Generic design assessment of new nuclear power plants

Solid radioactive waste, spent fuel and disposability for the UK HPR1000 design - AR05

Detailed assessment – final report

10 January 2022

Version 1

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Executive summary

This report covers our detailed assessment of the Requesting Party's (RPs) 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 and others, 2021).

We assessed the RP's derived waste inventory for the UK HPR1000 covering operational and decommissioning wastes as well as spent fuel. We assessed the RP 's proposed approach to managing these wastes across the whole facility life cycle (from commissioning through to operations and decommissioning), 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 (GDF) is out of scope of GDA. The management of failed fuel within the spent fuel interim store (SFIS) is also out of scope.

We identified 3 potential GDA issues in our assessment report for our public consultation on the GDA of the UK HPR1000.

- 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

These potential issues have now been resolved as a result of the additional information which the RP has provided to us through GDA.

We have raised 16 Assessment Findings:

Assessment Finding 17: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants, to ensure that the inventory for disposal is accurate, for the UK HPR1000.

Assessment Finding 18: 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, during the operational phase, with regard to minimising production of decommissioning wastes and their classification. The future operator should demonstrate that BAT is being applied.

Assessment Finding 19: A future operator shall ensure that the decommissioning plan is periodically reviewed to demonstrate that BAT is being applied with regard to decommissioning the UK HPR1000.

Assessment Finding 20: 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 facility's waste acceptance criteria.

Assessment Finding 21: 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 22: 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 23: 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 24: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal would be transferred to a GDF.

Assessment Finding 25: 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 26: A future operator shall demonstrate that the future detailed design of the spent fuel interim store will deliver the long-term storage requirements for maintaining the integrity of the fuel, to ensure that it will be disposable in the future.

Assessment Finding 27: A future operator shall ensure that monitoring and inspection of the spent fuel assemblies and canister within the spent fuel interim store are BAT.

Assessment Finding 28: A future operator shall ensure that the strategy for managing failed fuel over the lifetime of the UK HPR1000 is BAT to minimise discharges and maintains fuel in an acceptable condition to enable its future disposal.

Assessment Finding 29: A future site operator shall ensure that it addresses the disposability issues RWM raised within GDA, as part of the site-specific disposability assessment process.

Assessment Finding 30: 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 lifetime records.

Assessment Finding 31: 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 32: A future operator shall secure and use OPEX, including that available internationally, to demonstrate ensure that BAT is used to decommission the UK HPR1000, and that the generation of radioactive solid waste is minimised and is capable of being disposed of.

1. Introduction

This report provides our detailed assessment of the Requesting Party's (RP) 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 presents our assessment, with regard to our review of the management of solid waste, spent fuel and disposability, as part of our generic design assessment (GDA) process of the UK HPR1000. In addition, we also provide our responses to the relevant queries raised during our consultation. Our assessment reports provide the basis for our decision on whether to grant the RP a statement of design acceptability (SoDA).

We, the Environment Agency, expect any 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 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 RP should be able to demonstrate by the end of GDA that wastes arising from the operation of the UK HPR1000, as designed, are capable of being disposed of within the current regulatory system.

The Requesting Party for this GDA is constituted jointly by China General Nuclear Power Co (CGN), Électricité de France S.A. (EDF S.A.) and General Nuclear International Limited (GNI). General Nuclear System Limited (GNSL) is appointed by the above shareholders to act on behalf of the RP.

Our Process and Information document for Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID) provides guidance to the RP on our regulatory expectations (Environment Agency, 2016). Table 1 within the P&ID describes our expectations of the information the RP should provide in relation to the plants, processes and systems that will have a bearing on radioactive waste generation, treatment, characterisation and disposal. We also expect the RP 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 the disposal of higher activity waste (HAW))

The RP should provide information on the nature and quantities of wastes for disposal. This should take account of waste produced during normal operations, this includes waste arising from events that are expected to occur during the lifetime of the plant, for example refuelling and maintenance.

The preferred strategy of ‘concentrate and contain’ tends to direct wastes to the solid form rather than discharge via aqueous and gaseous routes (Environment Agency, 2010). 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 policies in England and Wales for the long-term management of HAW and spent fuel is via a geological disposal facility (GDF). A process to secure a suitable location is ongoing (BEIS, 2018). For GDA it is assumed that the GDF will be available to accept HAW arisings from the UK HPR1000. In advance of the availability of an operational GDF, the wastes and fuel will be stored on sites. RWM has developed a process of disposability assessment 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 the RP 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 would be required. Similarly, a future operator may choose to deploy other waste processing systems that differ from the RP’s proposals. However, we expect the RP 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 would be carried out at the site-specific 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, (Environment Agency, 2018) the RP 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 final detailed assessment has built on our preliminary assessment and is based on additional submissions and technical engagement with the RP.

2. Assessment

2.1 Assessment method

Our assessment method was as follows:

- Review relevant documentation that the RP 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 the RP to improve our understanding of the information it has provided and to explain any concerns we have with the information.
- Assess the techniques the RP proposed to prevent and minimise production of solid radioactive waste against our internal guidance and regulatory experience.
- Raise Regulatory Queries (RQs) to clarify our understanding of the information presented. Raise Regulatory Issues (RIs) or Regulatory Observations (ROs) where we believed the RP did not provide enough information. A summary of the RQs and ROs are provided within Appendix 2 and 3.
- Identify any GDA issues (GDAI) and/or Assessment Findings (AFs).

2.2 Assessment objectives

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

- enough information to address the shortfalls identified 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 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, 2021a). This reactor is currently under construction. The RP has used the FCG3 reactor design and operating experience (OPEX) from the operation of the Chinese Pressurised Reactor (CPR)1000 reactors 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

The RP 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, 2021a). The RP provided further information on the waste inventory derivation within the 'Waste Inventory for Operational Solid Radioactive Waste' (GNSL, 2021b) and the 'Solid Radioactive Waste Management Technical Source Term' reports (GNSL, 2021c). We have assessed these documents as part of our assessment of the inventory for the UK HPR1000.

For each waste stream the RP 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 non-radiological 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). Our assessment of the inventory and management of these wastes is provided within sections 3, 5.1 and 5.2.

LLW is waste which has an activity level equal to or less than 12 gigabecquerels per tonne (GBq/tonne) beta/gamma and 4 GBq/tonne alpha. VLLW is a sub-category of LLW. The major VLLW/LLW streams, which the RP states will arise from the UK HPR1000 are (GNSL, 2021a):

- 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 the RP's LLW inventory for the UK HPR1000.

We queried the OPEX that the RP had used to derive the average number of ventilation 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. The RP 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. The RP 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). The RP'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 the RP has updated the inventory.

We also raised RO-UKHPR1000-0036 and RQ-UKHPR1000-0514 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). We have reviewed further the information the RP submitted as part of the response to the RO, and the RP has made the case that the use of cuboidal filters is BAT for the UK HPR1000. As part of the response to the RO, the RP also assessed whether there would be any difference with regard to waste arisings from using either a cylindrical or cuboidal filter. Its assessment has demonstrated that the wastes arisings would be similar even if cylindrical filters were to be used in the future. Therefore, the conclusion from this RO is that the waste arising previously proposed for the UK HPR1000 are unaffected. Further information to support this conclusion is be provided within our BAT assessment report (Environment Agency, 2022a).

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.

The RP notes that the following ILW wastes streams will originate from the UK HPR1000 (GNSL, 2021a):

- ion exchange resins from the auxiliary systems, for example, the chemical volume control system and liquid waste treatment system
- spent filter cartridges from the auxiliary systems, for example the chemical volume control system and the 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

The RP 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 leaks into the secondary circuit. This would lead to an increase in ILW resins wastes. However, the

RP has stated that the material selected for the construction of the steam generator (Nickel alloy 690TT) is highly resistant to corrosion (GNSL, 2020b), and therefore the risk of such an event is minimised so far as is reasonably practicable (SFAIRP). The possibility for low activity resins to be ILW is 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 the RP provided.

We raised a number of RQs in relation to 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. The RP has addressed our concerns within the recent submissions. We also requested further clarity on the criteria used to identify the major radionuclides. The RP stated that the major radionuclides were identified using the principles set out within the 'Solid Radioactive Waste Management Technical User Source Term Report' (GNSL, 2021c) and are those radionuclides which contribute more than 10% of the total activity at creation (GNSL, 2021a). We are content that the RP 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. An RQ-UKHPR1000-1086 was raised to seek further information with regard to the failed fuel filters within the spent fuel pond and whether these would need replacing during the operational phase of the reactor. The RP has clarified that the filters will not need changing and that these filters will be part of the decommissioning LLW arisings. In addition, ONR raised RO-UKHPR1000-0056 with regard to the fuel route safety case for the UK HPR1000. The RO had the potential to affect the ventilation filter wastes arising, in the fuel building, should the design of the building be significantly modified. The information the RP provided gives us confidence that the impact of these changes to the waste arising is likely to be minimal and would not affect the waste management strategy. This will need to be confirmed at the site-specific stage. The responses to the RQs and the RO provide us with confidence that no additional ILW is likely to 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 (UK Parliament, 2016). The Joint Agencies Groundwater Directive Advisory Group (JAGDAG) provides a list of hazardous materials and non-hazardous pollutants (WFDUK, 2018). Therefore, we requested further information from the RP by raising RQ-UKHPR1000-0636, as to whether any hazardous materials and non-hazardous pollutants were present within the UK HPR1000 inventory. The RP highlighted a number of non-hazardous pollutants within the inventory, such as nickel, cadmium and antimony. We are satisfied that the RP 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 disposal facility operators will need this information to demonstrate compliance with the waste acceptance criteria (WAC) within the UK and to help compile the Nuclear Decommissioning Authority's (NDA's) UK radioactive waste inventory. In fact, LLWR Ltd and RWM as part of their disposability assessment have highlighted this as an issue that a future operator will need to address as part of the inventory (We address this further within sections 5.1 and 5.4). We have, therefore, raised the Assessment Finding below to ensure that this happens:

Assessment Finding 17: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants, to ensure that the inventory for disposal is accurate, 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 permeation of radionuclides across both the engineered and natural barriers of a disposal facility. The RP responded 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 the RP provide further information on the solid and non-aqueous waste inventory. We are satisfied for GDA that the RP has addressed this finding and that the operational inventory for LLW and ILW appears reasonable. We note that this will be further refined as the UK HPR1000 proceeds through its life cycle, and we will expect the future operator to continue to update its inventory.

3.2 Decommissioning wastes

Currently, there are no reactors being decommissioned in China and, therefore, the RP has had to develop a strategy and a plan for decommissioning the UK HPR1000 (GNSL, 2021d). The RP 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, UK Parliament 2016). To determine the preferred option for decommissioning the UK HPR1000, the RP has carried out an optioneering exercise (GNSL, 2021d). 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. the RP 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 (Environment Agency, 2010) for decommissioning the UK HPR1000 is that the generation of waste is either prevented or minimised. The RP needs to demonstrate that decommissioning considerations have been integrated into the design of the reactor, that the waste management hierarchy has been applied, and that environmental protection has been optimised. Our assessment will discuss this in more detail within section 4.

The RP 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

We note that within the decommissioning source term there is the potential for some parts of the RVI to be HLW at the point of generation. However, at the time of disposal the RVIs will have decayed to ILW. A future operator will further refine the classification of these wastes during the operational period of the reactor.

The RP has also developed a Preliminary Decommissioning Plan for the UK HPR1000, based on technologies available today (GNSL, 2021d). Using the decommissioning plan for the UK HPR1000, its knowledge of the design of the reactor and the derived decommissioning technical source term, the RP has proposed a Decommissioning Waste Management Plan, which provides an initial decommissioning inventory for the UK HPR1000 (GNSL, 2021e) 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. The largest volumes of radioactive decommissioning wastes are expected to be VLLW and LLW. Examples of these wastes are activated charcoal filter media, and building materials such as concrete and auxiliary piping. The RP 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.

The RP 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 the RP's decommissioning waste management plan noted that the inventory was solely derived from the decommissioning of the reactor building. We queried in 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 (the SFIS is out of GDA scope). The RP's response provides us with confidence that no further HAW wastes will arise from the decommissioning of these buildings. The RP 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. The RP clarified that the evaporators will be LLW and are not expected to need replacing over the 60-year lifetime.

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. However, we note that the decommissioning inventory will be further refined during the operational phase of the UK HPR1000, as more information becomes available.

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.

The RP 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 ($M5_{Framatome}$) 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 2021f). 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 the RP's response that the presence of gadolina is unlikely to impact on the disposal of the wastes, however we discuss this further within section 5.4.

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 one UK HPR1000 unit will be 2,985.

The RP 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, 2021g):

- 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 1,205 NFCCs will be produced over the lifetime of the reactor. Further information is provided within Appendix 4.

An RO was raised by ONR to seek clarity on the management of ICIAs and the safety case (RO-UKHPR1000-0037). The RP's response highlights that these wastes will be managed as ILW and HLW and that, 50% of the mass will be removed as LLW. The RP states that these wastes will not be decay stored to LLW and therefore there is no change to the waste classification of these wastes.

The RP 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 5 within our BAT assessment report to ensure that a future operator addresses this finding (Environment Agency 2022a).

We are content that the inventory with regards to spent fuel and NFCCs appears reasonable for GDA. The inventory for the SCCAs may be further refined in the future depending on the decision that a future operator makes regarding the removal of secondary neutron sources.

4. Minimising solid radioactive waste and spent fuel arisings

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

The RP, 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, 2021h). Our review of these arguments and the supporting evidence will be discussed within our BAT assessment report (Environment Agency, 2022a). However, within this report we provide a summary of how the RP 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. The RP has made a series of arguments to support its sub-claim

4.1.EC03.1 ‘Prevent and minimise the creation of radioactive waste and spent fuel’ (GNSL, 2021h), and sub-claim 4.1 EC03.4 ‘Minimise the mass/volume of solid and non-aqueous liquid radioactive wastes and spent fuel’ (GNSL, 2021h). We provide below a summary of the evidence which the RP 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’, the RP stated that the AFA 3GAA fuel is an advanced engineered fuel. The design of this fuel has taken account of many decades of OPEX and therefore the risks from fuel failures, during operation of the reactor, have been minimised. We note that the fuel design has incorporated several new design features to minimise the risk of failures (GNSL, 2021h, GNSL, 2020a). 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 (GNSL, 2021h, GNSL, 2020b), low relaxation springs and a greater contact area (GNSL, 2021h) and concave dishes at the end of the rods and chamfered edges (GNSL, 2021h).

In addition to the design of the fuel, the RP 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, the RP stated that there have been improvements to the testing arrangements and quality assurance procedures to help reduce the potential for fuel failures (GNSL, 2019b).

The cladding on the AFA 3GAA fuel is claimed to be highly resistant $M5_{Framaotme}$, which the RP has demonstrated has superior resistance to corrosion in previous designs (GNSL, 2020a).

ONR has raised RO-UKHPR1000-0015 to obtain additional information with regard to the risk that the presence of Chalk River Unidentified Deposits (CRUD) on the fuel cladding could pose to fuel failures. The CRUD on the surface of the cladding arises as a result of the deposition of corrosion products and other impurities from the circulation of the primary coolant. In extreme cases this can lead to the failure of the fuel cladding during operation of the reactor. Any increase in the likelihood of fuel failures will lead to an increase in the number of fuel assemblies being used and therefore a greater volume for disposal. We have reviewed the RP’s response to the RO and the supporting document (GNSL, 2021i). We note that the RP states that if CRUD were to form on the fuel, then the deposit is unlikely to lead to fuel failures. The formation of CRUD on the cladding of the fuel will be minimised by maintaining the coolant chemistry and the concentrations of impurities within the coolant. The RP states that during the operation of the UK HPR1000, a future operator will inspect the fuel rods to determine the extent of the formation of CRUD. Based on the information the RP provided, we see it as unlikely that the issues arisings from the formation of CRUD on the cladding would lead to a significant increase in the number of spent fuel assemblies for disposal. ONR will be assessing the impacts of fuel cladding failures from a safety perspective and dose to operators to ensure that ALARP is applied.

In support of argument E4.1.EC03.1-A2 ‘Minimising the concentration of fission products in the primary coolant by detection and management of failed fuel’, the RP stated that identifying and managing failed fuel will minimise the generation of solid waste. The inspection of new fuel prior to loading into the core, as the RP proposed, will minimise the risk of fuel failures. The UK HPR1000 has 2 systems for in-process sampling and monitoring of failed fuel during normal operations, one is the nuclear sampling system (NSS) and the second is the plant radiation monitoring system (PRMS). It also has 2 systems for detecting failed fuel during unloading, one is an online system located on the refuelling machine and the second an offline system within the spent fuel pool. Once identified, the spent fuel pool for the UK HPR1000 has specified storage locations to isolate the failed fuel and prevent the further spread of contamination. 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, 2021h).

In support of the argument E4.1.EC03.1-A3 ‘Minimising the quantity of spent fuel by core dimension design and cycle length selection’, the RP 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. The RP has identified an 18-month equilibrium fuel cycle as the optimum for fuel efficiency for the UK HPR1000 (GNSL, 2020d). 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 optimised. We have raised Assessment Finding 9 within our BAT assessment report to ensure that a future operator addresses this finding (Environment Agency, 2022a).

We have assessed the evidence the RP 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 will minimise the amount of spent fuel to be disposed of.

4.2 Corrosion control (Chemistry)

The RP 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 radioactivity level of waste by optimising the water chemistry in the primary coolant’) (GNSL, 2021h). Controlling the chemistry of the coolant will minimise the generation of corrosion and activation products, as well as minimising the production of waste from the maintenance of SSCs. The main controls on the coolant properties are (GNSL, 2021j, GNSL, 2021k):

- pH
- hydrogen concentration
- hydrazine (added at start up to scavenge 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). The RP's responses to these queries has led to an update of the 'Demonstration of BAT' document, but has had no impact on our conclusions (GNSL, 2021h).

We are content that by optimising the chemistry, the extent of corrosion and therefore subsequently activated products will be lowered. This will lead to either lower volumes of solid wastes, such as ion exchange resins being produced, or the activity per ion exchange bed may be lower, with the trade-off being that a larger volume of resin waste is generated. This will be a decision for a future operator to make.

4.3 Corrosion control (Material selection)

In addition to controlling the water chemistry, the RP 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 generation and activation of structure and component through material selection') (GNSL, 2021h). The choice of material will be important for minimising both operational and decommissioning wastes from the reactor. The RP 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. The RP 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. the RP 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. ONR has raised a number of RQs with regard to material selection, in particular in relation to cobalt. We are satisfied from the responses that the amount of cobalt within the construction materials for the UK HPR1000 has been minimised.

The RP 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 and within effluent abatement systems. For example, the RP proposes to use a thermally treated nickel alloy 690TT as the construction material for the steam generators (GNSL, 2020b).

4.4 Building layout

the RP 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 becquerel's 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.

The RP 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 become contaminated and subsequently will need to be disposed of.

The RP 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, 2020h).

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', the RP 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, 2020h).

The RP also highlighted that tools and equipment that will be used for maintenance operations will be kept within the controlled area within the reactor building (containment) and would 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 of our report.

In conclusion, we are content at the end of GDA that the RP has met our expectations for GDA with regard to minimising waste both with regard to volume and the activity in solid waste.

4.6. Decommissioning

The claims, arguments and evidence that the RP 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).

The International Atomic Energy Agency (IAEA) standards state that although decommissioning is the last stage of the life cycle of nuclear facilities, early consideration of it during the design stage plays an important role in achieving safe and effective decommissioning. An important part of effective decommissioning is minimising the amount of decommissioning waste that will be generated. The RP has reviewed the requirements for decommissioning and applied these to the decommissioning of the UK HPR1000 to ensure that the design of the reactor has taken account of decommissioning. the RP has made a claim that the design and intended operation will facilitate safe decommissioning using current available techniques. It has subsequently made the sub-claim 5.1.SC24.1 that the UK HPR1000 incorporates features that facilitate safe and effective decommissioning.

The RP has evaluated the design of the UK HPR1000 with regard to decommissioning. In doing this, the RP has highlighted a number of requirements that will be taken into account at the design stage, for decommissioning the UK HPR1000 (GNSL, 2020e). These requirements came from a range of standards, guidance and regulations within the UK and wider. The RP has subsequently developed a series of principles that will be applied to the design of the UK HPR1000 to ensure that decommissioning has been taken account of (GNSL, 2021l). These principles are:

- design measures to minimise activation and contamination
- physical and procedural controls to prevent the spread of contamination
- control of activation
- reduction in future dose uptake by decommissioning workers
- minimising the generation of radioactive waste

In ensuring that these principles are met, the RP has identified a series of design requirements for facilitating decommissioning and has applied these requirements to the design of the UK HPR1000. The RP summarised the main requirements that are important in minimising decommissioning wastes (GNSL, 2021l). The RP provided examples, where necessary, as to how it will aim to apply these to the design to the UK HPR1000:

- General layout of the site to facilitate transport, decontamination and undertake dismantling processes.
- Material selection and the careful choice of materials to minimise the generation of radioactive wastes, see section 4.3 for examples.
- Equipment design plays a crucial role in minimising the generation of radioactive waste, for example, in ensuring that liquors are not withheld within tanks.
- Process design to ensure that the migration and deposition of radioactive substances is minimised.
- Building and structure design to ensure that the radioactive waste is minimised, for example, the finishing of buildings to minimise the likelihood of radioactive substances penetrating into building materials.
- Layout design, as mentioned with section 4.4, is equally applicable to minimising the generation of decommissioning wastes.
- Waste management and the use of decontamination processes to ensure that waste can be either freely released or that it can be disposed of as a lower classification of waste.
- Radiological protection and the use of contamination zones, which are equally applicable to minimising the generation of decommissioning wastes.

We have evaluated the RP's report on the Consistency of Evaluation for Decommissioning the UK HPR1000. We are content that the RP has applied these requirements and principles with regard to minimising the amount of waste that will be generated and the disposal volume. However, we note that a future operator will need to ensure that these principles and requirements are applied at the detailed design stage.

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 bulk wastes. The RP has made best use of the OPEX available internationally to understand how decontamination could be applied to the UK HPR1000 (GNSL, 2020f, GNSL, 2021m). The RP 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 be 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 during operations. 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 18: 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, during the operational phase, 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, the RP proposes, as part of the decommissioning plan, to decontaminate the primary circuit. The RP plans to use CORD D UV as the preferred decontaminating agent for the primary circuit (GNSL, 2021m). We raised RQ-UKHPR1000-0646, as we noted that other decontamination agents could result in higher decontamination factors. The RP 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, the RP provided additional OPEX where CORD D UV has been applied on a nuclear power plant in Germany to decontaminate SSCs. Therefore, the arguments the RP 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 may improve. There should 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 19: A future operator shall ensure that the decommissioning plan is periodically reviewed to demonstrate 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 are to ensure that waste:

- is sorted and segregated
- is maintained within the principle of ‘concentrate and contain’
- can be appropriately characterised and packaged
- 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-UKHPR1000-0044 and RQ-UKHPR1000-0107 RQ-UKHPR1000-0141). The RP'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 container
- ILW/LLW waste storage areas

To address the above gaps, the RP carried out an optioneering exercise to identify the preferred options for treating solid and non-aqueous waste (GNSL, 2020g). A similar exercise was also carried out to identify the preferred options for managing the non-fuel core components (NFCCs) (GNSL, 2021g). 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 the RP as to how its optioneering exercises aligned with its 'Requirements on Optioneering and Decision Making Methodology' (GNSL, 2018a). The RP's response clarified the alignment of the solid waste optioneering report with its method, and we are content with the response.

The RP'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.

The RP 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 the RP 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 NDA's Technical Readiness Level (TRL) assessment process (NDA, 2014b). The RP subsequently carried out a multi-attribute decision analysis (MADA) against a series of criteria, of which 'environment' was included. The environmental criteria assessed were consistent with the waste hierarchy, conditioned waste volume, secondary waste generation and resource use. The RP 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 the RP'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 this 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 arises 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. We raised Assessment Finding 2 to ensure this takes place (Environment Agency, 2022b).

Our P&ID document requires the RP 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 is summarised within the RP's submission (GNSL, 2021a).

As part of the design of the UK HPR1000, the RP identifies that the waste auxiliary building as a building for segregating, treating and conditioning LAW on a site. However, some streams, such as the LLW concentrates will be conditioned within the waste treatment building and then sent to the waste auxiliary building for storage prior to sending off site for disposal. We note that the sampling of the wastes will, in most cases, be carried out as close as possible to where the wastes will be generated. The waste auxiliary building is part of the solid waste treatment system. The main areas of the building are:

- auxiliary areas
- receipt and dispatch areas
- LLW pre-treatment areas
- waste package storage areas
- half-height ISO (HHISO) freight loading, storage and inspection areas

The building contains a sorting box, a pre-compactor, roller conveyors, grouting facility, drum dryer and inspection devices for processing wastes. It also will have buffer storage for one year for 2 UK HPR1000 reactors, in case any future issues arise with sending the VLLW/LLW wastes off site for further treatment or disposal. However, we expect wastes that can be disposed of to be removed from site at the earliest opportunity. The RP has provided the design and layout of the waste auxiliary building at the conceptual level. However, we note that this building is out of GDA scope. We will expect more information on this building at the detailed design stage, and will assess this building with regards to BAT as part of our future regulatory engagement.

The RP highlighted 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. The RP 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 the RP proposes to segregate the dry active wastes arising from the UK HPR1000 into those wastes requiring metal melting, incineration, compaction or disposal. RQ-UKHPR1000-1362 and RQ-UKHPR1000-1553 were raised to seek further information on the processing of dry active wastes.

We note that for the treatment of LLW sludges and concentrates, the RP proposes to encapsulate these wastes. We have raised RQ-UKHPR1000-0992 to challenge why the RP 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. The RP’s response highlighted that there are potential issues with transporting concentrates due to the recrystallisation of boron, and that this would need a heated transport system, which currently is not available within the UK. In addition, the RP also states that there could be potential issues with the precipitation of solids at the injector system of an incinerator. The RP sought further advice from LLWR Ltd to support its conclusion. LLWR Ltd has also highlighted potential issues with this treatment option. Therefore, we accept that the option the RP chose represents BAT. A future operator may decide otherwise but should continue to assess this option as part of its ongoing review of BAT.

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, 2021h), the RP 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 Ltd’s projected future disposal inventory. A future operator will need to engage with LLWR Ltd before consigning these wastes to the repository to ensure that capacity is available.

The RP has obtained advice from LLWR Ltd with regard to accepting the LAW arisings from the UK HPR1000 (LLWR Ltd, 2020a). 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 the chosen option, would require further work with regard to the grouting process, the loading of resins, and to ensure that the discrete item limit is not breached
- metal wastes, and if direct disposal would be required rather than the chosen option of melting, and the potential impact of these being discrete items to be considered
- concentrates, and that the waste to grout ratio is managed to ensure that the waste is minimised in accordance with BAT
- filter cartridges and the potential for these items to be discrete items and must originate from LLW waste stream prior to compaction

- sludges will need to be suitably conditioned to meet the waste acceptance criteria (WAC) and discrete item limit
- that hazardous wastes could be associated with some of the waste streams

In addition, there were a number of general requirements LLWR Ltd highlighted, such as ensuring the wastes meet the activity limits, that the options chosen will be BAT, and that the WAC is met. In response to LLWR Ltd's agreement in principle, the RP has addressed each of the points raised to demonstrate that a future operator should be able to address them (GNSL, 2020h).

We have assessed both the advice from LLWR Ltd and the RP's response and we expect that a future operator could 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. 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, the RP has estimated the volumes of wastes that will arise from decommissioning the UK HPR1000 reactor (see Appendix 5). The RP proposes to use the same facilities for treating low level decommissioning waste as for operational wastes, where possible. However, for GDA, the RP 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 of GDA. We will expect a future operator to engage with the relevant disposal operator to ensure that all decommissioning LLW is disposable nearer the time for decommissioning the UK HPR1000, and to ensure that the options chosen are BAT.

We have written an Assessment Finding to ensure that a future operator will engage with the operator for the disposal facility:

Assessment Finding 20: 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 facility's waste acceptance criteria.

We welcome the inclusion of FAP-4-26 within the PCER, which will be addressed at the site licensing phase.

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 RWM 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 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 and others, 2021). 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 require the RP to produce an RWMC that covers its arrangements for managing all HAW arisings from the UK HPR1000.

The RP has produced 2 RWMCs; one details the arrangements for managing the ILW arising from the UK HPR1000 (GNSL, 2021n), while the second highlights the arrangements for HLW (GNSL, 2021o).

The RP has demonstrated how the RMWCs address our expectations within the joint guidance by mapping the sections of the RWMC to the relevant parts of the guidance. Previously, we raised the point that the RWMCs will need to incorporate the information from RWM's disposability assessment of HAW arising from the UK HPR1000. The RP has addressed this point as part of the response to our RO-UKHPR1000-0041.

The RWMCs, which the RP has produced, meet with our expectations for GDA, with regards to ensuring that the management of HAW should protect people and the environment. The RWMCs should 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 21: 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.

We welcome the inclusion of FAP-4-27 within the PCER, which will be addressed at the site licensing phase.

5.2.2 Managing operational and decommissioning HAW

For the UK HPR1000, the RP plans to process the operational HAW solids through the solid waste treatment system. The solid waste treatment system contains 7 sub-systems within it, of which 5 are involved in the treatment of the operational ILW wastes (the management of NFCCs will be discussed in section 5.3.2). The 5 sub-systems that will be involved in the treatment of the operational ILW are:

- dry active waste (DAW) treatment sub-system (treats ILW/LLW boundary DAW)
- spent resin flush and storage sub system (treats ILW resins)
- spent filter cartridge changing subsystem (treats ILW spent filter cartridges)
- the wet solid waste and receipt and treatment subsystem (treats ILW/LLW boundary condensates and sludges)
- ILW package system (package ILW and ILW/LLW boundary waste packages)

The solid wastes will be characterised, segregated, conditioned and stored within the solid waste treatment system (SWTS) (GNSL, 2021a). 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 separation tank for the low activity resins and 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 2 storage tanks for concentrates and the metering tank, 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 devices and a mobile grout encapsulation facility and characterisation tools
- 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. Several RQs were raised to seek additional information on the processing of these materials (RQ-UKHPR1000-1108, RQ-

UKHPR1000-1361, RQ-UKHPR1000-1553). We will discuss the processing of ICIAs 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.

5.2.3 Characterisation and segregation

To meet our expectations, it is essential that the RP can demonstrate that characterisation and segregation of the wastes is possible for the UK HPR1000. The RP has provided an overview of the processes and locations for sampling solid radioactive wastes for the UK HPR1000 (GNSL, 2021p). The RP 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. the RP has provided further information about the sampling and characterisation of concentrates in response to RQ-UKHPR1000-1108. 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. The RP 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, the RP 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 should 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 22: 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.

Segregation of the UK HPR1000 HAW wastes should 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. The RP provides examples of this, such as:

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

In addition, sampling will also be used to identify the different classification of sludges and concentrates before these are treated, therefore ensuring that these wastes are segregated. 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, the RP has reviewed the relevant standards and guidance relating to decommissioning, for example, International Atomic Energy Agency (IAEA) guidance (IAEA, 2018). The RP 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 the RP'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, 2021d). The RP has made best use of the 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 surface from the bulk concrete, a future operator can minimise the volume of HAW that will be disposed of to a future GDF. We note that the current decommissioning plan is based on the use of technologies that are available today. When it comes to decommissioning the UK HPR1000, newer technologies will have been developed that could potentially further enhance the characterisation and segregation of solid wastes. We expect a future operator to maintain an awareness of any future developments to characterise and segregate solid wastes.

We are content that the RP 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 should 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 20 to ensure that an operator does this.

5.2.4 Packaging and conditioning

The RP 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, 2020g). We discussed the process that the RP used at the beginning of section 5 of this report. The RP has also carried out an optioneering exercise to identify the preferred option for the containers in which the wastes will be packaged (GNSL, 2020i).

The RP has selected dewatering of the ion exchange resins within a 500L robust shielded container as the preferred option for processing HAW ion exchange resins. RQs have been raised to request further information from the RP with regard to processing ILW resins (RQ-UKHPR1000-0047 and RQ-UKHPR1000-0799). The resins will be dried, so that the residual ‘free’ 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 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 the RP's approach to the packaging and conditioning of ILW resins is likely to lead to a disposable product, without foreclosing future options.

The RP has identified the preferred option for conditioning and packaging the spent filters as grout encapsulation within a $3m^3$ box. The RP 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. We note from RWM’s disposability assessment that further furniture may need to be added to the box to support the filters.

For a number of ILW streams, the RP has identified several 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. The RP states that there is the potential for ILW concentrates, sludges and dry active wastes to be decay stored to LLW. In addition, further information was sought in RQ-UKHPR1000-1460 and RQ-UKHPR1000-1108 on the management of boundary wastes. 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 at the point of generation and will be packaged into a 210L drum, with a shielded cask around it (if necessary) 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, 2021a) and the RP 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.

The RP proposes to decay store ILW concentrates and sludges. The RP'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. The RP provided us with further information on the processing of concentrates and sludges via the solid waste treatment system via RQ-UKHPR1000-0411, RQ-UKHPR1000-1108 and RQ-UKHPR1000-1361. The RP 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. The RP'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 the RP’s response. Once these wastes have decayed they will be disposed of to a LLW facility, which for GDA is the LLW repository at Drigg.

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 generic 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.

The RP has sought disposal advice from RWM with regard to the encapsulation of ILW sludges and concentrates in a 500L drum. A future operator will need to have an alternative strategy that it can implement if it does not think that the decay strategy is justifiable. If the concentrates and sludges were to be conditioned within a 500L drum this would potentially involve changes to the encapsulation process and store, so that these containers can be handled across the solids waste treatment system (RQ-UK HPR1000-1460). We discuss RWM’s disposability assessment in relation to concentrates and sludges and use of the 500L drum within section 5.4.3. This option may be deployed in the future, but it will be for a future operator to decide this. However, a future operator will need to demonstrate that this option is BAT and why the decay option is not.

It will be for a future operator to determine the final strategy for managing the ILW concentrates and sludges. We are content, for GDA, that the RP has demonstrated 2 credible options for the disposal of these wastes. A future operator will have to demonstrate that the chosen option will be BAT and satisfy RWM via its disposability assessment process.

The RP has identified the preferred options for the conditioning and packaging of the ILW decommissioning wastes that will arise from the UK HPR1000 (GNSL, 2021e). 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 will be conditioned and packaged using the same processes as identified for the same wastes produced during the operational phase of the life cycle.

The RP has claimed that there is the potential for ILW/LLW boundary ion exchange resins to be generated during decommissioning. The RP plans to grout and decay store these resins until they are LLW. We raised RQ-UKHPR1000-0870 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, 2020g). The RP 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, the RP highlighted that the decommissioning resins are likely to contain negligible quantities of boron, which could potentially impact on the curing process. The RP also highlighted that Sizewell B disposes of its LLW resins using this approach. The current option chosen aligns with our expectations within our joint guidance that waste should be made passively safe as soon as possible. Therefore, we accept that the proposed approach would represent BAT for GDA and also would result in the storage of a passively safe product. However, we will expect a future operator to demonstrate that the approach for managing boundary decommissioning resins will still represent BAT nearer the time for decommissioning the UK HPR1000.

The RP 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 (RQ-UKHPR1000-0648) from the RP as to whether 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 UKABWR, a $3m^3$ box was the preferred option for packaging the RPVs (RQ-UKHPR1000-0648). The RP 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 the RP 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 options the RP chose are likely to lead to disposable packages. However, we note that, in a few cases, a future operator will need to demonstrate that the options the RP proposed 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 23: 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.

We welcome the inclusion of FAP-4-21 and FAP-4-24 within the PCER, which will be addressed at the site licensing phase.

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 Regulatory Environmental Principles (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.

The RP has considered international and UK guidance to develop its conceptual design for storing ILW for the UK HPR1000. We note that the RP has made use of the guidance to industry on the interim storage of higher activity wastes (NDA, 2017a). The RP has also used our Joint Guidance (Office for Nuclear Regulation, Environment Agency and others, 2021) 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. The design lifetime of the stores allows for packages to be stored on site for at least 100 years (GNSL, 2021a).

The RP 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, the RP has considered the impact on the environment as one of the assessment criteria. The RP 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, 2021q). The 210L drum will be stacked in stillages containing 4 drums.

As part of the assessment, ONR has raised the following RQs (RQ-UKHPR1000-0046, RQ-UKHPR1000-0477 and RQ-UKHPR1000-1311) and RO (RO-UKHPR1000-0040). We have provided input into the RO from an environmental perspective.

The RP 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 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. From the RP’s response there would appear to be no implications with regard to BAT. However, we note the design of the store is at a conceptual level for GDA and we will continue to review the implications of BAT at the detailed design phase in relation to our regulatory remit, as stated within our REPs.

The RP 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. It was also noted that the RP stated a contingency with regard to the storage capacity for the interim stores (10% based on OPEX from the operation of other stores), but did not substantiate this. Further information was requested from the RP with regard to the capacity of the stores and why the 10% value was deemed acceptable as a contingency factor. The RP provided further information with regards to the wastes that will be stored within the phase 1 and phase 2 stores. It also highlighted that based on the OPEX available, 10% was a typical contingency factor that was applied. We note from the reply that there are other options that could be used to increase the storage capacity. However, these would primarily be used if accidents were to occur, which we do not assess. We are content from the RP’s response that the stores’ capacity should be sufficient to store all waste packages. However, a future operator will need to review this periodically to ensure that this is the case.

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 the RP's response that this will be for a future operator to decide.

The RP 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. The RP 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. The RP has provided further information with regard to the examination, monitoring and inspection of packages. However, we note that these will be developed further by a future operator. We note that a future operator will need to develop its arrangements for identifying and managing any non-compliant packages with regard to the letter of compliance (LoC) envelope for the packages within the store to ensure that they will be disposable in the future and that no non-compliant waste packages are transferred to the GDF. We have raised the following Assessment Finding to ensure that this is done:

Assessment Finding 24: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal would be transferred to a GDF.

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

As part of RO-UKHPR1000-040, information was requested about the environmental conditions within the store. The RP has provided an overview of the parameters that will need to be considered in ensuring that the condition of the packages will be maintained. These parameters will need to be taken account of during the detailed design phase and during the operation of the ILW store.

Within RO-UKHPR1000-0040, ONR highlighted that there was limited information with regard to inspection of the store itself. Though this is primarily focused on the safety of the store, it will obviously play an important role in ensuring the public and the environment are protected. The RP has provided further information on what an operator will need to develop in the future. We are content for GDA that sufficient information has been provided, and that this will be developed further during the detailed design stage. We will continue to work with ONR to ensure that the future development of the ILW store will meet all regulatory requirements.

In reviewing the responses to RO-UKHPR1000-0040 to the Environment Agency, we are confident that an interim store can be designed and constructed that will maintain all packages in a condition that will meet with our regulatory expectations and will be disposable to a GDF. We note that for GDA the design of the ILW store is at a conceptual level and will be further developed at the detailed design stage. We will continue to review the design of the store as part of our ongoing regulatory process, along with ONR, during the detailed design stage and over the lifetime of the stores to ensure that BAT is being applied and that the packages will be disposable in the future.

We welcome the inclusion of FAP-4-22 within the PCER, which will be addressed at the site licensing phase.

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

5.3.1 Spent fuel

We expect the RP to demonstrate that it has a credible strategy for managing spent fuel and that BAT will be applied to achieve this. The RP 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 note that ONR is the lead regulator for the safe storage of spent fuel on a nuclear licensed site.

We provided the RP with our expectations regarding managing spent fuel (Office of Nuclear Regulation and Environment Agency, 2018). Those expectations of interest to us at this stage 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

The RP'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 of up to 100 years (based on the design lifetime of the store) (GNSL, 2021a, GNSL, 2020r). After the interim storage period, a future operator will begin transferring the SFAs to a GDF, which for the nuclear new build (NNB) programme, based on RWMs current working assumptions, will begin in 2145 (GNSL, 2021s).

The condition of the water within the spent fuel pool is maintained by the fuel pool cooling and treatment system. 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 ILW 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˚C, which is the normal operating limit (GNSL, 2021t). The heating of the pool water will result in gaseous discharges from evaporation and these will be collected and treated by the HVAC system within the fuel building. This is be discussed within our BAT assessment report (Environment Agency, 2022a).

The RP has carried out a detailed optioneering exercise to identify the preferred option for the interim storage of the SFAs (GNSL, 2019c). Two options were assessed in detail, 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. The RP identified dry storage within a metal canister/concrete silo 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, the 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 drying and dry storage of spent fuel, and we will expect a future operator to learn from the available OPEX when drying the fuel and operating the SFIS for the UK HPR1000. We discuss this within section 5.3 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. The RP has provided limited information on the drying process, as this depends on the chosen design of the spent fuel storage canister. However, we note that there is significant OPEX internationally and at Sizewell B on the drying of spent fuel. The drying process involves vacuum drying the assemblies, followed by purging the spent fuel/canister arrangement with an inert gas such as helium (GNSL, 2021u). We requested further information from the RP on what level of dryness will be required before the SFAs can be transferred to the SFIS for long-term storage (RQ-UKHPR1000-0741). The RP 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 this:

Assessment Finding 25: 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. The RP 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, 2021v, 2021w). A second store will accommodate the arisings from the next 30 years of operation, plus potentially some decommissioning wastes. The RP 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 for learning across the storage of the fuel. ONR will consider this from a safety perspective.

The RP states that the SFAs will be stored within the SFIS for a period of up to 100 years. The RP has based the conceptual design and operating limits for the SFIS on the best available OPEX and publicly available information (GNSL, 2021v, 2021w, 2021r). The RP has proposed conceptual design as being 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. We identified a potential GDA Issue in our report for public consultation requiring the RP to provide information on the long-term storage requirements for the spent fuel as well as information that the conceptual SFIS design will have the capability to meet these requirements.

The integrity of the SFAs during long-term storage is important to the Environment Agency, as the plan is to transfer the SFAs in the future to a disposal container that will be compliant with the design of the GDF. The actual transfer of the SFAs to a disposal container is out of scope for GDA. The RP has provided us with information to demonstrate that the M5Framatome alloy cladding and structural components of the SFAs are highly resistant to corrosion (GNSL, 2021x). We note that during the interim storage period, the SFAs will be stored within a container, under an inert atmosphere, that is, under helium gas. The inert atmosphere should prevent further corrosion of the SFAs. In addition, the RP has also provided information from Framatome with regard to the fuel criteria needed to ensure long-term integrity of the fuel during dry interim storage. Framatome has highlighted the main mechanisms by which fuel cladding could fail under dry storage conditions (GNSL, 2021x). The limiting degradation mechanism with regard to dry storage is thermal creep, which is dependent on the temperature of the SFAs and the internal pressure that will be applied to the cladding, which will stress the cladding (the hoop stress). Framatome has highlighted a number of studies that have been carried out internationally to define the criteria required for the long-term storage of SFAs. In addition, it has also assessed the likelihood of hydrogen embrittlement affecting the performance of the cladding. Framatome has concluded that it is unlikely that hydrogen will impact the performance of the cladding. It has subsequently defined the maximum temperature and pressure that will need to be complied with to ensure the integrity of the cladding within the SFIS. The RP currently assumes that the maximum temperature of the SFAs within the SFIS will be 400 degrees Celsius. This limit falls within the range highlighted by Framatome. With regard to hoop stress, the RP proposes to use a limit that is significantly lower than the limit proposed by Framatome.

ONR, as the competent authority for the interim storage of SFAs, on site has also assessed this area. The storage of spent fuel on site is an area of mutual interest to both ONR and ourselves. We note that within ONR's assessment (ONR, 2021) of the long term storage the SFAs that they are not content that the RP has provided evidence of the criteria that will preclude embrittlement of the fuel cladding by hydrogen realignment. ONR have stated that they expect to see further refinement of the criteria and the evidence to substantiate this by a future operator of the UK HPR1000. As a result of this conclusion, ONR has undertaken an assessment to evaluate if there is sufficient flexibility within the generic design of the UK HPR1000 to accommodate any future changes to the fuel criteria. ONR has concluded that they are confident that there is a low risk of the fuel criteria not being able to be delivered by the current generic design of the UK HPR1000. ONR has raised an AF within their assessment report to address this. We support ONRs conclusions.

With the flexibility in the operation of the UK HPR1000 and that the design of the SFIS is at a conceptual level, we see no reason why the criteria for ensuring the integrity of the fuel cannot be delivered at the site specific stage.

We note that currently there is no OPEX to support the storage of SFAs over the 100-year time period. In addition, there have been no transfers of the SFAs from the interim storage canister to a disposal container internationally. We have raised Assessment Finding 29 as we require a future operator to continue to engage with other operators, who are further along the life cycle for the dry storage of spent fuel, to ensure that they capture any learning regarding storage of the fuel and its future transfer to a disposal container.

Thus taking account the information provided by the RP, our assessment and the outcomes from ONR’s assessment we are content that the potential GDA issue we identified in our preliminary assessment report and consultation document has been addressed. However a future operator will need to substantiate all fuel criteria at the site specific stage to ensure that the integrity of the cladding of the fuel is maintained to demonstrate that it does not impact on disposability. We are confident that there is sufficient flexibility within the design and operation of the reactor and the SFIS to ensure that this will be the case. We have raised an Assessment Finding to ensure that a future operator does this:

Assessment Finding 26: A future operator shall demonstrate that the future detailed design of the spent fuel interim store will deliver the long-term storage requirements for maintaining the integrity of the fuel, to ensure that it will be disposable in the future.

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. The RP 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. The RP’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 the RP 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 this has not currently taken place.

Therefore, we raised RQ-UKHPR1000-0741 to request further information on whether visual inspection of the canister was possible. The RP's response reassured us that there was the potential to visually inspect the canister if needed, but that this will depend on the final canister/silo design chosen. A future operator will address this 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 27: 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 the RP of its statement that the chlorine content of the concrete silos will not be monitored (RQ-UKHPR1000-0741). The RP'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, the RP 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, 2021t). ONR raised an RQ (RQ-UKHPR1000-1086) to gain additional information about the failed fuel cells within the pond.

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 on the RP '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.

The RP'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 the RP chose is currently applied at other reactors within the UK and internationally.

The RP highlighted a number of options that a future operator could develop to transfer the failed fuel from the spent fuel pool to the SFIS. The RP 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 the RP'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. Therefore, we have included the following Assessment Finding:

Assessment Finding 28: A future operator shall ensure that the strategy for managing failed fuel over the lifetime of the UK HPR1000 is BAT to minimise discharges and maintains fuel in an acceptable condition to enable its future disposal.

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.

We welcome the inclusion of FAP-4-23 within the PCER, which will be addressed at the site licensing stage.

5.3.2 Non-fuel core components (NFCCs)

The NFCCs inventory has been described within section 2 of this report. The RP has carried out an optioneering exercise to identify the lead options for treating and packaging the NFCCs (GNSL, 2021g).

For managing the rod cluster control assemblies (RCCAs) and stationary core component assemblies (SCCAs), he RP has chosen to store and dispose of these wastes together as an integral part of the spent fuel assembly (SFA). The RP'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. The RP's response highlights that the RCCAs and SCCAs will not be characterised and that their activities will be calculated theoretically. However, we note within the post-GDA commitments report that the RP has made a commitment to assess whether this will be required in the future (GNSL, 2021y). The activities of these wastes are provided within the 'Activated Structure Supporting Report' (GNSL, 2020j).

Degradation of the RCCAs and SCCAs within the spent fuel pool is unlikely as the RP states that the chemistry of the spent fuel pool will be closely controlled and therefore minimise the risk from corrosion. The RP does not plan to inspect the RCCAs and SCCAs within the spent fuel pool, and from the information it 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 the RP's proposed management of the SCCAs and RCCAs. Information was requested as to whether there would be sufficient capacity at the refuelling stage to accommodate the RCCAs and SCCAs. The RP's strategy is to store the RCCAs and SCCAs together as an integral part of the SFAs. The RP'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. The RP'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. The RP 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 note that RWM raised an issue about ensuring that the carryover of water is minimised, to ensure that there are no issues with regard to placing such items within a GDF. We discuss this further within section 5.4.4 of this report. We accept, from the RP's response, that the likelihood of corrosion of the RCCAs and SCCAs is low. The RP'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 the RP provided regarding the conditioning, packaging and storage of the RCCAs and SCCAs, to ensure that the wastes can be retrieved for disposal, appears reasonable.

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 are discussed more within reference (GNSL, 2021g).

The RP carried out an optioneering exercise to identify the preferred option for the conditioning and packaging of ICIAs. The preferred option involves a number of steps (once the fuel has been removed):

- placing a shielded winding machine on top of the reactor pressure vessel
- cutting the section of the ICIA residing out with the core and protruding through the top of the shielding cover of the winding machine, 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, which will be HAW
- placing the wound ICIA within a robust shielded container containing additional internal stainless steel shielding (approximately 150mm thickness)
- transferring 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 (approximate 14 years) before transferring to the ILW interim store

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.

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 the RP demonstrates that the chosen option for managing ICIAs represents good practice. In addition, RQs were also raised to gain further information about the management strategy for ICIAs and the container that will be used to store and dispose of these wastes (RQ-UKHPR1000-1188 and RQ-UKHPR1000-1281). We previously raised a potential GDA Issue requesting that the RP provides further substantiation for the proposed strategy for the management of ICIAs. We also asked if any changes to the strategy were identified, whether this would have any impact on the disposal of the ICIAs.

The RP has provided this information. We note that the option to decay store the ICIAs, so that they become LLW is unlikely to be an option, as it would require a significant length of time for these wastes to become LLW (more than 100 years).

In addition, the RP has also assessed a number of potential alternative management strategies, as part of its optioneering assessment for the management of ICIAs, to ensure that the option chosen is indeed the lead option. The RP has assessed whether the ICIAs could be stored either cut or uncut within the spent fuel pond, or whether a separate instrument pond was possible within the reactor building. The RP also considered whether the operations to remove the ICIAs could be carried out away from the reactor vessel. In all cases, it was demonstrated that these options were not feasible or would result in significant modification to the reactor. From the evidence provided, the option for using the shielded winding machine to remove the ICIAs as the lead option would appear to be justified. We note that ONR will continue to review this area at the detailed design stage from a safety perspective. We will continue to work with ONR to ensure that there are no future changes to the strategy that could impact on disposal. However, for GDA we are content that the RP has addressed this issue, that the strategy proposed would appear to be the lead option and that there is likely to be no impact on the disposal container. We address other issues relating to the container within section 5.4.3, where we discuss RWM’s advice.

5.4 Disposal of HAW and spent fuel and NFCCs

5.4.1. RWM’s disposability assessment process

If the UK had a GDF, then the facility would have a waste acceptance criteria for accepting the wastes. However, this is not the case and currently the UK does not have such a facility. The current assumption and scope of GDA assumes that all HAW will be disposed of at a future GDF, in line with UK government policy. As a result, we expect the RP to obtain a view from RWM on the disposability of HAW (Environment Agency, 2016). We also expect the RP to consider and respond to the points RWM raised as part of its assessment. Our P&ID document requires the RP 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 disposal system safety case (gDSSC) for an illustrative GDF. This safety case suite tries to bound the uncertainties associated with the disposal of wastes to a GDF. The generic safety case is based around 6 illustrative designs; 3 for low heat generating wastes and 3 for high heat generating wastes. The designs are currently proposed for 3 different geologies: higher strength rock (HSR), lower strength sedimentary rock (LSSR) and for evaporites (GNSL, 2021s). As part of the disposability process, operators of UK nuclear facilities and GDA RPs seek advice from RWM to demonstrate that their proposals for conditioning and packaging of their HAW will be compatible with the current conceptual design for a GDF and, in particular, will not impact on the transport, operational and post-closure safety cases for such a design. As the UK's GDF programme develops, and a site is selected, the disposability assessment process will become more refined. However, the current disposability assessment process against these generic safety cases and conceptual designs provides a waste consigner with the confidence that its proposals for conditioning and the packaging of wastes are likely to be acceptable. It does not however, guarantee that the packages will be accepted. This will only be possible once a waste acceptance criteria has been developed for a GDF in the UK.

Currently, the disposal inventory for a GDF, the generic safety case and the concept design for the GDF takes account of a 16GW NNB programme, consisting of 6 EPRs and 6 AP1000s (GNSL, 2021s). A GDF will start to receive ILW wastes from 2040 and SFAs from 2075, based on the current working assumptions. However, we note that there is a degree of uncertainty associated with these dates. The waste being consigned to a GDF at these dates will be legacy HAW and SFAs from current UK facilities. ILW wastes from the NNB reactors will not be transferred to a GDF until at least 2100 and SFAs will not be transferred until about 2145. The RP's current plan is for a future operator to begin transferring waste to a GDF in 2130.

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). A LoC demonstrates that the licensee's proposal is compliant with the current conceptual designs for a GDF and its safety cases.

For GDA purposes, a single stage disposability assessment process is provided for the RP. This is typically at the pre-conceptual level and consists of 3 main parts:

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

These 3 phases are similar to the approach used in a detailed assessment that a future operator will need to progress through in order to obtain a LoC. A future operator will be able to build on the GDA disposability assessment if it chooses to implement the waste management proposals the RP put forward. We will continue to assess RWM's assessment of a future operator's proposals for disposing of its HAW as it progresses through the various stages, as part of our ongoing regulatory scrutiny.

5.4.2 Disposability assessment

The RP has stated 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) (GNSL, 2021h).

The RP has sought advice on the following wastes:

- spent resins ILW 500L robust shielded drum
- spent filter cartridges ILW grouted in a $3m^3$ box
- concentrates ILW grouted in a 500L drum
- sludges ILW grouted in a 500L drum
- reactor pressure vessel ILW grouted in a 4m box with 100 mm concrete shielding
- reactor vessel internals ILW grouted in a $3m^3$ box
- decommissioning concrete ILW grouted in a 4m box with 100mm concrete shielding
- ICIAs ILW 500L robust shielded drum with 150mm stainless steel shielding
- RCCAs HLW co-disposal within spent fuel disposal container
- SCCAs HLW co-disposal within spent fuel disposal container
- spent fuel HLW disposal within spent fuel disposal container

At this early stage in the development of the reactor design and operating regime, the proposals put forward by the RP are essentially just an outline. The detailed arguments and all the supporting evidence will not be available until the detailed design stage of the reactor and as it moves through its operational life cycle.

The GDA disposability assessment process has been based on the following assumptions:

- The UK HPR1000 will be operated for 60 years.
- It is uncertain when operation of power production from a UK HPR1000 would begin in the UK. In the GDA disposability assessment for the UK HPR1000, estimates of the time-dependent properties, for example, those related to radioactive decay, are assessed from the time the waste is generated. Discussion of the implications for management of the radioactive waste assumes that the reactor’s latest operational period will be 2070 to 2130, as the RP did not propose any operational dates for the UK HPR1000. This date is later than that for other reactors assessed through GDA.
- The fuel used in the UK HPR1000 will be manufactured from freshly mined uranium.
- It is assumed that ILW and spent fuel from the UK HPR1000 will arrive at a geological facility in a packaged state ready for disposal.
- Operational waste streams are transported to a GDF one year after arising, except ICIAs which are transferred after 10 years.
- Decommissioning waste streams are transported to a GDF 15 years after the end of operation.
- Spent fuel assemblies are transported to a GDF 10 years after the end of operations.

The wastes arising from the UK HPR1000 are typical of those that will arise from other PWRs that have gone through the GDA process.

5.4.3 RWM’s assessment of the disposability of proposed ILW packages

As previously mentioned, during GDA we expect to see evidence that for each of the higher activity waste streams there is at least one identified option that could be relied upon, with reasonable confidence, to produce a disposable waste package. A future operator will be expected to assess these options at the site-specific stage to determine that the options chosen are still valid, noting that new technologies and approaches may be developed in the future.

In developing the waste package inventory, RWM has supplemented and refined the radionuclide inventory data set the RP submitted. This is to ensure that the inventory for the assessment is bounding and addresses the potential uncertainties that exist at this stage. In addition, this would also ensure that the inventory data will address all the radionuclides that RWM are concerned about. This additional data was obtained from RWM's substantial knowledge base on similar waste that will be disposed of at a UK GDF, and from RWM’s disposability assessment of other PWRs, such as Sizewell B and other reactors which have gone through GDA. The approach used to enhance the inventory was dependent on the wastes being considered. RWM has subsequently derived an average and maximum inventory for each of the ILW waste packages. RWM’s approach is reasonable at this stage in the GDA process and we accept that this information will become more refined as the UK HPR1000 progresses through the detailed design and operational stages of its life cycle. The data used within the assessment is provided within Part 2 of the disposability assessment report (GNSL, 2021z).

In all cases, the RP proposes to use packages that are currently acceptable to RWM. We note that the RP proposes to modify the package that will be used to package the ICIAs, however this is still based on a robust shielded container design. We will discuss this later within this section of the report. The packages that will be used for packaging the low heat generating wastes (LHGW) will be 500L drums, robust shielded containers, $3m^3$ boxes and 4m boxes.

The RP proposes to dewater the ILW resins within a robust shielded container. RWM has highlighted that a future operator will need to demonstrate that the resins can be dewatered sufficiently. As previously stated within this report, Sizewell B has used a similar process for packaging ILW resins and RWM has assessed this. We are confident that the dewatering process can achieve the required residual water levels. We also note RWM highlights the potential issue of voidage within the package. RWM is continuing to assess the impact of voidage on a GDF, but seeks assurances that the voidage can be filled at a later date, if necessary. We are confident that the packaging of the resins does not foreclose future treatment options for minimising the amount of voidage within these packages. We are content for GDA that the option chosen is likely to lead to a disposable product.

RWM’s assessment of the RP’s proposal for the packaging of spent filter cartridges has highlighted that additional furniture may be required to support the filters. In addition, the RP will need to provide additional information with regard to any pre-treatment of the cartridges, as this could affect the infiltration of the grout into the wastes. However, the RP’s proposal is based on well-known practices for producing disposable products. We are content for GDA that a future operator can address the issues raised.

The RP proposes to condition the concentrates and sludges using cement within a 500L drum. We note, from RWM’s assessment, that there are chemical species (in particular, boric acid and zinc) within these wastes that could retard or inhibit the cementation process. We have previously sought further information from the RP with regard to this issue (RQ-UKHPR1000-0991). RWM has raised the presence of zinc and its impact on the cementation processes in previous GDA assessments. The RP states that the levels present are unlikely to affect the setting of the grout. However, we will expect a future operator to carry out the relevant research to develop an encapsulation formula for these wastes as part of the ongoing assessment process by RWM, to ensure that a passive waste form can be produced. We agree with RWM's conclusion and the action raised.

RWM has assessed the RP's packaging proposal for ICIAs in a robust shielded container without any encapsulant. We note RWM has raised the issue about the dryness of these materials. A future operator will need to demonstrate this is the case. However, we do not expect significant quantities of water to be associated with these wastes. We note that these packages will have significant voidage associated with them (estimated to be approximately 20%). However, as in the case for packaging resins, we do not see this option foreclosing the future treatment, to ensure that the voidage is minimised.

RWM has also raised an issue about the design of the container for packaging the ICIAs. The container itself is a standard container, but the addition of 150mm of stainless steel shielding within the container is a new aspect for RWM to assess. Within the UK, lead has previously been used in these containers to provide additional shielding as and when required. However, lead is a hazardous material with regard to the groundwater pathway. RWM is currently assessing the impact of lead within a GDF. Using a stainless steel liner instead of lead would address this issue. Therefore, this would be a positive step in protecting the environment. We note that the RP has stated that these packages are available commercially (RQ-UKHPR1000-1188). However, a future operator will need to demonstrate that the packages will not impact on the generic disposal system safety case (gDSSC). A future operator will need to demonstrate this as part of the site-specific disposability assessment process.

We note that the radiogenic heat output from the ICIA packages is likely to be greater than the 3 watts (W) target at the time of disposal vault backfilling. However, the 10-year decay storage period used in the GDA disposability assessment is conservative, as the majority of ICIAs will have been stored on site for a significantly longer period of time, allowing for further decay. Therefore, we would not expect the ICIA's heat output to challenge the temperature limit for the backfill. We also note the uncertainty with regard to the implementation of the GDF programme and the significant uncertainty as to when backfilling will occur. In addition, it will also be possible for this to be delayed if required. RWM could also undertake an emplacement strategy to address this issue if it were considered a challenge at the time of disposal. Therefore, we are content that this issue can be addressed going forward and that the packages are likely to be disposable.

The main waste streams that will arise from decommissioning the UK HPR1000 are concrete, the RPV and the RVIs. In addition, there will be a small quantity of ion exchange resins and spent filter cartridges that will originate from the ongoing operation of the spent fuel pond. The RP proposes to treat the resins and filter cartridges in a similar way to the ion exchange resins and filters that have been produced as part of the operational phase of the UK HPR1000. Therefore, these have not been assessed as part of the current disposability assessment and will need to be taken into account of at the time of decommissioning.

We raised RQ-UKHPR1000-1770, as we noted within the Decommissioning Waste Management Plan that the RP has stated that most dismantling operations will take place after 15 years of decay. However, we note that the Preliminary Decommissioning Plan states that the major dismantling operations will occur at the end of 10 years. We therefore sought clarification from the RP on which was correct, and whether there were any implications with regard to the inventory and management of HAW and, in particular, disposal of the wastes. The RP clarified that the information within the Preliminary Decommissioning Plan was correct and there would be no implications for the disposal of the decommissioning wastes.

With regard to the disposal of concrete from decommissioning operations, the RP has proposed to encapsulate the concrete within a 4m box. RWM has assessed this approach and is content. We note that a future operator will need to provide additional information on whether the concrete contains steel reinforcement as part of the ongoing assessment process. We also note that the shielding within the transport package will also have to be optimised. A future operator will need to be able to demonstrate that the grout can infiltrate the voidage within the wastes.

With regard to the RPV, there are a number of transport issues that have been raised. ONR, as the lead regulator for transport, will be the competent authority for these issues. However, we note that RWM will need a future operator to provide additional information with regard to voidage and the heterogeneity of the RPVs (in terms of the degree of activation). A future operator should be able to address both these points as part of the future assessment process.

We note that the RP has chosen a 15-year decay period for the decommissioning wastes (GNSL 2021s). This is very conservative, as it is likely that decommissioning wastes will need to be stored for a lot longer before transporting off site. RWM has highlighted that the proposal for packaging the RVIs and their transport off site, after 15 years, will likely challenge the heat output criteria at the time of backfilling. This is similar to that observed for the ICIAs, however the heat output is significantly greater. We sought further information from RWM with regard to how long these wastes would have to be stored to reach an acceptable output. RWM has indicated that it will need to be around 30 to 40 years. This is similar to the length of decay that has been used in other GDAs. We do not envisage this to be a significant issue as, based on RWM’s current plan for a GDF, it will not close until 2190. Therefore, even based on RWM’s conservative approach as to when the UK HPR1000 will be operating, the wastes could still be delivered to a GDF before closure.

The RVI have a high carbon-14 activity associated with them. Carbon-14 is an important radionuclide when assessing the generic environmental safety case (ESC) for a GDF. RWM continues to assess the ESC from a generic site and will gain more specific information at the siting phase in implementing a GDF. A future operator will need to provide RWM, as part of its disposability assessment at the site-specific stage, with the relevant carbon-14 activity for these wastes, so that RWM can assess the implications of this from a post closure perspective.

The loading of RVI into a $3m^3$ box is noted to be close to the mass limits for these packages. RWM has questioned whether the loading the RP proposed is achievable. RWM has recommended that a future site operator considers reassessing the amount of waste per package. We accept this conclusion by RWM and a future site operator should assess this as part of the ongoing disposability assessment. We note that lowering the mass within a box could lead to a greater number of packages needing to be disposed of. However, we would not expect this to alter the disposal area significantly, as the area of a GDF is dominated by the high heat generating waste (HHGW).

A future operator will also need to demonstrate that the grout media will not be affected by the high dose rates from these waste streams.

In a number of cases, the decommissioning operations are likely to generate particulates from a number of cutting operations. Currently within GDA, this is difficult to assess as the cutting technique has not currently been chosen. Therefore, a future operator will need to ensure that a packaging option for particulates is proposed nearer the time that the UKHPR1000 will be decommissioned.

RWM has assessed the impact of disposing of the ILW arisings from the UK HPR1000 on the overall size of the GDF in the 3 geologies. If the wastes were to replace one of the reactors already considered as part of the NNB programme (an EPR or AP1000) within the gDSSC, there will be no increase in the area of a GDF. However, if these wastes are additional to the wastes arising from the 6 EPR and 6 AP1000 already planned, then this is likely to result in fractional lengths of an extra vault being required. Therefore, the waste arising from the UKHPR1000 will have little, if any, impact on the size of a GDF.

We note RWM has identified a number of findings with regard to transport and operational safety. ONR is the competent authority with regard to these regulations, and so we have not discussed these within this report.

Post closure safety case

RWM has assessed the impact of disposing of the waste on the generic post closure safety case, to assess the long-term environmental safety that the engineered barriers provide. This safety assessment demonstrates how the disposal system will evolve over a significant period of time.

With regard to the groundwater pathway, RWM has concluded that there are no implications with regard to problematic radionuclides, or with regard to the activities associated with the wastes that will arise from the UK HPR1000.

RWM has also assessed the impact of solubility and sorption on the post closure safety assessment. RWM noted 2 potential sources that could lead to a decrease in sorption of the radionuclides and therefore enhance transport of radionuclides to the surface. These were degradation products from the ion exchange resins and the impact of cellulose degradation products. However, in both cases, RWM has assessed the impact from the arisings from UK HPR1000 to be negligible.

RWM has also assessed the impact of voidage and we have discussed this previously.

With the exception of the carbon-14 issue raised with regard to the disposal of RVI, the amount of carbon-14 that will arise from the degradation of the wastes is likely to be acceptable. RWM noted that the carbon-14 release from all packages of unshielded ILW (UILW) and unshielded LLW (ULLW) in the gDSSC is several orders of magnitude higher than that for the RVI.

There will be no impact from the risk of human intrusion as a GDF is likely to be situated away from potential receptors, therefore limiting the risk of intrusion.

A future operator will need to provide further information in relation to the non-radiological pollutants. We have previously raised Assessment Finding 17 (section 3.1), so that a future operator improves its inventory with regard to these pollutants.

RWM noted that the disposal of the UK HPR1000 LHGW is unlikely to increase the criticality risk associated with the post closure phase of the GDF's life cycle.

Therefore, RWM has concluded that the operational and decommissioning ILW wastes are likely to be disposable within a GDF from a post closure perspective, based on the current generic safety case and concept designs. We agree with RWM's conclusions but note that the issues identified will need to be addressed by a future operator during further engagement with RWM, as part of the site-specific disposability assessment process.

We have summarised the action points RWM raised as part of its assessment of the UK HPR1000 ILW wastes within Appendix 7. We have only highlighted those of relevance to the Environment Agency.

The RP has reviewed the findings from RWM's assessment and has sought to address each of the findings and how a future operator will address these as part of the site-specific disposability assessment process (GNSL, 2021az). We note the RP has divided the findings into specific issues (SI) and normal business (NB) so that they can assign a degree of prioritisation to these findings. SIs are issues with the potential to challenge the current waste management strategy or that could have an uncertain impact on the proposal for GDA. However, as mentioned previously, we will expect a future operator to address all findings as part of the ongoing LoC assessment. We reviewed the RP's comments on RWM's findings, and we are content that the RP has proposed that a future operator will address these findings. We will continue to monitor the progress of the disposability assessment and how a future operator addresses these issues as part of our ongoing regulatory remit.

5.4.4 RWM's assessment of spent fuel and NFCCs packaged with spent fuel

Spent fuel arising from the operation of the UK HPR1000 will be stored on site for at least 100 years. However, the length of time will depend on the availability of a GDF (GNSL, 2021a). Currently, RWM's planned date for accepting spent fuel from NNB into a GDF is 2145. However, there is obviously a degree of uncertainty associated with this date. RWM's assessment process for HHGW is not as well developed as that for assessing ILW wastes, as the placement of HHGW is dependent on the geology in which a GDF is sited.

The RP has highlighted, at a high level, 3 potential options by which the spent fuel could be packaged into a disposal container. A decision on which approach will be chosen will depend on a future operator's continued discussions with RWM and the design of a GDF. The transfer of the SFAs, containing the RCCAs and SCCAs, into a disposal container and its subsequent transfer to a GDF is out of GDA scope. The RP has provided a very high level approach as to how a future site operator may achieve this.

RWM's assessment has been based on concept packages that are based on the current generic concept that RWM has developed for the HHGW side of the generic GDF design. For spent fuel, RWM has proposed 2 different types of containers which could be chosen to the proposed concepts. One of these is based on a copper container, while the other is based on a carbon steel container. The choice of container will depend on the properties of the host rock of a GDF. RWM's disposability assessment assumes that 4 SFAs will be packaged into each disposal container. The RP has proposed that the SCCAs and RCCAs will be co-disposed within the SFAs. In total, 747 disposal containers will be used, and in 602 of these RCCAS/SCCAs will be placed. The disposal container is an important component of the safety case for the safe disposal of spent fuel. It accounts for one of the barriers in the defence in-depth approach for protecting the environment. The disposal containers required to package the SFAs from the UK HPR1000 will be slightly longer than those for the current design, due to the co-disposal with the RCCAs and SCCAs.

RWM has assessed the inventory data the RP provided for both the SFAs and the RCCAs and SCCAs. The inventories were enhanced for both the SFAs and the RCCAs/SCCAs to ensure that all radionuclides of interest were captured by the inventory data to be used during the assessment. The supplementary data was obtained from RWM's extensive knowledge base with regard to these waste types. The RP's data set will be improved as further information is gained during the operation of the UK HPR1000, such as the burn up of the fuel and the waste package loading. RWM's approach has been conservative to ensure that the data set that is used will be bounding. The data used for the assessment is provided within part 2 of the disposability assessment (GNSL, 2021z). We support RWM's approach in deriving the inventory for the assessment. From the data, RWM has deduced an average and maximum activity for a package containing spent fuel and RCCAs/SCCAs. RWM has raised a recommendation that a future operator's records will need to contain sufficient information to support its future disposability cases.

As previously mentioned, the fuel used is a uranium dioxide with $M5_{Framatome}$ cladding. The enrichment of the fuel can vary, but at equilibrium operations it is typically 4.45% uranium-235. The burn up range is typically 47GWd/tU (average) and 50GWd/tU (maximum). More efficient use of the fuel will result in less waste being disposed of to a GDF. However, higher burn up of the fuel (better use of it) will lead to a spent fuel with a higher content of fission products and actinides, resulting in a higher thermal output. In addition, within a number of the spent fuel assemblies, there will be gadolinia, which is a burnable neutron absorber. The content of gadolinia within the rods will vary depending on the location of the assembly within the reactor core. RWM's assessment did not take into account the presence of gadolinia. However, RWM has assessed this previously and the presence of gadolinia is unlikely to impact on the disposal of the SFAs. A future operator will need to provide this information as part of the ongoing site-specific disposability assessment.

The approach the RP proposed for the co-disposal of RCCAs and SCCAs with SFAs is a new approach and RWM has not assessed this before. However, Sizewell B also plans to co-dispose of these wastes. Information from a future Sizewell B disposability assessment will support a future operator's disposability case at the siting phase of the UK HPR1000. The co-disposal of these wastes will result in fewer waste packages being consigned to a GDF, therefore we support this approach. However, we note that if the wastes were not compatible, there is the option to package them separately when they are transferred to a disposal container, prior to transferring to a GDF. Therefore, future disposal options for packaging these wastes are not foreclosed, if they are required.

Overall, we are content with RWM's approach to ensuring that the inventory for the spent fuel and NFCCs combined is suitable, and that the inventory likely bounds the arisings from the UK HPR1000.

Burn up and thermal criteria for a GDF

Prior to SFAs being transported to a GDF, they will undergo a period of interim storage at the site. The RP's spent fuel management strategy has been described previously in section 5.3.1.

RWM's assessment does not take account of the type of interim storage that is applied, but does account for the length of time the SFAs are in interim storage. As previously mentioned, RWM's generic assessment is based on 6 disposal concepts, which RWM has developed as part of its gDSSC. The safety of the environment, with regard to disposing of HHGW, relies on the integrity of the container, the performance of the engineered barriers and the host geology in which the GDF is sited. These barriers will retard the transport of radionuclides to the surface. The disposal containers will be placed within a series of disposal holes along a series of tunnels, which will then be backfilled with either bentonite, in the case HSR and LSSR, or crushed rock salt for an evaporite geology. The performance of the engineered barriers can be affected by the heat output from the disposed SFAs and therefore for each of the geologies, RWM has derived thermal criteria at which the buffers need to be maintained to ensure that their performance is not degraded. These criteria have been derived from international programmes that are further developed than our own for a GDF. For HSR, the bentonite buffer should not exceed 100 degrees, for LSSR the buffer should not exceed 125 degrees and for evaporites the buffer should not exceed 200 degrees Celsius and therefore the HSR is the bounding case (GNSL, 2021s).

RWM has modelled the temperature differential across the disposal package, the buffer and the host rock for the spent fuel arising from the UK HPR1000. It has been established that additional cooling may be required for the buffer not to be affected. For the HSR case, a SFA package, with the average activity, would require a further 5 years, whereas for a package with the maximum fuel activity, a further 54 years of cooling would be required. For the other geologies, the additional cooling periods are less. It should be noted that there are significant uncertainties such as burn up and period of interim storage associated with the fuel inventory for the current assessment, and these uncertainties will be refined once the reactor is operational and the fuel is packaged. However, RWM has proposed that by ‘checker boarding’ (a mix of average and maximum activity packages within the same disposal package) the cooling time can be reduced to 38 years for the maximum activity inventory. RWM has also highlighted a series of additional options that could be implemented to lower the thermal output from a disposal container, such as decreasing the number of fuel assemblies within a container or increasing the interim storage period. We note that for the current assessment it is assumed that all fuel will be transferred to a GDF after 10 years of interim storage. The majority of the SFAs will be stored on site for a longer period of time before being transported to a GDF.

RWM has concluded that the SFAs arising from the UK HPR1000 can be managed such that the spent fuel is unlikely to affect the performance of the buffer. We agree with RWM’s conclusions, but note that a future operator will need to refine its strategy going forward to ensure the thermal output from the SFAs will not affect the buffer.

Disposal design

The spent fuel packages will be stored for a period within a spent fuel pool before being transferred to the SFIS for further storage. Before transferring the fuel to the SFIS, the fuel and RCCAs/SCCAs will be dried using a vacuum drying process. We discuss this in further detail within section 5.3.2. RWM has highlighted that a future operator will need to demonstrate that there is limited carry over of water as a result of the co-disposal approach. The dryness of the packages is crucial to minimising the amount of gas that will be generated. In addition, removing the water will also prohibit any further corrosion of the SFAs. We note that a future operator will probably need to carry out further work to demonstrate this. ONR has raised RQs (see section 5.3.2) to seek further information with regard to the drying process, which would support our conclusions that a future operator can minimise the amount of water carry over.

As stated earlier, RWM has developed its inventory for geological disposal and its gDSSC, based on a 16GW new nuclear build programme (which consists of 6 EPR (each producing 1.6GW(e)) and 6 AP1000 (each producing 1.14GW(e)). The spent fuel wastes that will be generated by the UK HPR1000 are similar to those for other PWRs and therefore are interchangeable with those that are already taken into account as part of the gDSSC.

RWM has assessed that if the UK HPR1000 spent fuel wastes were added to the 16GW new build programme, then 747 extra containers would be required. This would increase the footprint of a GDF in all 3 geologies by approximately 4%. However, if the wastes from the UK HPR1000 were exchanged with either those of the EPR or AP1000, then there would be no change in the overall footprint. We are satisfied with RWM's assessment of the impact on the generic design of the GDF and do not envisage a significant, if any, increase in the size of the GDF. RWM will continue to assess this impact as part of its ongoing GDF programme, dependent on further engagement with a future operator.

Impact on the environmental safety case

The environmental safety case (ESC) is part of the gDSSC, along with the transport and operations safety cases. The ESC demonstrates the performance of the system over the long term following closure of the facility. It assesses how the facility will evolve and its potential impact on the environment and the public. The case looks at how the engineering and natural barriers will perform and will contain radionuclides. It also assesses the impacts and dose that receptors will receive if the radionuclides were to reach the surface. RWM has assessed whether the disposal of the UK HPR1000 spent fuel/RCCAs/SCCAs would challenge the current understanding and conclusions from previous assessments within the gDSSC. RWM has assessed the impact of radionuclides, non-radionuclides from the groundwater pathway, gas pathways, from human intrusion, non-radionuclides assessments, and criticality based on illustrative design and the host environment. The higher strength rock assessment is assumed to be bounding as this rock formation is likely to have the highest groundwater flows through it.

In assessing the release of the radionuclides from the fuel, RWM takes no account of the cladding of the fuel, therefore RWM has assumed conservatively that when the containers degrade the fuel will release its radionuclides into the engineered barriers of the GDF. These radionuclides will be dependent on the fuel composition, burn up and other factors. RWM’s assessment has demonstrated that there is no significant difference between the release of radionuclides from the fuel originating from the UK HPR1000 and that from other PWRs.

Concerning the groundwater pathway, the disposal of the spent fuel from the UK HPR1000 does not present any issues with problematic radionuclides and activity of radionuclides.

The risk from inadvertent human intrusion into a GDF is minimised as any GDF will be sited in areas where natural resources are not present.

The vast majority of metal components that will be present as part of the inventory is not likely to be an issue. However, a future operator will have to ensure that it provides RWM with a credible inventory of non-radioactive components for the spent fuel/RCCAs/SCCAs packages. We have discussed this issue previously. A future operator will need to ensure it has records of potential non-hazardous pollutants and hazardous materials for the spent fuel/RCCA/SCCA inventory.

We note that for assessment of post closure criticality, RWM will need to take account of burn up credit as part of the criticality post closure safety case. We are aware that RWM is carrying out work in this area as part of its science and technology plan. We also note that RWM, as part of its gDSSC, has assessed the probability of a criticality within the post closure phase and has modelled the impact this could have on the engineered barriers. RWM continues to develop its understanding within this area, but based on the current generic concepts, RWM does not envisage a post closure criticality affecting the performance of the engineered barriers (RWM, 2014).

Overall, we are content that the post closure safety case is unlikely to be affected by the disposal of the spent fuel/RCCAs/SCCAs from the UK HPR1000. However, we note that RWM will require further information from a future operator as part of the ongoing disposability assessment process to verify that this is the case.

We have summarised the action points RWM raised as part of its assessment of the UK HPR1000 spent fuel/RCCAs/SCCAs wastes within Appendix 8. We have only highlighted those relevant to the Environment Agency.

As for the HHGW, the RP has accepted the issues RWM raised that will need to be addressed as part of the site-specific disposability assessment (GNSL, 2021az). The RP has divided the findings into SI and NB categories, as it did for the LHGW. The RP has addressed each of the issues that RWM raised with regard to its disposability assessment. We reviewed this document and were generally content. However, we challenged the classification of the issue relating to the co-disposal of SFA with SCCAs and the fact that RWM has previously not assessed this area, as the RP had classified this as a NB. As a result of the challenge, it has now classified this as an SI, which we accept. We also sought further information as to the classification of the issue with regard to the drying of the SFA/RCCAs/SCCAs and in particular the water carry over. However, the RP has kept this issue as NB based on its current understanding. A future operator will still need to demonstrate that this is achievable.

Previously within our preliminary assessment we raised a potential GDA Issue 6 and also RO-UKHPR1000-0041 to ensure that the RP provided sufficient information with regard to the disposal of HAW arising from the UK HPR1000 within the timeframe of this GDA. The RP has provided this information, which we have assessed. In addition, the RP has also updated its RWMCs and PCER with the relevant disposability advice. We are content that the RP has addressed both the GDA issue and the RO. However, we note that there are a number of issues, which RWM has raised as part of the disposability assessment process that a future operator will need to address at the site-specific stage. Therefore, we have raised an Assessment Finding to ensure that it does this:

Assessment Finding 29: A future site operator shall ensure that it addresses the disposability issues RWM raised within GDA, as part of the site-specific disposability assessment process.

5.5 Managing records and knowledge

Our REPs (Environment Agency, 2010) and 'Joint guidance on higher activity wastes' (Office of Nuclear Regulation and others, 2021) provide our expectations with regard to managing records and knowledge.

The RP 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.

The RP provided an overview of how it proposes to manage its records through its Management of 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. The RP 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 30: 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 lifetime records.

We welcome the RP's inclusion of FAP-4-20 as part of the PCER to ensure that a future operator will address this issue at the site-specific stage.

As we previously mentioned within section 5.3.1, the UK has limited experience regarding 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, the knowledge base should grow in the future. We note that the RP is aware of the significant international experience in relation to the dry storage of spent fuel. We will therefore 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.

Assessment Finding 31: 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.

The RP highlights 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. The RP 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 effective remediation plan
- preserve important information when implementing a deferred strategy

The RP is aware of various decommissioning knowledge management repositories that exist internationally, which a future operator could also use. These repositories of information will ensure that a future operator can demonstrate that BAT is being applied to the decommissioning of the reactor. An RQ was raised to seek further information about the management of decommissioning records and the management arrangements that will ensure that this is carried out at the site-specific stage (RQ-UKHPR1000-1252). We were content with the RP’s response. We support the RP's proposals to develop and make use of these repositories, in order to support and optimise the decommissioning of the UK HPR1000. Therefore, we have raised the following Assessment Finding to ensure that a future operator does this:

Assessment Finding 32: A future operator shall secure and use OPEX, including that available internationally, to demonstrate ensure that BAT is used to decommission the UK HPR1000, and that the generation of radioactive solid waste is minimised and is capable of being disposed of.

6. Compliance with Environment Agency requirements for GDA

We summarise how the RP’s submission has addressed our P&ID and our REPs:

- P&ID Item 3 - We are content that the RP has identified the main plants and systems that will be involved in the treatment of solid wastes, non-aqueous wastes and spent fuel.
- P&ID Item 4 - We are content that the RP has identified the main plants and systems that will be involved in the treatment of solid wastes, non-aqueous wastes and spent fuel.
- P&ID Item 5 - We are content that the RP has addressed this principle.
- P&ID Item 6 - We are content that the RP has addressed this item, but a future operator will need to identify the techniques it will apply.
- Principle RSMDP3: Use BAT to minimise waste - the RP has demonstrated that BAT has been incorporated into the UK HPR1000 design for the operational waste streams. With regard to decommissioning, we are content at this stage that for GDA the UK HPR1000 has made best use of the OPEX available to demonstrate that the reactor can be decommissioned and that the wastes that will be produced have been identified. We note the decommissioning plan will continue to be developed going forward and characterisation of the reactor at the time of decommissioning could result in additional waste being identified. However, for GDA, we are content that the design and waste arisings have been minimised.

- RWMDP8: Segregating wastes - the RP has demonstrated that the design of the UK HPR1000 will allow waste streams to be segregated, to optimise the disposal routes and minimise the generation of radioactive wastes. The RP has indicated that different routes will be used for processing LLW and HAW within the solid waste treatment system. Further information will be needed for the detailed design stage. However, we are content that, for GDA, the RP has met with our expectations. Therefore, we are content that this principle has been met. With regard to decommissioning the RP acknowledges the importance of segregation to ensure that decommissioning wastes are managed appropriately and that the disposal routes are optimised. Techniques for this will be developed nearer the time for decommissioning. However, we are content that the design of the UK HPR1000 does not prevent waste from being segregated.
- RSMDP9: Characterisation - the RP has at a high level described the sampling and characterisation that can be performed on the UK HPR1000. However, we note that the techniques that will be used will be determined at a later stage. We are content that the RP has provided sufficient information for GDA.
- RSMDP11: Storage - We are content that this principle has been addressed for GDA.
- RSMDP15: Requirements and conditions for disposing of wastes - the RP has obtained advice from both LLWR Ltd and RWM with regard to disposal of LAW and HAW. We are content that the RP has addressed this principle for GDA.
- DEDP1: Decommissioning strategy - We are content that the RP has addressed this principle for GDA.
- DEDP2: Decommissioning plan - the RP has produced a preliminary decommissioning plan. We note that this plan will continue to be developed over the life cycle of the UK HRP1000. We are content that the plan meets the requirements of this principle for GDA.
- DEDP3: Considering decommissioning during design and operation - the RP has demonstrated, for GDA, that the design of the reactor has taken account of decommissioning. We note that this will continue to be developed at the detailed design stage. We are content that the RP has addressed this principle for GDA.

7. Public comments

7.1 The Requesting Party’s public comments process

The RP had received 4 public comments to its online GDA comments process relating to managing solid radioactive wastes, decommissioning and the disposal of spent fuel.

On 28 November 2017, the RP received a comment from the public with regard to the dry storage of spent fuel and its comparison with wet storage. The RP 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. The RP 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 the RP has carried out an optioneering exercise to identify the preferred option for storing spent fuel. The RP 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 the RP 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, the RP 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 that ONR, as the competent authority for transport and safety, are best placed to address. Section 5.3 of this report provides further information with regard to this topic.

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

On 31 August 2018, the RP 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. The RP 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 it 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. We provided further information on this topic within section 5.4 of this assessment report.

The RP states that with regard to decommissioning and the storage of spent fuel, this is part of another government process, known as the Funded Decommissioning Programme (FDP). A future operator would need to put forward a decommissioning plan and a funding plan for decommissioning, interim storage of waste and spent fuel, and their disposal in a GDF. This is a statutory requirement and the future operator would have to obtain approval of their FDP from the BEIS Secretary of State before construction of nuclear facilities at the site could begin. The RP has carried out an optioneering exercise to determine the preferred option for decommissioning the UK HPR1000 and immediate dismantling has been chosen. The RP has also demonstrated that the UK HPR1000 can be decommissioned using today's technology. We are content that the RP has addressed this query.

On 31 August 2018, the RP 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. The RP'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. The RP states that the UK government now requires an operator to put aside funds for decommissioning the reactor. This is a legal requirement. The RP 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. The RP has taken account of decommissioning when designing the reactor to prevent or minimise the generation of solid wastes. We are content that the RP’s response has addressed the comment.

7.2 Environment Agency public consultation

We received a number of comments, in response to our interim conclusions within the assessment report we published for our public consultation on the GDA of the UK HPR1000. We have reviewed these comments and provide our response within this section.

We received response UKHPR1000-009, which requested further information with regard to the comparison of solid waste discharges arising from the UK HPR1000 with other PWRs. The inventory for the UK HPR1000 has been derived from OPEX from the operation of PWRs in China. In addition, RWM has noted within its assessment that the HAW waste arising from the UK HPR1000 is considerably less than that for other GDA PWRs that RWM has assessed. However, it should be noted that the waste management practices could be different for each of the PWRs. Also, the operating conditions of the PWRs will be different and therefore any direct comparison with other PWRs would have significant uncertainties associated with the volume of wastes that would be generated. However, it is noted that the types of wastes are similar to those for other PWRs. We also note within section 4 of this report that a number of improvements are being made to the UK HPR1000 to minimise the amount of waste that will be produced both during the operation of the reactor and when it is decommissioned. For example, the ion exchange beds within the UK HPR1000 will have a greater capacity to hold radioactivity than those that have been applied in China, which will lead to a smaller volume of ion exchange waste.

We note that the same response questions the fact that on-site storage will be required until a GDF is available, and that the disposal of SFAs has the potential to affect the bentonite buffer around the GDF. The RP proposes to begin transferring HAW to a GDF in 2130. Until then, on-site storage of the ILW waste will be required. For SFA arising from the UK HPR1000, these will not be transferred to a GDF until 2145 at the earliest. Therefore, on-site storage will be required until then. We and ONR will continue to regulate on-site storage of ILW wastes and SFAs until all wastes are transported to a GDF. The provision of a GDF is a matter for government policy and this is described within the document ‘Implementing Geological Disposal’ (BEIS, 2018). Any alternative solution to a GDF is out of the scope for GDA.

With regard to the impact of the thermal output from the SFAs, on the barriers within a GDF, RWM has addressed this as part of its assessment. We discuss this within section 5.4.5 of this report.

We received response UKHPR1000-011, which requested further information on the existence and capacity of the supply chain to further minimise the disposal of radioactive waste to the LLW repository and a GDF. The response also raised a concern about the implementation of a GDF, which we have addressed in our response to UK HPR1000-009 and within section 5.4.1 of this report. As part of the GDA assessment, the RP has obtained disposability advice from both LLWR Ltd and RWM. In both cases, both parties are confident that the wastes arising from the UK HPR1000 will be disposable. LLWR Ltd operates a waste services contract, where waste treatment technologies within the supply chain can be utilised. This has yet to be developed for a GDF, due to the fact that the UK is still in the early stages of implementing such a facility. However, the NDA and the current sites within the UK continue to assess and develop options for the treatment of HAW, and as part of this they will have to demonstrate that the waste arisings have been minimised. For GDA, the scope ensures that only technologies that are currently available are used to treat the wastes arising from the UK HPR1000. We have assessed the RP’s optioneering exercises, for both conditioning and packaging of the wastes, and are content with the options chosen for GDA.

We received response UKHPR1000-014 seeking assurances that our scrutiny of RWM’s advice will be rigorous and that we will have assessed the issues with regard to the long-term storage requirements for the SFAs. We have scrutinised the RP’s submission to gain confidence that the waste will be disposable to a GDF. Safe storage on site is regulated by ONR. We have assessed RWM’s advice and are content with the conclusions that it has reached. We discuss this within section 5.4 of this report. As part of our assessment, we have referred to RWM’s gDSSC and the supporting documentation as part of our assessment of RWM’s disposability assessment for GDA. We have used our Joint guidance on higher activity waste on site and our knowledge of previous disposability assessments for similar wastes. We have also, when necessary, sought further information from the RP and RWM with regard to their submission and assessment. As highlighted within section 5.4.1 of this report, the disposability assessment for GDA is the first step in a multi stage process for assessing the compatibility of the RP’s proposals for conditioning the HAW within a future GDF. In addition, as part of our ongoing regulatory remit, we will continue to assess a future operator's proposals to RWM with regard to the conditioning and packaging of the HAW arisings from the UK HPR1000. We note that the uncertainty associated with the decommissioning wastes, at present, will be greater than that for the operational wastes. However, the RP has used its knowledge of its reactor to provide a reasonable initial estimate of the decommissioning waste inventory. This will be refined during the operational phase of the reactor, as more information becomes available and will be available for the disposability assessments at the siting stage. We address the query with regard to the long-term storage of the fuel within section 5.3.1 of this report.

Response (UKHPR1000-014) also requests additional information with regard to a number of additional areas: These are:

- whether a GDF can accommodate the wastes that will arise from the UK HPR1000
- whether there will be resources, technology and controls necessary to maintain HAW and spent fuel safely in interim storage until a GDF is available
- what the conditions will be like on a low-lying site (generic or Bradwell) vulnerable to inundation storm surges, coastal and processes

With regard to the query about whether the GDF can accommodate the waste arisings from the UK HPR1000, we have discussed this within sections 5.4.3 and 5.4.4 of this report.

ONR is the lead regulator for the storage of wastes on site. Therefore, it will be the lead authority on assessing whether the proposal for the storage of HAW on site is acceptable from a safety perspective. We have reviewed the information the RP provided from an environmental view and we are content with what the RP has proposed for GDA. More information will be provided at the site-specific stage, with further information provided on aspects such as specific technologies, waste acceptance controls and resources. We will assess whether any of this information will impact on the environment as part of our ongoing regulation.

With regard to the query about an assessment of the conditions on a low-lying site and the implications this will have on the storage of the waste, this is a site-specific issue. This has not been assessed as part of GDA, as it is out of scope.

We also note that response UKHPR1000-014 highlights the uncertainties that exist with regard to the implementation of a GDF, and questions our conclusions regarding the wastes that are planned to be disposed of to a GDF. It is government policy that we will have a GDF and we are working to that assumption in GDA. At the time this point was raised we did not have the RWM assessment and it was noted as a potential GDA Issue at the time of consultation. Now that we have received and reviewed that information, we note that a number of issues have been raised. However, as the aim of the disposability assessment is to provide confidence that at least one option can lead, in principle, to a disposable package, we are content that the RP has provided this for GDA. It should be reiterated that the disposability assessment for GDA is the first stage in a multi-stage process. A future operator will need to address all the issues that RWM has raised, as part of the GDA disposability assessment, to obtain a LoC.

Consultation response UKHPR1000-014 has also raised a series of questions with regard to the decommissioning wastes that will arise from the UK HPR1000. In particular, it raises the following queries:

- that no reactor in China has been decommissioned so far and therefore raises concerns about the available OPEX
- whether there are any materials where currently there is no solution with regard to disposal
- about the overall assessment the Environment Agency made and why we are not willing to provide an overall statement on the assessment of the decommissioning of the UK HPR1000

We agree that currently no reactors in China have been decommissioned. However, internationally there are a number of PWRs that have been decommissioned and the UK HPR1000 would present similar challenges to these reactors. In fact, as the RP has considered decommissioning as part of the design of the UK HPR1000, it is our view that this will lead to a reactor that will produce less wastes at the time of decommissioning, compared to older PWRs. The RP has reviewed the OPEX available internationally with regard to dismantling the plant and decontaminating the reactor. The RP has applied this knowledge to the decommissioning plan for the UK HPR1000. The RP's approach to decommissioning the UK HPR1000 is based on currently available technologies. However, the UK HPR1000 will not be decommissioned for a considerable time and therefore new technologies and approaches to decommissioning such reactors will have been developed. A future operator will continue to review its decommissioning plan during the operational phase of the reactor's life cycle, and we would expect this as part of our ongoing regulation of an operator. We are content that what the RP has provided is acceptable for GDA.

We note that the same response highlights the decommissioning experiences at Bradwell A. Bradwell A has twin Magnox reactors, designed and constructed in the early days of the UK nuclear programme that are very different to a PWR. PWRs are more common around the world and, as stated previously, have been decommissioned. Therefore, the use of Bradwell A as an example, although we note the concerns raised, is not necessarily a suitable comparison, as, for example, the fuel element debris that has arisen at Bradwell A will not be a waste stream for the UK HPR1000. In addition the management of the wastes and spent fuel during the operation of the UK HPR1000 will be different to that which was implemented for Bradwell A.

Our assessment has not identified any materials that cannot be disposed of. However, there is always the possibility that during operations additional wastes could be identified. These would need to be captured by a future site operator as part of the waste inventory. A future site operator will then need to seek advice from RWM or another competent authority with regard to the disposal of any new wastes identified. We note that RWM has highlighted within its disposability assessment that particulate matter arising from cutting operations during the decommissioning of the UK HPR1000 will need to be conditioned and packaged in a form suitable for disposal. The RP has not done this for GDA, as knowledge of the actual cutting tool to be deployed will be needed.

We received response UKHPR1000-015 with regard to the implications of the disposal of high burn up fuel within the GDF. RWM has assessed the impact of high burn up on a GDF and we have discussed this within section 5.4.4 of this report. RWM will continue to review this as it moves towards the implementation of a GDF at a specific site(s).

We received a comment (UKHPR1000-017) with regard to interim store design being at a conceptual level and that no real detail in the design has been put forward and assessed. ONR is the lead regulator for the safety and storage of waste packages on site and therefore will review the design of the stores from a safety perspective. For GDA, we only expect the ILW store to be at the conceptual level of detail and that further information will be provided at the detailed design stage. Sections 5.2.5 and 5.3.1 of this report provide additional information of our assessment, but our focus is primarily on discharges (but discharges from the conceptual stores are out of GDA scope) and ensuring that the wastes remain disposable. We are content with the information that the RP has provided for GDA with regard to our regulatory remit.

We note the response also highlights the fact that currently waste from other Magnox Ltd sites is accepted at Bradwell A. This is out of scope for GDA, as this is a generic assessment and does not consider a specific site or sites, therefore this issue cannot be addressed at the GDA stage.

We received a comment (UKHPR1000-018), which sought further information on the timeline for storage of ILW and spent fuel on the site. The assumption within GDA is that the stores will be designed to store wastes for at least 100 years. The RP has proposed that the transfer of wastes to a GDF will begin in 2130. This is aligned with the current plan that RWM is working to, that LHGW from the NNB programme can begin being transferred to a GDF from 2100, and SFAs can begin being transferred from 2145. Section 5.4 provides additional information regarding the disposal of wastes and SFAs. We also note that the response queries whether it is the operational lifetime that is being discussed. This is not the case. It is the lifetime of the reactor, which includes the decommissioning phase.

Response UKHPR1000-018 sought further information with regard to the activities of the wastes. This information is presented within Appendix 4.

Response UKHPR1000-019 also sought further information on the timeline for interim storage. We have already addressed this as part of our response to UK HPR1000-018 and within section 5.2.5 and 5.3.1 of this report.

We received responses UKHPR1000-021 and UKHPR1000-026, which requested further information on the availability of the GDF. We have provided this information within section 5.4 of our report and in response to UKHPR1000-009.

We received a response UKHPR1000-027 questioning whether any of the potential GDA issues that we raised in our consultation document could have been closed during GDA. We have dealt with each of the GDA Issues within our report and these can be found within sections 5.3.1, 5.3.2 and 5.4. We conclude that the issues can be closed. In one case, we have raised an Assessment Finding so that a future operator continues to address this area. We also note the same response questions that we raised a potential GDA Issue with regard to the disposal of ICIAs. The issue was raised as the retrieval and storage strategy was not clear, and there could have been an implication for the disposal route and advice if the ICIAs had been decayed to LLW. However, this has now been addressed to our satisfaction for GDA.

We received response UKHPR1000-037 querying whether the waste forms are acceptable to be handled at the UK's waste disposal facilities. The RP has received disposal advice from LLWR Ltd and RWM. In both cases, the RP plans for a future operator to use packages and conditioning treatments, which are currently acceptable to both LLWR Ltd and RWM. In both assessments, a number of points have been raised that a future operator would need to address as part of its ongoing engagement with both disposal operators.

We received response UKHPR1000-043 that questioned the waste classification of the RPV. The RP has modelled the heat output from the RPV and it has concluded that the heat output is in the ILW range and does not need additional cooling. The heat output from the RPV has been modelled from 5 years to 100 years after the end of operations. Even at the point of generation, it is unlikely to be HLW. With regard to disposal, the RPV will be ILW at the time of disposal. It is more likely that potentially components of the RVI may be HLW at the point of generation. However, an operator will be able to refine the classification of the decommissioning wastes during the operational period of the reactor and the initial decommissioning phase.

Response UKHPR1000-043 also questions the use of incineration for treating the disposal of LLW resins. LLWR Ltd has assessed the use of this approach for the treatment of LLW resins and does not see this as an issue. However, the direct disposal of resins to the LLW disposal facility has not been ruled out. As highlighted within section 5.1 of this report, there are some issues that will need to be addressed if the resin were to be disposed of directly to the facility. If incineration is selected for the resins, it will be carried out by a permitted operator who will need to comply with its permit and ensure that discharges to the atmosphere meet with the legal requirements. In addition, by incinerating the resins, the volume of waste that will need to be disposed of will be significantly less, which will align with the waste management hierarchy. A future operator would need to demonstrate that incineration is BAT.

The same response questions the use of the 210L drum for a GDF. Within our assessment report we do note that a 210L drum is not a suitable package for a GDF. RWM's assessment has been based on the 500L drum, which is an acceptable package for a GDF. However, there is a potential option that if the waste in a 210L drum did not decay to LLW, these drums would need to be over packed using a waste package that is compliant with a GDF. However, a future operator will need to obtain advice from RWM regarding this option.

The same response also questions the storage of SFAs on-site and when they will be transferred to a GDF. We have already addressed a similar response as part of our response to UKHPR1000-009 above.

We note that the response (UKHPR1000-043) has also questioned the OPEX available with regards to the use of the $M5_{Framatome}$ cladding. This material has superseded another alloy called Zircalloy-4, which has been used over several decades for the cladding of PWR fuel assemblies. The RP has demonstrated that the properties of $M5_{Framatome}$ alloy perform as well, if not better, than the Zircalloy-4. Therefore, we are content that, based on the OPEX for both alloys, there is sufficient OPEX to support the RP's conclusions.

We received response UKHPR1000-047, which requests further information regarding the amount of spent fuel and the storage requirements. We have provided this information within sections 3.3 and 5.3.1 of this report.

The same response has raised the issue of how we plan to address our potential GDA Issue on the SFIS requirements. We have addressed this within section 5.3.1 of this report.

The comment also seeks further information in relation to what level of design knowledge and intellectual property is required to safely decommission the nuclear reactor and how this would be achieved by a party other than the RP. For GDA, the decommissioning of the UK HPR1000 is based on currently available technologies. Issues relating to intellectual property and knowledge transfer to allow a third party to decommission the UK HPR1000 are out of the scope for GDA. Some aspects of the arrangement for transferring information to a future operator are assessed as part of AR01 (Management Safety and Quality Assurance [MSQA]) and will be considered further at the site-specific stage.

The same comment also asks whether RQ-UKHPR1000-0992 has been resolved. It has, and we provide our assessment within section 5.1.

The same response asks about incineration on-site, but we have not stated within our report that incineration will occur on site. Incineration will be off-site and will make use of LLWR Ltd's waste services contract (see Appendix 4).

The same response asks about decommissioning and what will be left after 60 years. Decommissioning will not have begun while the reactor is still operation and therefore, at the end of the 60-year period, the reactor will be as it was at the end of operations. However, the site will be decommissioned back to an agreed end state, which the RP has assumed will be a green field site. However, this would be a discussion for a future operator and its stakeholders to have in the future.

8. Conclusions

With regard to our assessment of the UK HPR1000 management of solid wastes, spent fuel our 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.
- Generally, a good description of how solid wastes and spent fuel arisings will be minimised at source is provided at the level of information that we would expect for GDA.
- All LLW arisings from the UK HPR1000 are likely to be disposable. There are a number of outstanding issues for a future operator to address, but these are site-specific.
- The design of the UK HPR1000 has considered decommissioning and, therefore, minimised the generation of solid wastes. We note that this will continue to be developed as part of the detailed design stage.
- We are confident that the RP 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 options chosen for conditioning and packaging of the HAW solid wastes can potentially produce disposable products. RWM has raised a number of issues that will need to be addressed as part of the future disposability process that a site operator will undertake.
- We are content that the conceptual design for the ILW store is BAT and that the packages will be maintained in an environment that will ensure that they will be disposable. We will expect a future operator to continue to assess the application of BAT for the construction and operation of the second stage of the stores.

We have raised the following assessment findings for a future operator to address:

Assessment Finding 17: A future operator shall ensure that its characterisation programme will identify any hazardous materials and non-hazardous pollutants, to ensure that the inventory for disposal is accurate, for the UK HPR1000.

Assessment Finding 18: 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, during the operational phase, with regard to minimising production of decommissioning wastes and their classification. The future operator should demonstrate that BAT is being applied.

Assessment Finding 19: A future operator shall ensure that the decommissioning plan is periodically reviewed to demonstrate that BAT is being applied with regard to decommissioning the UK HPR1000.

Assessment Finding 20: 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 facility's waste acceptance criteria.

Assessment Finding 21: 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 22: 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 23: 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 24: A future operator shall develop arrangements for identifying and managing non-compliant waste packages, to ensure that only packages that are suitable for disposal would be transferred to a GDF.

Assessment Finding 25: 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 26: A future operator shall demonstrate that the future detailed design of the spent fuel interim store will deliver the long-term storage requirements for maintaining the integrity of the fuel, to ensure that it will be disposable in the future.

Assessment Finding 27: 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 28: A future operator shall ensure that the strategy for managing failed fuel over the lifetime of the UK HPR1000 is BAT to minimise discharges and maintains fuel in an acceptable condition to enable its future disposal.

Assessment Finding 29: A future site operator shall ensure that it addresses the disposability issues RWM raised within GDA, as part of the site-specific disposability assessment process.

Assessment Finding 30: 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 lifetime records.

Assessment Finding 31: 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 32: A future operator shall secure and use OPEX, including that available internationally, to demonstrate ensure that BAT is used to decommission the UK HPR1000, and that the generation of radioactive solid waste is minimised and is capable of being disposed of.

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Material Selection Report of Steam Generator. GHX00100034DPCH03GN, Revision C, October 2020.

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Decommissioning Technical User Source Term Report. GHX0050009DNFP03GN, Version E, June 2020.

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Supportive Report of BAT on Nuclear Design. GHX00800007DRDG03GN, Revision D, January 2020.

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GNSL, 2021d.

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List of abbreviations

AF	Assessment finding
ALARP	As low as reasonably practicable
BAT	Best available techniques
BEIS	Department for Business, Energy and Industrial Strategy
BERR	Department for Business, Enterprise and Regulatory Reform
CPR	Chinese Pressurised Reactor
CVCS (or RCV)	Chemical volume control system
CSTS (or TEP)	Coolant storage and treatment system
DSSC	Disposal system safety case
EMIT	Examination, maintenance, inspection and testing
EPR	European Pressurised Reactor
FAP	Forward action plan
FDP	Funded Decommissioning Programme
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	Higher activity waste
HEPA	High efficiency particulate air filter
HHGW	High heat generating waste
HHISO	Half height isofreight
HLW	High level waste
HSR	Higher strength rock
IAEA	International Atomic Energy Agency
ICIA	In-situ core instrument assembly
ILW	Intermediate level waste
IWS	Integrated Waste Strategy
IX	Ion exchange
JAGDAG	Joint Agencies Groundwater Directive Advisory Group
LAW	Lower activity waste
LHGW	Low heat generating waste
LLW	Low level waste
LLWR	Low Level Waste Repository
LoC	Letter of compliance
LSSR	Lower strength sedimentary rock
LWTS (or TEU)	Liquid waste treatment system
MADA	Multi-attribute decision analysis
MSQA	Management Safety and Quality Assurance
NDA	Nuclear Decommissioning Authority
NFCCs	Non-fuel core components
NNB	Nuclear new build
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 and monitoring system
PWR	Pressurised water reactor
R&D	Research and development
RCCA	Rod cluster control and assembly
REPs	Regulatory Environmental Principles
RGP	Relevant good practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor pressure vessel
RQ	Regulatory Query
RSR	Radioactive Substance Regulation
RWM	Radioactive Waste Management Ltd
RWMC	Radioactive Waste Management Case
RVI	Reactor vessel internals
SCCAs	Secondary core component assemblies
SFA	Spent fuel assembly
SFAIRP	So far as is reasonably practicable
SFIS	Spent fuel interim store
SGBS (or APG)	Secondary generator blowdown system
SoDA	Statement of design acceptability
SSC	Structures, systems and components
SSER	Safety, security and environmental report
SWTS (or TES)	Solid waste treatment system
TRL	Technical readiness level
UKRWI	United Kingdom Radioactive Waste Inventory
VDS (or RPE)	Nuclear island vent and drain system
VLLW	Very low level waste
WFDUK	Water Framework Directive United Kingdom
Zn	Zinc

Appendix 1 Requesting Party documentation assessed

- Pre-Construction Environmental Report Chapter 3 - Demonstration of BAT, Rev L GHX00510003KPGB02GN (2021)
- Pre-Construction Environmental Report Chapter 4 - Radioactive Waste Management Arrangements, Rev L GHX00510004KPGB02GN (2021)
- Pre-Construction Environmental Report Chapter 5 - Approach to Sampling and Monitoring, Rev L GHX00510005KPGB02GN (2021)
- Pre-Construction Safety Report Chapter 10 - Auxiliary Systems, Rev I GHX00620010KPGB02GN (2021)
- Pre-Construction Safety Report Chapter 21 - Reactor Chemistry, Rev I GHX00620021KPGB02GN (2021)
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- Pre-Construction Safety Report Chapter 24 – Decommissioning, Rev I GHX00620024KPGB02GN (2021)
- Pre-Construction Safety Report Chapter 28 - Fuel Route and Storage, Rev I GHX00620028KPGB02GN (2021)
- Pre-Construction Safety Report - Chapter 29 Interim Storage of Spent Fuel, Rev I GHX00620029KPGB02GN (2021)
- Requirements on Optioneering and Decision Making, Rev A HPR/GDA/PROC0012 (2018)
- Analysis of Applicable Codes and Standards, Rev E GHX00100024DNFF02GN (2020)
- Production Strategy for Radioactive Waste Management, Rev E GHX00100078KPGB03GN (2020)
- Solid Radioactive Waste Management Technical Source Term Report, Rev D GHX00530008DNFP03GN (2021)
- Waste Inventory for Operational for Operational Solid Radioactive Waste, Rev E GHX00100069DNFF03GN (2021)
- Activated Structures Source Term Report, Rev D GHX00800003DRDG03GN (2020)
- Integrated Waste Strategy, Rev G GHX00100070DNFF03GN (2021)
- Management Proposal of Waste Non-Fuel Core Components, Rev F GHX00100064DNFF03GN (2021)
- Radioactive Waste Management Case for ILW, Rev E GHX00100066DNFF03GN (2021)
- Radioactive Waste Management Case for HLW, Rev E GHX00100065DNFF03GN (2021)
- 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 E GHX00100063DNFF03GN (2021)
- 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 F GHX00100010DCHS03GN (2021)
- 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 E GHX08PTR001DNHX03GN (2020)
- Minimisation of Radioactivity Route Map, Rev E GHX0010002DNHS03GN (2021)
- 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 F GHX17TES001DNFF45GN (2020)
- TES- Solid Waste Treatment System Design Manual Chapter 2, Rev D 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 G GHX17TES004DNFF45GN (2021)
- TES- Solid Waste Treatment System Design Manual Chapter 5 - Layout Requirements and Environment Condition, Rev D GHX17TES005DNFF45GN (2020)

- TES-Solid Waste Treatment System Design Manual Chapter 6 - System Operation and Maintenance, Rev F GHX17TES006DNFF45GN (2021)
- TES-Solid Waste Treatment System Design Manual Chapter 9, Rev D GHX17TES009DNFF45GN (2019)
- TEU Liquid Waste Treatment System Design Manual Chapter 4 - System Design, Rev F GH917TEU004DNFF45GN (2021)
- TEU Liquid Waste Treatment System Design Manual Chapter 6 - Operation and Maintenance, Rev D GH917TEU006DNFF45GN (2020)
- RCV Chemical and Volume Control System Design Manual Chapter 4 - System and Component Design, Rev E GHX17RCV004DNHX45GN (2021)
- RCV Chemical and Volume Control System Design Manual Operation and Maintenance, Rev E GHX17RCV006DNHX45GN (2021)
- Spent Fuel Assembly Source Term Supporting Report, Rev E GHX00100002DRDG02GN (2021)
- Technology Optioneering on Spent Fuel Interim Storage, Rev B GHX00100057DNFF03GN (2019)
- Spent Fuel Interim Storage Facility Design, Rev H GHX00100081DNFF03GN (2021)
- The Matching Analysis of Selected SFIS Technology with current UK HPR1000 Design, Rev E GHX00100080DNFF03GN (2021)
- Fuel Handling Process and Operations, Rev D GHX00100008DPFJ45GN (2020)
- Demonstration Report for the Fuel Failure Mechanism in Fuel Route, Rev 3 GHX42500020SFSL44GN (2021)
- AFA 3GAA Fuel Assembly Description for HPR1000 Reactor, Rev 3 GHX42500001SFSL44GN (2019)
- UK HPR1000 - Fuel Assembly Anti-Debris Filter Hydraulic Test, Rev 2 GHX42500008SFSL44GN (2019)
- UK HPR1000 - Operating Experience with AFA 3GAA Fuel Assemblies, Rev 3 GHX42500009SFSL44GN (2020)
- Preliminary Safety Evaluation of SFIS, Rev H GHX00100046DNFP03GN (2021)
- UK HPR1000 Long Term Storage of Spent Fuel – Design Criteria, Rev 3 GHX42500032SFSL44GN (2021)
- Assessment of Fuel Crud for UK HPR1000, Rev B GHX00100061DRAF03GN (2021)
- Decommissioning Technical User Source Term Report, Rev E GHX00530009DNFP03GN (2020)
- Decommissioning Waste Management Proposal, Rev F GHX71500009DNFF03GN (2021)
- Design Requirements for Decommissioning, Rev C GHX71500016DNFF03GN (2020)
- Consistency Evaluation for Design of Facilitating Decommissioning, Rev E GHX71500005DNFF03GN (2021)
- Decontamination Processes and Techniques during Decommissioning, Rev D GHX71500010DNFF03GN (2021)

- Preliminary Disassembly Programme for the Main Equipment Decommissioning, Rev F GHX71500001DPZS03GN (2020)
- Preliminary Decommissioning Plan, Rev G GHX71500004DNFF03GN (2021)
- Safety Case Strategy of Decommissioning, Rev A GHX71500013DNFF03GN (2018)
- General Requirements for Decommissioning of Nuclear Power Plants, Rev B GHX71500011DNFF03GN (2020)
- Decommissioning Building Dismantling Process, Rev F GHX71500001DWJG03GN (2021)
- Higher Activity Waste and Spent Fuel Disposability Assessment Delivery Strategy, HPR-GDA-REPO-0150 (2020)
- UK HPR1000 HAW and SF Disposability Assessment End of June 2020 Status, HPR-GDA-REPO-015, (2020)
- GDA: Disposability Assessment for Wastes and Spent Fuel arising from Operation and Decommissioning of the UK HPR1000: Part 1 Main Report, Rev 1 GDA-REC-RWM-000003_001 (2021)
- GDA: Disposability Assessment for Wastes and Spent Fuel arising from Operation and Decommissioning of the UK HPR1000: Part 2 Supporting Data, Rev 2 GDA-REC-RWM-000003_002 (2021)
- GDA: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the Operation and Decommissioning of the UK HPR1000 PWR, Rev 1 GDA-REC-RWM-000004 (2021)
- Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability, Rev B GHX00100098DNFF03GN (2021)

Appendix 2 Regulatory Queries

- 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. The RP 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. The RP was asked to provide further information with regard to accumulation and storage.
- RQ-UKHPR1000-0047 (29/01/2018) Design for decommissioning and meeting the UK regulatory requirements for decommissioning. The RP was asked to provide more evidence to support that the decommissioning of the reactor would meet the UK's regulatory requirements.
- RQ-UKHPR1000-0106 (24/05/2018) Management of waste non-fuel core components (NFCC) from generation to disposal. The RP 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.
- RQ-UKHPR1000-0107 (24/05/2018) Gaps and differences between Chinese and UK practices in management of solid radioactive wastes and development of the Integrated Waste Strategy. The RP 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. The RP was asked whether there were any problematic or boundary wastes in relation to the inventory for the UK HPR1000.
- RQ-UKHPR1000-0405 (01/08/2019) Management of RCCA and SCCA. The RP 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. The RP was asked for further information with regard to the description of the ICIAs, characterisation of ICIAs, retrieval of ICIAs, segregation of wastes, and management of the waste packages.
- RQ-UKHPR1000-0407 (01/08/2019) Management of ILW resins. The RP was asked to provide further information with regard to minimising the generation of resin, its 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. The RP 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. The RP 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. The RP 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. The RP was asked to 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. The RP 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. The RP 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. The RP 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 questioned the formation of zeolites and silica.
- RQ-UKHPR1000-0547 (18/11/2019) Solid and non-aqueous radioactive wastes. The RP 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. The RP 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. The RP was asked for clarification on the major gamma emitters from LLW.
- RQ-UKHPR1000-0551 (18/11/2019) Processing of APG resins. The RP 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. The RP 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. The RP 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 an operator could develop for transferring the fuels into SFIS, whether the management strategy would rule out any disposal options for the fuel, and whether RWM's advice took account of failed fuel.

- RQ-UKHPR1000-0636 (12/02/2020) Hazardous substances and non-hazardous pollutants. The RP 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. The RP 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. The RP 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. The RP was asked to justify the choice of containers for packaging reactor pressure vessel (RPV) and reactor vessel internal (RVI) wastes during decommissioning.
- RQ-UKHPR1000-0664 (09/03/2020) Justification of safety of rod cluster control assemblies (RCCAs) and stationary core component assemblies (SCCAs). The RP was asked for more information with regard to the amount of RCCAs and SCCAs and their management within the fuel building and management and evolution within the SFIS.
- RQ-UKHPR1000-0697 (26/03/2020) PCSR Chapter 21 - Chemistry Regime - Hydrogen Control. The RP was asked about the hydrogen concentration limits and impacts on areas such 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. The RP was asked about the impact of zinc injection on other radionuclides, and the impact on materials such as welds. The RQ also requests further information on the impact on fuel and materials within the primary circuit and the effects on the spent resins and filters.
- RQ-UKHPR1000-0702 (26/03/2020) Topic report on zinc injection in the primary circuit Rev D. The RP 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. The RP 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. The RP 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. The RP 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. The RP was asked to clarify the drying limit for taking fuel into SFIS. The RP 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. The RP was asked about the waste classification of the evaporators that will be decommissioned. Additional information was required with regard to dismantling the evaporators.
- RQ-UKHPR1000-0776 (01/05/2020) Average number of ventilation filter cartridges. The RP 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. The RP was asked to clarify the waste volumes of ion exchange resins that would be produced for the UK HPR1000. The RP 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. The RP 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. The RP 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. The RP was asked to clarify points with regard to RO-UKHPR1000-0005.
- RQ-UKHPR1000-0870 (16/06/2020) Treatment of decommissioning ILW/LLW boundary resins. The RP was asked why grout encapsulation was the preferred option for conditioning ILW/LLW boundary resins, compared with incineration.
- RQ-UKHPR1000-0991 (04/08/2020) The effects of Zn on encapsulated wastes.
- RQ-UKHPR1000-0992 (04/08/2020) Incineration of LLW sludges and concentrates. The RP was asked to provide information to support its justification that LLW sludges and concentrates could not be incinerated, and therefore would be BAT.
- RQ-UKHPR1000-1086 (4/09/2020) Failed Fuel Special Storage Cell.
  The RP was asked to provide additional information with regard to the design of the failed fuel storage assembly. It was also asked to provide further information with regard to the waste that will arise from the storage cell.
- RQ-UKHPR1000-1108 (14/09/2020) Further detail on the management of concentrates. The RP was asked to provide additional information with regard to the management of concentrates through the TES system.

- RQ-UKHPR1000-1188 (13/10/2020) Queries relevant to ONR's assessment action of RO-UKHPR1000-0037 actions 1 and 2 submissions. The RP provided additional information relating to the container and the shielding that will be used. Additional information was also provided on the heat capacity of the containers and discrepancies with regard to the number of containers.
- RQ-UKHPR1000-1252 (10/11/2020) Documents and records for decommissioning. The RP was asked to provide additional information with regard to the identification of records that are important for decommissioning and also with regard to the management arrangements to ensure that these are put in place at the site-specific stage.
- RQ-UKHPR1000-1281 (16/11/2020) ICIA material and removal. The RP provided additional information about the removal of ICIAs from the core and how this is done.
- RQ-UKHPR1000-1311 (25/11/2020) Conceptual proposal of ILW interim storage facility. The RP was asked to provide further justification as to why the 2-phase construction was the chosen option, primarily focusing on ONR's regulatory remit.
- RQ-UKHPR1000-1361 (09/12/2020) Retrieval of sludges from tanks and sumps in RPE and TEU systems. The RP was asked to provide information on the retrieval of the sludges from tanks and sumps and their subsequent management through the TES.
- RQ-UKHPR1000-1362 (09/12/2020) Collection and on-site transfer of dry active waste. The RP was asked to provide further information on the transfer of dry active waste, covering segregation, and arrangements in place for managing these wastes from point of generation to storage on site. Information was also sought about the drying of these wastes.
- RQ-UKHPR1000-1460 (28/01/2021) Boundary wastes and the use of the 210L shielded cask. The RP was asked for information regarding the management of boundary wastes and also the use of the 210L and 500L drum. Additional information was also requested on the use of the shielded cask.
- RQ-UKHPR1000-1553 (22/02/2021) Dry active waste characterisation and drying. The RP was asked to provide more information on the types of dry active waste, and how waste will be segregated at the start and the drying process.
- RQ-UKHPR1000-1770 (02/07/2021) Decay period for deriving the decommissioning waste inventory. The RP was asked to clarify the period at which the decommissioning wastes will be dismantled and when the wastes will be transferred to a GDF. In addition, the RQ sought clarification as to whether there was any impact on the disposal of wastes if any changes to the dismantling period were noted.

Appendix 3 Regulatory Observations

- 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. The RP 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. The RP 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. The RP 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. The RP was also asked how the risks will be managed with regard to boron dilution faults.
- RO-UKHPR1000-0036 (26/03/2020) HEPA filter type. The RP was asked to evaluate the choice of HEPA filter for the UK HPR1000, whether the choice has considered fugitive discharges, and 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. The RP was asked about the waste classification of ICIAs, the strategy for managing ICIAs, whether relevant good practice (RGP) has been used and whether the strategy will achieve 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). The RP 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-UKHPR1000-0041 (24/04/2020) Disposability of higher activity waste from the UK HPR1000. The RP 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.
- RO-UKHPR1000-0056 (10/11/2020) Fuel Route Safety Case. The RP was asked to provide a suitable and sufficient safety case for the handling of spent fuel.

Appendix 4 Summary of operational wastes from the UK HPR1000

The following information is taken from the RP's Pre-Construction Environmental Report, chapter 4.

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
ILW spent resins	caesium-134 and 137, cobalt-58 and 60, nickel-63, iron-59 and silver-110m	Cross-linked polystyrene spheres	Arising from demineraliser in the FPCTS, CVCS, CSTS, LWTS and SGBS if steam generator fails	$1.9m^3$	5.8×10^2	Dry within robust shielded containers and then dispose to a GDF
LLW resins	silver-110m, antimony-124 and 125 and iron-59	Cross-linked polystyrene spheres	From 2 demineralisers in the SGBS	$9.7m^3$	2.35×10^{-2}	Package within 210L drum and then transfer off site for incineration
Concentrates	cobalt-60, iron-55, nickel-63 and silver-110m	Evaporator concentrates contaminated with activated and fission products	Arise from LWTS evaporator	LLW $1.47m^3$	4.37	Grout in a 210L drum and then dispose to the LLW repository

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
Concentrates	cobalt-60, iron-55, nickel-63 and silver-110m	Evaporator concentrates contaminated with activated and fission products	Arise from LWTS evaporator	ILW 0.73m^3	22.8	Grout in a 210L drum, decay store and then dispose to the LLW repository
Sludges	cobalt-60, nickel-63, iron-55 and silver 110m (only for ILW sludges)	Contamination with activated and fission products	Arise from tanks and sumps in the within the auxiliary circuit	LLW 0.05m^3	4.18	Grout in a 210L drum and dispose of to the LLW repository
Sludges	cobalt-60, nickel-63, iron-55 and silver 110m (only for ILW sludges)	Contamination with activated and fission products	Arise from tanks and sumps in the within the auxiliary circuit	ILW 0.05m^3	59.6	Grout in a 210L drum, decay store and then dispose of to the LLW repository
Spent filter cartridges	cobalt-58, chromium-51, iron-55 and silver-110m	Stainless steel support, glass fibres and organics	Arise from the CVCS, FPCTS, CSTS, LWTS, SGBS and VDS	LLW 0.65m^3	6.18 x10^{-3}	Packaged in a 210L drum and super compacted off site
Spent filter cartridges	cobalt-58, chromium-51, iron-55 and silver-110m	Stainless steel support, glass fibres and organics	Arise from the CVCS, FPCTS, CSTS, LWTS, SGBS and VDS	ILW 1.14m^3	9.14 x10^2	Grout in a 3m^{3}box and dispose of to a GDF

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
Dry active waste (Combustible)	cobalt-58 and 60, niobium-95 and iron-55	Paper, plastic, cloth	Operations and maintenance activities	LLW 126.81m^3	2.77	Package in 210L drum and incinerate off site
Dry active waste (Combustible)	cobalt-58 and 60, niobium-95 and iron-55	Paper, plastic, cloth	Operations and maintenance activities	ILW 17.94m^3	16.2	Package in 210L drum, decay store and then dispose of to the LLW repository
Dry active waste (Metals)	cobalt-58 and 60, niobium-95, iron-55	Metals	Operations and maintenance	LLW 10.44m^3	2.77	Package in a metal box and sent off site for melting
Dry active waste (Metals)	cobalt-58 and 60, niobium-95, iron-55	Metals	Operations and maintenance	ILW 1.56m^3	16.2	Package in 210L drum, decay store, transfer in metal box off site for melting
Dry active waste (compactable)	cobalt-58 and 60, niobium-95 and iron-55	Cable, plastics	Operations and maintenance	LLW 14.79m^3	2.77	Package in 210L drum and then send off site for compaction

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
Dry active waste (compactable)	cobalt-58 and 60, niobium-95 and iron-55	Cable, plastics	Operations and maintenance	ILW 2.21m^3	16.2	Package in 210L drum, decay store, then send off site for compaction
Dry active waste (non-compactable/non-combustible)	cobalt-58 and 60, niobium-95, iron-55	Concrete and glass	Operations and maintenance	LLW 4.35m^3	2.77	Packaged in iso-freight for disposal to LLW repository
Dry active waste (non-compactable/non-combustible)	cobalt-58 and 60, niobium-95, iron-55	Concrete and glass	Operations and maintenance	ILW 0.65m^3	16.2	Packaged in iso-freight for disposal to LLW repository
Oil	cobalt-58 and 60, niobium-95, nickel-63, iron-55	Lubricating oil	Maintenance of hydraulic equipment	VLLW/LLW 0.13m^3	2.12 x10^{-4}	Packaged in a 210L drum and incinerate off site
Organic solvent	cobalt-60, iron-55 and nickel-63	Organic solvents	Normal operations for example removing contamination from reactor bolts	VLLW/LLW 0.2m^3	1.38 x10^{-4}	Packaged in a 210 L drum and incinerate off site

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
Ventilation filter cartridges	cobalt-60, iron-55, nickel-63	Stainless steel support with glass fibres	HVAC systems	LLW 29.7m^3	1.62 x10^{-2}	Package within a bag and sent off site for super-compaction and subsequent disposal at the LLW repository
RCCAs	silver-109m, cadmium -109, chromium-51, iron-55	Control cluster assemblies	Arise from the reactor core	HLW	Black 2.98 x10^8 and Grey 1.53 x10^8	Package in disposal canister with spent fuel and co-disposed with spent fuel
SCCAs	chromium-51, iron-55, antimony-122 and 124,	Thimble plug, primary and secondary neutron sources	Arise from the reactor core	HLW	7.73 x10^7 (TPAs), 5.4 x10^8 (PNSAs) and 8.79 x10^8 (SNSA)	Package in disposal canister with spent fuel and co-disposed with spent fuel
ICIAs	cobalt-58, chromium-51, iron-55, cobalt-60	Instruments used to core properties such as temperature and neutron flux	Arise from reactor core	ILW 0.01m^3	4.0 x10^3	Packaged in robust shielded container and disposed of to the GDF

Waste type	Main radionuclides	Description	Source	Annual arisings (unless stated)	Average activity beta/gamma (GBq/tonne)	Waste management route
ICIAs	cobalt-58, chromium-51, iron-55, cobalt-60	Instruments used to core properties such as temperature and neutron flux	Arise from reactor core	HLW $0.13m^3$	2.96×10^7	Packaged in a robust shielded container, decay stored and disposed of to the GDF

Appendix 5 Summary of decommissioning wastes

Waste type	Waste classification	Waste volume (m^3)	Waste container	Total waste package volume (m^3)
RPV	ILW	50	4m box	374
RVI	ILW	18	$3m^3$ box	74
Concrete	ILW	150	4m box	352
Spent resins	ILW	40	500L robust shielded drum	110.5
Spent filter cartridges	ILW	1.4	$3m^3$ box	7.4
Other equipment and concrete wastes	VLLW/LLW	12021	Half-height isofreight container	28196

Appendix 6 Forward action plans

The following list identifies the forward action plans which relate to PCER Chapter 4. These are the areas that a future operator will need to consider at the site licensing phase:

- FAP-4-1 Transfer radioactive waste management records to a future operator and the future operator should engage with the operators of disposal facilities to ensure all necessary information is captured.
- FAP-4-2 Review their own appropriate proposals representing BAT and ALARP (in relation to solid wastes, spent fuel and decommissioning wastes).
- FAP-4-3 Further develop the ILW interim store design compliance at the design stage through further BAT and ALARP analysis.
- FAP-4-4 Further develop the SFIS design compliance at the design stage through further BAT and ALARP analysis.
- FAP-4-5 Undertake optioneering study for selection of the package containers for decommissioning HAW.
- FAP-4-6 Develop and maintain the IWS.
- FAP-4-7 Undertake the acceptability analysis and obtain relevant agreements from LLW Repository Ltd for LAW.
- FAP-4-8 Undertake the disposability assessment for HAW and spent fuel based on waste characteristics and their management proposal following the LoC process to eliminate the issues identified during GDA and obtain relevant agreements from RWM.
- FAP-4-9 Develop and maintain the RWMC or equivalent documentation for spent fuel, HLW and ILW to demonstrate that the HAW can be managed effectively.

Appendix 7 Summary of RWM's ILW assessment findings to be addressed during future disposability assessment interactions

The main findings RWM raised within its assessment for the disposal of ILW wastes are:

- For post closure phase, the RVI waste packages challenged the heat output criteria at the time of disposal vault backfilling.
- For the post closure phase, the RVI have a high specific activity for carbon-14 and although this is similar to other waste streams from equivalent systems, further consideration should be given in the future to the carbon-14 inventory and the release rate in future disposability assessments.
- For ICIA waste packages the radiogenic heat output of the maximum package, with a conservatively assumed decay period of 10 years, may exceed the target value of 3W at the time of backfilling of the disposal vault.

In addition to the above main findings, RWM has also raised a number of packaging issues and general issues:

RPV/RVI

- The waste loading of the RVI within a $3m^3$ box are near the mass limits for the package, and the package efficiency may not be achievable.
- The high internal dose rates within the RVI waste packages and the radiogenic heating may have implications for the long-term integrity of the grouted waste form.
- For the RVI and the RPV, the degree of heterogeneity due to the variation in irradiated regions and the ability for the grout to infiltrate the waste.

Concentrates/sludges

- It will be necessary to develop encapsulant formulations and demonstrate that the waste has been rendered into a passive form.

Decommissioning concrete

- Accounting for the presence of stainless steel reinforcement within the decommissioning ILW concrete.
- For concrete waste the dose rates are significantly below the limits for transport and therefore there is potential for optimisation of the packages.

Spent filter cartridges

- For cartridge filters in a $3m^3$ box, detailed packaging solutions are required to ensure that, for example, the filters are encapsulated and the voidage is minimised. The voidage within packages needs to be controlled to ensure that the barrier within the GDF performs as expected.

ICIAs

- For the ICIA wastes, the RP has proposed a new container, based on a robust shielded container with 150mm stainless steel shielding within it. RWM's assessment highlights that this container will need some development and a future operator will need to provide evidence to support that the container will perform as expected.

Non-encapsulated wastes

- For non-encapsulated wastes, such as the ion exchange resins and ICIAs, a future operator will need to demonstrate that free water can be removed from the wastes.
- There is the potential that the voidage within the package will need to be addressed in the future.

General issues

- In RWM's assessment of the ILW and the fuel, it highlights the lack of information with regard to the presence of toxic/hazardous materials, but in particular more comprehensive information and data, including the impurities in irradiated materials, hazardous substances and non-hazardous pollutants.
- During a number of the decommissioning operations, particulate matter will be produced from cutting operations and will need to be quantified and a disposal option developed.

Appendix 8 Summary of RWM's spent fuel/RCCAs/SCCAs assessment findings to be addressed in future disposability assessments

The main findings that RWM raised within its assessment for the disposal of spent fuel/RCCAs/SCCAs wastes are:

Main issues

- For criticality compliance RWM will need to take credit for burn up, so that compliance with the post closure criticality case can be made. A future operator will need to ensure that its records will contain the relevant information to allow RWM to do this. RWM has not assessed the intentional inclusion of neutron sources before.
- Fuel management options will need to be assessed to allow for disposal of the UK HPR1000 spent fuel within the current assumed closure date for a GDF, to comply with the buffer temperature requirements.

Packaging specific and general issues

- Steps will need to be taken to ensure that water carry over is minimised during the drying process for the spent fuel assemblies, to minimise the risk of corrosion and gas build up with the package.
- Ensure that the requirements for the disposal of spent fuel from the UK HPR1000 are considered when designing the disposal container.
- Limited dates have been provided with regard to hazardous materials and non-hazardous pollutants, therefore a more comprehensive inventory will be required for future disposability assessments.
- Information with regard to the amount of gadolinia present within the spent fuel assemblies will need to be provided and recorded within the waste packages records. Further assessment of this area will be carried out as part of the future disposability assessment.

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