifecycle approach to radioactive waste management and the relationship between HAW and solid LLW. The diagram indicates potential areas of opportunity for alternative waste management routes, *e.g.* through characterisation and segregation of waste to allow appropriate sentencing such that low level wastes follow the LLW route. For some of these wastes, this might include consideration of the further interface with 'out of scope' wastes[3] (*e.g.* wastes that fall within the scope of the Waste Framework Directive [11]). The NDA expects SLCs to consider the most appropriate management route for radioactive wastes and to seek optimal solutions where it is practicable to do so.

The waste hierarchy is therefore an important tool not just for the NDA strategy but also for site operations. The hierarchy is not a rigid set of rules that should be followed at any cost but recognises the different stages of the lifecycle and the wide range of other factors that must be taken into account. Waste producers should follow a suitable management assessment process informed by appropriate characterisation to optimise their solutions (*e.g.* BAT assessment[4]), which should consider attributes including but not limited to: safety, security, transport, environmental impact, socio-economic impact, cost and affordability. Therefore an approach that takes into consideration near and long-term risks and hazards, volume of the particular waste streams and single or multi-site issues should reveal benefits that can be realised. The NDA considers the waste hierarchy one of the key principles for implementing the reference strategy and in developing alternative strategic options.

The NDA is promoting a lifecycle approach to waste management. Figure 7 shows the key steps in the lifecycle for the main categories of waste and the opportunities to provide greater integration at the classification boundaries.

[3] All materials are radioactive to some extent, however there are some wastes which are not required to be subject to specific regulatory control, because the levels of radioactivity contained within it are either not possible to control, or are so low that regulation is not warranted. Such radioactive wastes are classified as 'out of scope' and can be disposed of in the same manner as other municipal, commercial and industrial wastes.

[4] 'BAT' is defined (using the definition in article 2 of the IPPC Directive) as the most effective and advanced stage in the development of activities and their methods of operation, which indicates the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and impact on the environment as a whole.

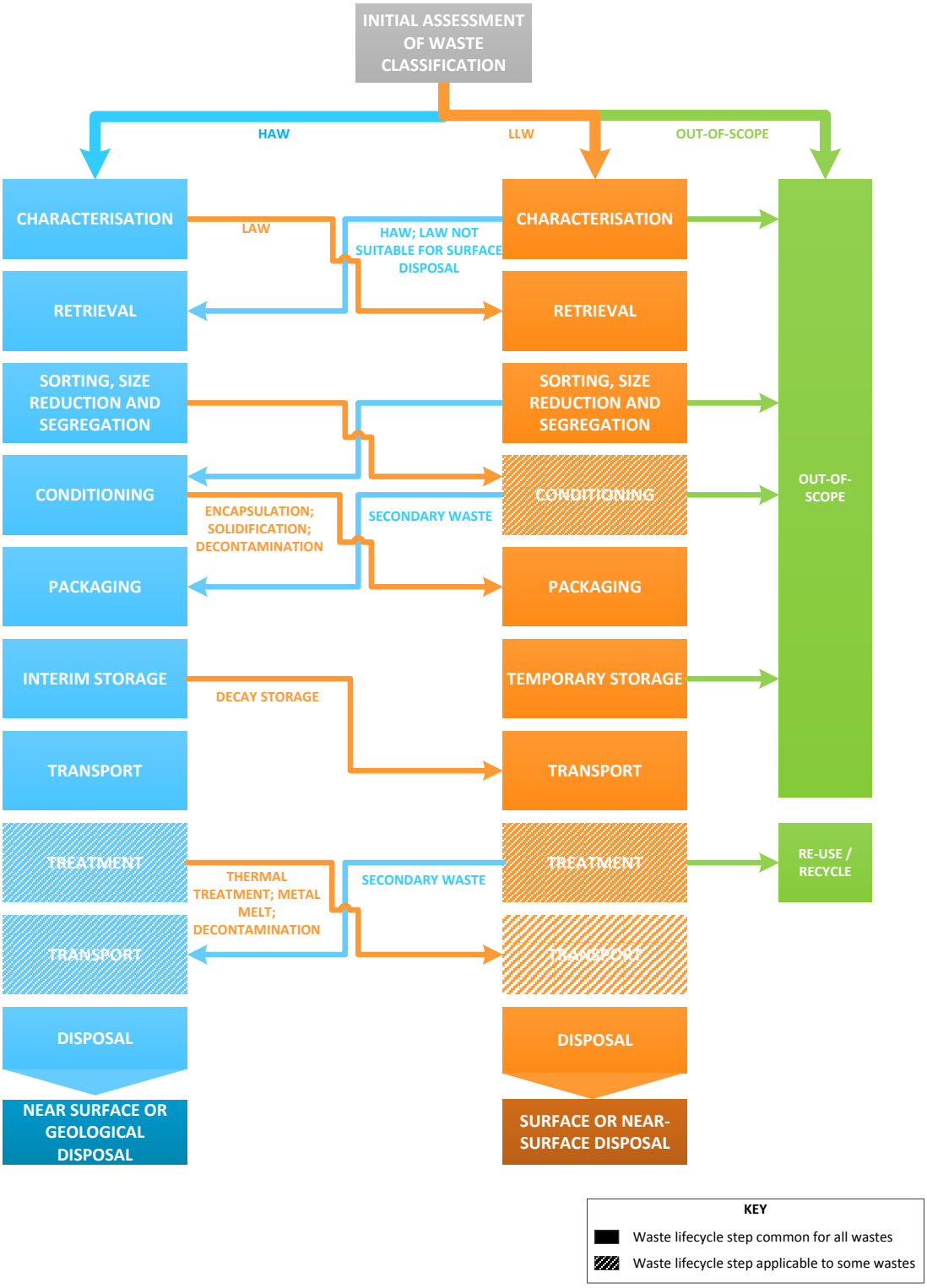


FIGURE 7 RADIOACTIVE WASTE MANAGEMENT – LIFECYCLE STEPS AND INTEGRATION OPPORTUNITIES

3. The NDA's Higher Activity Waste Strategy

3.1 Scope of the NDA HAW Strategy

The NDA has previously published a Stage A Credible Options paper on HAW management [12]. Due to the diversity of wastes to be managed and the complex relationships with other NDA driving strategies it is not considered possible to pursue a Gate B preferred option position that is applicable to all HAW and it was decided that a standalone strategy for NDA HAW should be developed. The HAW strategy promotes the pursuit of preferred options for HAW at a detailed level, e.g. for components of the HAW inventory such as Graphite.

This strategy primarily covers the NDA's HAW. However, the NDA works with other waste owners to explore co-ordinated strategies to help implement UK-wide approaches to waste management. This strategy covers such interactions and highlights the main strategic tasks underway. It should be noted that the exception to this is where the NDA's wholly-owned subsidiary RWM is accountable for the implementation of geological disposal of all HAW, except in Scotland.

As HAW is a complex management area the NDA evaluates the inventory as broken down into four distinct types of waste:

- Wet ILW
- Solid ILW
- Graphite
- HLW

Further information on these distinctive waste types is provided in Appendix 1 and to help strategy development 'topic strands' have been identified by the NDA [12]. These topic strands allow the NDA to address tasks in specific areas related to the main management stages of storage and disposal and be able to define scope in terms of the inventory characteristics, as HAW is a diverse subject area. Moving forward we will review this approach as we develop our radioactive waste strategy.

Our overarching strategy is to treat and package HAW into a form that can be safely and securely stored for many decades. Our current planning assumptions are that, at the appropriate time, the stored waste in England and Wales will be transported to and disposed of in a GDF. The 2014 White Paper on Implementing Geological Disposal recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. For HAW arising in Scotland long-term management will be in near-surface facilities consistent with its policy on HAW published in January 2011 and its associated implementation strategy. Overseas owned HAW products are being returned to foreign customers under existing contracts, which typically includes waste substitution.

The HAW strategy is multi-faceted and as well as considering the different types of waste to be managed there needs to be an appreciation of how the wastes were generated in the first place or are to be generated in the future, and in this context there are three main groups:

Legacy wastes – raw wastes in storage, which are typically wet or mobile ILW, that need to be retrieved from ageing facilities and converted into a form suitable for long-term interim storage and/or disposal. In some circumstances it may not be practicable to achieve a disposable product in a single management step especially where there is an overriding

need for risk reduction. Other ILW streams are also considered in this area although they are inherently less hazardous, e.g. graphite fuel element debris, scrap metal. Our current priority is to expedite the retrieval of HAW from ageing facilities.

Operational wastes – wastes associated with current operating facilities that have a clear and underpinned waste management route in place, including the continued operation of vitrification and encapsulation plants to support reprocessing.

Decommissioning wastes – typically, large volume solid ILW and graphite wastes associated with decommissioning including Sellafield active plant and equipment and Magnox reactors. Many of these waste streams may not arise for some decades and their form and volume depend on the decommissioning strategy. Due to the high volumes of decommissioning waste arisings and the timescales involved, there are potentially significant strategic development opportunities to be realised for integrated waste management.

For each HAW topic strand a number of credible options were developed and reported in HAW topic strategy Gate A position paper. Each of the credible option positions have now been updated and are presented in Appendix 2. It will be necessary at times to examine strategic opportunities at a common waste level or for specific waste groups, e.g. contaminated metals, at sub-topic level. Progress with individual strategic projects is described in section 3.8.

3.2 Current position

The NDA's HAW strategy objective is "*to treat and package retrieved HAW and place it in safe, secure and suitable storage facilities until it can be disposed of, or be held in long-term storage in the case of a proportion of HAW in Scotland*".

The top of Figure 8 shows that the baseline for HAW management in lifetime plans was often founded on site specific retrieval, treatment, conditioning and packaging (almost exclusively cement encapsulated), followed by interim storage until disposal in a GDF or a near-surface facility for wastes arising in Scotland. Since the NDA's inception, the development of HAW strategy has taken strides towards a more flexible approach whereby opportunities to improve waste management are pursued at every stage within the lifecycle. This is summarised in the bottom half of Figure 8.

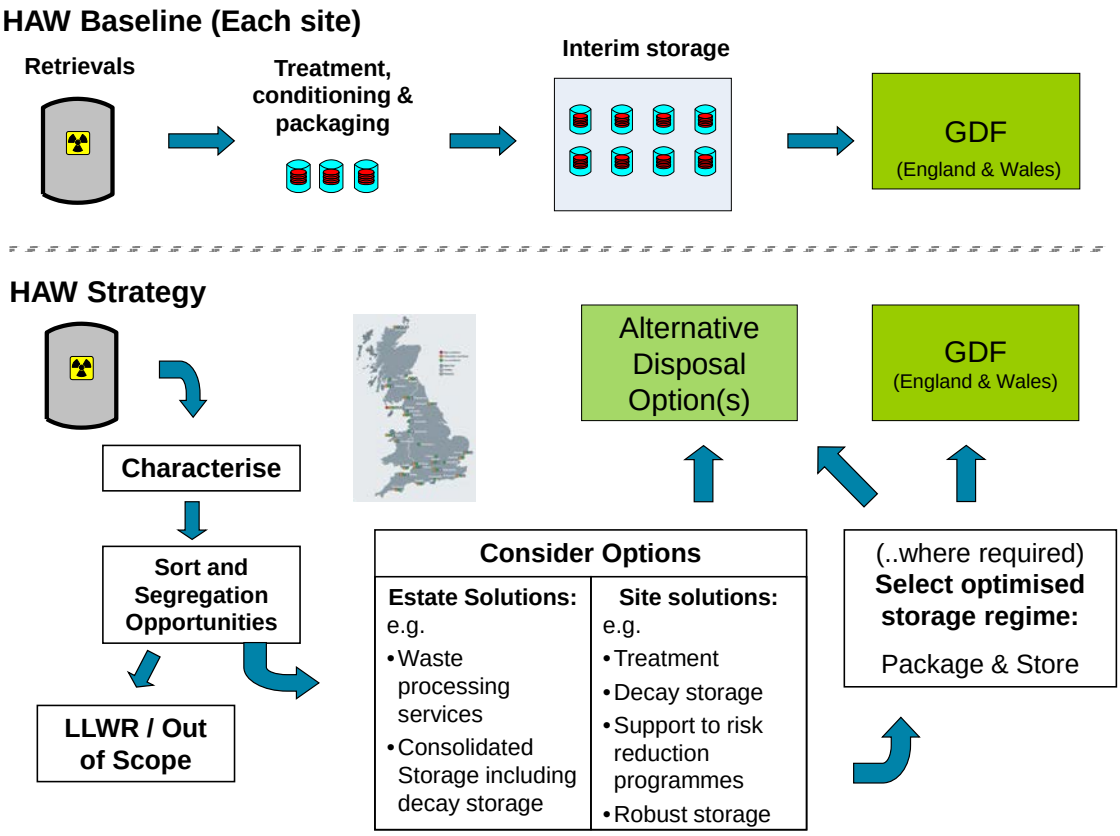


FIGURE 8 PROPOSED DEVELOPING STRATEGY FOR HAW AS COMPARED TO REFERENCE STRATEGY BASELINE APPROACH

The NDA has now established a baseline for its sites in Scotland to comply with Scottish government's long term HAW policy. As a starting position, Dounreay, Chapelcross and Hunterston A sites have adopted a 300-year on-site storage period followed by a programme assumption that packaged HAW will be transported to an off-site near-surface facility or facilities for long-term management. The range of opportunities to be explored against this initial baseline in Scotland will be dependent on the outcome of the consultation on Scottish government's implementation strategy [13]. In the near to medium-term there is complete alignment between the UK and Scottish positions of achieving passive safety and demonstrating robust storage arrangements in support of long term management arrangements.

The focus of implementation of a reference strategy is around the following aspects:

- Prioritise the retrieval, conditioning and passive storage of HAW currently held in historical storage facilities
- Applying the waste management hierarchy to minimise the volume of HAW generated
- Understanding the characteristics and quantities of HAW that will unavoidably be generated to enable early consideration and planning of treatment and disposal options
- Having the appropriate infrastructure and resources in place to manage the waste to enable successful hazard and risk reduction programmes, decommissioning, site remediation and disposal

- Making waste packages and package records that are 'right first time' to protect people and the environment while minimising lifecycle costs
- Taking care of waste packages during care and maintenance and interim storage such that they will not require rework or repackaging (for disposal or continued storage)
- Ensure transport requirements are being addressed, as part of any waste management process

The HAW inventory demands a wide range of management approaches to deliver the entire programme to completion. This is because of the considerable varieties of wastes to be managed and the extensive timescales involved where, for many of the NDA-owned sites closure plans, may not begin until the end of this century or early next century.

Although at face value the objective of the HAW strategy is very simple it is not always possible to achieve this objective in a single step, direct approach. On occasions other complicating factors mean that the approach to achieving the objective needs to be undertaken in a staged manner. Some of the reasons for this include:

- The complex nature of some poorly characterised heterogeneous waste streams
- The condition of some raw waste storage facilities (and the need to make swift progress with retrieval operations)
- An evaluation of programme deliverability and prioritisation, which will include affordability considerations

Therefore the NDA's HAW strategy recognises the importance of supporting the required progress on managing legacy facilities, *e.g.* Sellafield legacy ponds and silos.

3.2.1 Sellafield legacy ponds and silos

Prior to the establishment of industry-wide modern standards for waste processing and storage facilities to enable the conversion of wastes to a passive safe and disposable form, a large amount of ILW was produced and consigned in raw form to a variety of, ponds, tanks, silos and other storage facilities. At Sellafield the legacy ponds and silos storage facilities date from the late 1940s onwards (see Figure 9), when the national imperatives were very different to those today. These facilities were not designed with consideration of long-term issues such as evolution of the wastes, retrieval, facility decommissioning or the ultimate fate of the waste. Wastes were poorly segregated and full inventory records, which are now recognised as an important requirement for waste management, were not captured to the standard which would be required today. These facilities are not suitable for longer-term interim storage of wastes.

The approach nowadays is very different. We expect Sellafield Ltd and other holders of legacy wastes to work closely with RWM to reduce near-term hazards and, where possible, produce largely passive products by conditioning promptly into a form suitable for interim storage and ultimate disposal. This is being achieved through waste retrieval, waste treatment and effective conditioning, while applying modern standards in regard to safety, environmental, key stakeholder and cost factors for new facilities.

FIGURE 9 FIRST GENERATION STORAGE POND AT SELLAFIELD

There is a pressing need to retrieve wastes from a number of our legacy waste management facilities at Sellafield and this is highlighted within the NDA's strategy [1]. Legacy ponds and silos comprise four main facilities at Sellafield which were used historically to prepare fuel for reprocessing or to store waste and are Pile Fuel Storage Pond (PFSP), First Generation Magnox Storage Pond (FGMSP), Magnox Swarf Storage Silos (MSSS) and Pile Fuel Cladding Silo (PFCS). Radioactive materials have accumulated during operations and remain in facilities afterwards, pending the development of a retrieval capability. Over a number of decades the condition of facilities has deteriorated and there is increasing urgency to reduce the risk they pose. We recognise that to deliver the overall reduction in risk and hazard that is core to our mission we may need to accept short-term increases in risk while quiescent states are disrupted during retrieval, such as during the installation of retrieval equipment or due to changes in the partitioning of waste between the solid and liquid phased during retrieval. We will work with Sellafield Ltd and the regulators to safely manage this balance. The waste management challenges associated with the legacy ponds and silos inventory are unique due to:

- Very high radioactivity inventories (alpha, beta and gamma)
- The complex nature of some poorly characterised mixed waste streams
- The asset condition of the legacy raw waste storage facilities (and the need to make near-term progress with retrieval operations)
- An evaluation of programme deliverability and prioritisation, which will include affordability considerations
- Highly constraining environments, e.g. significant hydrogen generation, facilities not designed for retrievals, available footprint

Therefore the NDA's HAW strategy needs to consider the Sellafield legacy ponds and silos programme separately from the rest of the estate due to the urgent need to deliver risk reduction in order to mitigate intolerable risks and potential delays in planned treatment capability. In addition, our strategy requires safe storage solutions that do not foreclose long-term management options. For the majority of the wastes stored in these ageing facilities at Sellafield achieving a single step approach to retrievals and waste conditioning to produce disposable waste products in a timely manner is difficult. We have come to understand that a single step approach may be inappropriate and an alternative strategic solution is being pursued. Where there are initial overriding safety concerns, a progressive risk and hazard reduction strategic solution of waste retrievals and raw waste containerisation can be employed, with final conditioning and packaging for disposal being deferred until a later date (see Figure 10).

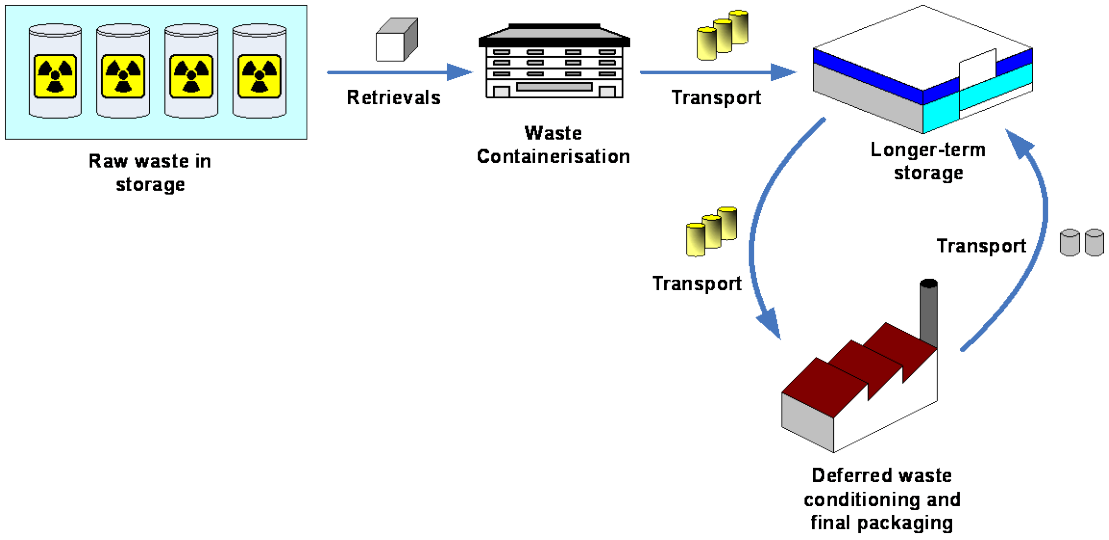


FIGURE 10 EXAMPLE OF A CONTAINERISATION STRATEGY WITH DEFERRED FINAL WASTE CONDITIONING

Adopting a staged process avoids commitment to a complete solution where we have an incomplete picture of the wastes themselves. Importantly, each stage brings an opportunity to reduce uncertainty and learn more about the waste, enabling the more effective development of options to prepare the waste in a form suitable for disposal. During this period where final conditioning for disposal is deferred, continued engagement between the regulators, SLC and RWM is required and an agreed forward programme put in place to underpin the journey from an interim or raw waste form to the final product.

For the PFCS, MSSS, FGMSP wastes and some legacy fuels this initial containerisation strategy is now the baseline position due to the need to balance timely risk reduction activities against the desire to produce disposable products. The initial step addresses the immediate risk by the timely waste retrievals and emplacing raw material within specifically designed robust containers or tanks in a modern storage facility. Such an approach allows time for development of an effective treatment step (or steps) to ensure the wastes are suitable for disposal in a GDF. The NDA and the regulators expect the highest safety and security standards within these modern storage facilities that will allow for the import and export of waste containers and development of effective monitoring and inspection regimes. The NDA, with support from Sellafield Limited, will continue to develop a robust long-term

HAW treatment strategy that closely considers the development of innovative solutions and a programme approach to waste treatment on the Sellafield site.

The near-term focus for legacy ponds and silos programmes is bulk retrievals of the waste and in some circumstances it may be acceptable to leave behind small volumes of difficult to retrieve wastes in the legacy facility for an agreed period of time where there is a clear benefit in support of site decommissioning and remediation imperatives. These residual wastes may be subject to *in situ* management practices that are necessary to aid longer-term asset management requirements prior to facility reactor dismantling. For example, the use of waste 'fixatives' to fix contaminants and prevent further contamination or even in situ local treatment technologies could be deployed. The management of any legacy ponds and silos residual waste techniques would be a Sellafield Limited responsibility and subject to normal regulatory approvals.

The progressive risk and hazard reduction strategy for legacy ponds and silos HAW is consistent with the following NDA waste management principles:

- Supporting key risk and hazard reduction initiatives by enabling a flexible approach to long-term waste management. For some wastes it may be necessary to adopt a multi-stage process to achieve a final disposable product; this could include the separate management of bulk retrievals and residual material to support hazard reduction programmes
- Take into consideration the entire waste management lifecycle, including how waste management supports other NDA strategic or wider UK initiatives such as large-scale decommissioning programmes

In support of developing solutions for legacy ponds and silos HAW, the aims of the programme include:

- Future waste treatment options are not foreclosed
- Maximise the opportunities to characterise the waste that facilitate future treatment, transport and disposal
- Residual wastes retained in legacy facilities to be minimised and techniques to be deployed on an exceptional case-by-case basis
- Likely disposal requirements are established early with RWM and, where possible, interim storage enacted in such a way as to minimise the steps to achieving this (*e.g.* avoiding double handling etc.)
- Deliver the next generation of treatment plants that are effective in terms of: producing disposable products, volume management and financially affordability

The progressive risk and hazard reduction strategy applied to legacy ponds and silos wastes is not without risk and has consequences that must be considered. For example, with interim storage of raw waste, consideration of factors such as waste evolution and corrosion, along with subsequent final treatment has to be addressed. A multi-step process to achieve a final disposable waste form must not compromise the necessary safety, security and environmental standards. It is, rather, a practical interpretation of the wider HAW strategy to allow risk and hazard reduction to be addressed as a priority. It remains a strategic requirement that waste is retrieved in a timely manner, safely stored and ultimately disposed of to the appropriate disposal facility in compliance with the NDA strategy and government policy.

3.3 Drivers for change

Nuclear sites within the NDA estate are at different stages within their waste management and site remediation programmes and this has an influence on the nature of any potential opportunities. There is a changing landscape where, over the coming decades, Sellafield will continue to progress treatment and storage of HAW whereas other sites, notably Dounreay and the Magnox sites, will start to enter quiescence, as nearer-term HAW treatment and decommissioning programmes draw to a close.

The current lifetime plans for Magnox and EdF Energy sites in England and Wales for final site clearance are predicated on the assumption that an HAW disposal route will be available. Even so, relatively small volumes of HAW will continue to be treated during the 2020s and 2030s at Magnox and Dounreay sites although it is assumed that most decisions on waste packaging and infrastructure requirements will have been determined some time before these dates. It is also possible that for some wastes arising on NDA or non-NDA sites there may be the case for cross-industry solutions to be developed rather than sites working in isolation, *e.g.* allow for inter-site transfers of wastes to enable waste producers to gain access to those sites with appropriate existing waste management capability.

Beyond 2020 and before large-scale reactor decommissioning activities, the Sellafield site will see the most intensive operations in regard to HAW management and should be able to provide a broader nuclear industry service where the case can be made and to take full advantage of its experience and expertise. Movement of waste between sites would only be acceptable where justification can be made [27] and provided there were no adverse safety, security and programme implications for the achievement of the Sellafield decommissioning and waste management strategies. This includes appropriate evaluation of safety and ensuring that broader stakeholder acceptability can be achieved.

Implementation of the NDA HAW strategy will address those areas of radioactive waste management that should benefit most from further development work. The importance and urgency associated with developing these strategic areas will differ and provide the building blocks for the overarching radioactive waste management strategy that will be established. The content of the programme will evolve as underpinning work is completed, opportunities are progressed and priorities change.

Overall, the NDA believes there are opportunities at a strategic level to reduce risk (programme uncertainties, cost, etc.) in the HAW management programme for the NDA sites and also the potential to provide a step change in benefit. Most of the opportunities are likely to centre on improvements within the reference strategy, with an emphasis on effective use of the waste hierarchy.

Areas for strategic improvement are targeted at significant risks such as Sellafield legacy plants, and of significant opportunity, for example, wastes that are close to the boundary between ILW and LLW specific activity level (boundary wastes) and sharing waste management infrastructure although in this case it is acknowledged that many waste streams will continue to follow a reference strategy with tactical opportunities at a specific waste, site or SLC level.

The strategic opportunities for HAW can be summarised as follows:

- Alternative options that provide risk mitigation against the current baseline in clearly identified areas of HAW management

- Alternative options that provide a step change in benefits against the current baseline position

Another important aspect of the strategy is to support and improve the baseline plan by considering the following activities:

- Optimisation of waste characterisation and segregation to reduce volume of HAW for disposal
- Effective implementation of HAW volume reduction initiatives
- Optimisation of HAW treatment and longer-term storage assets
- Alternative HAW packaging to support long-term performance, volume reduction and/or programme cost savings

Policy for HAW management in England is long-term management by geological disposal, whereas in Scotland the policy is for management in near-surface facilities. It is imperative that the NDA ensures the best use of these facilities as and when they become available.

A clear driver for HAW management is to significantly reduce the overall volumes of HAW where practicable to do so. This would result in fewer waste packages, reduce the number of HAW storage facilities (when compared to the baseline plan) and could ultimately lead to reduced reliance on a GDF through the use of alternative management and disposal routes. However, such a waste reduction driver needs to take into account the need to make progress in supporting site decommissioning programmes and the need to ensure that waste management activities are carried out safely.

Due to the very broad range of waste types to be managed the HAW strategy needs to enable a flexible approach to treatment, storage and disposal especially where risk reduction is a key priority. Waste management is an important enabler for decommissioning and ultimate site remediation; restrictive waste management practices could lead to programme delays, increase waste volumes and poor product performance. The NDA endeavours to make best use of current and planned waste management facilities. We support innovation and also appreciate that a careful balance is required, that recognises the value of industry standards and the benefit of the application of existing good practice. The NDA is therefore keen to build on existing estate experience and expertise and develop further standard approaches learning from the successful HAW Interim Storage Industry Guidance, which should be used to improve SLC waste management practices. Examples of 'guidance' the NDA could develop are in regard to radioactive waste characterisation or the treatment of problematic radioactive wastes. Some of the specific waste treatment areas that the NDA is developing are described in the HAW Treatment Framework [9].

As the HAW inventory encompasses a diverse range of streams a single approach to waste conditioning will result in a sub-optimal approach overall. The treatment of challenging wastes may require the development of innovative solutions, while at the lower end of the HAW spectrum management practices could be developed where much could be learned from the implementation of the UK's LLW industry strategy and use of services that help to reduce reliance on a GDF, *e.g.* metal treatment and waste volume reduction. Approaches more closely founded on the application of the waste hierarchy will form a strong environmental proposition. For example, previous LLWR work [14] has indicated that there is approximately 150,000m^3 of anticipated waste arisings at the LLW/ILW boundary which are predominantly concrete, mixed waste and metals. A significant proportion of these

wastes (approximately 50%) may be classifiable as LLW and the vast majority (over 90%) is expected to arise from the NDA estate. These wastes therefore form a category of waste of significant interest within the UK nuclear industry as waste management strategies for it are typically not well defined.

As well as seeing opportunity for improvement there are other drivers for development of radioactive waste management strategy. These are also reflected in the strategy development programme and include: mandates from government through policy change; input from stakeholders; working with other waste owners; the need for continuous improvement; and responding to changing needs in the industry (for example, transition from operational to decommissioning sites).

In summary, the NDA HAW strategy advocates a progressive change to radioactive waste management and has highlighted a number of issues and potential opportunities where the overall strategic aims can be summarised as follows:

- To provide robust, coordinated plans for the management of HAW on the NDA sites
- To provide and facilitate opportunities with waste owners outside the NDA estate where overall business benefits can be demonstrated
- To support ongoing risk and hazard reduction initiatives on the NDA sites
- To strive towards significant cost savings and other benefits by optimising the approach to radioactive waste management
- Where possible, to seek opportunities for greater integration of waste management practices especially at the ILW/LLW boundary
- To promote the effective use of the waste hierarchy
- To support effective knowledge management involving the development of standard approaches
- To continue to develop frameworks for management of common wastes or waste groupings that would support optioneering or optimisation studies
- To provide opportunities for the development of an HAW service to the industry, which would support efficient management of HAW. This approach could also lead to the development of UK centre(s) of excellence for some of the HAW inventory
- To take into close consideration the impact and relationship with other the NDA driving strategies and use the Critical Enablers to help underpin HAW strategy development and implementation

To help take the strategy forward, the NDA will continue to lead or sponsor work activities that involve:

- Supporting current and future radioactive waste policy implementation
- Leading and delivering strategy development tasks
- Sponsoring industry integrated project teams
- Creating strategic guidance
- Promoting and monitoring relevant SLC practices

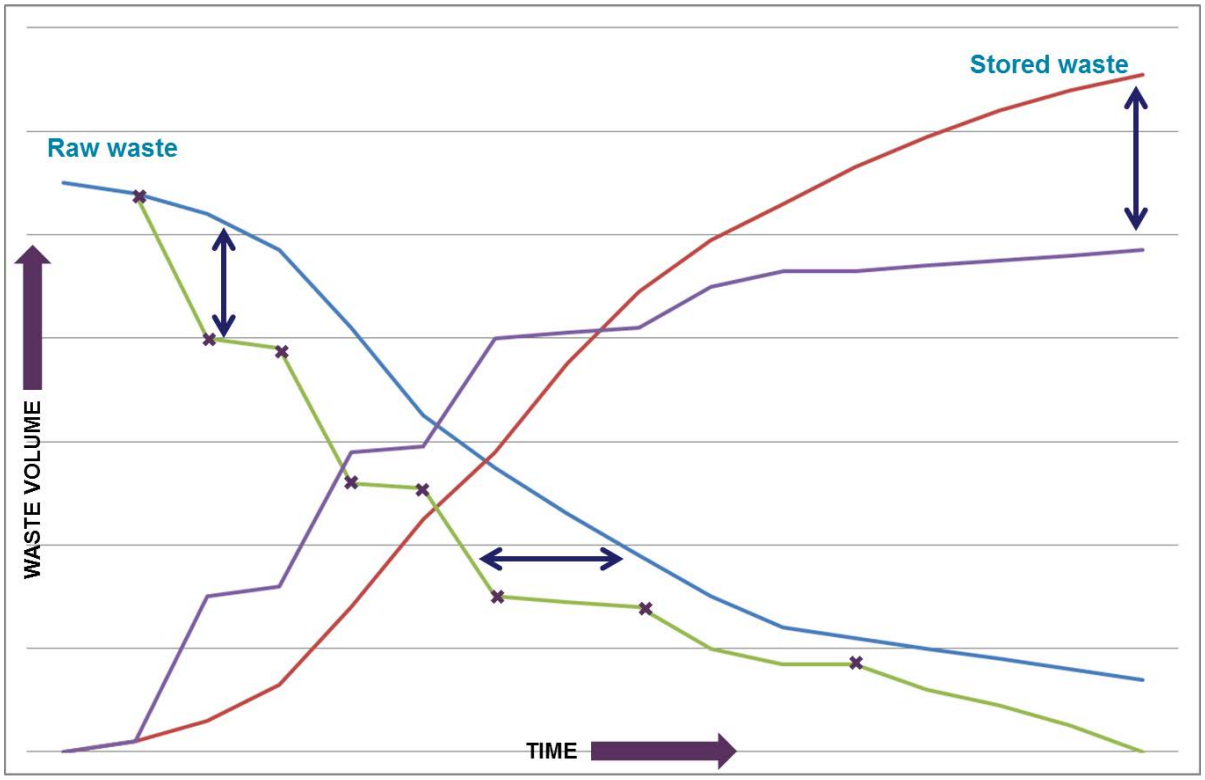


FIGURE 11 IMPACT OF THE HAW STRATEGY

Within the Higher Activity Waste strategy there is effectively a reference strategy (the technical baseline whereby SLCs treat HAW and safely store it, pending disposal) and the reference strategy will ultimately deliver the NDA mission. We also recognise there are opportunities to improve upon this reference strategy. Those improvements could be about treating HAW earlier, faster, minimising the volume of waste for disposal or delivering solutions more cost effectively. The HAW strategy is to pursue implementation of the reference strategy and to address these strategic opportunities.

This is represented in the figure above that shows how waste volume (y-axis) changes over Time (x-axis). The blue curve is showing HAW reference strategy, the NDA estate is progressing baseline plans, continuing to treat the raw waste over a long period of time, shown by unconditioned raw waste volumes decreasing as the waste is retrieved from legacy facilities and treated. The red curve is a reflection of this reference strategy being implemented and the volume of treated waste increasing as it is gradually accumulating in stores.

The green line illustrates specific strategic opportunities being implemented and examples of these could be an accelerated programme and/or an alternative treatment technology. Implementing the opportunity enables retrieval of waste faster or sooner than the reference strategy would have delivered. This could give earlier hazard reduction or a step change benefit in terms of reduced cost, for example. The purple line is a response to the implementation of strategic opportunities and shows treated waste accumulating in stores faster than the reference strategy would deliver. The net result of this is more efficient treatment of HAW within the NDA estate and a reduced volume of waste to manage due to the use of alternative treatment technologies.

3.4 The NDA Waste management principles in support of strategy development and implementation

As explained earlier, management of HAW is a complex area, which is compounded by the need to address very long time periods, especially when long-term storage and GDF operational timescales are included.

The NDA's overarching reference HAW strategy is: ***to convert the HAW inventory into a form that can be safely and securely stored for many decades. At the appropriate time the stored waste in England and Wales will be transported to and disposed of in a GDF and the NDA will continue to work with Scottish government to implement its policy for the long-term management of HAW at its sites in Scotland.***

The following NDA waste management principles provide a framework to inform complex strategic decisions that take due account of the overarching NDA HAW strategy position and the main drivers for change:

- Supporting key risk and hazard reduction initiatives by enabling a flexible approach to long-term waste management. For some wastes it may be necessary to adopt a multi-stage process to achieve a final disposable product; this could include the separate management of bulk retrievals and residual material to support hazard reduction programmes
- Take into consideration the entire waste management lifecycle, including how waste management supports other NDA strategic or wider UK initiatives such as large-scale decommissioning programmes
- Applying the waste hierarchy, which is recognised as good practice and should be used as a framework for waste management decision-making. This enables an effective balance of priorities including value for money, affordability, technical maturity and the protection of health, safety, security and the environment
- Promoting timely characterisation and segregation of waste, which delivers effective waste management
- Where appropriate provide leadership, giving greater integration across the estate and the supply chain, in particular by seeking opportunities to share treatment and interim storage assets, capabilities and learning
- Supporting and promoting the use of robust decision-making processes to identify the most advantageous options for waste management
- Enabling the availability of sustainable, robust infrastructure for continued operations, hazard reduction and decommissioning (See Asset Management Strategy and People Strategy)

3.5 Strategic opportunities in the HAW management lifecycle

Application of the waste hierarchy is a fundamental principle of radioactive waste management and an expectation of the Joint Regulatory Guidance on the management of radioactive waste [15] with the intention of preventing or minimising the quantity and activity of radioactive waste destined for disposal. The NDA requires its SLCs to produce an

Integrated Waste Strategy (IWS) for the sites they manage on behalf of the NDA. These are used to help deliver decommissioning and clean-up work and are expected to identify the challenges and solutions for dealing with the waste throughout the whole lifetime of the site.

An integrated approach to waste management needs to consider the whole lifecycle from effective sorting and segregation techniques at source, appropriate waste characterisation and minimisation techniques, and conditioning and packaging in the optimal container for the appropriate storage and disposal route.

The overall approach to the HAW management lifecycle should consider the following areas where potential strategic opportunities have also been highlighted:

a) Effective waste characterisation

Waste characterisation is an essential waste management activity used to:

- Establish the physical, chemical and radiological properties of the waste and support planning and inventory management
- Ensure the optimum waste management route is being pursued by understanding the key risks and opportunities associated with the HAW inventory
- Confirm that HAW being transferred to treatment, storage and disposal facilities meets agreed specifications, constraints and waste acceptance criteria (WAC)

Therefore the NDA supports timely waste characterisation where practicable to help manage uncertainties in the HAW inventory and provide further information to support effective waste management practices. Where direct characterisation may be difficult to achieve or is known to add limited value it is important that underpinned assumptions used as a substitute for hard data are appropriately justified and reviewed periodically. Waste characterisation can support significant business benefits including:

- Devising better approaches to waste retrievals and treatment
- Refining the inventory estimates of ILW volumes to ensure appropriate waste sentencing
- Minimising the risk of over-sizing and/or over-engineering of HAW treatment and storage facilities

The NDA will consider the need for development of further guidance on radioactive waste characterisation by continuing to work with the SLCs and regulators to understand any issues identified.

b) HAW/LLW boundary wastes

The NDA recognises that waste categorisation is a useful simplification for planning purposes although it is ultimately the safety case that determines the actual route utilised. Recent work has initiated the evaluation of opportunities for the management of boundary waste and disposal using a risk-based approach [16]. The NDA is now seeking optimisation and a risk-based approach throughout the waste management lifecycle rather than relying on early categorisation and subsequent distinct and separate ILW and LLW planning. The NDA will continue to support collaborative working between RWM and LLWR and its SLCs to address opportunities at the LLW/ILW boundary where guidance has been produced to

aid SLC decision making [17]. Engagement with relevant stakeholders, particularly the regulators, is important to pursuing these tactical options.

There are a number of interfaces between the Higher Activity Waste and Lower Level Waste topics, many of which provide opportunities for optimising the overall approach to radioactive waste management and minimising waste. These opportunities include:

- Early waste management planning to minimise or avoid waste generation (for example through effective design and operations of new facilities)
- Sorting and segregation techniques to separate ILW from LLW items within mixed waste streams
- Decontamination techniques to treat waste, particularly surface-contaminated material, allowing the leftover bulk material to be managed:
    - As a lower category of radioactive waste
    - As Directive waste
    - For reuse or recycling
- Greater consideration of the opportunities presented by the process of radioactive decay where alternative disposal routes for some waste may become available in the future. Hence, alternative packaging options may be considered that are compatible both with current storage arrangements and possible future alternative disposal requirements[5]

At the lower end of the ILW category there is now a strategic presumption that the current baseline can be improved upon to help minimise overall HAW volumes. These lower activity ILW streams are often significant volumes associated with large-scale decommissioning, *e.g.* Magnox reactors, where there is time to implement more innovative solutions. As highlighted in section 1, the boundary between ILW and LLW is defined by two numerical values that quantify the specific activity of alpha and beta/gamma bearing materials. Above the boundary waste is ILW and below LLW. However, the disposal of radioactive waste is determined by the use of WAC, derived from risk-based assessments, for a particular disposal facility rather than the actual ILW or LLW category described in UK policy.

The risk-based approach to deriving waste acceptance criteria means that waste categorised as LLW might fail to meet the WAC for the LLWR and therefore have to be managed via the equivalent HAW route. There are a number of examples of these types of wastes for which storage is the only current management route.

While the current available near-surface disposal routes in the UK are limited to waste categorised as LLW, the risk-based management approach means that new near-surface facilities could accommodate wastes categorised as ILW. This is reflected in the Scottish

[5] Where the timescales for alternative disposal routes are very long uncertainties in final disposition may need to be managed by adopting a conservative packaging approach in line with packaging approaches currently proposed for a GDF and long term storage.

government's long-term HAW policy which recognises that near-surface disposal is a possible management option for some wastes arising in Scotland.

c) Reuse/recycle

Some radioactive wastes may be deemed suitable for reuse or recycling. Some waste materials may be decontaminated or decay stored to allow for recycle/reuse opportunities now or in the future within the industry. There are also large numbers of ILW interim packages across the estate where the container could be reused or even recycled, *e.g.* 200 litre drums.

d) Waste volume reduction

The need to consider waste reduction is captured within a number of the NDA waste management principles (see section 3.4) which apply throughout the lifecycle of a facility (including design, construction, operation and decommissioning).

The NDA continues to support waste minimisation activities that strive towards reducing the capacity required for long-term interim storage, transport movements and final disposal. Even though HAW disposal facilities are at a conceptual stage it is assumed that the volume of material to be disposed of should be minimised and in alignment with the waste hierarchy. The volume of HAW to be managed will have a significant impact on the lifecycle cost and, just as important, will also have an impact on safety, security and the environment. Investigating opportunities for waste volume reduction is a principle that the NDA expects all of its SLCs to closely consider as part of any waste management programme.

Significant waste volume reduction may be achieved by mechanical means, *e.g.* supercompaction, chemical dissolution, or by chemical conversion that separates volatile species from a non-volatile residue. For example, high temperature processing of ILW could result in a low volume concentrated waste form that could exist as a glass or ceramic material and an off-gas waste stream, which will require some form of aerial discharge abatement.

The NDA will continue to support collaborative working in order to drive forward the implementation of thermal treatment technologies for the treatment of HAW [9].

Further waste volume optimisation may be achieved by increasing the waste packaging efficiencies by amending or creating new container designs, *e.g.* new box design for decommissioning wastes or removing the need for cement encapsulation for certain waste streams. Some radioactive wastes may be deemed suitable for co-processing with other radioactive wastes, *e.g.* as void fillers or even the possibility of converting or adding waste into encapsulant for other wastes.

Furthermore, innovative approaches to container manufacturing could result in significant costs savings, *e.g.* a major cost factor for the production of a waste container is the manufacturing process rather than the material of choice. New materials may also reduce costs or improve package performance and the effort of seeking new container materials should be encouraged, *i.e.* SLCs will have a greater choice of materials recognising the extensive timescales within the Lifetime Plans (LTPs). A greater diversification of waste container types needs to be carefully managed, as there could be unintentional consequences in relation to package handling and disposal where significant costs may be incurred and operational complexity may be introduced.

HAW packaging will need to follow the Disposability Assessment Process (also known as the 'Letter of Compliance' (LOC) process). The NDA expects early dialogue between waste producers and RWM especially when more innovative solutions are being sought.

e) Chemical conversion

Chemical conversion of ILW streams will result in more passive products especially when dealing with wastes containing relatively high concentrations of reactive metals, *e.g.* aluminium, magnesium alloys (Magnox) and uranium. The conversion of metal to its corresponding oxide may also aid long-term product performance in terms of storage and subsequent disposal. It should also be recognised, that for certain high hazard wastes a multi-step approach to disposal could support the implementation of more novel approaches to waste conditioning.

f) Storage and disposal

The principles of the waste hierarchy equally apply to HAW interim storage and disposal. HAW stores are large robust facilities that require considerable resource in the construction, operations and decommissioning. It is important that waste should be minimised as a result of a store build programme and where appropriate recycled materials could be used. Likewise, the build, operations and closure of HAW disposal facilities needs careful planning to minimise waste production. Reducing the overall volumes of HAW to be managed will have a significant impact on the number of stores to be built (when compared to the baseline plan) and the number of disposal vaults to be constructed in a disposal facility. While reducing waste volumes is beneficial overall it is also appropriate to ensure that storage capacity is used efficiently. The NDA will continue to encourage industry to investigate the sharing of storage solutions and in particular, maximise the utilisation of storage capacity in existing stores.

3.6 Interfaces with other NDA topic strategies

The HAW strategy has a number of links and interactions with other NDA topic strategies and critical enablers. Where these interactions are at a fundamental level they have been termed primary interactions. Others are a secondary effect as a result of either certain options being chosen or from the introduction of additional scope into site baselines.

The primary interactions include themes such as Site Decommissioning and Remediation, where waste routes enable site activities and Spent Fuel, where there are significant interactions in the future and HAW strategy could be an enabler. In addition, HAW strategy relies on other critical enablers such as Transport and Logistics as an enabler for strategic opportunities and for movement of waste to treatment and disposal facilities.

a) *Site decommissioning and remediation*

There is a need for close working between the HAW and decommissioning strategies, as without appropriate waste management routes in place, the progress of decommissioning activities is limited. There is also a need to recognise that the way in which the decommissioning is undertaken will have significant implications for the HAW inventory that needs to be managed (e.g. sorting and segregation at source). The timescales for the decommissioning of existing facilities and clean-up operations have a direct impact on HAW management and the alternative strategic options that could or must be explored. Legacy facilities at Sellafield are the prime example where the baseline HAW risk and hazard reduction strategy is often not possible in a single step and near-term retrieval programmes followed by deferred waste treatment is the preferred route.

There is also a direct link between Magnox reactor decommissioning and waste management where the current position is a substantial quiescent period after sites have entered the Care and Maintenance phase. Final site clearance of the Magnox sites in England and Wales is not

planned to be undertaken until the latter stages of this century when HAW is assumed to be transferred directly to a GDF using mostly self-shielded four metre boxes. Significant changes to the Magnox decommissioning strategy could have an impact on HAW management, *e.g.* a change in waste packaging requirements would need to be assessed as part of the overall business case, which would also consider disposability in a GDF.

To achieve the NDA site end states it is assumed that off-site management of HAW will be required, which is reliant on available disposal routes or the ability to move HAW between sites to support final site clearance.[6] Currently there are no plans to dispose of any HAW on existing NDA sites although this option may be investigated if a case for change can be made, *e.g.* support to policy development work for some of the HAW inventory. The NDA recognises that regulatory approval would be required before any on-site disposal of HAW could proceed.

b) ***Spent fuel and HLW***

The current baseline position for spent fuel (that is destined for disposal) and for the UK's HLW, is a planning assumption that they are included in the inventory for disposal in a GDF and they are considered as part of the implementation of geological disposal. Provision is made for its management through inclusion in the Derived Inventory [18] and the Disposal System Technical Specification [19] that defines the requirements that the disposal system must satisfy (see the Spent Fuel strategic theme of the NDA Strategy for more detail).

c) ***Plutonium and uranics***

Plutonium and uranics are nuclear materials that are not declared as wastes but are included in the inventory for disposal in the Implementing Geological Disposal White Paper as a planning assumption. If in the future a proportion of these nuclear materials are deemed to have no further use then they will be managed as wastes through geological disposal. Plutonium and Uranics are topic strategies within the Nuclear Materials strategic theme of the NDA Strategy.

In line with government policy, the NDA is developing options for the reuse of plutonium [20]. Some of the options under consideration may offer opportunities in terms of co-disposal of wasteforms such that other wastes or uranium, for example, could potentially be co-disposed of. These opportunities will be explored further in the future to determine whether there is benefit in pursuing this approach.

d) LLW strategy

There is a strong interaction between HAW strategy and the LLW strategy area, as the management approach to the lower end of ILW will be similar to LLW management. In addition, the baseline strategy for HAW includes actively exploring opportunities of waste recategorisation by decontamination, decay storage and improved waste characterisation that will lead to an overall increase in LLW volumes. It has also been noted that some LLW, *e.g.* bulk reactor graphite, is destined for a GDF although alternative treatment and disposal options are being explored. Both strategies also embrace the waste hierarchy.

[6] The NDA is responsible for defining the Site End States (SES) for each site*, i.e.* the condition to which designated land and its associated structures and infrastructure need to be decommissioned and the land restored. An Interim End State (IES) may be defined prior to reaching the SES. An IES is a type of interim state that describes the condition of the site after all the physical decommissioning and remediation work has been completed. The period between an IES and SES may be used to remediate residual contamination *via* natural processes (e.g. monitored natural attenuation) or for compliance monitoring.

Any change in the waste acceptance criteria for current and future LLW disposal facilities could have a major impact on the overall volumes of waste managed as HAW, as volumes of LLW are much larger. Even small changes in LLW disposal acceptance criteria could lead to a significantly higher proportion of LLW needing to be managed as HAW.

3.7 Critical enablers of the HAW Strategy

The Critical Enablers to NDA Strategy support the overall delivery of our mission. Within the Critical Enablers strategic theme there are a number of topic strategies and they all have some influence on the HAW Strategy. The following are of particular importance:

Research and development

The NDA's HAW management programme needs to be technically underpinned to ensure effective delivery. SLCs are focused on delivering the contracted mission of site decommissioning and clean-up. They are not necessarily looking to identify or pursue broader opportunities and therefore the NDA's Direct Research Portfolio (DRP) supports the development of innovative technologies for the retrieval, treatment, storage and disposal of HAW. The development of alternative HAW strategies will require supporting R&D and this will be achieved via the SLC R&D programmes and the DRP. The NDA-wide baseline improvement initiatives are often supported by R&D.

Ongoing engagement with the Nuclear Waste and Decommissioning Research Forum (NWDRF) and in particular the Working Group on Waste Packaging and Storage (NWDRF WP&S WG) is focussed on a prioritised set of technical issues. The Working Group develops DRP project proposals, which are aligned to the key HAW strategy areas.

Information governance

Effective and robust information and knowledge management systems are necessary for the development of HAW strategic opportunities or the implementation of the baseline plan. Furthermore, knowledge retention over very long timescales, e.g. many decades, is an essential consideration.

The primary product of HAW management is a waste package and its associated waste package record. The waste package record has to support future operations over the lifetime of the waste package namely interim storage, transport and disposal. The requirements on what information constitutes a waste package record for each step are broadly the same but there are some specific differences and so each lifecycle step must be considered.

People

Execution of HAW strategy will require people with the appropriate range of skills to provide capability across all relevant disciplines involved in the waste management lifecycle. This should be an important consideration in the funding of future work programmes. The timing and execution of the required skill sets is vital to the success of HAW management. HAW management is a long-term venture where inter-generational issues, including skills retention, need to be addressed. In particular, suitably qualified and experienced people will continue to be needed who have a thorough understanding of chemical and waste processing hazards in order to support safe and secure management of HAW.

Transport and logistics

Transport is an integral part of the waste management lifecycle. The availability of transport routes is an essential part of treatment, storage and disposal especially when dealing with

UK-wide or multi-site solutions. At a tactical level, programme logistics will also allow the NDA to optimise its waste export scheduling (the programme for transferring waste from storage to a GDF) with respect to road and rail travel and potentially consideration of sea transport around the UK.

Supply chain

Successful radioactive waste management programmes are reliant on significant infrastructure support programmes, primarily through the supply chain, for example R&D, container manufacture, treatment plant development, facility construction and engineering. The supply chain has a very important role to play and the NDA will ensure suppliers are actively engaged through normal arrangements, e.g. engagement through NDA supply chain events. Key to a suitable, affordable and dynamic supply chain is a medium to long-term plan which provides sufficient detail and certainty to allow the supply chain to invest in the necessary skills and experience.

The NDA's Supply Chain strategy is to help maintain and, where necessary, create and develop a healthy, vibrant, effective and competitive supply chain. Such a supply chain will be successful, deliver value for money, be affordable, and manage risk and opportunities appropriately. We want our estate to be seen as the nuclear client of choice. To achieve this we will seek to remove inefficiencies for both the supply chain and our estate. This reflects the importance of the supply chain to our mission.

Asset management

The asset management strategy aims to secure the sustained capability to manage the NDA's assets and hence support mission delivery through reliable asset performance and optimised asset investment decisions. The asset management interface with HAW strategy will also help to secure the required level of throughput, reliability, availability and maintainability (TRAM) performance of facilities through:

1. Identifying and managing the delivery of the asset management organisational capability required.

2. Helping to integrate and prioritise HAW management asset requirements (e.g. stores and infrastructure) within the overall mission delivery.

3. Enabling an optimisation of HAW physical and other assets across the estate.

The asset management programme is focussed on the identification and effective management of assets critical to HAW management. The development and implementation of an HAW critical asset dashboard to provide a transparent oversight of performance, risk and investment decisions has been undertaken by SLCs and is an essential development over the next strategy period.

Non-NDA liabilities

The HAW strategy discusses management arrangements and opportunities associated with others' wastes (i.e. third-party wastes or non-NDA liabilities), and the NDA engages directly with all HAW waste owners to ensure consistency of approach. This is of particular interest as some of the NDA sites already have third-party owned HAW located on them as a result of historic activities and current practices. The treatment, storage and management of these wastes are addressed under specific contracted terms or explicit arrangements are in place for their future disposal in a GDF.

Opportunities with other HAW owners that have the potential to provide a wider benefit to the UK are considered in detail, on a case-by-case basis. Where the NDA is asked to consider

making provision for the management of additional third-party HAW, this will be subject to a detailed assessment to determine the potential impact on the NDA and the SLCs' LTPs.

International relations

Many countries face similar waste management challenges to those of the UK. This is particularly true in respect of HAW-related activities, including the treatment, storage and disposal of these wastes. It is important that the NDA takes cognisance of the experience of other countries in developing approaches to these activities as this helps us deliver more cost-effective solutions in the UK. This is done in a number of ways. For example, the NDA is represented on a number of international committees such as those of the IAEA and the OECD NEA which have direct relevance to developing guidance and implementing good practice relevant to delivering the HAW strategy. The NDA has also elicited international peer review of the HAW storage guidance through the IAEA to ensure the UK is implementing international good practice.

With specific reference to RWM and geological disposal, the NDA encourages involvement in international collaboration programmes with its counterpart organisations in other countries. This takes place either bilaterally or through international organisations such as the Club of Agencies and the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM). This again ensures that the NDA takes account of international good practice, both technological and sociological, in delivering the UK government's geological disposal programme.

There are a number of bilateral agreements with the NDA's overseas counterpart organisations. Under the auspices of these agreements the NDA representatives get together with subject matter experts in those organisations to share and possibly jointly develop solutions to the estate's most pressing technical challenges.

3.8 NDA strategic projects

In May 2012 the NDA published its Integrated Waste Management (IWM) Strategy Development Programme and continues to deliver strategic tasks in relation to the overall programme objectives [21]. The IWM Strategy Development Programme was established in order to demonstrate progress against the NDA strategy commitments that came into effect in April 2011. The HAW strategic tasks form the majority of this IWM programme with an emphasis on targeting areas that could have significant impact and also takes into consideration the waste management lifecycle. The IWM programme will be reviewed during financial year 2016/17 following the publication of the NDA Strategy effective in 2016.

The following sections highlight the current strategic position with respect to each of the main areas of the IWM Strategy Development Programme.

3.8.1 Waste storage consolidation

Since its formation in April 2005 the NDA has considered waste and materials co-location opportunities, an important commitment within the first NDA Strategy [22]. In March 2009 the NDA published the UK HAW Storage Review [23] which gave detailed consideration to waste consolidation opportunities. It was noted that there is limited scope to affect the overall ILW interim storage position because the proportion of ILW disposal units that might be affected by the application of alternative storage consolidation options is only a few percent of the total ILW interim-stored inventory across our sites. The Review stated

"*Theoretically there should be benefits from consolidating waste storage rather than building individual stores at all of the sites where ILW is produced. For example, avoiding the construction of stores at some sites should reduce construction activities, capital cost and subsequent security costs. On the other hand transfers between sites would bring in new transport costs and issues of local stakeholder concern.*"

The NDA's strategy published in April 2016 [1] has continued to highlight the importance of waste consolidation and fuel co-location for some of the inventory where opportunities support specific business objectives including, where appropriate, working with other waste owners. The business objectives that waste consolidation may help to realise include:

- reduction in site footprint – early de-licencing or de-designation parts of an existing site may lead to reduced overhead and support costs and potentially enable commercial opportunities for NDA
- hazard and security level reductions – minimising the number of sites storing nuclear materials, spent fuel and other high hazard HAW can give a clear reduction in security and hazard requirements at the site transferring the waste while not having a significant impact on safety and security levels at the recipient site
- optimal use of infrastructure – an opportunity to develop an industry-wide approach to optimising the waste management lifecycle by reducing the number of storage and treatment facilities and creating capabilities that address key issues such as waste characterisation, mobile treatment facilities, mobile workforce, transport and logistics
- early site clearance – progressing the mission at one or more sites sooner than declared in lifetime plans resulting in significant lifetime cost savings and safety, security and environmental impacts should be neutral or even positive

The effect of any proposed transfer on the recipient site(s) needs to be taken into account and should consider; programme schedule, regulator positions, planning consents and the views of local stakeholders.

Waste consolidation strategic projects include:

- Exotic Fuels, Nuclear Materials and Waste Management – Magnox at Harwell (formerly RSRL), Credible & Preferred Options [24]
- Intermediate Level Waste Storage Solutions - Central and Southern Scotland [25]
- Optimising the number and location of Interim Intermediate Level Waste (ILW) Storage and FED Treatment (Dissolution) Facilities in Magnox Limited [26]

As stated above, the number of opportunities for waste consolidation is limited. As time progresses the opportunities will become more targeted, e.g. could only involve two or three sites. NDA will continue to engage with stakeholders and updates will be given at a range of stakeholder forums.

3.8.2 Reactor decommissioning wastes

A significant proportion of Reactor Decommissioning Wastes (RDW) is graphite and therefore the NDA has been focused on this inventory rather than investigating all of the ILW streams associated with Magnox Final Site Clearance. In January 2014, the NDA published a Strategic Position Paper on the Management of Waste Graphite [10] along with two supporting strategic options papers. The publication of these papers is consistent with the NDA's IWM strategy. The position paper summarises a number of tasks that have been

undertaken to better understand the challenges of managing radioactive graphite. The position paper outlines a number of key findings and sets out the NDA's position on this issue.

For reactor core graphite on sites in England and Wales, the NDA's work has demonstrated, through the identification of a number of alternative options, that the management of graphite waste by geological disposal provides a robust baseline strategy suitable for planning purposes. The extended period of quiescence that reactors are scheduled to enter means that there is sufficient time for alternative options to develop such that any future decisions on the management of radioactive graphite waste will be appropriately informed.
The NDA is in the process of closing out its current directly funded R&D tasks and RWM will continue to research the implications of graphite and carbon-14 on the geological disposal concept. Furthermore, the NDA will also continue to monitor international developments.
In addition to this strategic position the NDA has identified factors that would drive a review of this strategic position, for example a change in site remediation strategy. The NDA will continue to support Scottish government strategy implementation work, which could include more detailed consideration of near-surface disposal as well as long-term storage of graphite wastes.

3.8.3 Decay storage

Decay storage is seen as part of the 'toolkit' of management options for HAW, but is recognised to be only suitable for wastes with a radionuclide inventory that has a relatively short half-life, where radioactivity will decay on timescales consistent with the potential period of management and operation of the NDA sites. For some short-lived wastes there is uncertainty as to whether treatment, packaging and disposal to a GDF represents an optimal strategy, or whether there are opportunities to use a period of decay storage to enable future diversion of some ILW streams to LLW management routes and potentially near-surface disposal or free release as an end point.

There are a number of complex waste-specific and site-specific matters to take into consideration where the case for change is not obvious and the balance of costs and benefits require detailed evaluation. It is likely that many opportunities will be tactical, although, for some volumetrically significant wastestreams that occur on a number of sites, it is possible that some strategic options for co-ordinated decay storage may exist and studies have been undertaken to underpin strategy development in this area [16]. The NDA will consider the value of producing strategic guidance for decay storage, which could be included within the forthcoming update to the NDA storage guidance document.

3.8.4 Waste treatment

In the NDA's second strategy there was a commitment to consider alternative waste treatment technologies, to encourage innovation and open market solutions, and sustain R&D matched to the challenges of waste management. The NDA has been assessing the extent of possible HAW treatment options and as a result has published the HAW Framework to set out work plans in this area. The implementation of this framework is in its early stages, for example an Integrated Project Team (IPT) has been initiated in order to progress a thermal treatment demonstration facility. However, much work is yet to be done in helping to secure long-term sustainable funding for a thermal treatment R&D project.
Work under the HAW Treatment Framework will investigate and as appropriate initiate work in the following areas:

- Waste Encapsulation, *e.g.* the use of alternative encapsulants, a coordinated approach to encapsulation rather than individual project-by-project development
- Thermal Treatment
- Physical (Non-Intrusive): 'Non-encapsulation' of wastes and use of alternative container designs
- Physical and Chemical (Intrusive) decontamination
- Problematic Waste Management (Orphans)
- Decay Storage (see section 3.8.3)

The scope of the work will include ongoing and new strategic tasks, collaborative working through IPTs, RWM and LLWR projects and SLC innovations including the adoption of programme approaches to waste treatment, *e.g.* making best use of current and future planned facilities. The NDA will continue to work with the SLCs, RWM, LLWR, the regulators and the broader industry to help identify the main opportunities for ongoing and future strategic projects.

As part of delivering the HAW strategic principles in relation to treatment, the NDA is pursuing research aimed at improving the management of problematic wastes though an IPT. Problematic wastes arise at most nuclear sites where historic operations have generated typically small volumes of waste that are not immediately compatible with the sites existing treatment capabilities. In such cases, the waste often takes low priority and the site strategy is storage pending the development of a solution. Due to the small volumes and physical-chemical properties of the waste it can be relatively expensive to develop a treatment route or a new technology to manage the waste. It may be possible to develop and share technology across sites or even to transfer wastes to the technology rather than duplicate facilities. A number of activities are feeding into this work programme in order to provide clarity on the inventory of problematic wastes and facilitate innovation and the development of technologies to treat them. The NDA's approach will enable coordination of problematic waste treatment across the estate and increase the visibility of these waste challenges to the supply chain in order to match technology development with industry needs.

The NDA is also leading a UK initiative that is co-ordinating, monitoring and developing options in support of the long-term management of alpha bearing wastes, and in particular plutonium contaminated materials (PCM). This programme of work continues and is focused on the development and implementation of Sellafield, LLWR, Dounreay and AWE site strategies as well as monitoring and supporting the CHILW Harwell transfers to Sellafield, which is leading to a more joined-up approach to the management of alpha contaminated materials.

3.8.5 Ongoing and future strategic projects

Much of the NDA's early HAW strategy development work has been aimed at activities in support of long-term management of HAW, i.e. storage and alternative disposal. More recently, the NDA has been keen to investigate opportunities at earlier stages of the lifecycle where there is significant potential to minimise HAW volumes (alternative treatment) and avoid HAW production (boundary wastes). During the next strategy phase the NDA is proposing to tackle the issues at the waste source: approaches to radioactive waste characterisation, pre-treatment, opportunities for ILW recategorisation, and the continued need for minimising waste volumes. The NDA will also continue to support the Scottish government's implementation strategy, Welsh government's HAW policy position and,

through RWM, UK government's Implementing Geological Disposal Programme. By continuing to engage with key stakeholders including DECC and devolved administrations, the regulators, planning authorities, the NDA SLCs, RWM and other waste owners, the NDA has gained support in adopting the approach of:

- Placing greater emphasis on consideration of the entire waste management lifecycle
- Carrying out strategic tasks that have a greater impact on the earlier stages of the lifecycle:
    - Avoid HAW generation, e.g. decay storage, boundary wastes
    - Timely and effective characterisation
    - Greater focus on alternative waste treatments
    - Develop a national 'BAT' concept for certain waste types/groups
    - Industry guidance on the development and use of ILW containers
    - As appropriate, continue to engage and support other waste owners including non-nuclear estate

The above approach and proposed new initiatives will be subject to stakeholder engagement and therefore may be subject to change. HAW management has a wide range of interfaces with other strategy areas and as the work develops it must take into consideration these other areas where radioactive waste management is a key enabler.

The NDA has initiated projects that are addressing the main strategic opportunities and multi-site baseline improvements. The figure below provides an overview of how the main strategic tasks underway, or nearing completion, relate to the waste management lifecycle and the HAW strategy topic strands. The size of the orange ovals is a simple indicator of the relative level of focus and is for illustrative purposes only. The figure also includes major programmes that are outside the direct HAW strategic project area but are essential when supporting the overall HAW strategy*, i.e.* implementing geological disposal. The NDA also acknowledges that waste retrieval is often an activity that is a tactical site and waste specific issue. This shows the coverage of NDA projects in this HAW area and how they address waste management across the lifecycle.

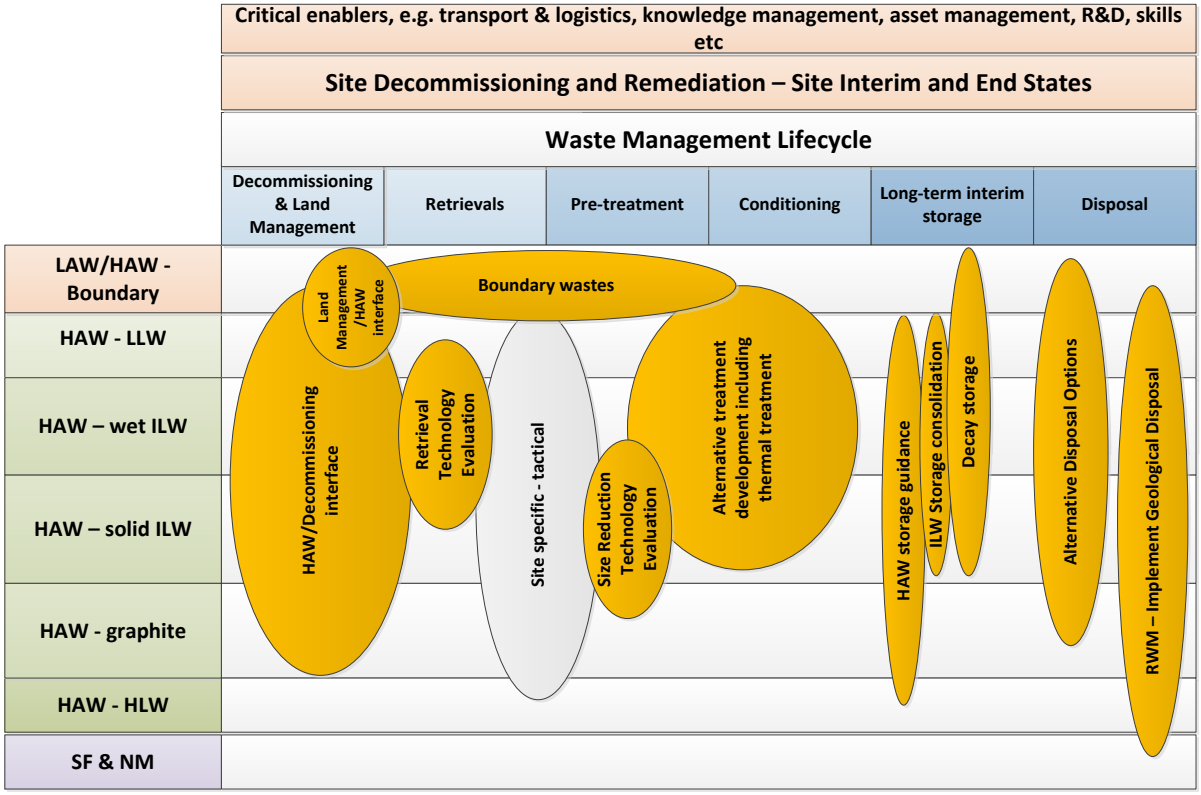


FIGURE 12 HAW STRATEGIC PROJECTS AND PROGRAMME AREAS

The table below summarises the key HAW strategic tasks to be investigated during the next NDA strategy phase and this includes ongoing tasks from previous commitments and new initiatives:

TABLE 1 NDA HAW STRATEGY PROJECTS, AIMS AND OUTCOMES

NDA Strategy Project	New, initiated or Existing task	Aim	Outcome
Characterisation of radioactive wastes	New	Timely characterisation information to support better application of the waste hierarchy including, sorting, segregating, reuse and recycling.	Continue to support and encourage SLCs in carrying out work that demonstrates the effective implementation of the waste hierarchy. Consider the development of additional guidance for radioactive waste characterisation.

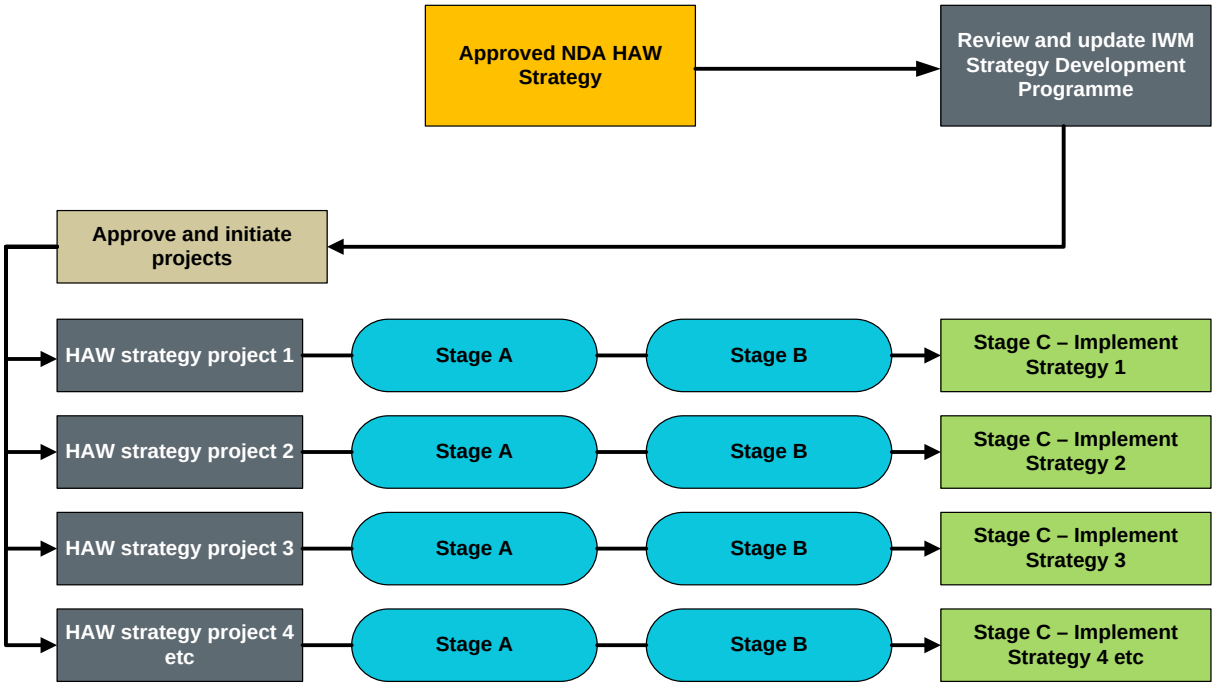
NDA Strategy Project	New, initiated or Existing task	Aim	Outcome
Boundary wastes	Existing	Management of waste according to the most appropriate disposal route using a risk-based approach. Consideration of the entire waste management lifecycle including how HAW management supports other NDA strategic or wider UK initiatives such as large scale decommissioning programmes.	The NDA will continue to sponsor work investigating opportunities at the LLW/ILW boundary and encourage joint working between LLWR and RWM. SLCs are also expected to work with LLWR and RWM to highlight any areas of opportunity.
Treatment	Initiated	Consideration of more treatment options (or wider use of existing treatment options) to broaden the UK capability	There is a need to develop a HAW treatment 'toolkit' to ensure future programmes are optimised. Making best use of current and future planned HAW treatment assets. The NDA IPT on thermal treatment has been initiated and will aim to secure long term funding for a thermal treatment demonstration facility. Sponsor activities in support of the NDA HAW Treatment Framework including DRP tasks, monitoring of SLC related programmes and strategic studies investigating decay storage. The NDA IPT has been initiated to focus on improved management of problematic wastes. Consider 'National BAT' approach for HAW treatment projects – may be a limited number and could be focussed on the larger sites supporting smaller waste producers rather than individual sites working in isolation. Future work should include investigating opportunities with other waste owners where there are obvious mutual benefits.

NDA Strategy Project	New, initiated or Existing task	Aim	Outcome
Specific waste streams	Existing	Consideration of more treatment options to broaden the UK capability In the majority of cases, to actively pursue the reference strategy and adopt UK-wide approaches to waste management as appropriate. Where appropriate, greater integration across the estate, in particular by sharing treatment and interim storage assets and capabilities.	The NDA will continue to explore opportunities for alpha contaminated wastes and monitor strategy implementation at those sites with relatively large volumes of PCM in particular.
Waste storage consolidation	Existing	Where appropriate, greater integration across the estate, in particular by sharing treatment and interim storage assets and capabilities.	Ability to share storage assets between nuclear sites for some of the inventory. Will be developed on a case-by-case basis.
HAW interim storage industry guidance	Existing	In the majority of cases, to actively pursue the reference strategy and adopt UK-wide approaches to waste management as appropriate.	Update to existing guidance and seek input from the NDA SLCs and other waste owners, which will consider a broader range of container types and radioactive decay.
Alternative disposal options	Existing	Support UK and devolved administrations' HAW policies including exploring options for near-surface disposal, e.g. reactor decommissioning waste and decay storage of short-lived ILW.	The NDA, working with Magnox and RWM, have developed initial evaluation criteria for HAW near-surface disposal suitability and will build on this work during the next the NDA strategy phase. Future work will also support Scottish government's HAW implementation strategy.
Geological disposal	Existing	Support UK government policy on Implementing Geological Disposal.	Continued support to UK government via RWM programme to deliver and operate a geological disposal facility for HAW in England and Wales.

3.8.6 Governance arrangements

The development of the NDA's HAW strategy is being pursued in a number of project areas where each strategy project manager is responsible for preparing a strategic business case and ultimate NDA sanction to allow for baseline change control and implementation. An HAW strategy project may address a whole topic strand or a particular waste grouping(s) and will take into consideration the NDA's Value Framework process [27]. However, the

strategy must be at NDA level and not site tactical level, as this is the responsibility of the individual SLC. Likewise, an HAW strategy project could also include a major multi-site baseline improvement initiative that requires direct input from the NDA. It might be appropriate for a project to highlight a long-list of possible options and follow the SMS process from Gate 0. To be successful, each project will be given the right level of resource and effective regulatory engagement is a prerequisite. The figure below is a summary of our approach to strategy development.



HAW Strategy Project may be delivered by:

- NDA Integrated Project Team (IPT)
- SLC/RWM specific project via Site Strategic Specifications
- NDA Integrated Waste Management specific task/project

FIGURE 13 IMPLEMENTATION OF HAW STRATEGY

Regular updates on progress made will be reported to key NDA stakeholders and credible and preferred options are often published for wider public comment. It is normal practice that implementation of a new strategy will require NDA Executive approval before any changes are made at site level.

When the case can be made, the NDA may also initiate a programme of work to develop industry guidance to enhance understanding on a particular area, taking into consideration relevant policies and regulatory requirements. The governance arrangements put in place are to some extent dependent on the nature of the task although it is likely that endorsement from the NDA Executive will be required as a minimum.

Implementing some alternative strategies could result in a significant decrease in costs when compared to the current baseline. Some strategies may be cost neutral or even result in cost increase but demonstrate clear benefits through the Value Framework process, where affordability will need to be taken account of. Ultimately the phasing of implementation of any alternative and baseline options will be determined by the NDA, where the process takes cognisance of the safety, security and environmental impacts and which will show the

priority of executing alternative HAW strategies against other activities and when funding is available.

In relation to strategy development, the NDA actively engages with its SLCs, RWM, regulators and government representatives to ensure all key issues and new challenges are captured and managed, which ultimately could lead to new strategic tasks. The NDA will also review all radioactive waste management fora led by the NDA to ensure all meetings continue to add value and engagement is as effective as possible.

3.9 Key risks, issues and assumptions

The main risks, issues and key assumptions associated with the implementation of the HAW strategy are explained below:

3.9.1 Risks

There are a number of potentially significant risks to the successful implementation of the HAW strategy that need to be managed and mitigated. During the development of this Strategy a number of key risks that may affect its implementation were identified through technical work and through dialogue with stakeholders. Conversely, implementation of the HAW strategy represents a significant opportunity which can be recognised at a number of levels. Risk and opportunity management are ongoing processes and it is therefore not appropriate to include specific risks and opportunities here.

Moving forward, risks associated with the strategy from an NDA point of view will be captured in our risk management process at the appropriate level. Actions will be undertaken to mitigate those risks and contribute to ensuring continued capability and capacity for the management of HAW in the UK. Other organisations involved in the implementation of the strategy should also manage relevant risks accordingly.

In addition to mitigation of risks, it is important to plan for implementation of the strategy and to realise the significant opportunities presented.

3.9.2 Issues

The following are recognised as factors that could influence the NDA's implementation of HAW strategy as they are issues that affect the environment in which decisions are taken. The following are considered as material considerations in HAW strategy work:

- The parallel implementation of UK and Scottish HAW long-term management policies. For example, Scottish policy may result in a different approach to storage for a proportion of HAW where either a store replacement programme is required or new innovative designs for long-term storage are adopted, *e.g.* much greater than 100-year design lives

- The NDA's planning is based on operations beginning in 2040 although the HAW storage strategy is not particularly sensitive to timescales unless the GDF programme is significantly delayed [28] and allows for a storage period of at least 100 years

- Correct level of funding is in place to ensure that high importance work areas are developed fully to enable site implementation. R&D is an essential component of this work

3.9.3 Assumptions

- For ILW in England and Wales the planning assumption is that a GDF will be operational from 2040
- For HLW, the planning assumption is that a GDF will be operational from 2075
- For all HAW, the Disposability Assessment process will be followed by all UK waste producers and owners
- Any delays to the GDF programme will not have an impact on the approach to longer-term interim storage. It is assumed that there will be no significant delays in the GDF programme

4. Key influences on NDA HAW strategy implementation

4.1 Implementation of geological disposal

The Department of Energy and Climate Change (DECC) published a White Paper on Implementing Geological Disposal in July 2014. The White Paper provides detailed contextual information in regard to the policy position and summarises the policy framework for implementing geological disposal.

The White Paper specifies a number of initial actions, led by the UK government and the developer (RWM) and consist of:

- National geological screening led by the developer
- Establishment of the policy framework for planning decisions in England led by the UK government
- Developing a process of working with communities, including community representation, community investment, and a means of obtaining independent views (led by the UK government)

The NDA's HAW strategy assumes that a GDF will be constructed and is reliant on its successful operation to provide long-term management solutions for wastes arising in England and possibly Wales. The NDA is keen for good progress to be made in implementing geological disposal as the permanent solution for HAW in England and Wales and will continue to support the UK government programme where the White Paper highlights current work and commitments to be undertaken by RWM to undertake a number of tasks including:

- National geological screening
- Engaging proactively with stakeholders and potential host communities to encourage support for the siting process
- Provide advice to waste producers on the compatibility of their waste conditioning proposals with future geological disposal, with the objective of avoiding the need for repackaging and the 'double handling' of wastes
- Specifying the records that will need to be retained to demonstrate compatibility of packaged waste with generic disposal concepts, and indicating where consignors' arrangements relating to specific groups of packaged waste are adequate
- Focussed, needs-driven R&D in support of geological disposal. The programme and its outputs are publicly available, and are scrutinised by independent regulators and CoRWM
- The NDA and RWM continue to review appropriate alternative long-term management options including learning from and engaging with overseas programmes, which could have the potential to improve the approach for some of the UK's HAW
- Updates, on an annual basis, of the estimated costs of the GDF programme

4.2 Scottish government HAW implementation strategy

Scottish government policy is for the long-term management of HAW in near-surface facilities [8]. Facilities should be located as near as possible to the sites where the waste is produced. While the Scottish government does not support deep geological disposal, it continues, along with the UK government and other devolved administrations, to support a

robust programme of interim storage and an ongoing programme of research and development.

Scottish government is developing an implementation strategy[7] and a consultation document was published in May 2015 [13]. Lifetime Plans for the NDA's Scottish sites have been updated to take account of Scottish HAW policy. The alternative disposal and baseline improvement options, *e.g.* thermal treatment, decay storage, being explored by this strategy will help to support implementation of Scottish government policy.

4.3 Interaction with planning authorities and stakeholder engagement

The NDA actively and regularly engages with stakeholders at a national level and locally with the communities around the sites in its ownership. The NDA recognises the important function of local planning authorities and will continue to encourage early dialogue between its SLCs and local government decision makers on radioactive waste matters. This helps inform (i) the preparation of local waste development documents and (ii) the handling of planning applications. Open and constructive discussions should help to ensure all relevant issues can be raised and resulting actions addressed in a timely manner.

At a national level the NDA's direct engagement with the planning authorities is normally co-ordinated *via* the Nuclear Legacy Advisory Forum (NuLeAF) and Scottish Councils Committee on Radioactive Substances (SCORRS). As the NDA's radioactive waste strategy develops, separate issue specific workshops may be held as appropriate and involve engagement at a local or regional level. Where these issues are also of significance to local communities around its sites, the NDA will continue to utilise the existing network of site stakeholder groups. Each sponsored NDA strategy project should produce its own stakeholder engagement plan to cover both national and local engagement, and dependent on the circumstances could require direct engagement by the NDA with individual planning authorities. It is the responsibility of the NDA project manager to ensure that an effective plan is in place and is being implemented. SLCs would lead on stakeholder engagement when strategic policy decisions have been confirmed and projects move into implementation.

Land use planning in the UK is a devolved matter and separate planning policies and guidance frameworks are in place and Appendix 3 provides a summary. A GDF is an infrastructure development of national significance and UK government believes it appropriate that the approach to land use planning reflects this. [29]

[7] See section 3.02, Scotland's Higher Radioactive Waste Policy 2011, The Scottish Government, Edinburgh 2011

Appendices

Appendix 1 – Categories of waste, spent fuel and nuclear materials

Intermediate Level Waste

ILW will be generated through continuing operations and future decommissioning of the NDA sites. Current estimates for existing and anticipated packaged volumes of ILW are in the region of 470,000 cubic metres (m^3).[8] ILW is radioactive waste with radioactivity levels exceeding the upper boundaries for LLW:

- Alpha emitters greater than 4 GBq/tonne
- Beta/gamma emitters greater than 12 GBq/tonne

Furthermore, ILW does not need radiological decay heat to be taken into account in the design of storage or disposal facilities.

ILW comes in a wide range of forms with the majority of the volume being made up of metals, sludges, organic materials, plutonium contaminated materials, cement and graphite. The radiological, chemical and physical forms of ILW are highly varied, ranging from large solid waste items that are relatively inert to wet sludges, which can be chemically reactive and heavily contaminated. ILW arises from a number of operations across the nuclear fuel cycle including:

- Research facilities
- Historical waste storage practices
- Fuel fabrication
- Reactor operation
- Spent fuel reprocessing
- Decommissioning

There are currently five different ways of storing ILW in the UK:

- The storage of untreated, *i.e.* raw waste, in historical facilities
- The storage of treated or packaged waste that needs further treatment before longer-term storage/disposal
- Interim storage of waste already conditioned for disposal
- The continued interim storage of wastes in modern engineered stores that will require further conditioning before disposal
- Interim storage of waste which is still *in situ* such as in reactor cores awaiting decommissioning

[8] UK National Waste Inventory 2013

A small proportion of LLW, currently estimated to be in the region of 14,000 m^3 by packaged volume, is also included in the HAW category, where this waste is currently unsuitable for disposal in the LLWR or the LLW facility at Dounreay.[9] Such LLW may consist of reactor core graphite or effluent treatment materials, where there is a potential for high concentrations of alpha activity or relatively high concentrations of long-lived radioisotopes.

High Level Waste

In the UK, HLW is heat-generating highly radioactive liquor arising from the reprocessing of spent nuclear fuel from both the UK and overseas Magnox and THORP operations, and the solid vitrified product that is produced by immobilising this liquid waste. The intense level of radiation means that shielding is always necessary to protect workers engaged in HLW operations. Sellafield is the only NDA site that stores HLW.

HLW generates significant heat from radioactive decay, which needs to be taken into account when designing and operating storage and disposal facilities for this material. This heat is generated predominantly from fission products such as caesium-137 and strontium-90, as well as transuranic elements such as americium-241. The heat generating fission product component of HLW decays away within a few hundred years, whereas the transuranic elements are much longer-lived.

Once vitrified, the UK HLW will be held in the Vitrified Product Store at Sellafield for 50 years or more to allow shorter-lived radionuclides to decay before emplacement in a geological disposal facility. The packaged volume of HLW destined for geological disposal has been estimated to be approximately 1,080 m^3. Some of the HLW that was generated through reprocessing of overseas spent fuel is returned to the country of origin, under defined waste substitution arrangements.

Spent fuel and nuclear materials

With the exception of research amounts of thorium held by Magnox at their southern sites and some spent fuels in the legacy facilities at Sellafield, HAW excludes spent fuel and nuclear materials, which are covered by the Magnox, AGR, exotics, plutonium and uranium NDA topic strategies. If any of these spent fuels and nuclear materials were declared as a waste then technically they would fall within the HAW strategy at that point in time. The recent White Paper on implementing geological disposal includes potential spent fuel and nuclear material inventories that may have to be accounted for as part of the disposal programme.[10]Scottish government's HAW policy on the long-term management of HAW does not include spent fuel and nuclear material, which are covered by the relevant UK policies.

Thorium products are considered within the NDA HAW topic strategy including thorium contaminated materials (TCM). Thorium products cover unirradiated and irradiated metal, oxide and nitrate materials. The volume of thorium material within the inventory is relatively small and the NDA's strategy for these materials is to condition for longer-term interim storage pending disposal at some point in the future.

[10] See para 2.17, Implementing Geological Disposal, A framework for the long-term management of higher activity radioactive waste, DECC, July 2014.

It may be possible that some of the thorium materials held by the NDA could be of value at some point in the future and could be returned to the market for reuse, for example, to support R&D activities.

Appendix 2 – HAW Strategic Position

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
Wet ILW – Interim Storage	The Wet ILW topic strand considers raw waste streams that are potentially mobile and include Magnox sludge, ion-exchange resins and oils.	Current arisings of Wet ILW are retrieved, conditioned and stored in engineered facilities and subsequently disposed of when a GDF becomes available or long-term management in near-surface facilities for wastes in Scotland. Current Lifetime Plans for the NDA's Scottish sites are being reviewed and updated to take account of Scottish HAW policy. Historical raw wastes and historical packaged wastes will be retrieved from ageing facilities and packaged into a disposable form and transferred to an engineered interim store. The timing of retrievals and waste treatment of the historical wastes is based on the NDA Lifetime Plans. As a contingency all sites must consider the possible impact of a delay in a GDF programme. To help with this contingency planning all new interim stores will have a design life of 100 years or more with appropriate care & maintenance programmes in place. There are unique challenges for some of Sellafield legacy wastes. Command 2919 (1995) states that where safety is overriding then the initial risk reduction processes can be supported. The NDA Strategy; section HAW Delivery – 'At facilities where our immediate priority is near-term risk reduction we are prepared to retrieve wastes and provide waste storage (containerisation) arrangements knowing that further waste treatment steps will be necessary prior to disposal. We will continue to work with RWM and our SLCs to improve this important risk reduction programme at Sellafield.'	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'Interim waste storage is an essential component of higher activity radioactive waste management. It is not itself a disposal solution, but it provides a temporary, safe and secure environment for waste packages that are awaiting final disposal in a GDF.'* The Scottish government's HAW policy states that: *'Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements.' The* policy states in section 2.04.03 that: *'There remains uncertainties as to how to deal with much of the waste, therefore the Scottish government policy at the present time is that long-term storage is still the primary long-term management option*.' See section 2 relating to treatment and long-term storage. Current NDA strategy positions related to this area include; • The NDA's overarching strategy is to treat and package the HAW inventory into a form that can be safely and securely stored for many decades. • In some circumstances it may not be practicable to achieve a disposable product in a single management step especially where there is an overriding need for risk reduction. Our current priority is to expedite the retrieval of HAW from ageing facilities. • The baseline treatment option for radioactive wastes is often cement encapsulation, which is unlikely to be the optimal solution for all future waste streams. We are therefore keen to continue to support the development of a range of waste treatment technologies for future programmes with the strategic aim of reducing overall volumes and making best use of current and future planned treatment assets. • Our plans for new and existing stores need to include maintenance programmes, refurbishment and, if required, replacement of some older stores. To support this planning process we developed industry guidance for longer-term storage of HAW.	• Where near-term safety considerations require relatively early solutions, ILW could be containerised in a raw, or part raw form, and undergo final conditioning prior to disposal.	Unique challenges for Sellafield legacy wastes mean this position is being adopted for some wastes. Command 2919 (1995) – where safety is overriding then the initial risk reduction processes can be supported. NDA strategy (2016): At facilities where our immediate priority is near-term risk reduction we are prepared to retrieve wastes and provide waste storage (containerisation) arrangements knowing that further waste treatment steps will be necessary prior to disposal.
				• The management approach of HAW and LLW at the classification boundary should be closely aligned and an optimised approach to radioactive waste management can be applied to make best use of capacity and capability within the industry. • Decay storage of suitable waste streams and allow for alternative management routes, e.g. management as LLW.	NDA strategy (2016): We will work with SLCs and regulators to help determine the main opportunities for alternative management of wastes at the ILW/LLW boundary and continue to sponsor work, including joint working between LLWR Limited and RWM. SLCs are also expected to work with LLWR and RWM to highlight any areas of opportunity. The NDA is preparing a Gate A decay storage position paper where the outcomes will be incorporated into the industry Storage guidance.

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
Wet ILW – Disposal	The wet ILW topic strand considers raw waste streams that are chemically reactive and/or mobile and include Magnox sludge, ion-exchange resins and oils.	The reference strategy is to transfer the conditioned waste to a GDF in line with the site export schedule. RWM has developed a Disposal System Specification. In Scotland, the policy is for long-term management of waste in near-surface facilities. Future work will be dependent on the outcome of Scottish government's consultation on its HAW implementation strategy.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'This White Paper sets out the UK government's framework for managing higher radioactive waste in the long term through geological disposal.'* In Scotland, the policy is for long-term management of waste in near-surface facilities. Scottish government's HAW policy states that: *'Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements.'*	• No alternative options for the disposal of such wastes in England and Wales. Possible alternative options to be explored at this time pending publication of Scottish government's HAW implementation strategy.	
Solid ILW – Interim storage	The solid ILW topic strand mainly considers large volume waste streams during decommissioning and final site clearance operations and excludes bulk reactor graphite. As a contingency all sites must consider the possible impact of a delay in a GDF programme. To help with this contingency planning all new interim stores will have a design life of 100 years or more with appropriate care &maintenance programmes in place. Especially within the Solid ILW topic strand, there are opportunities at the ILW/LLW boundary for a more flexible waste management approach to be adopted, *e.g.* decontamination to allow for LLW disposal. Some ILW will remain in the raw form and will be conditioned prior to disposal.	The current strategy is for individual sites to ensure that their waste storage arrangements meet the current export timescales to a GDF or long-term management in near-surface facilities for wastes in Scotland. Current Lifetime Plans for the NDA's Scottish sites have been reviewed and are in the process of being updated to take account of Scottish HAW policy.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'Interim waste storage is an essential component of higher activity radioactive waste management. It is not itself a disposal solution, but it provides a temporary, safe and secure environment for waste packages that are awaiting final disposal in a GDF.'* The Scottish government's HAW policy states that: *'Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements.' The* policy states in section 2.04.03 that: *'There remains uncertainties as to how to deal with much of the waste, therefore the Scottish government policy at the present time is that long-term storage is still the primary long-term management option*.' See section 2 relating to treatment and long-term storage. Current NDA strategy positions related to this area include; • The NDA's overarching strategy is to treat and package the HAW inventory into a form that can be safely and securely stored for many decades. • In some circumstances it may not be practicable to achieve a disposable product in a single management step especially where there is an overriding need for risk reduction. Our current priority is to expedite the retrieval of HAW from ageing facilities. • The baseline treatment option for radioactive wastes is often cement encapsulation, which is unlikely to be the optimal solution for all future waste streams. We are therefore keen to continue to support the development of a range of waste treatment technologies for future programmes with the strategic aim of reducing overall volumes and making best use of current and future planned treatment assets.	• Containerise solid ILW and defer conditioning.	Baseline strategy for certain existing streams in longer term storage, *e.g.* AGR graphite sleeves & MBGW in storage at Sellafield. Where such an approach is justified this option could support Scottish policy with respect to near-surface long-term management of HAW, *e.g.* decay storage. For new wastes this position could be difficult to justify unless overall benefits are underpinned and supported by the Regulators.
				• An *in situ* storage concept may also be considered for other nuclear facilities that supported GDF planning contingencies or decay storage opportunities, *e.g.* building *in-situ* waste storage following POCO. Following bulk waste retrievals it may not be always possible to remove all residuals and further management may be required.	The timing of solid ILW arisings is often dependent on individual site decommissioning strategies in relation to facility reactor dismantling programmes and will be subject to change, e.g. may consider the benefits of deferred decommissioning *versus* continuous decommissioning. CoRWM report to government on 'Interim Storage of HAW and the management of Spent Fuels, Plutonium and Uranium', March 2009, stated that 'too few sites have contingency plans' where the 2040 available date for the GDF is a planning assumption only. Some buildings across the estate hold ILW in-situ and will be decommissioned after 2040 and require no interim storage of the packaged wastes. What will happen if the GDF is delayed? Options need to be explored.

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
			• Our plans for new and existing stores need to include maintenance programmes, refurbishment and, if required, replacement of some older stores. To support this planning process we developed industry guidance for longer-term storage of HAW.	• Interim storage of decommissioning wastes, which are currently assumed to be processed and directly transferred to a GDF. Could include raw waste transfer and conditioning at GDF for certain waste streams.	CoRWM report to government on 'Interim Storage of HAW and the management of Spent Fuels, Plutonium and Uranium', March 2009, stated that 'too few sites have contingency plans' where the 2040 available date for the GDF is a planning assumption only. Some buildings across the estate hold ILW in-situ and will be decommissioned after 2040 and require no interim storage of the packaged wastes. What will happen if the GDF is delayed? Options need to be explored. This alternative option could also support the development of Scottish policy with respect to the long-term storage of HAW.
Solid ILW - Disposal	The solid ILW topic strand mainly considers large volume waste streams during decommissioning and final site clearance operations and excludes bulk reactor graphite.	Conditioned waste in storage will be transferred to a GDF in line with the NDA's site export schedule. RWM has developed a Disposal System Specification. Especially within the Solid ILW topic strand, there are opportunities at the ILW/LLW boundary for a more flexible waste management approach to be adopted, *e.g.* decay storage to allow for LLW disposal. Most ILW arising after 2040 will be conditioned into a disposable form and then transferred directly to a GDF. In Scotland the policy is for long-term management of wastes in near-surface facilities. Future work will be dependent on the outcome of Scottish government's consultation on its HAW implementation strategy.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'This White Paper sets out the UK government's framework for managing higher radioactive waste in the long term through geological disposal.'* The UK government's White Paper 'Implementing Geological Disposal', July 2014, para 2.34 stated '*The UK government has noted that other long-term management options could emerge as practical alternatives to geological disposal for some wastes in the future. In line with this, the NDA and RWM continue to review appropriate solutions including learning from and engaging with overseas programmes, which could have the potential to improve the long-term management of some of the UK's higher activity radioactive wastes.*' In Scotland the policy is for long-term management of waste in near-surface facilities. Scottish government's HAW policy states that: *'Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved. All long-term waste management options will be subject to robust regulatory requirements.'* The NDA's IWM strategy will continue to support Scottish government and the NDA decommissioning strategy investigating reactor dismantling timescales for Magnox reactors (see Graphite – disposal topic strand for further options).	• Condition solid ILW for near-surface disposal including the possibility of on-site disposal, regional disposal facility or a single centralised disposal facility.	There is ongoing work in support of Scottish government HAW policy that is investigating which waste streams may be suitable for near-surface disposal, which would be subject to further technical underpinning and stakeholder scrutiny. NDA strategy (2016): The UK policy on the long-term management of HAW recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. To support this policy position and Scottish government policy position of near-surface management of HAW we will explore a range of disposal options together with RWM and our SLCs.
				• Decay storage of suitable waste streams and allow for disposal as LAW or Out of Scope.	UK HAW Storage Review (2009); section 2.3 – All sites should consider separately those ILW materials that may be suitable for decay storage and ultimate disposal at a LLWR. CoRWM recommendations, full report (ref 700), July 2006 – Annex 3 inventory listed that decay storage/decontamination could lead to a reduction of 19,000 m3 of ILW. The NDA is preparing a Gate A decay storage position paper where the outcomes will be incorporated into the industry Storage guidance. This alternative option could also support Scottish policy with respect to the long-term storage of Higher Activity Wastes.
				• *In situ* disposal	Subject to the GDF implementation programme and no changes in the Magnox decommissioning programme timescales in England and Wales, there is no current case for change in terms of alternative disposal options for solid ILW arising in England or

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
					Wales and aligns to the graphite strategic position published by the NDA in January 2014. NDA strategy (2016): The UK policy on the long-term management of HAW recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. To support this policy position and Scottish government policy position of near-surface management of HAW we will explore a range of disposal options together with RWM and our SLCs. The NDA may consider *in situ* disposal as a possible option for some of the wastes although this position currently excludes Magnox decommissioning wastes in England & Wales (see above). Future work in support of Scottish government's HAW policy will be dependent on the outcome of its HAW implementation strategy consultation process.
Graphite – Interim Storage	The future decommissioning of Graphite cores from Magnox nuclear reactors will result in the single largest volume waste stream in the UK inventory. The reactor cores are mainly made up of interlocking graphite blocks. Graphite Fuel Element Debris, Pile Graphite and AGR graphite sleeves are also considered as part of this topic strand.	Deferred reactor dismantling is the current strategy for the interim storage of graphite reactors. Bulk reactor graphite will not arise as a waste until the latter end of this century and beyond. For graphite waste arisings before 2040, the material may be retrieved, conditioned into a disposable form or in some acceptable cases, retrieved and containerised with deferred conditioning. Actual waste management arrangements will be site or waste stream specific.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'Interim waste storage is an essential component of higher activity radioactive waste management. It is not itself a disposal solution, but it provides a temporary, safe and secure environment for waste packages that are awaiting final disposal in a GDF.'* In support of this current strategy for graphite waste management the following opportunities could be explored and is subject to a change in the current NDA decommissioning strategy for Magnox reactor sites: • Reduced Care & Maintenance period for reactor dismantling. • Extended care and maintenance period for Magnox reactors in support of Scottish policy. The NDA IWM strategy will continue to support Scottish government and the NDA decommissioning strategy investigating reactor dismantling timescales for Magnox reactors.	• Storage of conditioned bulk reactor graphite pending disposal to GDF. • Storage of unconditioned graphite (deferred final conditioning).	CoRWM report to government on 'Interim Storage of HAW and the management of Spent Fuels, Plutonium and Uranium', March 2009, stated that 'too few sites have contingency plans' where the 2040 available date for the GDF is a planning assumption only. Some buildings across the estate hold ILW *in situ* and will be decommissioned after 2040 and require no interim storage of the packaged wastes. What will happen if the GDF is delayed? The possibility of unencapsulated graphite products for interim storage and disposal following the LoC process. Regulatory acceptance is a key requirement throughout. These alternative options could support Scottish policy with respect to the long-term storage of Higher Activity Wastes.
Graphite - Disposal	The future decommissioning of Graphite cores from Magnox nuclear reactors will result in the single largest volume waste stream in the UK inventory. The reactor cores are essentially made up of interlocking graphite blocks. Graphite Fuel Element Debris, Pile Graphite and AGR graphite sleeves are also considered as part of this topic strand.	The waste treatment and disposal of reactor graphite is seen as a key enabler for the Magnox decommissioning programme. Before disposal the core reactor graphite waste will be conditioned into a disposable form and then transferred directly to a GDF. The impact of relatively large inventories of long-lived radioisotopes C-14 and Cl-36 will also need to be considered as part of any programme. In Scotland, the policy is for long-term management	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'This White Paper sets out the UK government's framework for managing higher radioactive waste in the long term through geological disposal.'* In Scotland, the policy is for long-term management of waste in near-surface facilities. Scottish government's HAW policy states that: *'Facilities should be located as near to the site where the waste is produced as possible. Developers will need to demonstrate how the facilities will be monitored and how waste packages, or waste, could be retrieved. All long-*	• The NDA summary position on the management of graphite HAW highlighted disposal, treatment and recycling options. These align with the options previously outlined for graphite. **Disposal options** 1. **GDF disposal** to the planned disposal facility for higher activity wastes arising in England & Wales 2. **Near-surface disposal** to a new specialised facility Permitted in line with the Near-surface Guidance on the	NDA strategy (2016): The UK policy on the long-term management of HAW recognises that it is appropriate to investigate alternative options to a GDF for some of the inventory where there could be the potential to improve the overall management of HAW. To support this policy position and Scottish government policy position of near-surface management of HAW we will explore a range of disposal options together with RWM and our SLCs. Subject to the GDF development and no changes in the Magnox decommissioning programme timescales in England and Wales, there is no case for change in terms of

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
		of wastes in near-surface facilities. Future work will be dependent on the outcome of Scottish government's consultation on its HAW implementation strategy.	*term waste management options will be subject to robust regulatory requirements.'* The NDA's IWM strategy will continue to support Scottish government and the NDA's decommissioning strategy investigating reactor dismantling timescales for Magnox reactors.	Requirements for Authorisation 3. **In-situ disposal** (necessarily assumes reactor mounding is selected as an alternative site remediation and decommissioning strategy) 4. **LLWR disposal** (existing specialised facility) 5. **Permitted landfill disposal** (existing or future commercial facilities) **Treatment options** 6. **Treatment to make subsequent management of the waste easier**, followed by consignment to appropriate waste routes e.g. decontamination to remove key radionuclides 7. **Treatment to minimise the volume of solid waste for disposal**, followed by consignment to appropriate waste routes e.g. steam reformation, thermal treatment, etc. **Recovery for reuse or recycling** 8. **Recovery for beneficial reuse or recycling**	pursuing alternative disposal options for HAW graphite arising in England or Wales.
UK owned HLW - disposal	HLW arises as a consequence of reprocessing and is a by-product resulting from the separation of uranium & plutonium from the fission products. HLW only arises at Sellafield.	The current strategy is to package the vitrified HLW for disposal and then transfer to a GDF from 2075.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'This White Paper sets out the UK government's framework for managing higher radioactive waste in the long term through geological disposal.'* The UK government currently sees no case for having more than one facility if it can be avoided and if one facility can be developed to provide suitable containment for the whole waste inventory.	• No alternative options for the disposal of such wastes to be explored. If deemed appropriate, alternative GDF options could be explored in the future and examples may include: • Following a period of interim storage conditioned HLW is disposed of to a separate HLW/SF GDF. • Following a period of interim storage conditioned HLW is disposed of to a separate glass waste form GDF.	Alternative options are not being explored at this stage. Current work is generic and will help technical underpinning.
UK owned HLW – interim storage	HLW arises as a consequence of reprocessing and is a by-product resulting from the separation of uranium & plutonium from the fission products. HLW only arises at Sellafield.	The strategy for HLW is to convert all the liquid waste into a vitrified glass product, which is suitable for interim storage, for at least 50 years, and ultimate disposal. Any new store should have a design life of 100 years or more.	The UK government's White Paper 'Implementing Geological Disposal', July 2014, stated that *'Interim waste storage is an essential component of higher activity radioactive waste management. It is not itself a disposal solution, but it provides a temporary, safe and secure environment for waste packages that are awaiting final disposal in a GDF.'*	• No other options to be considered.	
Overseas owned HLW	HLW arises as a consequence of reprocessing and is a by-product resulting from the separation of uranium & plutonium from the fission products. HLW only arises at Sellafield.	Sellafield undertakes reprocessing for a number of overseas customers. The current strategy is to return HLW vitrified products to customers, as specified in the reprocessing contracts.	DTI statement of the UK government and devolved administrations' policy on Intermediate Level Waste Substitution, December 2004 stated that '*Government policy remains that the wastes resulting from the reprocessing of overseas spent fuel should be returned to the country of origin, and the HLW should be returned as soon as practicable after vitrification.'*	• No other options to be considered at this stage. This is a commercial arrangement that is being implemented. UK title to HLW is a possible option and is not being considered.	

Topic strand	Raw Waste Description	Current position	Reference documents – Policy and NDA Strategy	Alternative credible options	Reason for possible baseline change
Overseas owned ILW	Some ILW arises as a consequence of reprocessing and is a by-product resulting from the separation of uranium & plutonium from the fission products.	Sellafield undertakes reprocessing for a number of overseas customers. The current strategy is to enact ILW substitution whereby additional equivalent amounts of HLW vitrified products are returned to customers *in lieu* of ILW, as specified in the reprocessing contracts. Other overseas-owned ILW will be subject to agreed commercial arrangements.	DTI statement of the UK government and devolved administrations' policy on Intermediate Level Waste Substitution, December 2004 stated that '*Government policy remains that the wastes resulting from the reprocessing of overseas spent fuel should be returned to the country of origin, and the HLW should be returned as soon as practicable after vitrification. It [the government] accepts that, for ILW (and as now for LLW), this policy can be implemented by waste substitution arrangements that ensure broad environmental neutrality for the UK.'* Joint Scottish and UK government consultation, December 2010, on a proposed policy of radioactive waste substitution for the radioactive waste arising from historic fuel reprocessing contracts with overseas customers at Dounreay.	• No other options to be considered at this stage for Sellafield customers. ILW returns not deemed appropriate for the majority of materials as different packaging concepts adopted by different countries and waste substitution is an accepted position. Other options may be considered but will proceed on a case-by-case basis and will be subject to commercial and policy arrangements. As well as HLW substitution, the other options are as follows: • Return of ILW to customer • UK title to overseas owned ILW	

Appendix 3 – The roles of key organisations

The NDA

The Nuclear Decommissioning Authority (NDA) was established as a non-departmental public body by the 2004 Energy Act; it is the UK's main national radioactive waste management organisation. Its stated mission is:

Deliver safe, sustainable and publicly acceptable solutions to the challenge of nuclear clean-up and waste management. This means never compromising on safety or security, taking full account of our social and environmental responsibilities, always seeking value for money for the taxpayer and actively engaging with stakeholders [11].

On incorporation, the NDA assumed responsibility for all of the UK's civilian, state-owned nuclear sites. These include the Sellafield site, the Low Level Waste Repository, the Magnox power stations and the sites of former prototype and experimental reactors. Management of these sites is contracted out to individual Site Licence Companies (SLCs). As operators and licence holders, the SLCs have prime responsibility for the safety of their sites. The role of the NDA is to ensure that the objectives and activities of the SLCs are consistent with its mission.

The NDA develops a strategy for integrated and optimised management of waste across its estate and the strategy is then delivered under contract by the SLCs, such that the NDA is the strategic authority and client. The Energy Act 2004 requires the NDA to review and publish its strategy at least every five years. The current NDA Strategy is effective from April 2016 and this HAW strategy supports the implementation of that strategy, including the development of a Radioactive Waste Strategy for the NDA's wastes. Excluding disposal, the delivery of the HAW strategy is the responsibility of the SLCs and is documented in their Site Integrated Waste Strategies and Lifetime Plans.

Radioactive Waste Management Limited (RWM)

The NDA has a responsibility for implementing geological disposal for HAW and has established RWM as the geological disposal delivery organisation. Reflecting its responsibilities, RWM's mission statement is:

To deliver a geological disposal facility and provide waste management solutions.

RWM has responsibility for planning and ultimately implementing geological disposal of HAW in accordance with government policy. This includes ensuring such wastes generated throughout the UK are conditioned and packaged in a manner suitable for eventual disposal. In order to discharge this responsibility, RWM is developing plans for the implementation of geological disposal using an iterative disposal system development process. In this process the Disposal System Specification incorporates external requirements to guide the design and safety assessment processes, which in turn iteratively leads to refinements and changes in the specification.

[11] Nuclear Decommissioning Authority (the NDA), Business Plan, Financial year beginning April 2014 to financial year ending March 2017, April 2014

In advance of the availability of a geological disposal facility, RWM provides advice on the packaging of HAW for geological disposal. This is generally undertaken via the Disposability Assessment Process (also known as the 'Letter of Compliance' (LOC) process). The primary aim of which is to minimise the risk that the conditioning and packaging of radioactive wastes results in packages incompatible with geological disposal, as far as this is possible in advance of the availability of waste acceptance criteria for a geological disposal facility. As such, it is an enabler for early hazard reduction on all UK nuclear sites. Disposability advice is also provided to support development of strategic options for spent fuel, plutonium and uranium, as well as the generic design assessment process for new build reactors. Disposability advice is provided to the UK nuclear industry and other waste producers. The Disposability Assessment Process is supported by a suite of waste package specification and associated guidance documentation.

RWM also takes on the role of higher activity waste integrator, providing support to the NDA and supporting waste producers through the provision of technical advice, sharing relevant experience and collaborating on work to realise opportunities connected to the whole lifecycle of the waste.

Site Licence Companies and PBOs

The NDA has prepared guidance on the roles of the SLC and the Parent Body Organisation (PBO) in the support of the NDA's Operating Model.[12] This model is applied across the NDA estate with the exception of the Sellafield site where the nature of the site and its extensive work programme has necessitated a unique contractual model to be put in place[13]. The NDA has developed a set of Key Principles describing the roles and main processes are as follows;

- The NDA is the enduring owner of the sites, assets and decommissioning liabilities on its estate. The NDA contracts the operation and decommissioning of its sites to SLCs
- The sites are operated by SLCs who are enduring organisations with appropriate management systems and competence to operate the sites. SLCs carry the primary responsibility for safe and environmentally responsible operation of their site(s) and are closely regulated for the delivery of this
- Each SLC is a legal entity with its own board of directors with responsibilities and duties in law, including to ensure that the sites they operate under contract to the NDA are operated safely at all times
- SLCs are owned by PBOs, selected by the NDA through a competitive process who, through a combination of secondments, reach-back and consultancy, provide governance of the SLC and ensure that it is optimised for its decommissioning mission by the provision of expertise, innovation and change in accordance with their contract with, and bid commitments to the NDA
- The NDA retains responsibilities to set overall strategy, allocate funding to SLCs from its agreed resources, sanction individual expenditure within its delegated authority, run competitions to select PBOs, and to account to government for the assets,

[12] The NDA Operating Model Guidance on the Roles of the Site Licence Company and the Parent Body Organisations, Revision 4, May 2013.

[13] After 6 years of operating the market led PBO model at Sellafield, we made the significant decision to take direct ownership of the SLC as a subsidiary. This was deemed the most appropriate model for the management and operation of the site given the uncertainties and complexities in the work required.

liabilities and expenditure on its estate. The NDA sets the SLCs and PBOs some standardised reporting frameworks to ensure this

- All parties in the NDA model have responsibilities for the safe operation of nuclear licensed sites. All are legal users of the sites, through primary responsibility and accountability in law resides with the SLC. Under UK law, all parties with safety responsibilities have a duty to co-operate with each other

The Regulators

The nuclear regulators: Office for Nuclear Regulation (ONR), Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and Natural Resources Wales (NRW), are key stakeholders who hold SLCs to account to ensure that radioactive wastes are managed in a way that protects people and the environment. The regulators provide joint regulatory guidance on lifecycle management of HAW, which includes the expectation that SLCs will prepare radioactive waste management cases.[14] This is the overarching documentation that details the proposed lifecycle management of HAW and sets out the forward programme in safety and environmental terms. The joint guidance has recently been reviewed and updated. It covers a range of technical topics including, 'Conditioning and disposability' and 'Storage of radioactive waste'.[15]

At a strategic level the NDA will continue to engage early with the regulators and seek their views throughout the optioneering work to ensure it is robust by taking into consideration relevant safety, security and environmental factors. The NDA also encourages its SLCs to carry out early engagement with the regulators where any key issues can be identified and resolution sought in a timely manner. For instance, ONR normally expects that endorsed final LoCs (fLoCs) will be in place prior to permissioning bulk processing (as opposed to active commissioning) of ILW. Typically, an endorsed interim LoC (iLoC) is required to be in place prior to active commissioning.

Other waste owners

Ministry of Defence

The Ministry of Defence (MoD) published its Nuclear Liabilities Management Strategy in 2011 where a number of strategic themes have been considered including radioactive waste and are compatible with the NDA's strategic themes. MoD liabilities arise from building and operating submarines and the manufacture and management of nuclear weapons where it is noted that MoD's radioactive waste accounts for 1.5% of the total UK inventory by volume. The principles of the MoD's radioactive waste strategy aligns with the NDA strategy where the waste hierarchy is applied and HAW will be safely packaged and stored pending the availability of a GDF.

In relation to HAW disposal the MoD has stated "*At its current stage of development the strategy requires some MoD nuclear liabilities to be disposed of to a geological facility, or managed in line with Scottish government policy on higher activity waste where applicable. The MoD's approach accords with the Committee on Radioactive Waste Management recommendations for developing a robust programme of storage and long term management*

[14] Joint regulatory guidance on radioactive waste management, Office for Nuclear Regulation website

[15] Joint regulatory guidance on radioactive waste management, Office for Nuclear Regulation website

options."[16] It is the NDA's current assumption that in the long term all MoD HAW will be transferred to the GDF, which is consistent with UK policy.

The MoD within its Nuclear Liabilities Management Strategy has also made a commitment to work with the NDA and the regulators in ensuring appropriate waste management solutions are in place for their wastes, including the possibility of sharing storage facilities. The MoD, within its strategy, has also made the following commitment: "*The MoD is committed to working with the NDA and waste producers to ensure that this Strategy delivers best value for money for the UK. The MoD will explore the benefits of collaborative solutions*".

The Submarine Dismantling Project (SDP) is the MoD's programme to deliver a safe, secure and environmentally responsible solution for reactor dismantling 27 defueled submarines. This involves recycling the bulk of the submarine and safely disposing of small volumes of LLW/ILW. The Reactor Pressure Vessel (RPV) contains ILW and after removal from the submarine it must be stored for an interim period until it can be processed and transferred to a GDF once available.

The MoD is undergoing an option assessment and consultation process to determine a preferred location for the interim store for the RPV (reactor pressure vessel). Initially all UK nuclear licensed sites were screened on their availability and suitability. This resulted in a shortlist of five sites being taken forward for detailed assessment including a public consultation exercise. Of these sites, two are owned by the NDA and the NDA supported the MoD in facilitating information from the sites to support the assessment process. The selected site will be required to store the RPVs in a suitably designed store until such time as the waste can be transferred to the GDF, in accordance with UK policy. The store will be designed with a minimum 100-year lifetime to allow for scheduling the transfer to a GDF. The MoD site assessment process is expected to complete in 2016.

EdF Energy

EdF Energy, through its licence holder company EdF Energy Nuclear Generation Ltd (NGL), operates seven AGR power stations and one PWR power station.

EdF Energy has developed a Sustainable Approach to Waste Management (SAWM), which is linked to the way the business is operated. The SAWM Fleet Strategy summarises the overarching sustainable environmental strategy for managing all wastes associated with nuclear power generation and decommissioning of the NGL Fleet and activities at supporting sites.

HAW arises during operation of the power stations and will also result from reactor dismantling of higher activity radioactive plant during decommissioning. HAW waste streams include:

Advanced Gas-cooled Reactor stations

- Ion-Exchange Resins
- Sludges
- Blowdown Filters

[16] Ministry of Defence, Nuclear Liabilities: Management Strategy, 2011

- Miscellaneous Contaminated Items
- Miscellaneous Activated Components
- Fuel Stringer Debris
- Reactor dismantling Steel and Graphite
- Wastes not disposable at the LLWR (or another facility)

Pressurised Water Reactor stations

- Ion-Exchange Resins
- Filter Cartridges
- Miscellaneous Contaminated Items
- Miscellaneous Activated Components
- Reactor dismantling Steel and Concrete
- Wastes not disposable at the LLWR (or another facility)

The majority of HAW (by volume) is metallic and graphite wastes which will arise from reactor dismantling activities.

EdF Energy is working collaboratively with the NDA, Magnox and other stakeholders to share learning and to identify and develop opportunities for HAW management. EdF Energy is also working with Scottish government in its development of a strategy to implement the Scottish government HAW policy.

The following opportunities have been identified:

- Adopt a fleet approach to radioactive waste management cases at AGRs
- Adopt a fleet approach to Letters of Compliance (LoC) wherever practicable
- Take advantage of new service providers which emerge in the UK
- Take advantage of new waste processing technologies as they become commercially available in the UK
- Share waste processing facilities and packaged waste stores (Magnox or new nuclear build) where appropriate

Some of these opportunities are being developed now and others will be taken forward at appropriate times in the future as the sites move closer to decommissioning.

EdF Energy previously input to an NDA study which considered a more optimal position for ILW storage solutions in Central and Southern Scotland. The scope of the study assessed ILW arisings at Hunterston A, Hunterston B, Torness, Chapelcross and Rosyth and excluded any final site clearance decommissioning wastes. The study proposed the preferred option as being a joint Hunterston A/B solution where ILW from Hunterston B could potentially be transferred to the existing Hunterston A store. The NDA has continued to investigate ILW storage consolidation options at its Magnox sites in England and Wales and EdF Energy has also participated in the process. However, to date further shared storage opportunities have not been identified although dialogue between the two organisations is expected to continue for both the Hunterston position and for the sites in England.

Non-NDA Small Volume Waste Producers

A number of other waste owners generate relatively small quantities of HAW, where it is assumed that the HAW streams are exclusively ILW (rather than HLW or LLW). The 2013 UKRWI provides detail on the inventory of small producers of ILW and can be summarised as follows;

TABLE 2 PACKAGED VOLUME OF ILW FROM SMALL PRODUCERS

Site owner	When all wastes at 1.4.2013 and future arisings are packaged.	ILW
United Kingdom Atomic Energy Authority	Number of packages	193
	Packaged volume (m^3)	825
	Conditioned volume (m^3)	389
GE Healthcare	Number of packages	379
	Packaged volume (m^3)	249
	Conditioned volume (m^3)	202
Urenco	Number of packages	5.3
	Packaged volume (m^3)	3.0
	Conditioned volume (m^3)	2.5
Minor Producers	Number of packages	5.2
	Packaged volume (m^3)	19.1
	Conditioned volume (m^3)	13.3
Total	**Number of packages**	**583**
	Packaged volume (m^3)	**1,096**
	Conditioned volume (m^3)	**607**

All site owners will need to comply with the policy positions as described in section 5. In England and Wales it is assumed for planning purposes that all HAW will be transferred to a GDF and therefore RWM will be required to assess the waste as part of its normal LoC process. The LoC process is also applied to Scottish HAW as an indicator of the ability to comply with Scottish policy which requires long-term management in near-site, near-surface facilities. The NDA also expects to support small producers in some circumstances and allows access to its treatment and storage capability where the case can be made, for example, the repackaging and storage of disused sealed sources from universities, hospitals and UK industry where alternative management routes are not available.

References

1 Nuclear Decommissioning Authority. Strategy, Effective from April 2016.

2 Nuclear Decommissioning Authority. An overview of the NDA Higher Activity Waste, November 2015.

3 Nuclear Decommissioning Authority. UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, August 2010.

4 Nuclear Decommissioning Authority. UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry. February 2016.

5 Department of Energy & Climate Change. Lead Document setting out the United Kingdom's National Programme for the Responsible and Safe Management of Spent Fuel and Radioactive Waste, August 2015.

6 Department of Energy & Climate Change. Implementing Geological Disposal. A Framework for the long-term management of higher activity radioactive waste. July 2014.

7 Welsh Government (2015), Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste.

8 Scottish Government, Scotland's higher activity radioactive waste policy 2011. ISBN: 978-0-7559-9892-0

9 Nuclear Decommissioning Authority. Higher Activity Waste Treatment Framework, October 2015

10 Nuclear Decommissioning Authority. Strategic position paper on the management of waste Graphite, January 2014.

11 Directive 2008/98/EC on waste. Waste Framework Directive, 2008.

12 Nuclear Decommissioning Authority. Higher Activity Waste, Credible Options (Gate A), February 2011.

13 The Scottish Government. Consultation on an Implementation Strategy for Scotland's Policy on Higher Activity Radioactive Waste. 2015

14 LLWR (2010), Conditioned Waste Disposal Study, Report no. TI/34/10/ellwr2663, Issue 1, March 2010.

15 Office for Nuclear Regulation. Joint regulatory guidance on radioactive waste management, the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales to nuclear licensees, February 2015.

16 Radioactive Waste Management Limited, Geological Disposal. Upstream Optioneering: Summary of LLW/ILW Opportunities, July 2015.

17 Low Level Waste Repository Limited. Guidance on decision making for management of wastes close to the LLW and ILW categorisation boundary that could potentially cross the LLW boundary National Waste Programme NWP/REP/016 – Issue 2 – Feb 2013.

18 Nuclear Decommissioning Authority. RWMD, Derived Inventory,

19 Nuclear Decommissioning Authority. Geological Disposal, Generic Disposal System Technical Specification, December 2010.

20 Nuclear Decommissioning Authority. Progress on approaches to the management of separated Plutonium position paper, January 2014

21 Nuclear Decommissioning Authority. Integrated Waste Management Strategy Development Programme

22 Nuclear Decommissioning Authority. the NDA Strategy 2006

23 Nuclear Decommissioning Authority. UK Radioactive Higher Activity Waste Storage Review, March 2009.

24 Exotic Fuels, Nuclear Materials and Waste Management – RSRL Harwell, Credible & Preferred Options (Gates A & B), August 2011

25 Intermediate Level Waste Storage Solutions - Central and Southern Scotland Preferred Option, April 2013

26 Optimising the number and location of interim Intermediate Level Waste (ILW) storage facilities on Magnox Limited and EdF Energy sites in England and Wales, Credible Options, May 2013

27 Nuclear Decommissioning Authority. The NDA Value Framework, January 2016.

28 Nuclear Decommissioning Authority. Industry Guidance, Interim Storage of Higher Activity Waste Packages – Integrated Approach, November 2012.

29 Localism Act 2011