Preliminary detailed assessment of solid radioactive waste, spent fuel and disposability for General Nuclear System Limited's UK HPR1000 design - AR05

Version 1, 11 January 2021

We are the Environment Agency. We protect and improve the environment.

We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

Published by:

Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH

www.gov.uk/environment-agency

Further copies of this report are available from our publications catalogue:
http://www.gov.uk/government/publications
or our National Customer Contact Centre:
03708 506 506

Email: nuclear@environment-agency.gov.uk

Executive summary

This report covers our Generic Design Assessment (GDA) of General Nuclear System Limited's (GNSL's) submission on solid radioactive waste, spent fuel and disposability of waste for the United Kingdom Hualong Pressurised (Water) Reactor design (UK HPR1000) as required in Table 1 of our Process and Information Document (P&ID) (Environment Agency, 2016).

Our assessment has considered the submission in relation to relevant UK policy, legislation and guidance, including the Environment Agency's Radioactive Substance Regulation (RSR), Regulatory Environmental Principles (REPs) (Environment Agency 2010). We have also considered our 'Joint guidance on the management of higher activity radioactive waste on nuclear licensed sites' (Office for Nuclear Regulation et al, 2015a).

We assessed GNSL's derived waste inventory for the UK HPR1000 covering operational and decommissioning wastes as well as spent fuel. We assessed GNSL's proposed approach to managing these wastes across the whole life cycle, covering characterisation, segregation, conditioning and packaging, storage and final disposal. We assessed proposals for managing both lower activity wastes (LAW) and higher activity wastes (HAW). The packaging of spent fuel into a disposal container and its subsequent transfer to a geological disposal facility is out of scope of GDA. The management of failed fuel within the spent fuel interim store (SFIS) is also out of scope.

Our preliminary conclusion is that GNSL has made good progress in addressing our requirements, and has, in many cases, addressed our requirements. However, at the time of writing there are a number of Regulatory Observations yet to be resolved that could impact on the final outcome of GDA. These relate to:

- the management of in-core instrument assemblies (ICIAs)
- the requirements for the long-term storage of spent fuel and the SFIS design
- the disposability of HAW and spent fuel

We have identified 3 potential generic design assessment Issues (GDAI) and 14 Assessment Findings (AF).

- **Potential GDA Issue 4: GNSL is required to provide information in relation to the long-term storage requirements for the spent fuel and to demonstrate that the conceptual design for spent fuel interim store (SFIS) will deliver these requirements.**
- **Potential GDA Issue 5: GNSL is required to provide further substantiation of the proposed strategy for the management of in-core instrument assemblies (ICIAs) and if any changes to the strategy is decided, to assess the impact on the disposal of ICIA wastes.**
- **Potential GDA Issue 6: GNSL is required to demonstrate that all higher activity waste (HAW) arisings from the UK HPR1000 will be disposable.**
- **Assessment Finding 14: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants that will be associated with the waste inventory for the UK HPR1000.**
- **Assessment Finding 15: A future operator shall assess whether there are benefits in periodic decontamination of the UK HPR1000 primary circuit and its related systems and auxiliary circuits with regard to minimising production of**

decommissioning wastes and their classification. The future operator should demonstrate that BAT is being applied.

- **Assessment Finding 16: A future operator shall ensure that the decommissioning plan is periodically reviewed to ensure that BAT is being applied with regard to decommissioning the UK HPR1000.**
- **Assessment Finding 17: A future operator shall review periodically the options for the treatment and disposal of solid low level waste from the operation and decommissioning of the UK HPR1000. The future operator shall ensure that the options implemented are BAT and will meet the disposal facilities waste acceptance criteria.**
- **Assessment Finding 18: A future operator shall periodically update the Radioactive Waste Management Case or equivalent documentation in accordance with the Environment Agency's and ONR's joint guidance, in order to demonstrate that the higher activity waste is being managed across the whole life cycle.**
- **Assessment Finding 19: A future operator shall develop its characterisation strategy and approach to segregation for solid and non-aqueous wastes further at the detailed design stage, to ensure that it can demonstrate that BAT is being applied.**
- **Assessment Finding 20: A future operator shall ensure that the proposed conditioning and packaging options for the higher activity wastes for the operational and decommissioning waste arisings from the UK HPR1000 are BAT.**
- **Assessment Finding 21: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal will be transferred to a GDF.**
- **Assessment Finding 22: A future operator shall ensure that it deploys BAT for the conditioning of the spent fuel, prior to transferring the spent fuel assemblies to the spent fuel interim store.**
- **Assessment Finding 23: A future operator shall ensure that the monitoring and inspection of the spent fuel assemblies and canister, within the spent fuel interim store are BAT.**
- **Assessment Finding 24: A future operator shall ensure that the strategy for managing failed fuel over the life time of the UK HPR1000 is BAT.**
- **Assessment Finding 25: A future operator shall engage with the operators of the disposal facilities to ensure that their requirements are complied with for both low activity wastes' and higher activity wastes' records.**
- **Assessment Finding 26: A future operator shall continue to secure international OPEX with regard to the dry storage of spent fuels and ensure that it applies learning from the international OPEX to the storage of the UK HPR1000 fuel arisings.**

Assessment Finding 27: A future operator shall secure and use OPEX, including that available internationally, to ensure that BAT is used to decommission the UK HPR1000 and that the generation of radioactive solid waste is minimised and it is capable of being disposed of.

Contents

1. Introduction

This report provides our detailed assessment of General Nuclear System Ltd's (GNSL's) submission in relation to managing solid radioactive waste, spent fuel and the disposability of solid radioactive waste, arising from the UK HPR1000 reactor design. Our assessment of liquid and gaseous discharges will be covered within our assessment reports on BAT and radioactive discharges.

This report is based on information received at the time of writing. Any subsequent or updated information will be assessed alongside the responses to our consultation. Our final assessment results will be published in our Decision Document at the end of GDA. Our target date for completion of GDA is January 2022.

We, the Environment Agency, expect a new nuclear power plant to be designed so that the quantity of waste that will be generated across the life cycle of the reactor will be minimised and optimised, using the best available techniques (BAT). In addition, we expect all wastes that will arise from the UK HPR1000 reactor to be disposable if they cannot be recycled or reused. The Requesting Party (RP) should be able to demonstrate that wastes arising from the operation of the UK HPR1000, as designed, are capable of being disposed of within the current regulatory system. The RP for this assessment is General Nuclear System Limited (GNSL).

Our Process and Information document for Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID) provides guidance to GNSL on our regulatory expectations (Environment Agency, 2016). Table 1 within P&ID describes our expectations of the information GNSL should provide in relation to the plants, processes and systems that will have a bearing on radioactive waste generation, treatment, measurement, assessment and disposal. We also expect GNSL to provide a detailed description of the waste management arrangements, over the life cycle of the reactor, including:

- strategic considerations with respect to radioactive waste management which underpin the design
- a description of how radioactive waste and spent fuel will arise over the life cycle of the reactors
- a description of how the production, discharge and disposal of radioactive waste will be managed (this should take into account a view from Radioactive Waste Management Ltd (RWM) on disposal of higher activity waste (HAW))

GNSL should provide information on the nature and quantities of wastes for disposal. This should take account of waste produced during normal operations and also from other events that are expected to happen over the lifetime of the plant.

The preferred strategy of 'concentrate and contain' tends to direct wastes to the solid form rather than discharge via aqueous and gaseous routes. By minimising the quantity (both mass and volume) of the solid wastes, the UK can make better use of its finite disposal capacity. An added benefit of minimising the quantity of solid waste is that the number of transfers to a disposal facility will be reduced, resulting in additional environmental benefits.

Currently, the UK can only dispose of very low level waste (VLLW) and certain low level wastes (LLW). It does not yet have an operational facility to dispose of higher activity wastes (HAW), which comprise intermediate level wastes (ILW), high level wastes (HLW) and some types of LLW. Spent fuel is not currently classified as a radioactive waste, but operators of new nuclear power plants are required to assume that spent fuel will not be reprocessed.

Government policy for the long-term management of HAW and spent fuel in England and Wales is via a geological disposal facility (GDF). A process to search for a suitable location is ongoing (BEIS, 2018). In advance of the availability of an operational GDF, the current strategy is to safely interim store the wastes and spent fuel. A process of disposability assessment has been developed to minimise the risk that conditioning and packaging of HAW now will prevent the production of waste packages that are incompatible with geological disposal in the future (NDA, 2014a).

The scope of the Environment Agency's assessments within the GDA process is the reactor and those buildings, processes and functions which are related to managing solid radioactive waste, non-aqueous liquids and spent fuel over the lifetime of the site. We acknowledge that the information GNSL provided for decommissioning wastes will have a greater degree of uncertainty due to the long timescales before these wastes would arise and their subsequent disposal is required. However, we expect GNSL to be able to demonstrate in principle that the HAW decommissioning wastes can be conditioned, packaged and disposed of. Assessment of the conceptual design of the HAW and spent fuel stores is included in our assessment, however the decommissioning of these building is not. Further assessment of the stores will be carried out at the detailed design stage. The transfer of spent fuel from the spent fuel interim store (SFIS) to a facility to package it for disposal and its subsequent transfer to a GDF is out of GDA scope.

We use a 2-stage process to carry out GDA: initial assessment, followed by detailed assessment. Our initial assessment of solid waste and spent fuel had the following findings, which we will expect to be addressed by the end of GDA. (Environment Agency, 2018) GNSL should provide information on:

- the generation of problematic wastes during the reactor life cycle
- the volume, activity and composition of the waste generated during operation and decommissioning of the reactor
- the options selection and arrangements for interim storage of solid wastes
- the optimising of solid waste disposal, including identifying boundary wastes
- engaging with waste disposal operators about disposability of wastes and spent fuel
- the expected number of fuel assemblies that will be produced over the lifetime of the reactor
- the proposed conditioning and packaging of spent fuel
- the quantity of the likely solid waste and spent fuel disposals
- the arrangements for monitoring solid waste and non-aqueous waste

This detailed assessment has built on that initial assessment and is based on additional submissions and ongoing technical engagement with GNSL.

2. Assessment

2.1. Assessment method

Our assessment method was to:

- review relevant documentation that GNSL supplied, covering the Integrated Waste Strategy (IWS), radioactive waste management arrangements and the supporting documentation covering solid and non-aqueous liquid wastes, the management of spent fuel, decommissioning of the UK HPR1000, ILW and SFIS storage reports, radioactive waste management cases for ILW and HLW and information with regard to the current progress of RWM's disposability assessment. A summary of the documents is provided within Appendix 1

- hold technical meetings with GNSL to improve our understanding of the information it has provided and to explain any concerns we have with the information
- assess the techniques GNSL proposed to prevent and minimise production of solid radioactive waste against our internal guidance and regulatory experience
- raise Regulatory Observations (ROs), Regulatory Queries (RQs) and Regulatory Issues (RIs), where appropriate. A summary of the RQs and ROs are provided within Appendix 2 and 3
- identify any potential GDA issues (GDAI) and/or Assessment Findings (AFs)

2.2. Assessment objectives

Our assessment objectives are to determine whether GNSL has provided the following:

- enough information to address the findings within our initial assessment report
- identified sources of solid radioactive waste across the life cycle of the UK HPR1000
- demonstration of BAT in relation to arisings of solid radioactive waste for both operational and decommissioning phases
- information on treatment and conditioning of solid radioactive waste produced across the life cycle of the reactor
- information on the disposal routes for solid radioactive waste
- quantification of LLW and ILW arisings across the life cycle of the reactor
- an adequate integrated waste, spent fuel strategy and decommissioning strategy
- adequate and reliable information on fuel composition, characteristics and proposed fuel burn up
- adequate and reliable information on spent fuel quantities and operating strategies in regard to spent fuel generation
- adequate information on the short and long-term management proposals for spent fuel and how this aligns with a disposal endpoint
- sufficient arguments that spent fuel from the UK HPR1000 would ultimately be disposable
- sufficient information supplied to RWM to carry out its disposability assessment acceptance
- acceptance of RWM's findings
- identified at least one packaging and conditioning route for operational and decommissioning wastes that could be relied on with reasonable confidence to provide disposable waste packages in a future GDF

3. Waste arisings

For the UK HPR1000, Unit 3 at the Fangchenggang (FCG3) reactor in China is the reference design (GNSL, 2020a).This reactor is currently under construction GNSL has used the FCG3 reactor design and OPEX from the operation of the CPR1000 to estimate the waste arisings for the UK HPR1000. There are a number of CPR1000 reactors currently operating within China and the HPR1000 is a further development of the CPR1000.

3.1. Operational waste arisings

GNSL provided an outline of the solid and non-aqueous wastes which will arise during the operational phase of the life cycle for the UK HPR1000, within the 'Pre-Construction Environmental Report (PCER) - Radioactive Waste Management Arrangements' (GNSL, 2020a). GNSL provided further information on the waste inventory derivation, within the 'Waste Inventory for Operational Solid Radioactive Waste' (GNSL, 2020b) and the 'Solid Radioactive Waste Management Technical Source Term' reports (GNSL, 2019a). We have assessed both these documents as part of our assessment of the inventory for the UK HPR1000.

For each waste stream GNSL has summarised:

- the type of waste
- its chemical and physical properties
- its radioactive waste classification (in accordance with the UK classifications for radioactive waste)
- the average and maximum activities of the wastes streams
- the annual and lifetime arisings
- whether there will be any hazardous materials associated with the waste
- the major radionuclides associated with the waste

The major classes of radioactive wastes that will arise during the operational phase of the reactor's life cycle will be very low level waste (VLLW), low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW). The HLW wastes that will originate from the UK HPR1000 will be the non-fuel core components (NFCCs) that originate from the reactor core. Our assessment of the inventory and management of these wastes is provided within sections 3.3 and 5.3.2.

LLW is waste which has an activity level equal to or less than 12 gigabecquerels per tonne (GBq/tonne) beta/gamma and 4GBq/tonne alpha. VLLW is a sub-category of LLW. The major VLLW/LLW streams which GNSL states will arise from the UK HPR1000 are (GNSL, 2020a):

- the steam generator blowdown systems resins, which arise from the purification of the blowdown from the steam generators
- concentrates which are produced from operation of the evaporators in the liquid waste treatment system
- sludges which accumulate within sumps and tanks of the auxiliary circuits and need to be washed out, for example, nuclear island vent and drain system and liquid waste treatment system
- ventilation filters from the heat and ventilation and air conditioning (HVAC) systems

- spent filters used within the auxiliary systems to protect the ion exchange resins, for example, within the spent fuel pool treatment system and the liquid waste treatment system
- dry active wastes, such as metals, combustible materials, personal protective equipment from everyday operations
- oil and solvents arising from maintenance operations and pumps

The projected annual volume of non-conditioned VLLW/LLW that will arise from the UK HPR1000 is approximately $198m^3$.

We raised a number of RQs to query GNSL's LLW inventory for the UK HPR1000.

We queried the OPEX that GNSL had used to derive the average number of filters that will arise from the UK HPR1000 (RQ-UKHPR1000-0776), because there was a series of step changes showing an increase in the number of filters used over a period from 2010 to 2013. We were uncertain of the reason for these step changes and also whether this has any impact on the estimated number of filters that will arise from the operation of the UK HPR1000. GNSL responded that the step changes in filter numbers were due to a change in strategy with regard to the use of pre-filters, and that it will be for a future operator to decide this for the UK HPR1000. GNSL also noted that the average number of filters estimated to arise from the UK HPR1000 has changed from 280 to 297 each year (due to a calculation error). GNSL's response also provided additional information demonstrating that the filter arisings from the UK HPR1000 are similar to other reactors which have been assessed via GDA. We are content with the response and that GNSL has updated the inventory.

We also raised RO-UK HPR1000-0036 and RQ-UK HPR1000-0514 to seek justification for the use of a cuboidal HEPA filter, which is the chosen filter type for the UK HPR1000 design, instead of the cylindrical filter which is currently seen as best practice within the UK (National Nuclear Ventilation Forum, 2018). A response to this RO is outstanding and we will assess the response as part of our ongoing assessment of the UK HPR1000. If the filter type is changed, we will expect the waste arisings to be optimised and an update of the waste inventory produced before the end of GDA. We have raised 'potential GDA Issue 3' within our BAT assessment report to ensure that GNSL does this (Environment Agency, 2021a).

A number of ILW streams will also arise as a result of operating the UK HPR1000. ILW wastes streams have an activity level greater than LLW. However, the heat output from these wastes is typically less than 2 kilowatt per cubic metre (kW/m^3) and, therefore, does not require specific management controls.

GNSL notes that the following ILW wastes streams will originate from the UK HPR1000 (GNSL, 2020a):

- ion exchange resins from the auxiliary systems, for example, the chemical volume control system and liquid waste treatment system
- concentrates which will be produced from operating the evaporators in the liquid waste treatment system
- sludges which will accumulate within the sumps and tanks of the auxiliary systems and will need to be washed out, for example, the liquid waste treatment system
- dry active wastes, such as metals, combustible wastes, personal protective equipment from everyday operations

GNSL notes that there is the potential for the low activity resins, which are normally LLW, to become ILW if there is a failure of a tube in the steam generator and activity can leak into the secondary circuit. However, GNSL has stated that the material selected for the construction of the steam generator (Nickel alloy 690TT) is highly resistant to corrosion (GNSL, 2019b), and therefore the risk of such an event is minimised SFAIRP. The possibility for low activity resins to be ILW is though considered in the design and relevant arrangements are in place to manage these safely and ensure environmental protection.

We summarise within Appendix 4 the nature and quantities of the operational wastes that will arise from the UK HPR1000, using information GNSL provided.

We raised a number of RQs in relation to our uncertainties in the information provided on operational waste arisings, in particular regarding the identification of the major radionuclides associated with LLW and ILW (RQ-UKHPR1000-0547 and RQ-UKHPR1000-0549). We noted within a number of the submission reports that the identification of the major radionuclides was inconsistent. GNSL has addressed our concerns within the recent submissions. We also requested further clarity on the criteria used to identify the major radionuclides. GNSL stated that the major radionuclides were identified using the principles set out within the ‘Solid Radioactive Waste Management Technical User Source Term Report’ (GNSL, 2019a) and are those radionuclides which contribute more than 10% of the total activity at creation (GNSL, 2020a). We are content that GNSL has addressed our query.

We also queried whether additional ILW wastes would arise from the fuel management route for the UK HPR1000 (RQ UKHPR1000-0553). The UK's radioactive waste inventory (NDA, 2019) noted that neutron absorber wastes originating from Sizewell B, the only operational PWR in the UK, could be ILW. GNSL's response provides us with confidence that no additional ILW will arise from the fuel route for the UK HPR1000.

As the Environment Agency, we are responsible for the protection of groundwater, under the Environmental Permitting Regulations (GB Parliament, 2016). The inventory for the UK HPR1000 highlights that carbon tetrachloride could be used in operating the UK HPR1000. GNSL stated that it will be for a future operator to decide what solvent is used and that this was just an example. This material is classified as a hazardous material according to the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) (WFDUK, 2018). Therefore, we requested further information from GNSL by raising RQ-UKHPR1000-0636, as to whether further hazardous materials and non-hazardous pollutants were present within the UK HPR1000 inventory. GNSL highlighted a number of non-hazardous pollutants within the inventory, such as nickel, cadmium, and antimony. We are satisfied that GNSL has assessed the inventory for hazardous materials and non-hazardous pollutants for this stage of GDA. However, a future operator will need to ensure that its radioactive wastes characterisation programme will take account of these pollutants. We note that this information will be required by disposal facility operators within the UK and to help compile the Nuclear Decommissioning Authority’s (NDA's) UK radioactive waste inventory. We have, therefore, raised the Assessment Finding below to ensure that this happens:

Assessment Finding 14: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants that will be associated with the waste inventory for the UK HPR1000.

We raised RQ UKHPR100-0548 to request information on the presence of complexants within the inventory. Complexants are chemical species that can enhance the permeation of radionuclides across both the engineered and natural barriers of a disposal facility. GNSL's response provides us with confidence that there are no significant concentrations of complexants within the inventory of the UK HPR1000.

From our findings within our initial assessment report, we requested that GNSL provide further information on the solid and non-aqueous waste inventory. GNSL has made significant progress in addressing this finding and we are confident that it will have done so by the end of GDA.

3.2. Decommissioning wastes

Currently, there are no reactors being decommissioned in China and, therefore, GNSL has had to develop a strategy and a plan for decommissioning the UK HPR1000 (GNSL, 2019c). GNSL has taken account of guidance from the International Atomic Energy Agency (IAEA) and other bodies as well as our regulatory guidance, legislation and national policy (IAEA, 2018a, 2016, 2008, GB Parliament 2016). To determine the preferred option for decommissioning the UK HPR1000, GNSL has carried out an optioneering exercise (GNSL, 2019c). This exercise assessed 3 strategies, which were thought to be viable for decommissioning the reactor. The strategies assessed were based on immediate and deferred decommissioning. GNSL identified immediate decommissioning as the preferred option for the UK HPR1000. This aligns with the UK government's policy for the decommissioning of nuclear new build (BERR, 2008). We note that a future operator may decide to use an alternative strategy for decommissioning the reactor.

A requirement for decommissioning the UK HPR1000 is that the generation of waste is either prevented or minimised. GNSL needs to demonstrate that decommissioning considerations have been integrated into the design of the reactor and that the waste management hierarchy has been applied and environmental protection has been optimised. Our assessment will discuss this in more detail within section 4.

GNSL has produced a Decommissioning Technical Source Term Report, which provides information on the decommissioning wastes streams (GNSL, 2020c). The decommissioning source term comprises:

- the activated structure source term: those components that will have been activated by irradiation and will be typically ILW in classification, such as, the reactor pressure vessel (RPV) and reactor vessel internals (RVI)
- the contamination source term: those structures, systems and components (SSCs) contaminated by activity migrating onto the surfaces and will be typically LLW

GNSL has also developed a Preliminary Decommissioning Plan for the UK HPR1000, based on technologies available today (GNSL, 2019c). Using the decommissioning plan for the UK HPR1000 and the derived decommissioning technical source term, GNSL has proposed a Decommissioning Waste Management Plan, which provides an initial decommissioning inventory for the UK HPR1000 (GNSL, 2020d) and summarises how these wastes could be managed.

The primary wastes that will be produced from decommissioning the reactor will be solid wastes. However, a small quantity of liquid and gaseous wastes, primarily from decontamination and dismantling processes, will also arise. These are out of scope for GDA. The largest volume of solid wastes will be non-radioactive and will be materials that can be recycled or reused. These wastes will be exempt from radioactive substances regulations. The largest volumes of radioactive decommissioning wastes are expected to be VLLW and LLW. Examples of these wastes are activated charcoal filter media, building materials such as concrete and auxiliary piping. GNSL states that a number of HAW streams will arise from decommissioning the UK HPR1000 such as reactor vessel internals, the reactor pressure vessel and concrete from the bio-shield.

GNSL currently estimates that the decommissioning radioactive raw waste volume for the UK HPR1000 will be approximately 12,280m^3.

A summary of the decommissioning wastes is presented within Appendix 5.

Our assessment of GNSL's waste management plan noted that the inventory was solely derived from the decommissioning of the reactor building. We queried (RQ-UKHPR1000-0647) whether any additional HAW would result from the decommissioning of other buildings on the nuclear island, such as the fuel and waste treatment buildings. GNSL's response provides us with confidence that no further HAW wastes will arise from the decommissioning of these buildings. GNSL has updated its supporting documents to reflect this information. However, we consider that during the operation of the UK HPR1000, there is the potential for other HAW streams to be identified. We will expect the future operator to ensure that any additional HAW streams are added to the waste management plan and are managed to meet with our regulatory regime at the time. Therefore, it is important that the future operator periodically reviews, and if necessary updates, the decommissioning waste management plan or an equivalent document.

We raised RQ-UKHPR1000-0775 to seek further information on the waste classification of evaporators at decommissioning and to understand whether these will need replacing during operations. GNSL clarified that the evaporators will be LLW and are not expected to need replacing over the 60-year lifetime.

We continue to assess whether the design of the UK HPR1000 has taken account of decommissioning. We do not expect this to impact on the decommissioning waste inventory significantly.

We are content that the method used to derive the decommissioning inventory for the UK HPR1000 is applicable for GDA. We also note that the major HAW streams are similar to those identified for other reactors in other GDA assessments.

3.3. Spent fuel and non-fuel core components (NFCCs)

Spent fuel is regarded as a waste within GDA, as currently there is no intention to reprocess the spent fuel from new nuclear reactors. This is consistent with the UK government's policy for new nuclear reactors as stated within the white paper (BERR, 2008). The production of spent fuel is an unavoidable consequence of operating a nuclear reactor.

GNSL has decided to use Framatome's AFA 3GAA fuel assembly. This is a uranium dioxide pellet fuel, based on modern engineering standards. The fuel is clad in a zirconia based alloy which has good resistance to both corrosion and mechanical deformation. The fuel assembly consists of 264 fuel rods, arranged in a 17 x 17 array (GNSL 2020e). Within a number of the assemblies, gadolinia (gadolinium oxide) is used as a burnable poison. We raised RQ-UKHPR1000-0739 to query the use of gadolinia and the impact this may have on the disposal of the spent fuel assemblies. We were content with GNSL’s response.

At equilibrium power generation the refuelling cycle for the reactor is assumed to be every 18 months, with typically 72 fuel assemblies being replaced every cycle. The burn-up rate of the fuel is typically 47 gigawatts-day per tonne of uranium (GWday/tU). The number of spent fuel assemblies (SFAs) that will be produced over a 60-year operational lifetime for the UK HPR1000 will be 2,985 (this is lower than for Hinkley Point C).

GNSL highlighted a number of NFCC wastes that will be produced over the operational period. These will be HLW and ILW wastes. The NFCCs that arise during the operational phase of the reactor will be (GNSL, 2019d):

- rod cluster control assemblies (RCCAs), which are either termed black or grey RCCAs and will contain either 24 or 8 control rods
- stationary core components assemblies (SCCAs), such as thimble plug assemblies, primary or secondary neutron sources
- in-core instrument assemblies (ICIAs), of which there are 3 types of monitoring instruments (type i, ii and iii)

Typically, about 1,145 NFCCs will be produced over the lifetime of the reactor. Further information is provided within Appendix 4.

An RO was raised on the management of ICIAs (RO-UKHPR1000-0037), to question whether the ICIAs can be decay stored to manage them as LLW, and also to question the management strategy for the ICIAs. Therefore, this RO could alter the classification of the ICIA wastes and alter the volumes for disposal to the LLW Repository and to a future GDF. This RO remains open and we will continue to assess impacts on the inventory as we progress through GDA. We will expect this to be accurately recorded in the wastes inventories and captured and agreed with RWM and the LLWR by the end of GDA. We have raised GDAI 5 to ensure this is done.

GNSL has also carried out an optioneering exercise to investigate whether the quantity of secondary neutron sources within the reactor core can be minimised or prevented. This could alter the volumes of stationary core component assemblies (SCCAs) used over the lifetime of the reactor. However, this will be a decision for the future operator to take. We have raised Assessment Finding 4 within our BAT assessment report to ensure that a future operator addresses this finding (Environment Agency 2021a).

4. Minimising solid radioactive waste and spent fuel

Our P&ID document (Environment Agency, 2016) and our REPs (Environment Agency, 2010) require GNSL to demonstrate that BAT has been applied and that the generation of wastes has either been prevented or minimised.

GNSL, via a series of claims, arguments and evidence, has argued that the design and operation of the UK HPR1000 reactor will be optimised with regard to BAT and the minimisation of radioactive wastes (GNSL, 2020f). Our review of these arguments and the supporting evidence will be discussed in detail within our BAT assessment report (Environment Agency, 2021a). However, within this report we provide a summary of how GNSL has applied BAT to minimise the production of solid wastes, follow the waste management hierarchy and protect the environment.

The amount of activity present and its behaviour within the primary circuit will have a significant influence on the production of solid radioactive waste. Therefore, minimising the activity circulating around the primary circuit will reduce the volume of solid wastes arising from the UK HPR1000. GNSL has made a series of arguments to support its sub-claim 4.1.EC03.1 ‘Prevent and minimise the creation of radioactive waste’ (GNSL, 2020f), and sub-claim 4.1 EC03.4 ‘Minimise the mass/volume of solid and non-aqueous wastes and spent fuel’ (GNSL, 2020f). We provide below a summary of the evidence which GNSL provides to support these claims.

4.1. Fuel design, manufacture and operation

As evidence to support its argument 4.1.EC03.1-A1 ‘Minimising the concentration of fission products in the primary coolant by the design, manufacture and management of the fuel', GNSL stated that the AFA 3GAA fuel is an advanced engineered fuel. The design of this fuel has taken account of many decades of operational experience and therefore the risks from fuel failures, during operation of the reactor, has been minimised. We note that the fuel design has incorporated several new design features to minimise the risk of failures (GNSL, 2020f, Framatome, 2019a). The new features, which have been incorporated into the design, are the addition of a 3mm mesh to the lower strut of the fuel assembly (Framatome, 2019b), low relaxation springs and a greater contact area (GNSL, 2020f) and concave dishes at the end of the rods and chamfered edges (GNSL, 2020f).

In addition to the design of the fuel, GNSL highlighted within its submission a number of improvements to the fuel manufacturing process. For example, using a water box and a blowing station to minimise the presence of zirconium chips on the external surfaces of the fuel cladding. In addition, as part of the improvements to the manufacturing process, GNSL stated that there have been improvements to the testing arrangements and quality assurance procedures to help reduce the potential for fuel failures (Framatome, 2019c).

The cladding on the AFA 3GAA fuel is a highly resistant Zircaloy, which GNSL has demonstrated has superior resistance to corrosion (Framatome, 2019a).

ONR has raised RO-UKHPR1000-0015 to question the impact of fuel crud on the risk of fuel failures. This RO is currently open and we will continue to assess it as part of our ongoing assessment as this may potentially impact on our preliminary conclusions, and potentially lead to an increase in fuel arisings if not adequately controlled.

In support of Argument E4.1.EC03.1-A2 'Minimising the concentration of fission products by detection and management of failed fuel', GNSL stated that identifying and managing failed fuel will minimise the generation of solid waste. The UK HPR1000 has two systems for in-process sampling and monitoring of failed fuel during normal operations, one being the nuclear sampling system (NSS) and the second being the plant radiation monitoring system (PRMS). It also has two systems for detecting failed fuel during unloading, one being an online system located on the refuelling machine and the second an offline system within the spent fuel pool. Managing failed fuel within the reactor and within the spent fuel pond is within the GDA scope. We support the early detection of failed fuel and its future management (GNSL, 2020f).

In support of the argument E4.1.EC03.1-A3 'Minimising the quantity of spent fuel by core dimension design and cycle length selection', GNSL has assessed the impact of the core dimensions and fuel cycles on the use of fuel. It has demonstrated that the amount of fuel used per unit of power production is less for the UK HPR1000 than an equivalent Chinese reactor, such as the CPR1000. GNSL has identified an 18-month equilibrium fuel cycle as the optimum for fuel efficiency for the UK HPR1000 (GNSL, 2019g). Therefore, the use of fuel within the reactor has been optimised. However, a future operator may decide to use a different refuelling cycle duration and, if so, would need to demonstrate that the waste management arrangements in place are adequate. We have raised Assessment Finding 11 within our BAT assessment report to ensure that a future operator addresses this finding (Environment Agency, 2021a).

We have assessed the evidence GNSL has provided to demonstrate that the modifications to the fuel design, manufacturing processes, the detection of failed fuel and the core dimensions and fuel cycle are optimised and will minimise solid wastes. We are content from an environmental perspective at this stage of GDA, however we will assess the outputs from RO-UKHPR1000-0015 and any future reports on the improvements to the fuel design before the end of GDA.

4.2. Corrosions control (Chemistry)

GNSL argued that control of the primary coolant chemistry is a crucial enabler in minimising the generation of solid radioactive waste across the life cycle of the reactor (Argument 4.1.EC03.1-A5 'Minimising the activity of waste by optimising the water chemistry of the primary coolant') (GNSL, 2020f). Controlling the chemistry of the coolant will minimise the generation of corrosion and activation products, as well as minimise the production of waste from the maintenance SSCs. The main controls on the coolant properties are (GNSL, 2020h, 2020i):

- pH
- hydrogen concentration
- hydrazine (added at start up to scavenge for oxygen)
- other impurities
- zinc concentration

ONR has raised a number of RQs in relation to the primary circuit chemistry, which may have impacts on the amount of solid wastes produced, in particular with regard to zinc addition (RQ-UKHPR1000-0488, RQ-UKHPR1000-0489, RQ-UKHPR1000-0701 and RQ-UKHPR1000-0702), pH control (RQ-UKHPR1000-0704)), hydrogen addition (RQ-UKHPR1000-0697)) and the control of impurities (RQ-UKHPR1000-0490). GNSL's responses to these queries has led to an update of the 'Demonstration of BAT' document, but has had no impact on our preliminary conclusions (GNSL, 2020f). We will continue to engage with ONR regarding the control of the coolant chemistry to ensure that there are no significant impacts on solid waste generation and changes to the coolant chemistry for the UK HPR1000.

RO-UKHPR1000-0031 has been raised to query control of boron in the primary coolant. Boron is added to the coolant to control the reactivity in the core. Lithium is added to balance the pH of the coolant. Note that as boron contributes to the control of reactivity and is important to safety, the outcome of this RO is unlikely to impact on our preliminary conclusions so far. This RO remains open and we will continue to monitor it as we progress with our assessment of the UK HPR1000.

4.3. Corrosion control (Material selection)

In addition to controlling the water chemistry, GNSL argues that the choice of material for the SSCs within the UK HPR1000 is important in minimising the quantity of solid waste that will be produced (Argument 4.1.EC03.1-A6 'Minimise corrosion products and activated structure and component through material selection') (GNSL, 2020f). The choice of material will be important for minimising both operational and decommissioning wastes from the reactor. A number of RQs have been raised with regard to material selection and understanding the impacts on the generation of solid wastes (RQ-UK HPR1000-016, RQ-UK HPR1000-0210, RQ-UK HPR1000-0696). GNSL highlights that the extent to which materials are activated and their resistance to corrosion are important in minimising and preventing the generation of radioactive wastes. GNSL has provided a number of examples where changes to the materials used in the construction of the UK HPR1000 will reduce the quantity of solid wastes, for example, reducing the use of silver coated seal gaskets within the primary circuit. Removing silver will reduce the concentration of silver-110m within the primary circuit. GNSL has also eliminated antimony from components within the primary circuit (except for secondary neutron sources) and minimised the amount of cobalt within materials. Reducing the concentrations in the primary circuit of species capable of being activated in the neutron flux of the core will reduce the quantity of these radionuclides within the solid wastes. A number of RQs have been raised with regard to material selection, in particular in relation to cobalt. We are satisfied from the response that the amount of cobalt within the construction materials for the UK HPR1000 has been minimised.

GNSL proposes to use corrosion resistant materials for the construction of the SSCs in the primary circuit. This will lead to a reduction in the concentration of corrosion products that will circulate within the primary coolant and deposit on other surfaces. For example, GNSL proposes to use a thermally treated Ni alloy 690TT as the construction material for the steam generators (GNSL, 2019b).

4.4. Building layout

GNSL has provided evidence to support argument 4.1EC03.4-A1 ‘Minimise the volume of structures, systems and components that will become radioactive waste’, in particular the plans to use radiation and contamination zoning and to optimise the building layout to minimise the generation of solid radioactive wastes. Radiation/contamination zoning involves zoning the buildings within the nuclear island into designated and undesignated areas. Designated areas are divided into supervised and controlled areas. Supervised areas are those areas where the contamination level is lower than 0.4 becquerels per square centimetre (Bq/cm^2), whereas controlled areas can have a contamination level greater than $0.4Bq/cm^2$. By keeping areas, such as the operator control rooms, outside the controlled areas, the amount of wastes resulting from the potential spread of contamination can be minimised. The engineering and management controls that will be in place will also minimise the amount of solid waste that could be produced.

GNSL has provided information with regard to building layout and how the close proximity of certain buildings to each other will lead to a reduction in the quantity of solid wastes. For example, the waste treatment building will be close to the buildings where the waste will be generated, therefore minimising the distance over which wastes may have to be pumped or transferred. In addition, the close proximity of the buildings will lead to a reduction in the amount of piping and concrete that will be used.

GNSL has demonstrated that it has rationalised the number of SSCs within the design for the UK HPR1000 over the previous CPR1000 design, leading to a reduction in plant and equipment that requires disposal following maintenance or decommissioning (GNSL, 2020f).

4.5. Maintenance and life cycle

In supporting its argument 4.1EC03.4-A2 ‘Minimise the volume of solid radioactive wastes by extending the design life of SSC and reusing maintenance equipment and tools’, GNSL states how it has optimised the lifetime of a number of components within the primary circuit and the auxiliary circuits, which treat the primary coolant and liquid wastes. Therefore, a future operator will not need to replace these components as often. For example, the filters and the demineralisers within the auxiliary systems are protected from high pressure and temperature by cut-offs, so that neither of the components will be damaged. In addition, the demineralisers and filters that will be used on the UK HPR1000 are more efficient than those used on the CPR1000 reactors (GNSL, 2020f).

GNSL also highlighted that within the reactor the tools and equipment that will be used for maintenance operations will be kept within the controlled area and will be reused whenever possible.

Argument 4.1EC03.4-A3 ‘Reducing the volume of solid waste and non-aqueous liquid waste requiring disposal by adopting efficient segregation, treatment techniques and container selection’, will be discussed in sections 5.2.3 of our report.

4.6. Decommissioning

The claims, arguments and evidence that GNSL presents apply equally to decommissioning wastes as to operational wastes. The vast majority of the decommissioning wastes that will arise from the UK HPR1000 will be solid wastes. Only a small fraction will be gases and liquids (which are out of scope of GDA).

GNSL has evaluated the UK HPR1000 design in order to demonstrate that the reactor design has taken account of decommissioning and, where possible, that the design will lead to the prevention or minimisation of wastes (GNSL, 2020j). For example, material selection, design layout, control of activation and waste management.

At the time of writing, we are content that GNSL has provided a reasonable overview of how the design of the UK HPR1000 will reduce the quantity of solid wastes during decommissioning. However, we will continue to assess this area as part of our ongoing assessment. ONR is also currently assessing the design of the UK HPR1000 and how the design has taken account of decommissioning. Although we expect minimum change to the solid waste inventory, we will continue to engage with ONR with regard to this area.

During decommissioning, a future operator will need to ensure that the generation of secondary wastes from such activities as decontamination and dismantling will be minimised. Decontamination can play an important role in reducing the quantity of solid wastes or can change the categorisation of the wastes. GNSL has made best use of the OPEX available internationally to understand how decontamination could be applied to the UK HPR1000 (GNSL, 2020k, 2020l). GNSL states that periodic decontamination, during the operational phase of the UK HPR1000, of the primary and auxiliary circuits could lead to a reduction in the volumes of solid waste. However, it also states that this will a decision for a future operator to make and decide if this will be BAT, as a number of factors will need to be considered before making the decision. These include factors such as secondary waste generation, effluent treatment and dose to workers. We will expect a future operator to assess this opportunity and to demonstrate that the chosen option represents BAT. We have raised the following Assessment Finding to ensure that this takes place:

Assessment Finding 15: A future operator shall assess whether there are benefits in periodic decontamination of the UK HPR1000 primary circuit and its related systems and auxiliary circuits with regard to minimising production of decommissioning wastes and their classification. The future operator should demonstrate that BAT is being applied.

We note that before dismantling the reactor GNSL proposes, as part of the decommissioning plan, to decontaminate the primary circuit. GNSL plans to use CORD D UV as the preferred decontaminating agent for the primary circuit (GNSL, 2020l). We raised RQ-UK HPR1000-0648, as we noted that other decontamination agents could result in higher decontamination factors. GNSL responded by highlighting the advantages and disadvantages for each of the processes. It was evident from the information it provided that the advantages in using CORD D UV far outweighed those of other decontamination agents. In addition, to support its choice, GNSL provided additional OPEX where CORD D UV has been applied on a nuclear power plant in Germany to decontaminate SSCs. Therefore, the arguments GNSL presented justify the selection of CORD D UV, however the final decision will be for a future operator to take.

Over the lifetime of the reactor, we acknowledge that the techniques for decontaminating and dismantling the UK HPR1000 reactor will improve. There will also be extensive international experience from the decommissioning of a number of PWRs from around the world, as they reach the end of their lifetime. A future operator will continue to develop the decommissioning plan for the UK HPR1000 over its operational period, and should make use of this international experience to ensure BAT is applied and that the decommissioning wastes will be minimised. We raised the following Assessment Finding to ensure that a future operator does so:

Assessment Finding 16: A future operator shall ensure that the decommissioning plan is periodically reviewed to ensure that BAT is being applied with regard to decommissioning the UK HPR1000.

5. Managing solid wastes and non-aqueous wastes

Our interests in the waste management practices selected is to ensure that waste:

- is sorted and segregated
- maintained within the principle of 'concentrate and contain'
- can be appropriately characterised and packaged
- and upstream practices do not affect disposability

The regulatory regimes in China and the UK are different and there are differences in the approaches to managing solid and non-aqueous radioactive wastes. In addition, the reference plant for the UK HPR1000 has been designed to meet Chinese requirements. An RO and several RQs were raised to question what gaps exist between the different approaches, within the UK and China, for managing the radioactive wastes that will arise from the UK HPR1000 (RO-UKHPR1000-005, RQ-HPR1000- 0044 and RQ-UKHPR1000-0107 RQ-UKHPR1000-0141). GNSL's response indicated the following gaps:

- treatment of ion exchange resins
- dry active waste segregation and treatment process
- oils and organic solvents treatment process
- low activity spent resins and ventilation filter cartridges management process
- management of RCCAs, SCCAs and ICIAs
- ILW waste shielding container
- ILW/LLW waste storage areas

To address the above gaps, GNSL carried out an optioneering exercise to identify the preferred options for treating solid and non-aqueous waste (GNSL, 2020m). A similar exercise was also carried out to identify the preferred options for managing the non-fuel core components (NFCCs) (GNSL, 2019d). We will discuss the NFCCs optioneering exercise in section 5.3.2 of this assessment report.

We raised RQ-UKHPR1000-0434 to request further information from GNSL as to how its optioneering exercises aligned with its 'Requirements on Optioneering and Decision Making Methodology' (GNSL, 2018a). GNSL's response clarified the alignment of the solid waste optioneering report with its method, and we are content with the response.

GNSL's solid waste optioneering exercise assessed both pre-treatment and the main treatment options for 13 solid and non-aqueous waste streams. The pre-treatment options were only evaluated at a high level and it will be for a future site operator to decide which pre-treatment process will be applied to each waste stream.

GNSL identified 4 high level options for treating the operational solid wastes that will arise from the UK HPR1000. These were: thermal (for example, incineration), chemical (for example, wet oxidation), physical (for example, super-compaction) and conditioning (for example, grout encapsulation). Within each of these options a number of techniques were identified and it was these techniques that GNSL screened to identify the main options. The first step in the process involved pre-screening the techniques to obtain a shortlist, which could be taken forward. The shortlist was based on 2 criteria, one being whether the techniques could be used within the UK, and the second whether the technology was established. The latter used the Nuclear Decommissioning Authority's (NDA's) Technical Readiness Level (TRL) assessment process (NDA, 2014b). GNSL subsequently carried out a multi-attribute decision analysis (MADA) against a series of criteria, of which environment was one. The environmental criteria assessed were consistent with the waste hierarchy, conditioned waste volume, secondary waste generation and resource use. GNSL then held a workshop, consisting of a number of experts, to identify the preferred technology for each waste stream. We have assessed the solid waste optioneering report and are content with GNSL's approach. The preferred options are summarised within Appendix 4 under 'waste management route'. A future operator may decide to use a different treatment option for the wastes streams, however we will expect the operator to demonstrate that the chosen option will still represent BAT.

We will discuss the options chosen in the subsequent sections of our assessment report.

5.1. Managing and disposing of lower activity waste (LAW)

LAW comprises solid wastes with a classification of low level waste (LLW) and very low level waste (VLLW). LLW is where the activity content is equal to or less than 12GBq/tonne beta/gamma and 4GBq/tonne alpha. VLLW is a sub category of LLW and, therefore, will be accounted for within this section. For this GDA, the UK's LLW Repository in Cumbria is the preferred option for the treatment and final disposal of all LAW that arise from the UK HPR1000 reactor. However, we will expect a future operator to take account of the proximity principle when deciding where best to treat or dispose of its LAW and we raised Assessment Finding 2 to ensure this takes place (Environment Agency, 2021b).

Our P&ID document requires GNSL to demonstrate that LAW arisings from the UK HPR1000 can be treated and disposed of via the routes available within the UK (Environment Agency, 2016). This will ensure that no low activity problematic wastes will arise from the UK HPR1000. The LAW that will arise from the UK HPR1000 are summarised within GNSL's submission (GNSL, 2020a).

Within GNSL's PCER submission on the 'Demonstration of BAT', it makes the sub-claim that solid wastes and non-aqueous wastes should be minimised (Sub-claim 4.1EC03.4) (GNSL, 2020f). GNSL argues that by applying efficient segregation, treatment techniques and selecting the containers, the conditioning of LAW can be optimised.

As part of the design of the UK HPR1000, GNSL identifies that the waste auxiliary building will be the main building for segregating, treating and conditioning LAW on a site. However, some streams such as sludges and concentrates will be conditioned within the waste treatment building. The waste auxiliary building is part of the solid waste treatment system. The building contains a sorting box, a pre-compactor, roller conveyors, grouting facility, drum dryer and inspection devices for processing wastes. GNSL will be providing further information in the future in relation to the design and layout of the waste auxiliary building within the report ‘Conceptual Proposal of Waste Auxiliary Building’, which we will assess as part of our ongoing assessment. However, we note that this building is currently out of scope for GDA.

GNSL highlights a number of examples to demonstrate that LAW can be segregated and that the quantity of waste that will be disposed of will be optimised. For example, by using different processing tanks within the solid waste treatment system, the low activity resins can be kept separate from the processing of the ILW resins, therefore ensuring that the waste disposal routes are optimised. We raised RQ-UKHPR1000-0551 to request further information with regard to processing the low activity resins through the solid waste treatment system. GNSL provided this information, which gave us confidence that the wastes will be segregated from the processing of the ILW resins. A further example is where GNSL proposes to segregate the dry active wastes arising from the UK HPR1000 into those wastes requiring metal melting, incineration, compaction or disposal.

We note that for the treatment of LLW sludges and concentrates, GNSL proposes to encapsulate these wastes. We have raised RQ-UKHPR1000-0992 to challenge why GNSL has identified encapsulation as the preferred technology for these wastes, noting that incineration could possibly be applied and would lead to a smaller volume of waste for disposal. This RQ remains open and we will assess GNSL's response as part of our ongoing assessment, as the conditioning route and the final volume of waste requiring disposal could change our preliminary conclusions.

As evidence to support the argument 4.1EC03.5-A2, ‘All solid and non-aqueous liquid lower activity wastes have been demonstrated to be compatible with waste treatment and disposal services available in the UK by obtaining an agreement in principle with the service provider’ (GNSL, 2020f), GNSL has sought an agreement in principle from LLWR Ltd with regard to its plans to condition and dispose of LAW arisings from the UK HPR1000. Currently, these wastes are not part of LLWR's derived future disposal inventory and a future operator will need to engage with LLWR Ltd before consigning these wastes to the repository to ensure that capacity is available.

GNSL has obtained an agreement in principle from LLWR Ltd with regard to accepting the LAW arisings from the UK HPR1000 (LLWR Ltd, 2020a). However, LLWR Ltd has raised a number of points where further information will be required from a future operator (LLWR Ltd, 2020a) such as:

- the direct disposal of spent resins if incineration was not an option
- metal wastes and if direct disposal would be required, and the potential impact of these being discrete items
- filter cartridges and the potential for these items to be discrete items
- sludges and meeting the waste acceptance criteria (WAC) and discrete item limit

In response to LLWR Ltd's agreement in principle, GNSL has addressed each of the points raised to demonstrate that a future operator should be able to address them (GNSL, 2020n).

We have assessed both the agreement in principle from LLWR Ltd and GNSL's response and we have no reason to believe that a future operator could not address the points LLWR Ltd raised if the LLW Repository was the chosen destination for the wastes. Consequently, we see no reason why the LAW wastes arising from the UK HPR1000 will not be disposable. However, we note that RQ-UKHPR1000-0992 challenges GNSL's approach to the treatment of LAW condensates and sludges and could potentially impact on our preliminary conclusions. A future operator will need to ensure that the proposed approaches will be BAT nearer the time of disposal and meet with our requirements and those of the disposal operator.

For decommissioning LLW and VLLW, GNSL has estimated the volumes of wastes that will arise from decommissioning the UK HPR1000 reactor (see Appendix 5). GNSL proposes to use the same facilities for treating low level decommissioning waste as for operational wastes, where possible. However, for GDA, GNSL is not required to seek disposal advice from LLWR Ltd for the treatment and disposal of decommissioning LLW, as it is currently out of scope. We have written an Assessment Finding to ensure that a future operator will engage with the operator for the disposal facility:

Assessment Finding 17: A future operator shall review periodically the options for the treatment and disposal of solid low level waste from the operation and decommissioning of the UK HPR1000. The future operator shall ensure that the options implemented are BAT and will meet the disposal facilities waste acceptance criteria.

5.2. Managing higher activity waste (HAW)

The higher activity waste (HAW) arisings from the operation and decommissioning of the UK HPR1000 reactor will be ILW, HLW and spent fuel. Currently, the UK has no disposal route for HAW and is in the process of engaging with communities across England and Wales with regard to the siting of a geological disposal facility (GDF). Therefore, at present all HAW is stored within well-engineered stores on nuclear licensed sites, pending disposal to a GDF.

5.2.1. Joint guidance on managing higher activity wastes

The regulators' (Environment Agency, the Office of Nuclear Regulation, Natural Resources Wales and the Scottish Environment Protection Agency) expectations with regard to the management of HAW is stipulated within our 'Joint guidance on the management of HAW' (Office for Nuclear Regulation et al, 2015). This guidance provides an overview of our expectations with regard to the characterisation, segregation, conditioning, packaging, storage and disposal of HAW. It also highlights our expectations with regard to records and knowledge management. A main requirement of the joint guidance is for a future licensee to produce a Radioactive Waste Management Case (RWMC). An RWMC provides various stakeholders with an overall view of how a licensee plans to manage its HAW and achieve the main elements of long-term safety and environmental protection.

The main purpose of an RWMC is to demonstrate:

- compliance with regulatory requirements
- compliance with national policy for radioactive waste management
- consistency with national and international standards of radioactive waste management
- how interdependencies are taken into account in all the steps in generating and subsequently managing radioactive waste

For GDA, we expect GNSL to produce an RWMC that covers its arrangements for managing all HAW arisings from the UK HPR1000.

GNSL has produced 2 RWMCs, one detailing the arrangements for managing the ILW arising from the UK HPR1000 (GNSL, 2020o), while the second highlights the arrangements for HLW (GNSL, 2020p). GNSL's RWMCs provide a reasonable summary of its current proposals for managing the wastes across the life cycle. Currently a major gap within the RWMCs is the disposability advice from Radioactive Waste Management

Ltd (RWM) and how GNSL plans to address any action points RWM raised in its assessment. We will expect this information to be added to the RWMCs before the end of GDA.

GNSL has demonstrated how the RMWC addresses our expectations within the joint guidance by mapping the sections of the RWMC to the relevant parts of the guidance. Therefore, we see no reason why GNSL cannot provide an RWMC, which will address our expectations by the end of GDA, so long as it addresses the actions with regard to RWM disposability advice and the relevant ROs with regard to managing HAW, which are currently open. The RWMCs should also provide a future operator with a good foundation on which to further build the HAW arrangements for the UK HPR1000. A future operator should continue to update the RMWCs, as and when required, in accordance with our joint guidance. We have raised an Assessment Finding to ensure that a future operator will do this:

Assessment Finding 18: A future operator shall periodically update the Radioactive Waste Management Case or equivalent documentation in accordance with the Environment Agency's and ONR's joint guidance, in order to demonstrate that the higher activity waste is being managed across the whole life cycle.

5.2.2. Managing operational and decommissioning HAW wastes

For the UK HPR1000, GNSL plans to process the operational HAW solids through the solid waste treatment system. Within this system, the solid wastes will be characterised, segregated, conditioned and stored (GNSL, 2020a). The operations performed by the solid waste treatment system occur within a number of buildings within the nuclear island. These are:

- the nuclear auxiliary building, which contains 2 holding tanks, where the resins are held before being transferred to the radioactive waste treatment building for conditioning. It also contains the spent filter cartridge system for changing the spent filters for a number of auxiliary systems
- the radioactive waste treatment building, which contains 2 tanks for holding the resins before loading them into a container. The building also contains the metering tanks which are used to consign a specific volume of concentrate into a drum for encapsulation. It also contains the spent filter replacement, transfer and retrieval device
- the ILW interim store where the waste will be stored long term until a GDF is available

Ion exchange resins, spent filters, sludges, concentrates and ILW dry active wastes will be processed through the solid waste treatment system. ICIAs will also be processed via this route, however we will discuss this within section 5.3.2 of this report.

Decommissioning wastes with similar characteristics to the operational solid wastes are likely to be processed through the solid waste treatment system. However, in some cases, the system may have to be modified, so that the decommissioning wastes can be processed. Additional facilities may also be required to characterise, segregate and condition the decommissioning wastes.

We have assessed the current system design manuals for the solid waste treatment system, which GNSL has provided as part its GDA submission. However, we note that there may be further updates to the current system before the end of GDA, and we will assess these as part of our ongoing assessment.

5.2.3. Characterisation and segregation

To meet our expectations, it is essential that GNSL can demonstrate that characterisation and segregation of the wastes is possible for the UK HPR1000. GNSL has provided an overview of the processes and locations for sampling solid radioactive wastes for the UK HPR1000 (GNSL, 2020q). GNSL provided further supporting information within the solid waste treatment system design manuals.

Grab sampling is one of the main techniques used for sampling HAW solids, such as ion exchange resins, condensates and sludges. Subsequent characterisation of these solids within a laboratory will provide the relevant information to facilitate the disposal of these wastes, such as the physical and chemical composition, activity and the radionuclides present. GNSL has not provided any details with regard to the specific characterisation techniques that it will use, as this will be a decision for a future operator to take.

In addition to grab sampling, GNSL will use dose measurements and scaling factors as methods to characterise the solid wastes, such as spent filters and ILW dry active wastes.

The information provided gives us confidence that the sampling of the solid wastes will be feasible for the UK HPR1000. However, we have written an Assessment Finding to ensure that a future operator will further develop its characterisation strategy and sampling approach for solid wastes, within the detailed design stage, to ensure that the approach will be BAT.

Assessment Finding 19: A future operator shall develop its characterisation strategy and approach to segregation for solid and non-aqueous wastes further at the detailed design stage, to ensure that it can demonstrate that BAT is being applied.

GNSL argues that to reduce the mass/volume of solid waste that needs disposal, efficient segregation will be essential (GNSL, 2020f).

Segregation of the UK HPR1000 HAW wastes will be achieved by separating the different classification of wastes when they are generated or by processing the different wastes via different routes, which have been incorporated into the design of the UK HPR1000. GNSL provides several examples of this, such as:

- the different treatment routes for ILW resins and LLW resins
- the different treatment routes for HAW sludges from LLW sludges
- the segregation of ILW dry active wastes at source from the LLW dry active wastes

We are confident that the design of the UK HPR1000 and the approach to sampling and characterisation will allow a future operator to perform effective characterisation and segregation of the solid wastes.

With regard to decommissioning wastes, GNSL has reviewed the relevant standards and guidance relating to decommissioning, for example, International Atomic Energy Agency (IAEA) guidance (IAEA, 2018). GNSL acknowledges the importance of characterisation and segregation in minimising the volumes of radioactive waste produced during decommissioning and in maximising the amount of solid waste that can be recycled or reused. Within GNSL's decommissioning plan we note that it is intended for a future operator to carry out a full characterisation survey of the UK HPR1000 reactor and licensed site before decommissioning. This will allow a future operator to better define its waste management strategy for decommissioning wastes and its decommissioning plan (GNSL, 2019c). GNSL has made best use of the operating experience (OPEX) available internationally to identify the technologies that could be used today to decommission the UK HPR1000. This OPEX provides further evidence to demonstrate that a future operator can use effective segregation during decommissioning to optimise the use of the UK's disposal capacity. For example, by using scabbling technologies to remove the highly active concrete layer from the bulk concrete, a future operator can minimise the volume of HAW that will be disposed of to a future GDF.

We are content that GNSL has demonstrated the importance of characterisation and segregation both during operations and decommissioning. We are content that the design of the UK HPR1000 can allow for effective characterisation and segregation and will allow a future operator to effectively use the waste management hierarchy and to minimise the volume and activity of waste generated during decommissioning. However, a future operator will need to further develop the characterisation and segregation strategies and processes to ensure that the techniques and approaches that will be applied will be BAT. We have raised Assessment Finding 19 to ensure that an operator does this.

5.2.4. Packaging and conditioning

GNSL has carried out an optioneering exercise to assess a range of potential technologies to treat the HAW that will arise from the UK HPR1000 reactor (GNSL, 2020m). We discussed the process that GNSL used at the beginning of section 5 of this report. GNSL has also carried out an optioneering exercise to identify the preferred option for the containers in which the wastes will be packaged (GNSL, 2020r).

GNSL has selected dewatering of the ion exchange resins within a 500L robust shielded container as the preferred option for processing HAW ion exchange resins. A number of RQs have been raised to request further information from GNSL with regard to processing ILW resins (RQ-UKHPR1000-0047 and RQ-UKHPR1000-0799). The resins will be dried, so that the residual water content within a container will be less than 1%. This approach, has been used at Sizewell B and several Magnox stations, as well as internationally. Using this approach to treat HAW ILW resins does not rule out any future conditioning options, as the resins can be easily retrieved. For example, if thermal treatment were to be developed within the UK, then the resins could be retrieved and thermally treated. We are content that GNSL's approach to the packaging and conditioning of ILW resins is likely to lead to a disposable product.

GNSL has identified the preferred option for conditioning and packaging the spent filters as grout encapsulation within a $3m^3$ box. GNSL has demonstrated, via the packaging optioneering study, that using a $3m^3$ box will allow the consignment of the maximum number of filters per package and, therefore, will minimise the overall volume of conditioned waste packages. We are content with the proposed approach for conditioning and packaging of spent filters.

For a number of ILW streams, GNSL has identified a number of potential boundary wastes that could be decay stored to become LLW. We raised RQ UKHPR1000-0141 to gain a better understanding of what boundary wastes could arise from the operation of the UK HPR1000 and how these may be managed. GNSL states that there is the potential for ILW concentrates, sludges and dry active to wastes to be decay stored to LLW. We see decay storage as an effective method for managing HAW and for optimising the disposal route for these wastes.

Intermediate level dry active wastes will be identified when they are generated and will be packaged into a shielded 210L with a shielded cask (if necessary) drum before being transferred to the ILW interim store for decay storage. It will take approximately 2 years for these wastes to decay to LLW (GNSL, 2020a) and GNSL has provided evidence to support this. Once decayed, the wastes will be transferred to the waste auxiliary building and will subsequently follow the same waste management routes as for low level dry active wastes. This primarily would be to send the wastes offsite for treatment and disposal at the UK LLW Repository.

GNSL proposes to decay store ILW concentrates and sludges. GNSL's favoured strategy is to encapsulate the ILW sludges and concentrates into a passive form within a 210L drum and then transfer the drums to the ILW interim store to decay. GNSL provided us with further information on the processing of concentrates via the solid waste treatment system via RQ-UKHPR1000-0411. GNSL has derived a series of curves for the decay of sludges and concentrates from ILW to LLW and it will take approximately 16.5 and 7.5 years respectively. We raised a RQ-UKHPR1000-0740 to request further information on these decay curves and whether the average or maximum activities of these wastes had been used to derive the decay curves. GNSL's response stated that the maximum activity values had been used and that this will provide a degree of conservatism with regard to the decay times. We accepted GNSL’s response. Once these wastes have decayed they will be disposed of to a LLW facility.

We note that if the ILW encapsulated sludges and concentrates did not decay sufficiently to LLW, then these drums will have to be disposed of to a GDF. The 210L drum is not an acceptable package for a GDF, based on RWM waste package specifications. A future operator would need to engage with RWM to determine if it was plausible to entomb the 210L drums within a compliant package for a GDF.

GNSL has sought disposal advice from RWM with regard to the encapsulation of ILW sludges and concentrates in a 500L drum. A future operator will have an alternative strategy that it can implement if it does not think that the decay strategy is justifiable. Currently, RWM is assessing this option. However, we will expect a future operator to demonstrate that BAT is still being applied if these wastes are diverted to a GDF.

It will be for a future operator to determine the final strategy for managing the ILW concentrates and sludges. We are content, at the time of writing this report, that GNSL has demonstrated 2 likely options for the disposal of these wastes. A future operator will have to demonstrate that the chosen option will be BAT. ONR are continuing to assess this area as part of their ongoing assessment, which may impact on our conclusions.

GNSL has identified the preferred options for the conditioning and packaging of the ILW decommissioning wastes that will arise from the UK HPR1000 (GNSL, 2020d). The preferred options identified are that the reactor pressure vessel (RPV) will be grouted within a 4m box, the reactor vessel internals (RVIs) will be grouted within a 3m^3 box, and the activated concrete will be grouted in a 4m box. Ion exchange resins and spent filters are to be conditioned and packaged using the same processes as identified for the same wastes produced during the operational phase of the life cycle.

GNSL has claimed that there is the potential for ILW/LLW boundary decommissioning ion exchange resins to be generated during decommissioning. GNSL plans to grout and decay store these resins until they are LLW. We raised RQ-UK-HPR1000-0870 to query this approach, as we noted that the preferred option for treating operational LLW ion exchange resins is incineration and that grout encapsulation of ILW ion exchange resins, produced during the operational phase, was deemed unacceptable. GNSL responded that the resins will need to be stored in a passively safe form while they decay to LLW, and will therefore need to be grouted. In addition, GNSL highlighted that the resins will not contain boron and therefore should be compatible with the grouting process. We will expect a future operator to demonstrate that the approach for managing boundary decommissioning resins will be BAT nearer the time of disposal, as there may be the option to minimise the volume of wastes that will be disposed of to a LLW facility.

GNSL has proposed that the RPV is segmented into a number of sections and grouted into a 4m box. Our assessment noted that within one box approximately only 15% of the volume of the waste container will be taken up by the actual waste. We requested further information from GNSL as to whether (RQ-UK-HPR1000-0648) other RWM compliant waste packages would result in a more efficient packaging of the waste. We also noted that, for the other reactors that have been assessed via GDA, such as the ABWR, a 3m^3 box was the preferred option for packaging the RPVs (GNSL RQ-UKHPR1000-0648).

GNSL argued that the number of cuts should be minimised due to ALARP considerations, and therefore the 4m box was the best option for packaging this waste. However, we agreed with GNSL that a future operator will need to assess whether other packages offer a better balance between ALARP and BAT, and therefore will allow for a better package efficiency and potentially a lower overall volume of waste. A future operator will need to consider this nearer the time for decommissioning the RPV.

We are content that the preferred options chosen by GNSL should lead to disposable packages. However, we note that, in a few cases, a future operator will need to demonstrate that the options proposed by GNSL will be BAT, especially for the decommissioning wastes. We have written an Assessment Finding to ensure that a future operator will look to demonstrate that the options chosen for packaging and the conditioning of the HAW will still be BAT:

Assessment Finding 20: A future operator shall ensure that the proposed conditioning and packaging options for the higher activity wastes for the operational and decommissioning waste arisings from the UK HPR1000 are BAT.

5.2.5. Interim storage of operational and decommissioning HAW

In England, the Office for Nuclear Regulation (ONR) is the lead regulator for the accumulation of wastes on a nuclear licensed site. However, our REPs, RSMDP 10 and 11 indicate that operators should be able to demonstrate that the conditions of the actual store and the packages within it will be maintained (Environment Agency, 2010). Our REPs also indicate that the packages should be able to be inspected and monitored during the storage period to ensure that they remain disposable in the future.

GNSL has considered international and UK guidance to develop its conceptual design for storing ILW, for the UK HPR1000. We note that GNSL has made use of the guidance to industry on the interim storage of higher activity wastes (NDA, 2017a). GNSL has also used our Joint Guidance (Office of Nuclear Regulation, Environment Agency and others, 2015) to understand our expectations with regard to the storage of HAW. A future operator will be expected to provide further information at the detailed design stage.

As the UK does not currently have a GDF, waste packages will be stored on site within environmentally controlled engineered stores. GNSL proposes to store the waste packages on site for at least 100 years (GNSL, 2020a).

GNSL has carried out a series of optioneering studies to assess the construction of the store, the stacking arrangement within the store and the type of storage area for the packages, such as shielded shaft or a vault. As part of the optioneering process, GNSL has considered the impact on the environment as one of the assessment criteria. GNSL has proposed, as the preferred option, that an ILW interim store will be constructed in 2 phases, and that the packages will be stacked vertically within the vaults within the store (GNSL, 2019e).

As part of the assessment, ONR has raised the following RQs (RQ-UKHPR1000-0046, RQ-UK-HPR1000-0477 and RQ-UK-HPR1000-0507) and RO (RO-UKHPR1000-0040). We have provided input into the RO from an environmental perspective. The Regulatory Observation still remains open at the time of writing.

GNSL argues that the 2-phased approach in constructing the stores will ensure that a future operator can make best use of the learning from the design and operation of the first store. This approach appears reasonable, in ensuring that BAT will be applied at all times across the lifetime of the stores. However, ONR has requested further information, via RO-UKHPR1000-0040, with regard to the safety justification for this 2-phased approach, and that a balanced approach has been used to arrive at this decision. We will take into consideration the response to this RO with regard to the 2-phase construction and whether there are any implications with regard to BAT and the disposal of the wastes.

We also raised RQ-UKHPR1000-0740 to query how the rate of arisings of the wastes will be taken into account when deciding when to construct the second phase of the store. We were content with GNSL's response that this will be for a future operator to decide.

GNSL has proposed that the first phase of the ILW interim store will accommodate the solid radioactive waste arisings from the first 30 years of operation of 2 UK HPR1000 reactor units. However, ONR noted that this does not taken into account any waste from accidents or any foreseeable incidents. It was also noted that GNSL stated a contingency with regard to the storage capacity for the interim stores, but did not substantiate this. Further information was requested from GNSL with regard to the capacity of the stores. We expect that all wastes can be stored under the appropriate conditions to ensure that they will be disposable. We have an interest in GNSL's response and will continue to monitor the outcomes of the RO as part of our ongoing assessment.

GNSL indicates that there will be different storage locations for shielded containers, unshielded drums and 3m^3 unshielded boxes. GNSL proposes to store the packages in a vertical array and within storage vaults. ONR has requested further information with regard to the design of the store and how the available OPEX has been used to attain the conceptual design.

GNSL proposes that the packages will be inspected in-situ, using a camera attached to the vault crane. The vertical stacking array will help this form of inspection. GNSL also proposes to have a maintenance area within the store, which will allow for packages to be inspected in greater detail, and for any maintenance of the packages to be carried out. However, there is limited information with regard to the inspection of the store itself. RO-UKHPR1000-0040 requests further information on the monitoring and inspection of packages and of the store. This will help ensure that people and the environment will continue to be protected. We will expect GNSL to provide this information before the end of GDA.

GNSL states that within the store that there will be a holding area for packages which either are, or have become, non-compliant during the storage period. The maintenance cell will be used to repair these packages. We note that a future operator will need to develop its arrangements for identifying and managing these non-compliant packages within the store to ensure that they will be disposable in the future.

Assessment Finding 21: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal will be transferred to a GDF.

There will also be a measurement cell within the store for measuring the gamma radiation, surface dose rate and contamination levels from the packages.

We are confident that, if GNSL can address the actions within RO-UKHPR1000-0040, an interim store can be constructed which will maintain the packages in a condition that will meet our regulatory expectations around the storage of radioactive waste and can be disposed of in the future to a GDF. We will continue to monitor GNSL's progress against the actions within RO-UKHPR1000-040 and engage with ONR as part of our ongoing assessment of the UK HPR1000.

5.3. Managing spent fuel and non-fuel core components (NFCCs)

5.3.1. Spent fuel

We expect GNSL to demonstrate that it has a credible strategy for managing spent fuel and that BAT will be applied to achieve this. GNSL will need to demonstrate that fuel can be managed in an environmentally safe way and that disposal of the fuel to a future disposal facility will be possible.

We provided GNSL with our expectations regarding managing spent fuel (Office of Nuclear Regulation and Environment Agency, 2018). These were:

- the feasibility that a preferred option can be implemented with regard to the management of spent fuel
- a proportionate evaluation of the generic design to determine the environmental impact from discharges and disposal from the associate facilities, and that BAT can be demonstrated
- feasibility of managing the fuel through its life cycle and not ruling out disposal options
- the options chosen should not constrain a future operator from taking a different decision with regard to managing the spent fuel

GNSL's fuel management strategy requires the spent fuel assemblies (SFAs) to be stored within the spent fuel pool for a short period, typically between 5 and 10 years, followed by interim storage for a period up to 100 years. After the interim storage period, a future operator will begin transferring the SFAs to a GDF (GNSL, 2020a, 2020s).

The condition of the water within the spent fuel pool is maintained by the fuel pool cooling and treatment systems. This system controls the chemistry and temperature and provides a sub-critical margin within the spent fuel pool (GNSL, 2018b). The treatment of the pool water during the storage of the spent fuel assemblies will produce a number of HAW waste streams. These will be predominantly spent filters and ion exchange resins.

The temperature of the spent fuel pond during operations will be kept below 50^{o}C, which is the normal operating limit (GNSL, 2020t). The heating of the pool water will result in gaseous discharges and these will be treated by the HVAC system within the fuel building, therefore protecting the environment. This will be discussed within our BAT and discharges assessment reports.

GNSL has carried out an optioneering exercise to identify the preferred option for the interim storage of the SFAs (GNSL, 2019f). Two options were assessed, one being wet storage of the spent fuel within a pool, while the second was dry storage within a metal canister/concrete silo arrangement. The optioneering exercise considered the protection of the environment, in particular criteria such as waste generation and discharges. Dry storage within a metal canister/concrete silo was identified, by GNSL, as the preferred option.

A future operator may decide to use a different approach to manage spent fuel, however we would expect the operator to demonstrate that the approach is BAT.

The UK's experience of dry fuel storage is limited to Sizewell B. However, Hinkley Point C power plant will also use dry storage for spent fuel. We note that there is extensive international experience with regard to the dry storage of spent fuel, and we will expect a future operator to learn from the available OPEX when operating the SFIS for the UK HPR1000. We discuss this within section 5.6 of this report.

In order for the spent fuel to be transferred from the spent fuel pool to the SFIS, the fuel must be dried. This minimises the risk of corrosion during the interim storage period, and will reduce the amount of gas that will be generated from the hydrolysis of water. GNSL has provided limited information on the drying process, as this depends on the chosen design of the spent fuel storage canister. The drying process involves vacuum drying the assemblies, followed by purging the spent fuel/canister arrangement with an inert gas such as helium (GNSL, 2020w). We requested further information from GNSL on what level of dryness will be required before the SFAs can be transferred to the SFIS for long-term storage (RQ-UKHPR1000-0741). GNSL responded by stating that the degree of dryness depends on the canister design chosen. Currently this is acceptable for GDA as we agreed that specific suppliers/vendors do not need to be identified at this stage. We will expect a future operator to apply BAT when drying the SFAs and to specify the drying limits at the detailed design stage. We have raised the following Assessment Finding to ensure that a future operator does so:

Assessment Finding 22: A future operator shall ensure that it deploys BAT for the conditioning of the spent fuel, prior to transferring the spent fuel assemblies to the spent fuel interim store.

The SFIS design is at the conceptual level for GDA and will be further developed by the future operator at the site-specific stage. GNSL proposes to construct the SFIS in 2 phases, with the first phase accommodating the spent fuel, HLW ICIA arisings from the first 30 years of operation (GNSL, 2020u, 2020v). A second store will accommodate the arisings from the next 30 years of operation plus potentially some decommissioning wastes. GNSL argues that the 2 phase construction will allow a future operator to apply the learning from the first store to the design and operation of a second store. We accept that the 2 stage construction will allow for BAT to be applied and learning across the storage of the fuel. This approach will allow a future operator to take account of any learning and technical developments to ensure that BAT will be applied to the second phase of the SFIS construction.

GNSL states that the SFAs will be stored within the SFIS for a period of up to 100 years. We expect GNSL to demonstrate that the SFIS design and operating conditions will maintain the integrity of the spent fuel for that period and will minimise the risk of fuel clad failures during storage. This will ensure that the disposal options for the spent fuel will not be foreclosed. GNSL has based the conceptual design and operating limits for the SFIS on the best available OPEX and publicly available information (GNSL, 2020u, 2020v, 2020s). GNSL sees the proposed conceptual design as a bounding case for the storage of the spent fuel, as the properties of the spent AFA 3GAA fuel are typical of the fuels that are dry stored around the world. However, at this stage of our assessment, GNSL has not provided us with any information with regard to the requirements for the long-term storage of the AFA 3GAA fuel. Consequently, we have not been able to assess whether the proposed conceptual design and conditions will ensure the long-term storage of the AFA 3GAA fuel. GNSL plans to provide this information before the end of GDA, which we will assess to ensure that the conceptual design will meet the long-term storage requirements and ensure that the fuel can be transferred to a disposal canister in the future. To ensure this information is provided we have written a potential GDAI:

Potential GDA Issue 4: GNSL is required to provide information in relation to the long-term storage requirements for the spent fuel and to demonstrate that the conceptual design for spent fuel interim store (SFIS) will deliver these requirements.

In addition to the storage conditions of the fuel, the condition of the storage canister is important in maintaining the integrity of the SFAs. The canister's integrity will ensure that the inert conditions within the canister will be maintained and that there will be no release of radioactive material into the environment. GNSL states that a breach in the integrity of the fuel cladding can be monitored by measuring the temperature of the cooling air from the concrete silo where the storage canister is kept. We raised a RQ (RQ-UKHPR000-0741) to seek further information on this approach. GNSL's response highlighted that modelling has been used to demonstrate that when the temperature of the silo is within the design limits, the storage system is performing as expected. If a breach in the fuel cladding were to occur, the temperature of air exiting the silo would rise, indicating a potential issue with the fuel or canister.

We noted from our assessment that this was the only technique that GNSL proposed to use to assess the integrity of the fuel and canister. We are aware that visual inspection of the canister within the silo is possible at Sizewell B, but has not currently been used. Therefore, we raised RQ-UKHPR1000-0741 to request further information on whether visual inspection of the canister was possible. GNSL's response reassured us that there was the potential to visually inspect the canister if needed, however that this will depend on the final canister/silo design chosen. This will be addressed by a future operator at the detailed design stage.

We will expect a future operator to demonstrate that BAT is being applied with regards to the monitoring and inspection of the canister during the storage period. This will ensure that the SFA's integrity is maintained and that the assemblies can be retrieved, in the future, and transferred to a disposal container. We have raised the following Assessment Finding to ensure that that a future operator does this:

Assessment Finding 23: A future operator shall ensure that the monitoring and inspection of the spent fuel assemblies and canister, within the spent fuel interim store are BAT.

We also sought clarification from GNSL of its statement that the chlorine content of the concrete silos will not be monitored. GNSL's response highlights that, from the available OPEX, these measurements are not routinely taken by other operators. A future operator should continue to assess whether this is BAT over the lifetime of the storage of the spent fuel.

We note that for the AFA 3GAA fuel, GNSL states that the number of fuel failures that will occur will be low. There are currently 5 failed fuel storage locations within the spent fuel pool (GNSL 2020t).

We raised RQ-UKHPR1000-0635 to gain a better understanding of the management of failed fuel, in particular with regard to its management within the spent fuel pool. The RQ also requested additional information with regard to GNSL's current understanding of being able to transfer failed fuels to the SFIS. We wanted to ensure that the strategy in place for the UK HPR1000 would not rule out any disposal options for the failed fuel assemblies. We also requested additional information on whether the current strategy for managing failed fuels would increase the volume of solid wastes and whether RWM's disposability assessment will take account of failed fuels.

GNSL's proposed strategy for managing failed fuel is to store it within the spent fuel pool for the operational phase of the life cycle, and to remove it into the SFIS before decommissioning the spent fuel pool. The strategy chosen by GNSL is currently applied at other reactors within the UK and internationally.

GNSL highlighted a number of options that a future operator could be develop to transfer the failed fuel from the spent fuel pool to the SFIS. GNSL also highlighted that there would be a vast knowledge base available to a future operator on how to manage failed fuels, as more PWRs are decommissioned around the world. We support GNSL's use of international OPEX on how to manage failed fuels. However, we will expect a future operator to demonstrate that the current strategy for managing failed fuels for the UK HPR1000 will be BAT. We wrote the following Assessment Finding:

Assessment Finding 24: A future operator shall ensure that the strategy for managing failed fuel over the life time of the UK HPR1000 is BAT.

RWM will not provide separate advice on the disposability of failed fuels. However, we understand that RWM's current assessment of spent fuels will bound the disposal of failed fuels. We are content that the management strategy for failed fuels at present would not appear to rule out any options for the disposal of failed fuel assemblies.

5.3.2. Non-fuel core components (NFCCs)

The NFCCs inventory has been described within section 2 of this report. GNSL has carried out an optioneering exercise to identify the lead options for treating and packaging the NFCCs (GNSL, 2019d).

For managing the rod cluster control assemblies (RCCAs) and stationary core component assemblies (SCCAs), GNSL has chosen to store and dispose of these wastes together as an integral part of the spent fuel assembly (SFA). GNSL's approach is the same as that proposed for conditioning and packaging the spent fuel assemblies.

RQ-UKHPR1000-0405 was raised to request further information on the characterisation and storage of the RCCAs and SCCAs within the spent fuel pool. GNSL's response highlights that the RCCAs and SCCAs will not be characterised and that their activities will be calculated theoretically. The activities of these wastes are provided within the 'Activated Structure Supporting Report'. (GNSL, 2020x).

Degradation of the RCCAs and SCCAs within the spent fuel pool is unlikely as GNSL states that the chemistry of the spent fuel pool will be closely controlled and therefore minimise the risk from corrosion. GNSL does not plan to inspect the RCCAs and SCCAs within the spent fuel pool, and from the information GNSL provided, with regard to corrosion of the RCCAs and SCCAs, it would appear that this is not required from a disposal perspective.

RQ-UKHPR1000-0664 was raised to gain further information about GNSL's proposed management of the SCCAs and RCCAs. Information was requested with regard to whether there would be sufficient capacity at the refuelling stage to accommodate the RCCAs and SCCAs. GNSL's strategy is to store the RCCAs and SCCAs together as an integral part of the SFAs. GNSL's response highlights that over a 10-year cycle the number of RCCAs and SCCAs that will be produced will be approximately 180 compared with 720 SFAs. Therefore, storing the RCCAs and SCCAs together within the pool should not present a challenge to a future operator.

The RQ queried whether the presence of the RCCAs and SCCAs within the SFAs would impact on the drying process and whether they were susceptible to degradation. GNSL's response notes that the RCCAs and SCCAs are an integral part of the SFA and will not be subject to degradation by mechanical means. GNSL also argues that once the SFAs are placed within the canister, the canister will be vacuum dried and then helium filled to prevent corrosion in an inert atmosphere. We accept, from GNSL's response, that the likelihood of corrosion of the RCCAs and SCCAs is low. GNSL's response also stated that for each canister the number of SCCAs and RCCAs compared with the number of SFAs will be relatively small and therefore should not impact on the drying process.

The information GNSL provided with regard to the conditioning, packaging and storage of the RCCAs and SCCAs, to ensure that the wastes can be retrieved for disposal, appears reasonable. We note that ONR is currently assessing this subject and could identify issues with regard to the storage of these wastes from a safety perspective that could impact on our preliminary conclusions. We will continue to engage with ONR as part of our ongoing assessment.

There are 3 types of in core instrument assemblies (ICIAs) that are used within the UK HPR1000 core. These are types i, ii and iii, which we have discussed previously within section 2.

GNSL carried out an optioneering exercise to identify the preferred option for the conditioning and packaging ICIAs. The preferred option involves a number of steps:

- placing a shielded winding machine on top of the reactor pressure vessel
- cutting the section of the ICIA residing out with the core as this will be conditioned as LLW for metal recycling
- using the shielded winding machine to extract the remainder of the ICIA from within the core
- placing the wound ICIA within a robust shielded container containing additional internal stainless steel shielding (approximately 150mm thickness)
- transfer the type iii ICIAs to the ILW interim storage before consigning to a GDF. Transfer the type i and ii ICIAs to the SFIS to decay storage to ILW before transferring to the ILW interim store

RO-UKHPR1000-0037 questions the waste classification that has been applied to the ICIAs and whether a portion of the ICIAs could in theory be decay stored to allow optimised disposal. The RO also requested that GNSL demonstrate that the chosen option for managing ICIAs represents good practice. This RO currently remains open and we will assess GNSL's response as part of our ongoing assessment.

In addition, the winding machine that will be used to retrieve the ICIAs has only been used in China and Russia. Currently, there is no UK OPEX with regard to using this technology. ONR is currently assessing the safety implications of this device and its use within the UK HPR1000, which could impact on the management of the ICIAs.

Both ONR's assessment and the outcome of the RO may potentially impact on the strategy for managing the ICIAs and their subsequent disposal. We note that if the waste classification of the wastes were to change, then this could impact on the volumes of ICIAs that will be disposed of as LLW and HAW. We understand from GNSL that LLWR Ltd's acceptance in principle will cover the disposal of the ICIAs as LLW. A change in the strategy could potentially impact on the RWM disposability assessment and therefore, we will continue to engage with ONR and monitor the progress of the RO, as part of our ongoing assessment, as described in the potential GDAI below:

Potential GDA Issue 5: GNSL is required to provide further substantiation of the proposed strategy for the management of in-core instrument assemblies (ICIAs) and if any changes to the strategy is decided, to assess the impact on the disposal of ICIA wastes.

5.4. Disposal of HAW and spent fuel and NFCCs

5.4.1. RWM's disposability assessment process

We expect GNSL to obtain a view from RWM on the disposability of HAW (Environment Agency, 2016). We also expect GNSL to consider the points raised by RWM from its assessment and to respond to any advice RWM provided. Our P&ID document requires GNSL to identify a credible route for the disposal of the HAW arisings from the UK HPR1000.

The overall objective of the disposability assessment process is to provide confidence that the conditioning and packaging of the HAW and spent fuel from the UK HPR1000 will meet with RWM's current generic safety case for a GDF. Site operators seek advice from RWM with regard to their proposals for conditioning and packaging the wastes. RWM carries out a comprehensive disposability assessment to assess whether the proposals are acceptable.

The RWM disposability assessment process has 3 main stages which a future operator will progress through to gain a letter of compliance (LoC) (NDA, 2014a). An LoC demonstrates that the licensee's proposal is compliant with the current generic design of a GDF and its safety cases.

RWM's process for assessing the HAW arisings from the UK HPR1000 is very similar to that performed at the siting stage. The 3 main parts of the assessment process are:

- phase 1: technical evaluation which assesses the waste package data, nature and quantities of the wastes and the wasteform properties
- phase 2: design impact evaluations where the GDF design impact and waste package properties are assessed
- phase 3: safety and environmental assessments where the transport, operational and post closure safety is assessed as well as environmental considerations

A future operator will be able to build on the GDA disposability assessment if it chooses to implement the waste management proposals put forward by GNSL.

5.4.2. Disposability assessment

GNSL has argued that disposability assessments have been carried out to demonstrate that all solid HAW are compatible with disposability concepts prepared by RWM for a GDF (argument 4.1.EC035-A3) (Environment Agency, 2020f).

GNSL has sought advice on the following wastes:

Waste stream	Waste classification	Container
Spent resins	ILW	500L robust shielded drum
Spent filter cartridges	ILW	Grout in $3m^3$ box
Concentrates	ILW	Grouted in 500L drum
Sludges	ILW	Grouted in 500L drum
Reactor pressure vessel	ILW	Grouted 4m box
Reactor pressure vessel internals	ILW	Grouted in $3m^3$ box
Decommissioning concrete	ILW	Grouted in 4m box
ICIAs	ILW	500L robust shielded drum with additional internal stainless steel shielding (150mm thickness)
Spent fuel	HLW	Spent fuel disposal container
RCCAs	HLW	Spent fuel disposal container
SCCAs	HLW	Spent fuel disposal container

The ILW sludges and concentrates are identified as potential ILW/LLW boundary wastes which could be disposed of to the LLW repository. However, obtaining disposability advice from RWM will ensure that a future operator has the information that it can build on if it were to decide decay strategy was not plausible. We have discussed this previously within section 5.2.4.

During the GDA assessment, GNSL made the decision to switch from Step 12 fuel to AFA 3GAA fuel produced by Framatome. In addition, RWM has requested additional data from GNSL so that it can carry out the disposability assessment. Both factors have substantially impacted on the disposability assessment programme. We noted that there was the potential risk of GNSL not having sufficient disposability advice by the targeted end of GDA. We raised RO-UKHPR1000-0041 to ensure that GNSL's plans were realistic and that all potential options were being pursued to ensure that the disposability assessment would be completed in good time.

RO-UKHPR1000-0041 requested that GNSL provide us with:

- an updated disposability submission
- an updated delivery plan
- updates on a regular basis
- a disposability assessment report to give us enough information to support our consultation
- a final disposability assessment report and the updated documentation by the end of GDA

GNSL has now submitted all the relevant information on the UK HPR1000 HAW and spent fuel to RWM (GNSL, 2020y). We have reviewed GNSL's submission as part of our assessment.

We note that RWM is assessing the ILW wastes and the spent fuel and NFCCs separately due to the delay in the fuel and NFCCs information. We support this approach as this will allow GNSL to progress with the outcomes from RWM's assessment of the ILW at the earliest opportunity.

We requested, via RO-UK HPR1000-041, that GNSL provide us with an up to-date plan, highlighting how it plans to carry out the disposability assessment and update the relevant supporting documents before the end of GDA. GNSL's updated plan provides us with confidence that the disposability assessment and the supporting documents will be updated by the end of GDA.

GNSL has provided us with an update on the current progress of RWM's disposability assessment (GNSL, 2020z, 2020aa). RWM has completed phase 1, phase 2 (see section 5.4.1 above) and the impact of disposal on human health and the natural environment for the ILW wastes and no issues have been identified. We note that a potential issue may arise in relation to the decommissioning wastes and the decay storage period before the wastes are transferred to a GDF. However, this issue is not unique to the UK HPR1000 and has been identified for other reactors' wastes that have assessed through GDA.

For the spent fuel and NFCCs, phase 1 and phase 2 have been completed, with no issues having currently been identified.

In a number of cases, we note that the waste and packaging is very similar to that used by other operators in the UK, such as the packaging of resins within robust shielded drums. We also note that for other GDAs the packaging of RPV and RVI is similar, and we would expect that these wastes will be disposable subject to assessment by RWM. However, we note that, in some cases, there is limited UK experience of the wastes being packaged and conditioned, using the approach proposed by GNSL.

We note that the addition of zinc to the coolant could impact on the encapsulation of wastes arising from the UK HPR1000. We have raised an RQ-HPR1000-0991 to request further information on the potential impact of zinc addition and on the grouting of wastes.

We also note that GNSL has begun an optioneering exercise to assess whether the use of secondary neutron sources could be minimised or even avoided for the UK HPR1000. GNSL has assessed several options, which a future operator will need to obtain OPEX specific to the UK HPR1000 before making a final decision on which option represents BAT. The impacts on disposability are limited or are actually positive as the number of secondary neutron sources to dispose of will increase very slightly or more likely will be less than the current estimate and should not therefore raise any significant concerns.

RWM's disposability assessment should be completed by the targeted end of GDA should provide us with confidence that the HAW arisings from the UK HRP1000 will be disposable. We have identified this as a potential GDAI, as we could not issue a statement of design acceptability (SoDA) without evidence that the ILW and spent fuel will be disposable. However, should RO-UK HPR1000-041 be closed before the end of GDA, this potential GDAI will cease to be an issue.

Potential GDA Issue 6: GNSL is required to demonstrate that all higher activity waste (HAW) arisings from the UK HPR1000 will be disposable.

5.5. Managing records and knowledge

Our REPs (Environment Agency, 2010) and Joint guidance on higher activity wastes (Office of Nuclear Regulation et al, 2015) provides our expectations with regard to managing records and knowledge.

GNSL indicates that a considerable amount of information associated with waste records will need to be managed and stored during the operational and decommissioning phases of the reactor's life cycle. A future operator will need to maintain these records to ensure that the wastes arising from the UK HRP1000 will be disposable.

GNSL provided an overview of how it proposes to manage its records through its Management and Safety and Quality Assurance (MSQA) arrangements, which will be handed over to a future operator. However, it will be for a future operator to develop the specific systems and processes for managing waste package records. GNSL provided a general overview of what information is likely to be retained as part of waste records, but this is not comprehensive. A future operator will need to engage with the operators of the disposal facilities to ensure that their requirements are captured for both LAW and HAW records. We have raised the following Assessment Finding to ensure that a future operator does this:

Assessment Finding 25: A future operator shall engage with the operators of the disposal facilities to ensure that their requirements are complied with for both low activity wastes' and higher activity wastes' records.

As we previously mentioned within section 5.3.1, the UK has limited experience with regard to the dry storage of spent fuel and, in particular, its long-term storage. This is currently limited to Sizewell B, but with Hinkley Point C opting for dry storage of spent fuel as its preferred option, this knowledge base will grow in the future. We note that GNSL is aware of the significant international experience in relation to the dry storage of spent fuel, and we will expect a future operator to continue to make use of this knowledge base and learn from it during the operational lifetime of the UK HPR1000. This will ensure that any issues that could impact on the disposal of spent fuel can be captured at the earliest opportunity. We wrote an Assessment Finding to ensure this will happen:

Assessment Finding 26: A future operator shall continue to secure international OPEX with regard to the dry storage of spent fuels and ensure that it applies learning from the international OPEX to the storage of the UK HPR1000 fuel arisings.

GNSL highlighted the importance of retaining records and knowledge that arises during the operation of the UK HPR1000 to optimise the decommissioning of the UK HPR1000 reactor. GNSL has provided an overview as to what records and knowledge should be considered and why they are needed. Some examples are to:

- support safe decommissioning
- determine the most cost effective means to decommission the UK HPR1000
- identify and assess risk and focus on the high risk areas
- protect the environment and execute an effect remediation plan
- preserve important information when implementing a deferred strategy

GNSL is aware of various decommissioning knowledge management repositories that exist internationally, which could also be used by a future operator. These repositories of information will ensure that a future operator can demonstrate that BAT is being applied to the decommissioning of the reactor. We support GNSL's proposals to develop and make use of such repositories, in order to support and optimise the decommissioning of the UK HPR1000. Therefore, we have raised the following Assessment Finding to ensure that the future operator undertakes does this:

Assessment Finding 27: A future operator shall secure and use OPEX, including that available internationally, to ensure that BAT is used to decommission the UK HPR1000 and that the generation of radioactive solid waste is minimised and it is capable of being disposed of.

6. Compliance with Environment Agency requirements for GDA

Requirements from P&ID and REPs	Comments
P&ID Items 3	We are content that GNSL has identified the main plants and systems that will be involved in the treatment of solid and non-aqueous wastes and spent fuel.
P&ID Item 4	We are content that GNSL has addressed this item for the majority of waste streams. However, there is a potential GDAI that will need to be closed before the end of GDA. A number of Assessment Findings have also been raised, which a future operator will need to address.
P&ID Item 5	We are content that GNSL has addressed this item for the majority of wastes streams. We note that the GDAI on ICIAs may change the volumes of wastes destined for the LLW repository and GDF. However, this should be addressed before the end of GDA.
P&ID Item 6	We are content that GNSL has addressed this item, but a future operator will need to identify the techniques it will apply.
Principle RSMDP3 - Use BAT to minimise waste	GNSL has demonstrated that BAT has been incorporated into the UK HPR1000 design for a number of waste streams. However, this will continue to be assessed as a number of ROs and RQs are still outstanding, which have challenged GNSL to demonstrate that the design is fully optimised. We are confident that these will be addressed by the end of GDA. With regard to decommissioning, GNSL has used the best available OPEX to demonstrate that the UK HPR1000 can be decommissioned. However, we are continuing to evaluate the design to ensure that decommissioning has been taken into account and will not lead to additional wastes. We will continue to assess, but are confident that GNSL will be able to demonstrate that BAT has been incorporated into the design before the end of GDA.
RSMDP8 Segregating waste	GNSL has demonstrated that the design of the UK HPR1000 will allow wastes streams to be segregated, to optimise the disposal routes and minimise the generation of radioactive wastes. GNSL has indicated that different routes will be used for processing LLW and HAW within the solid waste treatment system and the 'PCER Chapter 4 Radioactive Waste Management Arrangements'. Further information will be needed for the detailed design stage. However, we are content that for GDA, GNSL has met our expectations for segregating waste. With regard to decommissioning, GNSL has demonstrated that segregating wastes is crucial in ensuring that

Requirements from P&ID and REPs	Comments
	decommissioning wastes are managed appropriately, particularly in segregating non-radioactive wastes from radioactive.
RSMDP9 characterisation	GNSL has highlighted, at a high level, the sampling and characterisation of solid waste that can be performed on the UK HPR1000. However, we note that potential future technologies could be developed, and therefore it will be for a future operator to decide on the actual technologies that will be applied.
RSMDP11 storage	The proposed storage practices are outlined within the PCER and PCSR and the supporting documentation. Multi-layered containment of the solid wastes has been demonstrated to be part of the design. However, GNSL needs to provide further information on the interim storage of ILW wastes, such as the nature of the wastes that will be stored, the capacity of the store and the monitoring and inspection arrangements, to fully address our expectations. The evidence to support the claim that the AFA 3GAA spent fuel can be stored over the 100-year period within the conceptual design for the SFIS has yet to be fully demonstrated. However, we are confident that this will be achieved before the end of GDA.
RSMDP15 Requirements and conditions for disposing of wastes	GNSL has obtained disposal advice from LLWR Ltd, and we are content that LLW arisings from the UK HPR1000 will be disposable. We have had limited information in relation to RWM's disposability assessment of GNSL's proposals for the disposal of HAW and spent fuel arisings from the UK HPR1000. A GDAI has been raised, however we expect GNSL to address this by the end of GDA.
DEDP1 Decommissioning strategy	GNSL has produced a decommissioning strategy that highlights how the UK HPR1000 will be decommissioned. This will be through immediate dismantling, which aligns with the UK government's guidance. We are content that GNSL has taken account of DEDP1 in the design of the UK HPR1000.
DEDP 2 Decommissioning plan	GNSL has produced a preliminary plan as to how and when the UK HPR10000 will be decommissioned. However, we note that an update to this plan will be produced before the end of GDA. We do not expect this to impact on the waste management and disposal of the wastes. We are awaiting disposal advice from RWM with regard to the decommissioning wastes.
DEDP 3 Considering decommissioning during design and operation	GNSL has produced the document 'The consistency and Evaluation for Facilitating Decommissioning', which provides us with a good overview as to how the design of the UK HPR1000 has taken account of decommissioning. We are continuing to review this and the link to other documentation

Requirements from P&ID and REPs	Comments
	such as the OPEX. We do not expect this to have a significant impact on the decommissioning wastes that will arise from the UK HPR1000.

7. Public comments

Up to 30 June 2020, GNSL had received 5 public comments relating to managing solid radioactive wastes, decommissioning and the disposal of spent fuel.

On 28 November 2017, GNSL received a comment from the public with regard to the dry storage of spent fuel and its comparison with wet storage. GNSL responded by highlighting that, at this early stage in GDA, the options for storing spent fuel were still being considered. A full assessment of the dry and wet storage options would be developed, using the technical experience available from CGN and EDF as well as the OPEX available internationally. GNSL also stated that the SFIS design will have to demonstrate that BAT and ALARP requirements are being met. As part of our assessment, we note that GNSL has carried out an optioneering exercise to identify the preferred option for storing spent fuel. GNSL has considered both wet and dry storage options as part of this exercise. The optioneering study has assessed the options against criteria such as technical, safety environmental and economic. Dry storage of spent fuel was identified as the preferred option for the interim storage of SFAs. We are content with the optioneering process that GNSL has carried out. The comment also queried the wastes that will be produced for the transfer of the spent fuel to a disposal canister for dry storage. For both dry and wet storage of spent fuel, a future operator will have to transfer the SFAs to an appropriate facility to be packaged into a disposal canister. However, GNSL has not ruled out the option that the storage canister itself could potentially be disposable. A future operator will need to seek advice from RWM with regard to this option. The specific design of the spent fuel canister that will be used to store the spent fuel within the SFIS will not be chosen until the detailed design stage. There are a number of queries within this public comment for consideration by the ONR, as the competent authority for transport and safety, will need to address.

On 28 November 2017, GNSL received a comment with regard to the radioactive waste and BAT. GNSL's response states that BAT is not part of the Chinese regulatory system. We have assessed GNSL's approach to managing radioactive waste, and we are content that it is applying BAT. We would ensure, through our permitting process, that a future operator demonstrates BAT.

On 31 August 2018, GNSL received a comment with regard to the storage of radioactive waste and spent fuel on a site and the availability of a GDF. The comment also questioned the decommissioning strategy for the UK HPR1000 and the timescales for decommissioning. GNSL responded by stating that its submission was at the early stage of step 2 and that it would provide further information as part of the ongoing development of its submissions, as they progressed through GDA.

Radioactive Waste Management Ltd (RWM) is the organisation responsible for implementing a geological disposal facility (GDF) and understanding the waste inventory for a GDF. RWM has derived an inventory for disposal to a UK GDF. RWM's current inventory assumes that a GDF will need to accommodate the wastes from a new build programme of 6 UK EPR reactors and 6 AP1000 reactors, generating a total of 16GW of power. RWM will continue to develop its inventory and therefore will include the UK HPR1000 inventory at the appropriate time. As for transferring wastes from the site to a GDF, this will depend on the availability of the GDF. If the GDF is not available, regulators would require the operator to store the wastes in a way that continues to be safe and protects the environment.

GNSL states that with regard to decommissioning and the storage of spent fuel, this is part of another government process, known as the Funding Decommissioning Programme. GNSL needs to put forward a decommissioning plan and the funds for decommissioning and storing fuel for the UK HPR1000. This is a legally binding requirement for any new nuclear reactor being built within the UK. GNSL has carried out an optioneering exercise to determine the preferred option for decommissioning the UK HPR1000 and immediate dismantling has been chosen. GNSL has also demonstrated that the UK HPR1000 can be decommissioned using today's technology. We are content that GNSL has addressed this query.

On 31 August 2018, GNSL received a comment asking about the intensity and toxicity of the waste that will arise from the UK HPR1000 and whether it is of greater toxicity than other PWRs. It was also asked about the decommissioning costs and the fact that decommissioning at Bradwell A had been an experimental and learning experience and that the costs were unknown. GNSL's response identifies that the wastes from the UK HPR1000 will be similar to other PWRs and Sizewell B. It also provides comparisons of the amount of waste that will be generated compared with a coal fired power station. GNSL states that the UK government now requires an operator to put aside funds for decommissioning the reactor. This is a legal requirement. GNSL has highlighted that a future operator will be able to make use of the extensive knowledge base that will be available from the decommissioning of PWRs from around the world. This will ensure that the decommissioning of the UK HPR1000 is more efficient. GNSL has taken account of decommissioning when designing the reactor to prevent or minimise the generation of solid wastes. We are content that GNSL’s response has addressed the comment.

8. Conclusion

There are still a number of ROs and RQs that we and ONR have raised, which will need to be addressed by the end of GDA. However, our preliminary conclusions are as follows:

- All solid and non-aqueous wastes have been identified.
- A good description of the quantities, activities and composition for the majority of the solid wastes and spent fuel arisings has been provided. Further information will be provided by the end of GDA.
- Generally, a good description of how solid wastes and spent fuel arisings will be minimised at source is provided. However, there are a number of outstanding ROs and RQs that we are confident will be addressed before the end of GDA.
- All LLW arisings from the UK HPR1000 would appear to be disposable, however we have questioned whether the approach to LLW concentrates and sludges is BAT. There are a number of outstanding issues for a future operator to address, but these are site-specific.
- We continue to assess how the design of the UK HPR1000 has considered decommissioning and, therefore, minimised the generation of solid wastes. We are confident that GNSL will be able to demonstrate this before the targeted end of GDA.

- We are confident that GNSL can apply effective characterisation and segregation to the solid wastes for the UK HPR1000. However, a future operator will need to demonstrate that BAT is being applied.
- We are confident that the conditioning and packaging options chosen for the HAW solid wastes can potentially produce disposable products. However, RWM continues to assess these options.
- We are confident that if RO-UKHPR1000-0040 can be addressed, GNSL will have demonstrated that the conceptual design for the ILW store will be BAT and that the packages will be maintained in an environment that will ensure that they will be disposable.
- We are confident that if GNSL can address the GDAI with regard to long-term storage of the spent fuel, the SFIS design will maintain the integrity of the spent fuel assemblies, ensuring that the assemblies will be disposable in the future.
- The management strategy for the ICIAs could change and impact on our assessment. A change in strategy could impact on the disposal of the wastes. However, at the time of writing the report, we see no reason why the packages would not be disposable.
- We see no reason, at this stage of our assessment, why the proposals GNSL has put forward for packaging and conditioning HAW arising from the UK HPR1000 would not lead to disposable packages. However, we will assess RWM's assessment and how GNSL addresses any actions arising from the assessment, to ensure that there are no issues, before the end of GDA.

Three GDAI have been raised as a result of our assessment in relation to the management arrangements for solid and non-aqueous wastes and spent fuel and the disposal of these wastes:

- **Potential GDA Issue 4: GNSL is required to provide information in relation to the long-term storage requirements for the spent fuel and to demonstrate that the conceptual design for spent fuel interim store (SFIS) will deliver these requirements.**
- **Potential GDA Issue 5: GNSL is required to provide further substantiation of the proposed strategy for the management of in-core instrument assemblies (ICIAs) and if any changes to the strategy is decided, to assess the impact on the disposal of ICIA wastes.**
- **Potential GDA Issue 6: GNSL is required to demonstrate that all higher activity waste (HAW) arisings from the UK HPR1000 will be disposable.**

We have identified the following Assessment Findings:

- **Assessment Finding 14: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants that will be associated with the waste inventory for the UK HPR1000.**
- **Assessment Finding 15: A future operator shall assess whether there are benefits in periodic decontamination of the UK HPR1000 primary circuit and its related systems and auxiliary circuits with regard to minimising production of decommissioning wastes and their classification. The future operator should demonstrate that BAT is being applied.**

- **Assessment Finding 16: A future operator shall ensure that the decommissioning plan is periodically reviewed to ensure that BAT is being applied with regard to decommissioning the UK HPR1000.**
- **Assessment Finding 17: A future operator shall review periodically the options for the treatment and disposal of solid low level waste from the operation and decommissioning of the UK HPR1000. The future operator shall ensure that the options implemented are BAT and will meet the disposal facilities waste acceptance criteria.**
- **Assessment Finding 18: A future operator shall periodically update the Radioactive Waste Management Case or equivalent documentation in accordance with the Environment Agency's and ONR's joint guidance, in order to demonstrate that the higher activity waste is being managed across the whole life cycle.**
- **Assessment Finding 19: A future operator shall develop its characterisation strategy and approach to segregation for solid and non-aqueous wastes further at the detailed design stage, to ensure that it can demonstrate that BAT is being applied.**
- **Assessment Finding 20: A future operator shall ensure that the proposed conditioning and packaging options for the higher activity wastes for the operational and decommissioning waste arisings from the UK HPR1000 are BAT.**
- **Assessment Finding 21: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal will be transferred to a GDF.**
- **Assessment Finding 22: A future operator shall ensure that it deploys BAT for the conditioning of the spent fuel, prior to transferring the spent fuel assemblies to the spent fuel interim store.**
- **Assessment Finding 23: A future operator shall ensure that the monitoring and inspection of the spent fuel assemblies and canister, within the spent fuel interim store are BAT.**
- **Assessment Finding 24: A future operator shall ensure that the strategy for managing failed fuel over the life time of the UK HPR1000 is BAT.**
- **Assessment Finding 25: A future operator shall engage with the operators of the disposal facilities to ensure that their requirements are complied with for both low activity wastes' and higher activity wastes' records.**
- **Assessment Finding 26: A future operator shall continue to secure international OPEX with regard to the dry storage of spent fuels and ensure that it applies learning from the international OPEX to the storage of the UK HPR1000 fuel arisings.**
- **Assessment Finding 27: A future operator shall secure and use OPEX, including that available internationally, to ensure that BAT is used to decommission the UK HPR1000 and that the generation of radioactive solid waste is minimised and it is capable of being disposed of.**

References

Author	Reference
BEIS. 2018	'Implementing Geological Disposal - Working with Communities: An updated framework for the long-term management of higher activity radioactive waste' December 2018
BERR. 2008	'Meeting the Energy Challenge. A White Paper on Nuclear Power' January 2008
Environment Agency. 2010	'Radioactive Substance Regulation - Environmental Principles' Version 2, 2010
Environment Agency. 2016	'Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs' Version 3, 2016
Environment Agency. 2018	'Generic design assessment of candidate nuclear power plant designs - Initial assessment of General Nuclear System's UK HPR1000 design: Statement of findings' Version 1 November 2018
Environment Agency. 2021a	'Generic design assessment of new nuclear power plant: Preliminary detailed assessment of BAT for General Nuclear System's UK HPR1000 design - AR03' Draft 2, September 2020
Environment Agency. 2021b	'Generic design assessment of nuclear power plant: Preliminary detailed assessment of strategic considerations for radioactive waste management for General Nuclear System's UK HRP1000 design - AR 02' Draft 2, September 2020
Framatome. 2019a	'UK HPR1000 Operating Experience with AFA 3GAA Fuel Assemblies' GHX42500009SFSL44GN, (Framatome Document No. FS1-0043880), Revision 2.0, July 2019
Framatome. 2019b	'UK HPR1000 Fuel assembly Anti-Debris Filter hydraulic test' FS1-0043994, Revision 2.0, July 2019
Framatome.2019c	Prevention Measures on Radioactive Contamination for Fuel Manufacturing, GHX42500013SFSL44GN, (Framatome document No.FS1-0044542), Revision 3.0, Oct 2019.
GB Parliament. 2016	'The Environment Permitting (England &Wales) Regulations 2016' as amended May 2018
GNSL. 2018a	'Requirements on Optioneering and Decision Making' HPR-GDA-PROC-0012, Revision 0 May 2018

Author	Reference
GNSL. 2018b	'PTR-Fuel Pool Cooling and Treatment System Design Manual Chapter 2 Brief Introduction to the System', GHX17PTR002DNHX45GN, Revision A, July 2018
GNSL. 2019a	'Solid Radioactive Waste Management Report Technical User Source Term Report' GHX0050008DNFF03GN, Revision C, November 2019
GNSL. 2019b	'Material Selection Report of Steam Generator' GHX00100034DPCH03GN, Revision A, June 2019
GNSL. 2019c	'Preliminary Decommissioning Plan' GHX71500004DNFF03GN, Revision E, November 2019
GNSL. 2019d	'Management Proposal of Waste Non-Fuel Core Components' GHX00100064DNFF03GN, Revision D, November 2019
GNSL. 2019e	'Conceptual Proposal of ILW Interim Storage Facility' GHX00100063DNFF03GN, Revision C, December 2019
GNSL. 2019f	'Technology Optioneering on Spent Fuel Interim Storage' GHX0100057DNFF03GN, Revision B, March 2019
GNSL. 2020a	'Pre-Construction Environmental Report Chapter 4 - Radioactive Waste Management Arrangements' HPR/GDA/PCER/0004, Revision 001-1 October 2020
GNSL. 2020b	'Waste Inventory for Operational Solid Radioactive Waste' GHX00100069DNFF03GN, Revision D, June 2020
GNSL. 2020c	'Decommissioning Technical User Source Term Report' GHX0050009DNFP03GN, Version E, June 2020
GNSL. 2020d	'Decommissioning Waste Management Proposal' GHX71500009DNFF03GN, Version E, June 2020
GNSL. 2020e	'Pre-Construction Safety Report Chapter 5 - Reactor Core' HPR/GDA/PCSR/0005 Revision 001, January 2020
GNSL. 2020f	'Pre-Construction Environmental Report Chapter 3 - Demonstration of BAT' HPR/GDA/PCER/0003, Revision 001-1, October 2020
GNSL. 2020g	'Supportive Report of BAT on Nuclear Design' GHX00800007DRDG03GN, Revision D, January 2020

Author	Reference
GNSL. 2020h	Pre-Construction Safety Report Chapter 21 - Reactor Chemistry' HPR/GDA/PCER/0021, Revision 001, January 2020
GNSL. 2020i	'Topic Report on Zinc Injection in the Primary Circuit of UK HPR1000' GHX00100010DCHS03GN, Revision D, March 2020
GNSL. 2020j	'Consistency Evaluation for Design of Facilitating Decommissioning' GHX71500005DNFF03GN, Revision D, June 2020
GNSL. 2020k	'OPEX on Decommissioning' GHX71500008DNFF03GN, Revision D, April 2020
GNSL. 2020l	'Decontamination Processes and Techniques during Decommissioning' GHX71500010DNFF03GN, Revision C, June 2020
GNSL. 2020m	'Optioneering Report for Operational Solid Waste Processing Techniques' GHX0010005DNFF03GN, Revision D, June 2020
GNSL.2020n	'Response to LLWR Agreement in Principle' GHX00100099DNFF03GN, Revision B, June 2020
GNSL. 2020o	'Radioactive Waste Management Case for ILW' GHX00100066DNFF03GN, Revision C, April 2020
GNSL. 2020p	'Radioactive Waste Management Case for HLW' GHX00100065DNFF03GN, Revision C, April 2020
GNSL. 2020q	'Pre-Construction Environmental Report Chapter 5 - Approach to Sampling and Monitoring' HPR/GDA/PCER/0005, Revision 001-1, October 2020.'
GNSL. 2020r	'Selection of Waste Containers for Disposal of ILW' GHX00100055DNFF03GN, Revision C, June 2020
GNSL. 2020s	'Preliminary Safety Evaluation of Spent Fuel Interim Storage' GHX00100046DNFP03GN, Revision D, April 2020
GNSL. 2020t	'Pre-Construction Safety Case, Chapter 28 - Fuel Route and Storage', HPR/GDA/PCSR/0028, Revision 001, January 2020
GNSL. 2020u	'Pre-Construction Safety Case, Chapter 29 - Interim storage of Spent Fuel', HPR/GDA/PCSR/0029, Revision 001, January 2020

Author	Reference
GNSL. 2020v	‘Spent Fuel Interim Storage Facility Design’ GHX00100081DNFF03GN, Revision D, April 2020
GNSL. 2020w	‘Fuel Handling Process and Operations’ GHX00100008DPFJ45GN, Revision B, March 2020
GNSL. 2020z	‘Activated Structures Source Term Supporting Report’ GHX00800003DRDG03GN, Revision D, June 2020
GNSL. 2020aa	‘UK HPR1000 HAW Disposability Assessment Submission’ GHX00100035DNFF03GN, Revision D, June 2020
GNSL. 2020ab	‘Higher Activity Waste and Spent Fuel Disposability Assessment Delivery Strategy’ HPR-GDA-REPO-0150, June 2020
GNSL. 2020ac	‘UK HPR1000 HAW and SF Disposability Assessment End of June 2020 Status’ HPR-GDA-REPO-015, June 2020
IAEA. 2008	‘IAEA Safety Standards. Decommissioning of Facilities, General Safety Requirements’ Part 6 No GSR Part 6 2015
IAEA. 2016	‘IAEA Safety Standards. Safety Assessment for the Decommissioning of Facilities Using Radioactive Material, Safety Guide’ No WS-G-5.2 2008
IAEA. 2018	‘IAEA Safety Standards, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities, Specific Safety Guide’ No.SSG-47, October 2018
LLWR Ltd. 2016a	‘Low Level Waste Repository Ltd. Waste Services Contract, Waste Acceptance Criteria - Low Level Waste Disposal’ WSC-WAC-LOW Version 5.0 Issue 1 - July 2016
LLWR Ltd. 2020a	Letter Re: ‘Disposability in Principle Assessment for UK HPR1000’ GNSL Ref: GHX00100036DNFF03GN, January 2020
National Nuclear Ventilation Forum. 2018	National Nuclear Ventilation Forum, ES_0_1738_1, ‘Ventilation Systems for Radiological Facilities, Design Guide’ Issue 1, December 2018
NDA. 2014a	‘Geological Disposal: An Overview of the RWM Disposability Assessment Process’ WPS GD No. WPS650/03, April 2014
NDA. 2014b	‘Guide to Technology Readiness Levels for NDA Estate & its Supply Chain’ Issue 2, EDRMS22515717, November 2014

Author	Reference
NDA. 2017a	‘Industry Guidance Interim Storage of Higher Activity Waste Packages - Integrated Approach’ Issue 3, January 2017
NDA. 2019	‘UK Radioactive Waste Inventory 2019’ http://ukinventory.nda.gov.uk/ [Accessed 2 October 2020]
Office of Nuclear Regulation et al. 2015	‘The management of higher activity radioactive waste on nuclear licensed sites - Joint guidance’ from the Office of Nuclear Regulation, the Environment Agency, the Scottish Environment Protection Agency, Natural Resource Wales to nuclear licensees, Revision 2, 2015
Office of Nuclear Regulation and Environment Agency. 2018	Letter: UK HPR1000 ‘GDA Scope for Spent Fuel Interim Storage (SFIS)’ Reference 2018/329187, October 2018
WFDUK. 2018	‘JAGDAG Hazardous Substances Jan 2018’ http://wfduk.org/resources/groundwater-hazardous-standards [Accessed 2 October 2020]

Abbreviations

Acronym	Meaning
AF	Assessment Finding
ALARP	As low as reasonably practicable
BAT	Best available techniques
BEIS	Department for Business, Energy & Industrial Strategy
CVCS (or RCV)	Chemical volume control system
CSTS (or TEP)	Coolant storage and treatment system
EMIT	Examination, maintenance, inspection and testing
EPR	European pressurised reactor
FPCTS (or PTR)	Fuel pool coolant and treatment system
GDA	Generic design assessment
GDAI	GDA Issue
GDF	Geological disposal facility
GNSL	General Nuclear System Ltd
HAW	High activity waste
HLW	High level waste
IAEA	International Atomic Energy Agency
ICIA	In-situ core instrument assembly
ILW	Intermediate level waste
IX	Ion exchange
JAGDAG	Joint Agencies' Groundwater Directive Advisory Group
LAW	Low activity waste

Acronym	Meaning
LLW	Low level waste
LLWR	Low Level Waste Repository
LoC	Letter of compliance
LWTS (or TEU)	Liquid waste treatment system
MADA	Multi-attribute decision analysis
NDA	Nuclear Decommissioning Authority
NFCCs	Non-fuel core components
NSS	Nuclear Sampling System
ONR	Office for Nuclear Regulation
OPEX	Operating experience
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
P&ID	Process and Information Document
PRMS	Plant Radiation Monitoring System
PWR	Pressurised water reactor
R&D	Research and development
RCCA	Rod cluster control assembly
REPs	Regulation Environmental Principles
RGP	Relevant good practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party

Acronym	Meaning
RPV	Reactor pressure vessel
RQ	Regulatory Query
RSR	Radioactive Substances Regulation
RWM	Radioactive Waste Management Ltd
RWMC	Radioactive Waste Management Case
RVI	Reactor vessel internals
SCCAs	Stationary core component assemblies
SFA	Spent fuel assembly
SFIS	Spent fuel interim store
SGBS (or APG)	Steam generator blowdown system
SSC	Structures, systems and components
SSER	Safety, security and environmental report
SWTS (or TES)	Solid waste treatment system
TRL	Technology Readiness Level
UKRWI	United Kingdom Radioactive Waste Inventory
VDS (or RPE)	Nuclear island vent and drain system
VLLW	Very low level waste

Appendix 1 GNSL documentation assessed

Title	Revision, document number, year
Pre-Construction Environmental Report Chapter 3 - Demonstration of BAT	Rev 001-1 HPR/GDA/PCER/0003 (2020)
Pre-Construction Environmental Report Chapter 4 - Radioactive Waste Management Arrangements	Rev 001-1 HPR/GDA/PCER/0004 (2020)
Pre-Construction Environmental Report Chapter 5 - Approach to Sampling and Monitoring	Rev 001-1 HPR/GDA/PCER/0005 (2020)
Pre-Construction Safety Report V1 Amendment Report for Environment Agency Public Consultation	Rev 000 HPR/GDA/PCSRV1AR/0000 (2020)
Pre-Construction Safety Report Chapter 10 - Auxiliary Systems	Rev 001 HPR/GDA/PCSR/0010 (2020)
Pre-Construction Safety Report Chapter 21 - Reactor Chemistry	Rev 001 HPR/GDA/PCSR/0021 (2020)
Pre-Construction Safety Report Chapter 23 - Radioactive Waste Management	Rev 001 HPR/GDA/PCSR/0023 (2020)
Pre-Construction Safety Report Chapter 24 - Decommissioning	Rev 001 HPR/GDA/PCSR/0024 (2020)
Pre-Construction Safety Report Chapter 28 - Fuel Route and Storage	Rev 001 HPR/GDA/PCSR/0028 (2020)
Pre-Construction Safety Report - Chapter 29 Interim Storage of Spent Fuel	Rev 001 HPR/GDA/PCSR/0029 (2020)
Requirements on Optioneering and Decision Making	Rev A HPR/GDA/PROC0012 (2018)
Analysis of Applicable Codes and Standards	Rev D GHX00100024DNFF02GN (2019)
Production Strategy for Radioactive Waste Management	Rev D GHX00100078KPGB03GN (2020)
Solid Radioactive Waste Management Technical Source Term Report	Rev C GHX00530008DNFP03GN (2019)
Waste Inventory for Operational for Operational Solid Radioactive Waste	Rev D GHX00100069DNFF03GN (2020)
Activated Structures Source Term Report	Rev D GHX00800003DRDG03GN (2020)
Integrated Waste Strategy	Rev F GHX00100070DNFF03GN (2020)

Title	Revision, document number, year
Management Proposal of Waste Non-Fuel Core Components	Rev D GHX00100064DNFF03GN (2019)
Radioactive Waste Management Case for ILW	Rev C GHX00100066DNFF03GN (2020)
Radioactive Waste Management Case for HLW	Rev C GHX00100065DNFF03GN (2020)
Optioneering Report for Operational Solid Waste Processing Techniques	Rev D GHX00100056DNFF03GN (2020)
Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System	Rev D GHX00100068DNFF03GN (2019)
Selection of Waste Containers for Disposal of ILW	Rev C GHX00100055DNFF03GN (2020)
Conceptual Proposal of ILW Interim Storage Facility	Rev C GHX00100063DNFF03GN (2019)
Gap Analysis Report for Radioactive Waste Management	Rev B GHX00100060DNFF03GN (2019)
Optimal Options Study for Identified Gaps in Radioactive Waste Management	Rev D GHX00100060DNFF03GN (2020)
UK HPR1000 HAW Disposability Assessment Submission	Rev D GHX00100035DNFF03GN (2020)
UK HPR1000 Waste Enquiry Form	Rev C GHX00100036DNFF03GN(2019)
LLWR Ltd Disposability in Principle Assessment for UK HPR1000	GHX00100036DNFF03GN (2020)
Response to LLWR Agreement in Principle	Rev B GHX00100099DNFF03GN (2020)
A List of SSCs Affected by the Optimal Options	Rev B GHX00100062DNFF03GN (2020)
Topic Report on the Periodic Test Requirements of Radioactive Waste Management Systems	Rev A GHX71200002DNFF03GN (2019)
HPR1000 R&D History	Rev C GHX99980001DXZJ01MD (2020)
Topic Report Zinc Injection in the Primary Circuit of UK HPR1000	Rev D GHX00100010DCHS03GN (2020)
Topic Report on Radioactive Waste Minimisation for Mechanical Engineering	Rev C GHX00100055DNHX03GN (2020)
Design Substantiation Report on Associated Chemistry Control Systems: the Spent Fuel Pool	Rev B GHX08PTR001DNHX03GN (2019)
Minimisation of Radioactivity Route Map	Rev B GHX0010002DNHS03GN (2020)

Title	Revision, document number, year
Supportive Report of BAT ON Nuclear Design	Rev D GHX00800007DRDG03GN (2020)
Materials Selection Methodology	Rev C GHX00100006DPCH03GN (2019)
TES-Solid Waste Treatment System Design Manual Chapter 1 - System Design Manual Content and State	Rev E GHX17TES001DNFF45GN (2019)
TES- Solid Waste Treatment System Design Manual Chapter 2	Rev F GHX17TES002DNFF45GN (2019)
TES-Solid Waste Treatment System Design Manual Chapter 3 - Systems Function and Design Base	Rev E GHX17TES003DNFF45GN (2019)
TES-Solid Waste Treatment System Design Manual Chapter 4 - System and Component Design	Rev E GHX17TES004DNFF45GN (2019)
TES- Solid Waste Treatment System Design Manual Chapter 5 - Layout Requirements and Environment Condition	Rev C GHX17TES005DNFF45GN (2019)
TES-Solid Waste Treatment System Design Manual Chapter 6 - System Operation and Maintenance	Rev D GHX17TES006DNFF45GN (2019)
TES Solid Waste Treatment System Design Manual Chapter 9	Rev D GHX17TES009DNFF45GN (2019)
TEU Liquid Waste Treatment System Design Manual Chapter 2 - Brief Introduction to the System	Rev A GH917TEU002DNFF45GN (2018)
TEU Liquid Waste Treatment System Design Manual Chapter 4 - System Design	Rev D GH917TEU004DNFF45GN (2019)
TEU Liquid Waste Treatment System Design Manual Chapter 6 - Operation and Maintenance	Rev D GH917TEU006DNFF45GN (2019)
RCV Chemical and Volume Control System Design Manual Chapter 2 - Brief Introduction to the System	Rev A GHX17RCV002DNHX45GN (2018)
RCV Chemical and Volume Control System Design Manual Chapter 4 - System and Component Design	Rev B GHX17RCV004DNHX45GN (2018)
RCV Chemical and Volume Control System Design Manual Operation and Maintenance	Rev B GHX17RCV006DNHX45GN (2018)
Spent Fuel Assembly Source Term Supporting Report	Rev D GHX00100002DRDG02GN (2019)

Title	Revision, document number, year
Technology Optioneering on Spent Fuel Interim Storage	Rev B GHX00100057DNFF03GN (2019)
Spent Fuel Interim Storage Facility Design	Rev D GHX00100081DNFF03GN (2020)
The Matching Analysis of Selected SFIS Technology with current UK HPR1000 Design	Rev C GHX00100080DNFF03GN (2019)
Fuel Handling Process and Operations	Rev B GHX00100008DPFJ45GN (2020)
Demonstration Report for the Fuel Failure Mechanism in Fuel Route	Rev 2 Framatome Report FS1-0046697(2020)
AFA 3GAA Fuel Assembly Description for HPR1000 Reactor	Rev 3 Framatome Report FS1-0043782
UK HPR1000 - Fuel Assembly Anti-Debris Filter Hydraulic Test	Rev 2 Framatome Report FS1-0043994 (2019)
UKHPR1000 - Operating Experience with AFA 3GAA Fuel Assemblies	Rev 2 Framatome Report FS1-0043880
The Out of Pile Corrosion Performance of CZ Alloy	Rev B CNPRI-GH-F11-17NFC096-040 (2018)
Prevention Measures on Radioactive Contamination for Fuel Manufacturing	Rev A CPNRI-GH-F11-17NFC096-045 (2018)
Production Strategy for Spent Fuel Interim Store	Rev D GHX00100077KPGB03GN (2020)
Preliminary Safety Evaluation of SFIS	Rev D GHX00100046DNFP03GN (2020)
Decommissioning Technical User Source Term Report	Rev EGHX00530009DNFP03GN (2020)
Decommissioning Waste Management Proposal	Rev E GHX71500009DNFF03GN (2020)
Preliminary Decommissioning Plan	Rev E GHX71500004DNFF03GN (2019)
General Requirements for Decommissioning Nuclear Power Plants	Rev B GHX71500011DNFF03GN (2020)
OPEX on Decommissioning	Rev D GHX71500008DNFF03GN (2020)
Design Requirements for Decommissioning	Rev C GHX71500016DNFF03GN (2020)
Consistency Evaluation for Design of Facilitating Decommissioning	Rev D GHX71500005DNFF03GN (2020)
Decontamination Processes and Techniques during Decommissioning	Rev C GHX71500010DNFF03GN (2020)
Preliminary Disassembly Programme for the Main Equipment Decommissioning	Rev E GHX71500001DPZS03GN (2020)

Appendix 2: Regulatory Queries

Regulatory Query	Date issued	Title and summary
RQ-UKHPR1000-0016	18/12/2017	Justifying materials selection decisions for UK HPR1000 GNSL was asked for further information as to how it arrived at its choice of materials for structures, systems and components (SSCs).
RQ-UKHPR1000-0018	18/12/2017	Approach to justifying the primary circuit operating chemistry for the UK HPR1000 GNSL was asked to justify the primary chemistry and the addition of zinc to the primary coolant.
RQ-UKHPR1000-0044	29/01/2018	Radioactive waste management, spent fuel management and decommissioning: Basis of identification of gaps between UK context and Chinese practice for step 2 working plan and production of SSER for step 3. GNSL was asked to provide the standards, codes and guidance used to identify the main gaps in managing radioactive wastes between China and the UK. The RP was also asked to provide information as to how it will address these gaps.
RQ-UKHPR1000-0046	29/02/2018	ONR regulation of radioactive waste management and fuel storage GNSL was asked to provide further information with regard to accumulation and storage.
RQ-UKHPR1000-0105	24/05/2018	Decommissioning Strategy and Design for Decommissioning GNSL was asked to provide further information on the location of information within the PCSR on decommissioning.
RQ-UKHPR1000-0106	24/05/2018	Management of waste non-fuel core components (NFCC) from generation to disposal GNSL was asked to provide information of the amounts of NFCC that will be produced, taking account of uncertainties. The RP was also asked to provide information with regard to how these wastes will be managed safely and also whether the practices will be different for the UK compared with China.

Regulatory Query	Date issued	Title and summary
RQ-UKHPR1000-0107	24/05/2018	Gaps and differences between Chinese and UK practises in management solid radioactive wastes and development of the Integrated Waste Strategy GNSL was asked how the waste management strategy will take account of the differences in the management of radioactive wastes between China and the UK and how they will be implemented for the UK HPR1000.
RQ-UKHPR1000-0141	03/07/2018	Management of problematic wastes and boundary wastes GNSL was asked whether there were any problematic or boundary wastes in relation to the inventory for the UK HPR1000.
RQ-UKHRP1000-0210	12/02/2019	Material selection methodology We asked for further information in relation to the materials selected and how this was done.
RQ-UKHPR1000-0405	01/08/2019	Management of RCCA and SCCA GNSL was asked to provide further information with regard to managing RCCAs and SCCAs over the life cycle of the wastes, taking account of generation, characterisation, storage and any potential degradation issues.
RQ-UKHPR1000-0406	01/08/2019	Management of ICIA non-fuel core components GNSL was asked for further information with regard to: • description of the ICIAs • characterisation of ICIAs • retrieval of ICIAs • segregation of wastes • management of the waste packages
RQ-UKHPR1000-0407	01/08/2019	Management of ILW resins GNSL was asked to provide further information with regard to minimising the generation of resin, their characterisation, the management of resins within the solid waste treatment facility and the disposability of resins.
RQ-UKHPR1000-0411	05/08/2019	Management of ILW concentrates

Regulatory Query	Date issued	Title and summary
		GNSL was asked for information with regard to managing concentrates within the solid waste treatment system and how these will be processed and grouted.
RQ-UKHPR1000-0412	19/08/2019	Waste Minimisation GNSL was asked how the generation of wastes for concentrates, spent filter cartridges and sludges had been minimised.
RQ-UKHPR1000-0434	13/08/2019	Radioactive waste processing techniques GNSL was asked to provide further information on how the optioneering reports for liquids, gases and solids had met the expectations within 'Requirements on Optioneering and Decisions Making'.
RQ-UKHPR1000-0477	26/09/2019	Conceptual design of the ILW interim storage facility Provide information on: • the waste and package type to be stored • the optioneering study to determine the ILW store design • the reasons behind the 30-year storage capacity • contingency within the capacity for unplanned events • operational limits for the storage of packages • EMIT arrangements in place
RQ-UKHPR1000-0488	09/10/2019	Zinc injection in the primary circuit - follow up queries GNSL was asked about what wastes will result from zinc injection and the impact that zinc will have on corrosion.
RQ-UKHPR1000-0489	09/10/2019	Zinc injection in the primary circuit GNSL was asked about various aspects in relation to the OPEX for zinc injection and the information used to present the case for zinc injection for the UK HPR1000.
RQ-UKHPR1000-0490	09/10/2019	Impurity control GNSL was asked about the limits that have been defined for the UK HPR1000 and how the limits for the CPR1000 are applicable OPEX for the UK HPR1000. The RQ also

Regulatory Query	Date issued	Title and summary
		questioned the formation of zeolites and silica.
RQ-UKHPR1000-0547	18/11/2019	Solid and non-aqueous radioactive wastes GNSL was asked about the uncertainties associated with volumes and activities of the waste. They were also asked why different major radionuclides were identified in different reports for the same waste streams.
RQ-UKHPR1000-0548	18/11/2019	Complexants GNSL was asked for information as to whether complexants were present within the waste inventory for the UK HPR1000.
RQ-UKHPR1000-0549	18/11/2019	Gamma emitters from low level wastes GNSL was asked for clarification on the major gamma emitters from LLW.
RQ-UKHPR1000-0551	18/11/2019	Processing of APG resins GNSL was asked about the processing of resins between the nuclear auxiliary building and the waste treatment building for APG resins. Further information was asked about the processing of resins and whether there was sufficient redundancy within the systems for encapsulating the resins.
RQ-UKHPR1000-0553	18/11/2019	Waste streams via the fuel route GNSL was asked whether any LLW and ILW waste streams would be produced by operating and decommissioning the SFIS and fuel route. The RP was asked to provide volumes and activities and whether any advice would be required from RWM.
RQ-UKHPR1000-0635	12/02/2020	Management of failed fuel GNSL was asked: how the failed fuel management strategy was dependent on the operational history and the decommissioning strategy what the failed fuel management strategy was within the spent fuel pool whether the strategy would lead to any significant increase in wastes whether there were any current options that could be developed by an operator for transferring the fuels into SFIS

Regulatory Query	Date issued	Title and summary
		whether the management strategy would rule out any disposal options for the fuel whether RWM's advice took account of failed fuel
RQ-UKHPR1000-0636	12/02/2020	Hazardous substances and non-hazardous pollutants GNSL was asked to provide information on the hazardous substances and non-hazardous pollutants that will be present within the wastes arising from the UKHPR1000.
RQ-UKHPR1000-0646	26/02/2020	Justification for using CORD D GNSL was asked to justify the use of CORD D UV as a decontaminating agent for decontaminating the primary circuit, compared with using EPRI DFD.
RQ-UKHPR1000-0647	26/02/2020	Impacts of decommissioning on radioactive waste generation GNSL was asked: why only certain secondary wastes were included within the source term what additional waste streams would be generated from the spent fuel pond and waste treatment buildings the amount of waste that will be generated during storage of the failed and spent fuel during the decommissioning phase
RQ-UKHPR1000-0648	26/03/2020	Optimisation of packaging of waste container for decommissioning wastes GNSL was asked to justify the choice of containers for packaging reactor pressure vessel (RPV) and reactor vessel internal (RVI) wastes during decommissioning.
RQ-UKHPR1000-0697	26/03/2020	PCSR Chapter 21 - Chemistry Regime - Hydrogen Control GNSL was asked about the hydrogen concentration limits and impacts on such areas as fuel cladding. The RQ also asks about OPEX to support the limits chosen for the UK HPR1000.
RQ-UKHPR1000-0701	26/03/2020	Topic report on zinc injection in the primary circuit Rev. D GNSL was asked about the impact of zinc injection on other radionuclides, and the

Regulatory Query	Date issued	Title and summary
		impact on materials such as welds. The RQ also requests further information on the impact on fuel and materials within the primary circuit and effects on the spent resins and filters.
RQ-UKHPR1000-0702	26/03/2020	Topic report on zinc injection in the primary circuit Rev D GNSL was asked whether zinc injection would require increased frequency of the monitoring and sampling of other species in the primary circuit.
RQ-UKHPR1000-0704	26/03/2020	PCSR Chapter 21 - Chemistry Regime - pH Control GNSL was asked about the pH control in relation to corrosion, radioactivity build up, fuel impacts.
RQ-UKHPR1000-0739	17/04/2020	Environmental impacts of gadolinia GNSL was asked to provide a summary of the gadolina content within spent fuel arisings and to assess the impact on disposal. In addition, the RP was asked to assess the benefits of gadolina over the disbenefits.
RQ-UKHPR1000-0740	17/04/2020	Decay curves for HAW GNSL was asked whether the decay curves had been calculated based on average or maximum activities. Information was also sought about how the rate of arising would be considered when a second ILW interim store was built so that all wastes were kept in conditions suitable for disposal.
RQ-UKHPR1000-0741	17/04/2020	Inspection and monitoring fuel during interim storage GNSL was asked to clarify the drying limit for taking fuel into SFIS. GNSL was also asked about the monitoring that would be implemented with regard to the canisters and silos.
RQ-UKHPR1000-0775	01/05/2020	Decommissioning of evaporators GNSL was asked about the waste classification of the evaporators that will be decommissioned. Additional information was required with regard to dismantling the evaporators.

Regulatory Query	Date issued	Title and summary
RQ-UKHPR1000-0776		Average number of ventilation filter cartridges GNSL was asked to clarify the OPEX it had presented on the number of ventilation cartridges that would be produced for the UK HPR1000.
RQ-UKHPR1000-0783	07/05/2020	IX waste volumes GNSL was asked to clarify the waste volumes of ion exchange resins that would be produced for the UK HPR1000. GNSL was also asked to clarify how ion exchange beds in series would be operated, noting that this can minimise the amount of waste.
RQ-UKHPR1000-0799	14/05/2020	Processing of ILW resins GNSL was asked a number of questions relating to the processing of ILW resins via the solid waste treatment system.
RQ-UKHPR1000-0800	14/05/2020	Further detail on the storage and disposal of spent resins GNSL was asked a number of questions with regard to the storage of ILW resins and the final disposal of the resins.
RQ-UKHPR1000-0837	4/06/2020	Gap analysis for radioactive waste management GNSL was asked to clarify points with regard to RO-UKHPR1000-0005.
RQ-UKHPR1000-0870	16/06/2020	Treatment of decommissioning ILW/LLW boundary resins GNSL was asked why grout encapsulation was the preferred option for conditioning ILW/LLW boundary resins, compared with incineration.
RQ-UKHPR1000-0926	6/07/2020	Spent fuel canister, transfer cask and silo queries GNSL was asked about the safety function requirement of the water layer within the transfer cask. GNSL was also asked when the water layer was added and how it will be removed within the SFIS and residual water removed from the canister surfaces.

Appendix 3: Regulatory Observations

Regulatory Observation	Date issued	Title and summary
RO-UKHPR1000-0005	26/10/2018	Demonstration that the UK HPR1000 reduces the risks associated with radioactive waste management, so far as is reasonably practicable GNSL was asked to clarify the difference in radioactive waste management between the UK and China and to address the gaps. A radioactive waste management strategy was to be produced and, as a result of addressing the gaps, the RP was to highlight which SSCs will be affected or modified. Finally, the RP was asked to justify ALARP.
RO-UKHPR1000-0015	13/09/2019	Demonstration that risks associated with fuel deposits are reduced so far as is reasonably practicable GNSL was asked to characterise and quantify the fuel crud to be expected for the UK HPR1000 and to determine the behaviour and impact of these deposits. The RP was also asked how these deposits will be managed.
RO-UKHPR1000-0031	23/01/2020	Control of boron during normal operations and faults GNSL was asked to provide a description of the boron cycle, and to provide a coherent justification for the level of enriched boron that will be used. GNSL was also asked how the risks will be managed with regard to boron dilution faults.
RO-UKHPR1000-0036	26/03/2020	HEPA filter type GNSL was asked: • to evaluate the choice of HEPA filter for the UK HPR1000 • whether the choice has considered fugitive discharges • to assess the impact of the choice on disposability and waste generation
RO-UKHPR1000-0037	03/04/2020	In-core instrument assemblies radioactive waste safety case GNSL was asked about the waste classification of ICIAs, the strategy for managing ICIAs, whether relevant good practice (RGP) has been used and whether

Regulatory Observation	Date issued	Title and summary
		the strategy will deliver ALARP. The RP was also asked to provide evidence that these wastes will be managed safely.
RO-UKHPR1000-0040	15/04/2020	Providing an adequate safety case for the interim storage of intermediate level waste (ILW) GNSL was asked to provide a suitable and sufficient safety case for the interim storage of all ILW arisings from the operation and decommissioning of the UK HPR1000.
RO-UKHPR1000-041	24/04/2020	Disposability of higher activity waste from the UK HPR1000 GNSL was asked to: • update the RWM submission • produce a summary report highlighting the current status of the RWM disposability assessment • explore all options to accelerate the assessment • update the assessment work plan • provide a final assessment report and a report highlighting how it will address RWM's comments

Appendix 4: Summary of the operational wastes from the UK HPR1000

The following information is taken from GNSL Pre-construction Environmental Report (PCER), chapter 4 (GNSL 2020a).

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Waste management route
ILW spent resins	caesium-137, caesium-134, cobalt-60, cobalt-58, nickel-63,iIron-59 silver-110m	Cross-linked polystyrene spheres	Arising from demineraliser in FPCTS, CVCS, CSTS, LWTS and SGBS if the steam generator fails	1.9m^3	Dry within a robust shielded container and then disposal to a GDF
LLW spent resins	silver-110m, antimony-124, antimony-125, iron-59	Cross-linked polystyrene spheres	From 2 demineralisers in the SGBS	9.7m^3	Place within a 210L drum and Incineration off site
Concentrates	cobalt-60, iron-55, nickel-63, silver-110m	Evaporator concentrates contaminated with activated and fission products	Arise from the LWTS evaporator	LLW 1.47m^3	Grout in 210L drum, dispose to LLW Repository
Concentrates	cobalt-60, iron-55, nickel-63, silver-110m	Evaporator concentrates contaminated with activated and fission products	Arise from the LWTS evaporator	ILW 0.73m^3	Grout in 210L drum, decay store and dispose to LLW Repository
Sludges	cobalt-60, nickel-63, iron-55 silver-110m (only for ILW)	Contaminated with activation and fissile	Arising from tanks and sumps from auxiliary circuits	LLW 0.05m3	Grout in 210L drum and dispose to LLW Repository
Sludges	cobalt-60, nickel-63, iron-55	Contaminated with	Arising from tanks and sumps from	ILW 0.05m3	Grout in 210L drum, decay store

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Waste management route
	silver-110m (only for ILW)	activation and fissile	auxiliary circuits		and dispose to LLW Repository
Spent filter cartridges	cobalt-58, silver-110m, chromium-51, iron-55	Stainless Steel Support, glass fibres plus organics	Arise from CVCS, FPCTS, CSTS, LWTS, SGBS, VDS	LLW 0.65m^3	Package in 210L drum and super-compaction off site.
Spent filter cartridges	cobalt-58, silver-110m, chromium-51, iron-55	Stainless Steel Support, glass fibres plus organics	Arise from CVCS, FPCTS, CSTS, LWTS, SGBS, VDS	ILW 1.14m^3	Grout in 3m^3 box, dispose to a GDF
Dry active wastes (Combustible)	cobalt-60, cobalt-58, niobium-95, iron-55	Paper, plastic cloth	Operations and maintenance activities	LLW 126.81m3	Package in 210L drum, Incinerate off site
Dry active wastes (Combustible)	cobalt-60, cobalt-58, niobium-95, iron-55	Paper, plastic cloth	Operations and maintenance activities	ILW 17.94m3	Decay store and incinerate off site
Dry active waste (Metals)	cobalt-60, cobalt-58, niobium-95, iron-55	Metals	Operations and maintenance activities	LLW 10.44m^3	Package in a metal box and melt off site
Dry active waste (Metals)	cobalt-60, cobalt-58, niobium-95, iron-55	Metals	Operations and maintenance activities	ILW 1.56m^3	Decay store, then melt off site
Dry active waste (Compactable)	cobalt-60, cobalt-58, niobium-95, iron-55	Cable, plastics	Operations and maintenance	LLW 14.79m^3	Package in 210L drum and then compact off site
Dry active waste (Compactable)	cobalt-60, cobalt-58, niobium-95, iron-55	Cable, plastics	Operations and maintenance	ILW 2.21m^3	Decay store and compact off site
Dry active waste (Non-compactable/n	cobalt-60, cobalt-58,	Concrete, glass	Operations and maintenance	LLW 4.35m^3	Disposal to LLW Repository

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Waste management route
on combustible)	niobium-95, iron-55				
Dry active waste (Non-compactable/non combustible)	cobalt-60, cobalt-58, niobium-95, iron-55	Concrete, glass	Operations and maintenance	ILW $0.65m^3$	Decay store and disposal to the LLW Repository
Oil	cobalt-60, cobalt-58, niobium-95, nickel-63, iron-55	Lubricating Oil	Maintenance of hydraulic equipment	LLW/VLLW $0.13m^3$	Package in 210L drum and incineration off site
Organic solvent	cobalt-60, cobalt-58, niobium-95, iron-55	Organic Solvents	Normal operation like decontamination of reactor bolts	LLW/VLLW $0.2m^3$	Package in 210L drum and incinerate off site
Ventilation filter cartridges	cobalt-60, iron-55, nickel-63	Stainless steel supports with glass fibres	HVAC systems	LLW $29.7m^3$	Package within a bag and sent off site for super-compaction and disposal at the LLW Repository
RCCA	silver-109m, cadmium-109, chromium-51, iron-55	Control Cluster assemblies	Arise from reactor core	HLW Combined with SCCAs 605 assemblies over 60 years	Package in canister and co-dispose with spent fuel to a GDF
SCCA	chromium-51, iron-55, antimony-122, antimony-125	Thimble Plug, secondary neutron and primary neutron sources	Arise from the reactor core	HLW Combined with RCCAs 605 assemblies over 60 years	Package in canister and co-dispose with spent fuel to a GDF

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Waste management route
ICIAs	cobalt-58, chromium-51,iron-55, cobalt-60	Instruments used to measure core properties such as temperature and neutron flux.	Arise from reactor core	ILW 0.01m^3	Package in robust shielded container and dispose to a GDF
ICIAs	cobalt-58, chromium-51,iron-55, cobalt-60	Instruments used to measure core properties such as temperature and neutron flux.	Arise from reactor core	HLW 0.56m^3	Package in robust shielded container, decay store and dispose to a GDF

Appendix 5: Summary of the decommissioning wastes

The following information is taken from GNSL Pre-construction Environmental Report (PCER), chapter 4 (GNSL 2020a).

Waste type	Waste classification	Waste volume (m^3)	Waste container	Total waste package volume (m^3)
Reactor pressure vessel (RPV)	ILW	50	4m box	374
Reactor vessel internals	ILW	18	$3m^3$ box	74
Spent resins	ILW	40	500L robust shielded drum	110.6
Spent filters cartridges	ILW	1.4	$3m^3$ box	7.4
Concrete	ILW	150	4m box	352
Other equipment and concrete wastes	LLW/VLLW	12021	Half height isofreight container	28196

Would you like to find out more about us or your environment?

Then call us on

03708 506 506 (Monday to Friday, 8am to 6pm)

email

enquiries@environment-agency.gov.uk

or visit our website

www.gov.uk/environment-agency

incident hotline

0800 807060 (24 hours)

floodline

0345 988 1188 (24 hours)

Find out about call charges (www.gov.uk/call-charges)

Environment first:

Are you viewing this onscreen? Please consider the environment and only print if absolutely necessary. If you are reading a paper copy, please don't forget to reuse and recycle.