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Title

E3S Case Chapter 26: Radioactive Waste Management Arrangements

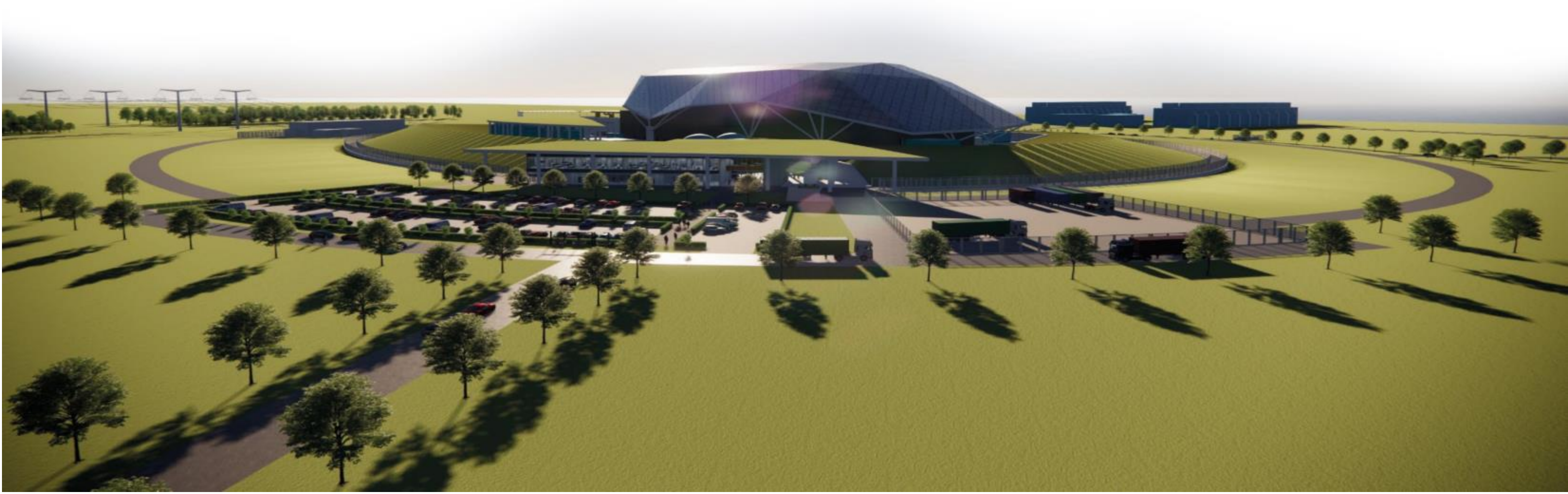
Executive Summary

This Radioactive Waste Management Arrangements (RWMA) document comprises Chapter 26 of the of the Environment, Safety, Security and Safeguards (E3S) case, for the Rolls-Royce (RR) Small Modular Reactor (SMR) The RWMA are primarily concerned with the management arrangements rather than physical processes and systems, noting however that the arrangements themselves will be focused on the systems that contain or create radioactive material in normal operations.

The RWMA are supported by a range of documentation and references which have been issued in support of the design development of the RR SMR. Key to the RWMA are the RR SMR lifecycle stages (comprising Planning and Design; Site Preparation and Clearance; Construction; Commissioning and Operation; and Reactor Decommissioning phases), site features (Reactor Island; Turbine Island; Cooling Water Island; Balance of Plant; Electrical Control and Instrumentation; and Civils and Infrastructure) and anticipated waste categories: Spent Fuel (SF)/Non Fuel Core Components (NFCCs); Dry Solid Intermediate Level Waste (ILW)/Low Level Waste (LLW); Wet Solid ILW/LLW; Liquid Radioactive Effluents; Gaseous Radioactive Effluents; and Decommissioning Wastes. Given the stage of the design process for the RR SMR, key assumptions relating to radioactive waste management assumptions have been made which will be reviewed and revised as design development progresses.

Key features of the RWMA are: the waste hierarchy (the legally defined system for incorporating environmental impacts into waste management decisions); BAT (for RR SMR this is captured in the BAT objectives and will be based on the Claim Arguments Evidence (CAE) model and be supported by evidence such as completed decision record templates and Pugh matrices); ALARP (this will be applied to all aspects of the SMR lifecycle stages to ensure that risks of exposure to ionising radiation are tolerable as low as is reasonably practicable); and the Disposability Assessment (Case)/Waste Package Records.

Risks and opportunities have been identified and have been captured (along with several of the areas described above) in a Forward Action (FA) plan.



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26.1.1 Introduction to Chapter

This report presents Chapter 26 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security & Safeguards (E3S) Case. Chapter 26 forms part of the Generic Environment Report (GER) and is a Tier 1 report in the E3S Case as defined in E3S Case Chapter 1: Introduction.

This report presents information on the Radioactive Waste Management Arrangements (RWMA) for the RR SMR and has been issued based upon the design information available following the completion of Preliminary Concept Definition (PCD).

26.1.2 Objectives

The objectives of this RWMA chapter are to:

1. Describe the sources and predicted arisings of solid radioactive wastes and Spent Fuel (SF) over the lifecycle of the RR SMR, and outline the proposed arrangements for managing solid radioactive waste and SF. The predicted arisings of liquid and aerial radioactive discharges are presented in Chapter 29.

2. Describe the proposed arrangements for managing radioactive waste arisings and SF over the lifecycle of the RR SMR, and how these are optimised to ensure the protection of people and the environment.

3. Demonstrate that the proposed RWMA are consistent with Relevant Good Practice (RGP) and meet the requirements of applicable legislation including those arising from the Environmental Permitting (England and Wales) 2016 Regulations (EPR16) (as amended) and associated regulatory guidance.

26.1.3 Scope

This Chapter identifies the high-level principles relevant to radioactive waste management that inform the design of the RR SMR and describes proposed arrangements for managing all forms (solid, liquid and gaseous) of radioactive waste and SF predicted to arise during the commissioning, power operations and decommissioning phases of the RR SMR lifecycle. It presents quantitative estimates of predicted solid radioactive waste and SF arisings (quantification of aqueous and gaseous radioactive waste discharges are outside the scope of this Chapter and are presented elsewhere in Chapter 29). Radioactive waste that could potentially be generated during site preparation and construction lifecycle phases (as a consequence of historic radioactive land contamination) is a site-specific matter and is outside the scope of this Chapter.

The Chapter covers radioactive waste predicted to be generated during all modes of normal operations (including expected events such as fuel pin failure) and the Structures, Systems and Components (SSCs) that handle and treat associated radioactive waste arisings. The solid waste arisings from the RR SMR are based on the design basis source term (which is more conservative than the best estimate source term used to quantify discharges to the environment).

Details of the design of facilities for interim storage of SF and intermediate and high-level wastes, pending the availability of a Geological Disposal Facility (GDF) are covered in Chapter 11 (radwaste) and Chapter 9A (Auxiliary systems, which covers SF).

26.1.4 Key Interfaces with Other Chapters

This chapter draws upon the information presented in other Chapters of the RR SMR E3S Case. Notable topic areas within E3S Case that support the production of, or are otherwise related to, this Chapter are detailed in Table 26.1-1.

Table 26.1-1 – E3S Chapters Interfacing with the RWMA

Chapter Number	Chapter Title	Overview of Chapter
1	Introduction & General Considerations	Chapter 1 is a joint chapter between Pre-Construction Safety Report (PCSR) and GER. It provides an overall introduction to the suite of 33 chapters that make up the E3S Case, including: an overview of E3S Case approach and structure; the Generic Design Assessment (GDA) context, Requesting Party (RP) organisation and programme; the engineering arrangements that facilitate development of the case; and a general plant description of the power station.
4	Reactor Systems (Fuel & Core)	Chapter 4 presents the overarching summary and entry point to the design information for the fuel and core design of the RR SMR. It describes the composition and configuration of fuel, control rods, etc. and associated operational parameters, and is a key supporting Chapter for the RWMA.
9A	Auxiliary Systems	Chapter 9A presents the overarching summary and entry point to the design and safety information for the Auxiliary Systems of the RR SMR. Auxiliary systems include the spent fuel handling and storage systems and ventilation systems which are relevant to RWMA.
11	Management of Radioactive Waste	Chapter 11 presents a summary of all forms (gaseous, liquid, solid) of RR SMR radioactive waste treatment, as well as the collection and drainage systems for radioactive wastes. It is closely linked to the RWMA.
12	Radiation Protection	Chapter 12 presents the radiation protection aspects for normal operations during all operational modes, as well as accident and beyond design basis conditions. This Chapter will at final issue include information that supports assessment of direct radiation ("shine") dose from radioactive wastes in storage.
20	Chemistry	Chapter 20 presents the safety Claims and arguments associated with the chemistry of the RR SMR, including how the chemistry regime minimises risks So Far As Is Reasonably Practicable (SFAIRP) and As Low As Reasonably Practicable (ALARP) using Best Available Techniques (BAT). Chemistry directly influences the types, activity and forms of radioactivity present in the reactor coolant and primary circuit structures; it therefore impacts the nature of the radioactive wastes generated and how such waste is managed.

21	Decommissioning and End of Life Aspects	Chapter 21 introduces the RR SMR decommissioning strategy and describes the stages for decommissioning. It describes the process for considering decommissioning at the design phase, provides a brief outline of RR SMR Decommissioning Plan and summarises the design decisions that support waste minimisation. It is closely related to the decommissioning aspects of the RWMA.
27	Demonstration of BAT	Chapter 27 provides detail on the RR SMR's holistic approach to Optimisation and describes how BAT is applied during the design of the RR SMR. It details the Claims, arguments, and evidence used to demonstrate that BAT has been applied in the design of the RR SMR and forms a key underpinning Chapter for the RWMA.
29	Quantification of Radioactive Effluent Discharges and Proposed Limits	Chapter 29 provides an assessment of potential discharges of aqueous and gaseous radioactive effluent from the RR SMR plant to the environment under normal operating conditions. It is a counterpart to this Chapter covering the quantification of aqueous and gaseous radioactive discharges to the environment, including the underlying assumptions and methodology.
30	Prospective radiological assessment	Chapter 30 presents the radiological assessment of doses to public and non-human species. It outlines the methods used to calculate dose and justifies why the data and assumptions used in the assessment are appropriate.

26.1.5 Fundamental Claims

The fundamental Claims for the RWMA have been identified, and the aspects of those Claims relevant to the scope of this chapter are:

1. Arrangements are in place for the management of radioactive wastes from all phases of the RR SMR lifecycle;

2. These arrangements, along with the systems that will implement these arrangements, have been optimised to minimise the generation of radioactive waste and discharges.

26.1.6 GDA Context

The requirements presented in Table 26.1-2 directly relate to RWMA and are taken from the EA 'GDA Guidance for Requesting Parties' [1]. This Chapter will, on final issue, meet the requirements set out in Table 26.1-2.

Table 26.1-2 – GDA Information Requirements for RWMA

GDA Requirement for RWMA	Information Source
Identify the strategic considerations for radioactive waste management which underpin the design.	*Chapter 26, Section 4.*

A description of radioactive wastes and spent fuel arisings throughout the nuclear power plant's lifecycle, including sources of radioactivity and other matters affecting radioactive waste arisings – lifecycle includes commissioning and decommissioning. *A description of the proposals for the management and disposal of all radioactive wastes, including solid, liquid and gaseous wastes and spent fuel, throughout the nuclear power plant's lifecycle – including commissioning, operation and decommissioning.* *A description of how the production, discharge and disposal of radioactive waste and spent fuel will be managed to protect the environment and optimise the protection of people.* *A description of the optimisation process used to identify and justify the proposed techniques as BAT (refer to Chapter 27 for detail).*	*Chapter 26, Section 5.* *Chapter 29 (aqueous liquid and gaseous quantification)* *Chapter 26, Section 5.* *This will be covered in future versions of Chapter 26 (the Disposability Case will be the source reference).* *Chapter 27 (BAT) will cover these requirements – the BAT methodology provides description of current process.*
GDA Requirement for Quantification of radioactive wastes	**Information Source**
For combustible and other radioactive wastes, the RP must estimate the annual arisings and disposals during operation and give an indication of the likely arisings during decommissioning. *The RP must identify wastes in terms of their:* • *Category – High Level Waste, Intermediate Level Waste, Low Level Waste, Very Low Level Waste* • *Physico-chemical characteristics* *Proposed management and disposal route.*	*Chapter 26, Section 5.* *Chapter 26, Section 5 (note that details of physio-chemical characteristics are not available at PCD and will be captured in future issues).* *Chapter 26, Section 5.*

26.2 Regulatory Context

26.2.1 Introduction

The management of radioactive wastes in the United Kingdom (UK) is a devolved matter and this subsection provides an outline of the regulatory and policy framework for the management of radioactive wastes in England and Wales. It identifies key requirements that will need to be addressed to demonstrate that sufficient arrangements are in place for managing the radioactive waste that will be produced from all lifecycle stages of the RR SMR.

26.2.2 International Policies and Strategies on Radioactive Waste Management

International radioactive waste management policies and strategies applicable to the UK originate from several international organisations. The International Atomic Energy Agency (IAEA) is the global intergovernmental organisation that promotes peaceful use of nuclear technology, and produces safety and security standards for member states. The Western European Nuclear Regulators Association (WENRA) is the co-operative organisation for nuclear safety within the European Union (and associated states), which also produces publications in support of nuclear safety. The requirements originating with IAEA and WENRA will be incorporated into the RR SMR via the requirements management database (DOORS) where appropriate and will also be captured in strategy documents such as the IWS.

26.2.3 National Policies and Strategies on Radioactive Waste Management

The regulation of radioactive waste management in England and Wales is founded upon several UK national polices, which implement international obligations or government policy objectives. Some of the key policies and strategies that have a direct bearing on RWMA are summarised below.

Policy for the Long-Term Management of Solid Low-Level Radioactive Waste in the United Kingdom

The 'Policy for the Long-Term Management of Solid Low-Level Radioactive Waste in the United Kingdom' [2] covers all aspects of the generation, management and regulation of solid Low Level Waste (LLW) and applies to both statutory bodies and those responsible for the production and management or disposal of wastes. It provides a framework within which LLW management decisions can be taken flexibility to ensure safe, environmentally acceptable and cost-effective management solutions that appropriately reflect the nature of the LLW concerned. The policy required the Nuclear Decommissioning Authority (NDA) to, among other things, develop a UK nuclear industry LLW strategy.

UK Strategy for the Management of Solid Low-Level Radioactive Waste from the Nuclear Industry

The central theme of the revised 'UK Strategy for the Management of Solid Low-Level Radioactive Waste from the Nuclear Industry' [3] is the implementation of the waste hierarchy.

It requires waste producers to manage their wastes in accordance with the waste hierarchy, which considers and utilises a range of methodologies to optimise waste management processes and make best use of existing assets.

UK Strategy for Radioactive Discharges and associated Statutory Guidance

The 'UK Strategy for Radioactive Discharges' [4] sets out how the UK is implementing its obligations in respect of the UK's commitments regarding radioactive discharges as a Contracting Party to the Oslo and Paris (OSPAR) Convention. In parallel, the UK Government published its 'Statutory Guidance to the EA concerning the regulation of radioactive discharges into the environment' [5], introducing the requirement (in England and Wales) to apply BAT to minimise and, where appropriate, eliminate radioactive discharges from regulated sectors into the environment.

Implementing geological disposal – working with communities: long term management of higher activity radioactive waste

This sets out the UK Government's policy framework for managing higher activity radioactive waste (in England) through geological disposal [6], including how the delivery body, Nuclear Waste Services (NWS, formerly Radioactive Waste Management, RWM[1]), will work in partnership with communities to identify a suitable location to host a GDF. It replaces the 2014 white paper and brings together the policy framework and updates, the context and final Working with Communities policy into this single document. The policy requires RWM to provide advice to waste producers on the compatibility of their waste conditioning proposals with geological disposal to avoid the need for repackaging and the 'double handling' of wastes.

The policy on implementing geological disposal in Wales is set out in 'Management and Disposal of Higher Activity Waste' [7] and 'Geological Disposal of Higher Activity Radioactive Waste: Community Engagement and Siting Processes' [8].

26.2.4 Environmental Permitting (England and Wales) Regulations 2016 (as amended)

The EPR16 (as amended) [9] provides the mechanism for the implementation of policy objectives and national strategies that relate to the generation and disposal of radioactive waste.

The management and disposal of radioactive substances from Nuclear Power Plants (NPP) are controlled under the Radioactive Substances Regulations (RSR), set out in Schedule 23 of the EPR16 [9]. The regulations ensure operators do not produce unnecessary radioactive waste, and that any waste generated is minimised and managed safely. Where radioactive waste is discharged to the environment, operators must demonstrate that BAT has been used to manage that waste, and to ensure that the impact of discharges on members of the public or non-human species have been minimised to levels that are As Low As Reasonably Achievable (ALARA).

Additional details on the regulatory controls regarding the discharge of aqueous and gaseous radioactive waste are presented in Chapter 29.

[1] NWS is the independent UK government body responsible for delivery of a UK national GDF for permanent disposal of HAW.

26.2.5 Alignment with Regulatory Objectives and Principles

The EA RSR Objective and Principles (ROPs) [10] set out the regulatory principles the EA applies in the delivery of their function as laid out in EPR16 and government policy.

The ROPs are supported by a set of RSR Generic Developed Principles (GDPs), which set out the EA's expectations on permit holders carrying out radioactive substances activities [11]. The key GDPs directly relevant to RWMA are identified in Table 26.2-1. GDPs specific to BAT and the radioactive discharges to the environment are presented in Chapters 27 and 29, respectively.

Table 26.2-1 – RSR: objective and principles and RSR generic developed principles: regulatory assessment

RSR Principle	Provisions
RSMDP1 – Radioactive Substances Strategy	A strategy should be produced for the management of all radioactive substances.
RSMDP3 – Use of BAT to Minimise Waste	The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.
RSMDP8 – Segregation of Wastes	The best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing might compromise subsequent effective management or increase environmental impacts or risks.
RSMDP9 – Characterisation	Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.
RSMDP10 – Storage	Radioactive substances should be stored using the best available techniques so that their environmental risk and environmental impact are minimised and that subsequent management, including disposal is facilitated.
RSMDP11 – Storage in a Passively Safe State	Where radioactive substances are currently not stored in a passively safe state and there are worthwhile environmental or safety benefits in doing so then the substances should be processed into a passively safe state.
RSMDP14 – Record Keeping	Sufficient records relating to radioactive substances and associated facilities should be made and managed so as: to facilitate the subsequent management of those substances and facilities; to demonstrate whether compliance with requirements and standards has been achieved; and to provide information and continuing assurance about the environmental impact and risks of the operations undertaken, including waste disposal.

RSMDP15 – Requirements and Conditions for Disposal of Wastes	Requirements and conditions that properly protect people and the environment should be set out and imposed for disposal of radioactive waste. Disposal of radioactive waste should comply with imposed requirements and conditions.
DEDP3 – Considering Decommissioning during Design and Operation	Facilities should be designed, built and operated using the best available techniques to minimise the impacts on people and the environment of decommissioning operations and the management of decommissioning waste.

26.2.6 Relevant Safety Legislation and associated Guidance

The Office for Nuclear Regulation (ONR) enforces the provision of the Health and Safety at Work etc. Act 1974 (HASW74) [12], the Energy Act 2013 [13], and their relevant statutory provisions in GB, including Nuclear Installations Act 1965 (NIA65) [14] and Ionising Radiations Regulations 2017 (IRR17) [15]. ONR achieves this through 36 standard Licence Conditions attached to all nuclear site licences. All the licence conditions apply and are relevant to activities involving management of radioactive waste, but Licence Conditions 4, 25, 32, 33, 34 and 35 are especially relevant [16].

ONR has published its Safety Assessment Principles (SAPs) [17] which provide a framework for regulators to assess safety (via safety cases) of existing or proposed nuclear facilities. The SAPs also provide guidance to designers and duty-holders on the required and appropriate content of safety cases and are consistent with other guidance on legal duties to reduce risk through the application of SFAIRP, ALARP, and ALARA. The SAPs define a total of seven principles (Table 26.2-2 – Safety Assessment Principles) related to radioactive waste management, covering the minimisation and control of waste at all lifecycle stages, strategies, waste characterisation, segregation, passive safety, and record keeping. ONR have also published a series of Technical Assessment Guides (TAGs) intended to give additional guidance to ONR Inspectors beyond that in the SAPs. Whilst not listed below these are also relevant.

Table 26.2-2 – Safety Assessment Principles

RW.1	Strategies for radioactive waste	A strategy should be produced and implemented for the management of radioactive waste on a site.
RW.2	Generation of radioactive waste	The generation of radioactive waste should be prevented or, where this is not reasonably practicable, minimised in terms of quantity and activity.
RW.3	Accumulation of radioactive waste	The total quantity of radioactive waste accumulated on site at any time should be minimised so far as is reasonably practicable.
RW.4	Characterisation and segregation	Radioactive waste should be characterised and segregated to facilitate its subsequent safe management.
RW.5	Storage of radioactive waste and passive safety	Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition.

RW.6	Passive safety timescales	Radiological hazards should be reduced systematically and progressively. The waste should be processed into a passive safe state as soon as is reasonably practicable.
RW.7	Making and keeping records	Information that might be needed for the current and future safe management of radioactive waste should be recorded and preserved.

26.3 RR SMR Lifecycle

26.3.1 RR SMR Lifecycle

As outlined in Section 26.1.3, the RWMA describes proposed arrangements for managing all forms (solid, liquid and gaseous) of radioactive waste and SF predicted to arise during the commissioning, power operations and decommissioning phases of the RR SMR lifecycle. This Section provides a brief overview of the RR SMR lifecycle phases.

The lifecycle of the RR SMR is broken down into five phases as illustrated in Figure 26.3-1.

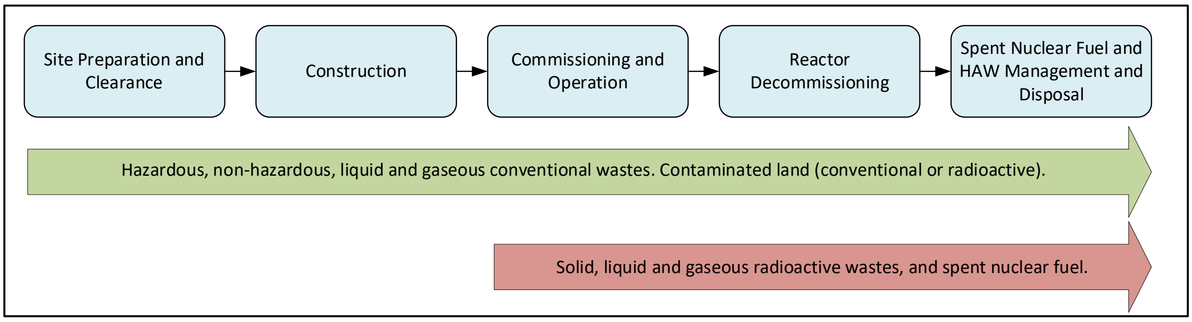

Figure 26.3-1: Overview of the Lifecycle Stages of the of RR SMR[2]

As is shown in Figure 26.3-1 the types of radioactive (and other types of) waste that will be produced will vary over the lifecycle stages of the RR SMR. SF and solid/liquid/gaseous radioactive wastes are expected to be produced only from the start of commissioning and operations, whilst conventional wastes (outside the scope of this Chapter) may be expected to be produced throughout the station lifecycle. It is recognised that there is potential for radioactive waste from historic radioactive land contamination land to be produced during the site preparation and construction phases, but this is a site-specific matter and therefore out of scope of this Chapter. The different types of radioactive waste that are expected to be produced are described in full (in terms of nature and provenance) in Section 26.5.

The following paragraphs provide short summaries of each of the lifecycle stages.

Planning and Design – This phase is not represented in Figure 26.3-1 as it is not one of the distinct lifecycle stages of the plant itself, but does cover all activities that will occur prior to the initial 'Site Preparation and Clearance' phase (i.e., to the left of the diagram). Although no radioactive waste will be produced at this stage, it is the stage which has the largest potential impact on the types and quantities of waste generated during operations and decommissioning (as Operating Experience (OPEX) from earlier generations of NPPs have demonstrated). This is because this is the stage during which design decisions regarding systems and the types of waste they will produce are made (along with underpinning, justification and demonstration of BAT, ALARP and secure by design), the management and strategy approaches are decided, and

[2] Note that radioactively contaminated land may be applicable to the site preparation stage (i.e., from historical contamination) but that would be site-specific. The generation of additional contaminated land during the operation of the RR SMR would be avoided or minimised (though the potential for this to occur is included in Figure 26.3-1) though engineering and operational controls.

design acceptability confirmed by regulatory authorities. Planning and design is therefore a crucial stage in the RR SMR lifecycle.

Site Preparations and Clearance – This is the initial phase when preparations ('Enabling Works') for the construction of the site infrastructure take place. This primarily involves on-site works such as clearance of any pre-existing structures, vegetation and topsoil, and installation of drainage, along with any required offsite works such as access upgrades. The wastes produced at this lifecycle stage are primary conventional (except in circumstances such as pre-existing radioactive contamination at the site), and the approaches taken at this stage (for Enabling Works and waste management) are site-specific.

Construction – This phase will comprise the preparatory works for construction (e.g. bulk earthworks for site levelling), construction/installation of the main plant and supporting infrastructure (e.g. cooling water outfall structures), and final works (e.g. site landscaping). The wastes produced during the Construction phase will likely be similar in nature to those at the Site Preparation and Clearance phase; primarily conventional (excepting pre-existing radioactive contamination) and site-specific in nature, likely with a focus on re-use of material (e.g. re-use of excavation spoil for landscaping).

Commissioning and Operation – Commissioning will be the first part of this phase, and will comprise preparation and testing of RR SMR plants and systems to enable them to enter routine operations, and active commissioning (e.g. testing of the reactor) will be when radioactive wastes are first produced. Operation will be the extended period during which the site is exporting electricity and will be routinely producing different types radioactive (and conventional) wastes (refer to Section 26.5). Waste will be generated during all operational modes including start up, power operation, shutdown and refuelling outage.

Reactor Decommissioning – This phase will comprise the decontamination, dismantling, waste removal and clearance of the site following the cessation of operations [3]. This phase will itself comprise seven distinct stages [4] which will take place over a period of 150 years [18], during which different types of radioactive (and conventional) wastes will be actively produced (e.g. from demolition works and waste packaging and export), and periods when the site will be in a quiescent state. The design process for the RR SMR incorporates a 'design for decommissioning' philosophy to facilitate safe and efficient decommissioning.

SF and Higher Activity Waste (HAW) Management – This phase will comprise the management of SF and other HAW (e.g. Non-Fuel Core Components (NFCCs)) retained on site following the completion of the Reactor Decommissioning phase. This radioactive waste will likely need to be retained on site due to the availability and phasing of waste acceptance into a GDF; waste packages from RR SMRs might not be accepted into a GDF until several decades after decommissioning is completed, so a period of on-site interim storage and management will be required. SF and HAW will be held within a dedicated storage facility, which will be shielded and able to undertake heat management as required, and will also provide the capability (likely in the form of a 'hot cell') for periodic inspections of the fuel to be undertaken over the course of the interim storage period. Once the waste is eligible to be exported from the site, a facility will likely need to be constructed to undertake repackaging of the waste. Once all of the waste has

[3] Note that under the Nuclear Site Licence decommissioning activities are considered to be part of operations, but in the IWS [27] and this document the decommissioning phase is being considered as a separate, discrete phase of the site lifecycle.

[4] Pre-closure Preparatory Work; Defueling and Post Operational Cleanout; Reactor De-commissioning; ILW and SF Storage; Remobilisation for Waste Disposal; ILW and SF Disposal; and Final Site Clearance and Delicensing of Site for Re-Use [18].

been packaged and removed from the site, all remaining structures will be removed, and the site can be released for reuse.

Details of the strategies and approaches for managing the radioactive wastes anticipated to arise during each of the above lifecycle phases are presented in the ensuing Sections of this Chapter.

26.4 Radioactive Waste Management Strategy, Principles and Arrangements

26.4.1 Introduction

This section presents a brief overview of the key arrangements and strategies that underpin the RR SMR RWMA, as well as the related high-level principles and considerations. These have largely been drawn from established RGP and regulatory requirements, expectations and guidance.

The RR SMR strategy for waste management is based on a number of principles and arrangements: BAT to eliminate and minimise the generation of waste; application of the waste hierarchy to as a framework to optimise waste management and to ensure optimised disposal route, ALARP as a the means to reduce and control ionising radiation doses SFAIRP [5]; and the Disposability Case which outlines the technical underpinning for the packaged waste to be accepted into a GDF.

The key principles and arrangements that the strategy is based upon are described below.

26.4.2 Waste Hierarchy

The waste hierarchy is a system for ranking and prioritising waste management options and approaches in accordance with what provides the most environmental benefit/minimises environmental impact.

The requirement for the waste hierarchy (illustrated in Figure 26.4-1) is outlined in The Waste (England and Wales) Regulations 2011 [19] for application to conventional wastes; and has been applied to radioactive waste management through the UK 'LLW Strategy' [3] and RSR guidance [20], with guidance on application provided in [21].

[5] It is noted that ALARP is more encompassing as per HASW74, but the radiological aspects are the focus in the context of the RWMA.

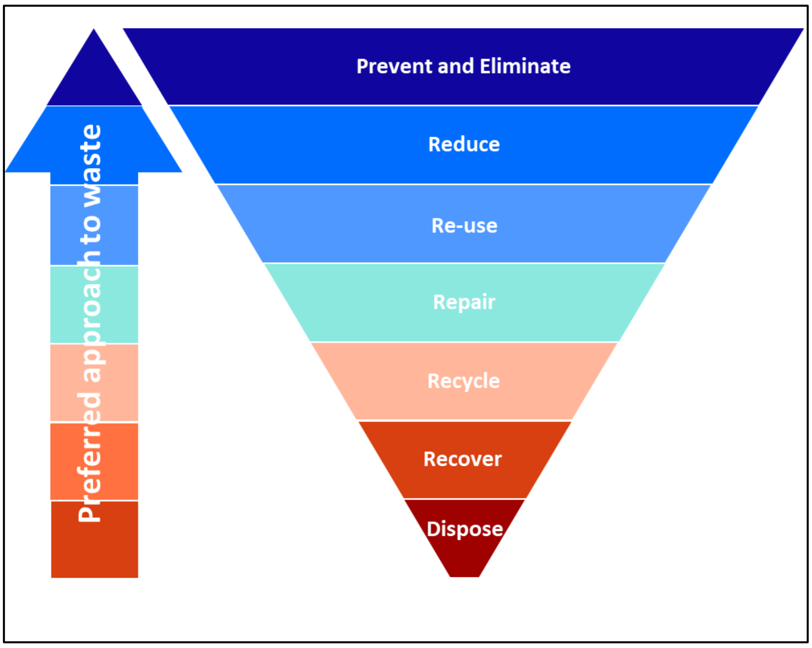

Figure 26.4-1: The Waste Hierarchy

The waste hierarchy is fundamental to decision-making on the management of radioactive wastes in the RR SMR project. It is not directly applied as a strict, quantitative hierarchy as many complex factors influence the optimal management of any given waste or material. Instead, the hierarchy is captured in Key Design Objective and Assessment Criteria (KDO) 5 used in options assessment: *"Minimise environmental impact: showing compliance with BAT principles for minimisation of conventional and radioactive waste and ensuring sustainable development".* The RR SMR KDOs explicitly incorporate criterion on environment, safety and security alongside technical feasibility, cost, and market factors. These constitute the assessment criteria used to evaluate design options and inform the decision-making process for significant design decisions and are described in greater detail in Chapter 27 (BAT) of the E3S case.

Waste minimisation' as defined here[6] encompasses the five stages of the waste hierarchy excluding prevention/elimination and disposal and describes the qualitative application of the hierarchy in options assessment. More specifically, the waste hierarchy is further incorporated into decision-making through a set of eight high-level Claims, covering radiological and conventional environmental aspects, established to support the demonstration of BAT in the design of the RR SMR. These Claims capture the requirements to eliminate or reduce waste generation in the first instance, minimise the volume and activity of waste requiring disposal (i.e., through implementing other stages of the hierarchy or for disposal to be undertaken using an appropriate route) and where disposal is required, ensuring that an optimised route is taken. Further details on these BAT Claims are presented in Chapter 27 (BAT) of the E3S case.

26.4.3 Application of BAT

The requirement to apply BAT in the design of the RR SMR to prevent or minimise the generation of radioactive wastes (and the resultant impact on people and the environment) is set out in the 'Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles' [22] and the 'Approach for the Demonstration of Optimisation through the Application of BAT' [23]. The approach for identifying and demonstrating the application of BAT in the design of the RR SMR

[6] This term, as described here and in the IWS, is used throughout RR SMR project documentation.

is presented in greater detail in Chapters 27 (Demonstration of BAT) and 31 (Conventional Environment) of the E3S case, for radiological and non-radiological aspects of the RR SMR, respectively.

26.4.4 Design Factors Relevant to BAT and Waste Management

One of the KDOs of the RR SMR is to '*Minimise environmental impact: showing compliance with BAT principles for minimisation of conventional and radioactive waste and ensuring sustainable development*'. To meet this objective, several design features have been incorporated into the design of the RR SMR to minimise the generation of radioactive waste [7], which are summarised in the following bullets:

1. **Primary Circuit Chemistry** – The chemistry of the primary circuit coolant in the RR SMR is designed to support reduction in tritium generation, which will greatly increase the scope and opportunities for recycling the primary coolant, along with minimisation of the discharge of radioactive and other effluents during normal operations (see below). This will be achieved through the following features:

   a) Soluble boron will not be used for reactivity control; and

   b) pH control will be based on potassium hydroxide rather than lithium hydroxide.

2. **Use of Reverse Osmosis (RO) and Vacuum Evaporator** – Application of RO/vacuum evaporation will enable effluent recycling (at rates of up to 98%) in conjunction with resin polishing of effluents, and is also consistent with the modularisation approach. The vacuum evaporator will provide additional volume reduction (with a high Volume Reduction Factor (VRF)) for the RO retentate, which is enabled by the boron-free primary circuit chemistry [8].

3. **Decay Storage of Intermediate Level Waste (ILW) Resins/Concentrates** – The decay storage of these waste streams will allow the activity and total volumes of ILW from these waste streams to be reduced, potentially allowing these wastes to be disposed of as LLW.

4. **Backwashable Filters** – The use of backwashable filters (in place of removeable cartridge filters) will significantly reduce the number of waste packages produced from this stream to be reduced by up to approximately 75%.

5. **Co-Packaging of Wet LLW** – This approach will reduce the total number of LLW packages that will require offsite management (estimates of savings not yet available).

6. **Cementation of ILW Waste** – This methodology has significant OPEX and is flexible and if applied with the general waste minimisation approach will allow the minimisation of the total number of waste packages that will require management (estimates of savings not yet available). This does not foreclose consideration of other encapsulation technologies that may become available in the future.

[7] Note that several of these approaches bring additional general benefits (e.g. the use of backwashable filters eliminates the need for a Filter Change Machine (FCM), but this list is focused on waste management gains.

[8] Bead resin volumes will also be reduced due to the boron free chemistry, as the treatment of primary and spent will be merged into a single system, which will eliminate the need for a separate filtration/ion exchange system.

Minimal liquid discharge is a design and operational approach and philosophy that is being applied to the RR SMR which describes the intent to use plant features and configuration that will maximise the reuse of fluids and effluents and minimise total discharges to the environment. This will be underpinned by a philosophy of concentrate and contain, underpinned by BAT decisions during design and operation. The key enabling aspects underpinning the philosophy are the waste minimisation approaches described above e.g. elimination of soluble boron and lithium from the primary circuit to minimise tritium production and the use of waste systems (e.g. RO and evaporator) that allow the preferential removal and concentration of contaminants and recycling of the 'clean' effluent.

Although the RR SMR plant will be optimised (in terms of design and operation) for recycling and reuse of effluents during normal operations, it will not be possible for all effluents to be recycled due to technical or BAT/ALARP reasons (e.g. potential accumulation of tritium in effluents such that it would not meet BAT/ALARP requirements to reuse it in the primary circuit). Therefore, the RR SMR will need to have a permit to allow operational discharge of radioactive effluent to the environment, even with the application of minimal liquid discharge.

26.4.5 Requirement to Demonstrate ALARP

ALARP will apply to all aspects of the SMR lifecycle to ensure that the risks to people from exposure to ionising radiation are tolerable and reduced as low as is reasonably practicable. The requirement to demonstrate and apply ALARP is outlined in the HASW74 [12] and IRR17 [15] (and captured in the context of the RR SMR project via Rolls-Royce SMR E3S Design Principles' [22]) which is consistent with relevant UK legislative requirements. Further details are presented in Chapter 24 (Summary of ALARP) as well as Chapter 12 (Radiation Protection) of the E3S case.

26.4.6 Disposability Assessment

The term 'Disposability Assessment' can refer to two separate (but related) processes that are undertaken in different contexts, defined as follows:

1. **GDA Disposability Assessment** – This refers to a preliminary judgement as to the potential acceptability for proposed generic waste packaging approaches. This process is led by the RP undertaking GDA through issue of a report outlining the proposed waste packaging approaches (along with underpinning information) which is assessed by regulators and NWS.

2. **NWS Disposability Assessment** – This refers to the process led and managed by the Waste Management Directorate of NWS, which is initiated when a waste producer approaches NWS with a specific packaging proposal (i.e. for particular containers and waste stream or streams). The proposal is formally assessed using a detailed procedure that considers multiple technical aspects of the waste, containers and associated information records, and leads to acceptance and endorsement (or rejection) through issue of a Letter of Compliance (LoC) (a process which is staged to conceptual, interim and final LoCs as the level of detail and confidence is developed).

The term 'Disposability Case' has been informally established (between NWS and the RR SMR project team) and will be applied in this section to minimise the potential for confusion over which Assessment is being referred to (this alternative term is applicable to this RWMA document, and to the RR SMR project more generally).

Obtaining an LoC for all of the HAW streams to be produced by the RR SMR will be one of the key aims in terms of RWMA, and the GDA Disposability Case is the first step in that process.

The Disposability Case for the RR SMR wastes is not available for Revision 1 of the E3S case however, an 'outline document structure' has been proposed and this provides a basis for future development of the Case. The proposed structure of the Disposability Case includes:

1. **Introduction** – Scope of the assessment.

2. **Approach to GDA Disposability Assessment** – Context, approach and intention.

3. **SMR Operations and Waste Strategy** – Summary of design and operations, and assumptions.

4. **Assessment of SF/NFCCs** – Description, management, storage and disposal.

5. **Assessment of Operational/Decommissioning ILW** – Operational and decommissioning waste streams/volumes and processing/packaging, container characteristics/packages/waste forms, and post closure safety/ chemical inventory.

6. **Assessment of the Disposal System** – Assessment of the overall RR SMR 'disposal system', comprising all parts of the packaging/storage systems/approaches.

7. **Summary and Conclusion**.

Though the Disposability Case was not available for this E3S Case revision, several specific technical aspects, and other considerations pertinent to the Case have been identified. These are summarised below.

Higher Activity Wastes

SF and NFCCs

1. The SF and NFCCs (where co-disposed with SF, either due to being unsegregated from SF or being co-managed due to being High Level Waste (HLW) upon arising) will undergo long-term dry storage in an SF store for a prolonged period after operations and decommissioning have been completed. This waste will likely be repackaged prior to offsite export to a GDF; the type of package that will be used is unknown at this stage but will be suitable for acceptance in a GDF.

2. The nature of the dry storage for SF that will be undertaken (packages, conditions control, duration, etc.) is key to underpinning eventual disposal.

3. Sizing of NFCCs will be crucial for ensuring compatibility with a GDF.

4. For SF, data/records (specifically on fuel composition and irradiation history, to support a GDF post-closure safety case) will be of fundamental importance for disposability.

ILW

1. NWS have provided advice that using 'standard' containers/packages (i.e., as established by nuclear industry OPEX, including encapsulation using cement or other encapsulants in 500 litre drums) will be the preference. However, the option to use other suitable materials in the future is not foreclosed.

2. Waste records will also be of crucial importance for ILW, and the provision of underpinning information as to how packaging data (e.g. regarding the chemical nature and quality of process inputs, such as cement powders) will be collected and stored is crucial.

Lower Activity Wastes (primarily comprising LLW)

1. Packaged LLW is not required to go through a formal assessment/LoC process (i.e. equivalent to the NWS Disposability Assessment) for acceptance at the Low Level Waste Repository (LLWR); instead, LLW should be packaged in acceptable containers and the radioactive inventory, chemical characteristics and other key parameters for the waste package will need to meet the LLWR Waste Acceptance Criteria (WAC).

2. Even though packaged LLW will not need an LoC, the anticipated LLW streams will be assessed as part of a future review against LLWR requirements. The LLWR WAC are periodically reviewed so the Disposability Case will need to demonstrate how these will be met throughout the operational and decommissioning phases.

26.4.7 Waste Package/Management Records

As noted above, waste package/management records are an inherent and crucial aspect of the Disposability Assessment/LoC process that the operator of the RR SMR will have to undertake in order to demonstrate disposability of waste packages. This subsection outlines the requirements that will need to be met.

The NWS 'Waste Package Data and Information Recording Requirements' document [24] provides guidance on the data and information recording requirements to cover the history of the packaged waste from the time of waste arising, through initial waste characterisation, waste package development, to package production, storage, transport and disposal into a UK national GDF. Once in the operational phase, the RR SMR will need to meet these requirements, along with those in the 'Long-term Management of Information and Records: Explanatory Material and Guidance' document [25] for long-term retention of waste records.

The key requirements on the operator of any facility that produces radioactive waste that may require disposal to a GDF are as follows:

1. The waste packager is responsible for the development of a data and information recording system that would establish the means of capturing information in order to create the disposability record for each waste package.

2. The range of information that would need to be recorded for each distinct waste package will be unique and the development of a tailored system may be required for each waste type and packaging campaign.

3. Information would be created over the entire lifetime of the waste package, from conception of the packaging process, through process development, waste package production, storage, transport and ultimately disposal.

4. Although much relevant information would arise during the development of the packaging process, information acquisition will continue into the waste package production stage and beyond. The information acquired after production would generally focus on storage conditions, interim movements, and package evolution.

5. The assessment of packaging proposals, as part of the Disposability Assessment process leading to potential endorsement, will assist in the development of the data and information recording system through discussion and agreement of the particular disposability record requirements.

It will need to be demonstrated to NWS that suitable data gathering arrangements (in line with the requirements described above) will be in place in the RR SMR waste management systems prior to system commissioning.

Three broad categories of data are expected to form a disposability record, as follows:

1. **Class A** – Underpinning and justification; information that applies to the waste type as a whole, in particular the documents that define the origin of the waste, the packaging process, the results of a development programme, waste container manufacturing specifications, the anticipated properties of the waste package and the waste package disposability record;

2. **Class B** – Specification; a concise statement of the precise requirements to produce a waste package that would be compliant with the obligations for storage, transport and disposal; and

3. **Class C** – Compliance; information collected about the as-manufactured waste packages, primarily required to demonstrate compliance with the specifications.

For the long-term management of waste package records, NWS outlines a number of different recording media, and also states that transfer of records to a long-term archive facility does not absolve a waste producer of a responsibility to manage and preserve data into the long term. For the RR SMR, the identification of optimal records production, management and long-term retention systems should not be attempted until there is a more detailed information available on the waste management systems, along with developed understanding of the waste types, natures, and volumes.

Rolls-Royce SMR has initiated early engagements with NWS regarding the fundamental requirements that the operator of the RR SMR will be required to meet, and the process for agreeing the systems and approaches for creating acceptable records. These will be developed in greater detail during the development of the Disposability Case (refer to Section 26.4.6) and the NWS Disposability Assessment process, when waste packaging proposals are submitted by RR SMR to NWS for formal endorsement through the Letter of Compliance (LoC; refer to Section 26.4.6) process.

It is accepted at this stage that waste package records will need to be 'born digital' i.e. to be recorded directly (i.e. through embedded sensors and systems) into digital format at the time of packaging, with no intermediary paper or other record (as has been the case with some legacy waste packaging systems at other sites), which have been the cause of the loss (i.e. total loss, or partial loss through fidelity problems, etc) of records data. Therefore, digital data collection systems will need to be incorporated into the design of waste management and packaging systems from conceptual stage onwards.

26.4.8 Radioactive Waste Management Risks and Opportunities

A number of risks and opportunities (related to the development of waste management strategies and design of the waste management systems) have been made for the RR SMR, and are summarised in the following subsections.

The RR SMR is at preliminary concept design. The RWMA (and all other operational considerations) are based on a design that is still maturing, and therefore a number of fundamental assumptions have been made which will be resolved as the design is completed. The following subsections outline these risks and opportunities in the context of radioactive waste management, and those directly applicable to particular waste streams. Note that future issues of documents including the 'Integrated Waste Strategy' (IWS) [26] will provide updates on the status of assumptions as the project develops.

Risks

The following risks have been identified as actively applying to the radioactive waste management strategy and arrangements (i.e. they were not available for Revision 1 of the E3S Case).

1. As noted above, waste volumes and activities are currently based on estimations. If these prove to be fundamentally inaccurate/incorrect, then new waste routes may be required and treatment and storage methods may no longer be suitable (e.g. suitability of ILW for decay storage and disposal to LLWR).

2. Reuse of effluents in the reactor is based on assumptions about achievable decontamination factors and water specifications, but if the final decontamination factors achieved are lower and/or the specifications change, then reuse may not be possible (which would be a departure from minimal liquid discharge and would likely result in the generation of greater waste volumes).

3. If multiple RR SMR units are deployed in the UK (and/or internationally) and undergo decommissioning on concurrent/overlapping timescales (fully or in part) then the capacity of waste management facilities could potentially be challenged.

Opportunities

The following opportunities have been identified as potentially available to the waste management strategy and arrangements:

1. If the VRF achievable by RO is greater than currently assumed, then the requirement for an evaporator may be reduced or eliminated.

The deployment of multiple RR SMR units in the UK (and/or internationally) could provide the opportunity for OPEX, equipment and technique sharing for different lifecycle phases.

Chapter 21 (Decommissioning and End of Life Aspects) will outline any new arrangements of opportunities that may come about from decommissioning activities being undertaken by the NDA. The NDA has stated that it will provide advice and information to the developers of new build programmes and new nuclear technologies, which may include opportunities for innovative decommissioning approaches.

26.4.9 Key Assumptions - Overview

The following assumptions relating to the development of the waste management strategies are broken down into the different technical areas they apply to. As noted, these assumptions may change in line with design development, and these will be updated in future as required to reflect the changes in assumptions with time.

26.4.10 Plant Level Assumptions

Design Evolution – All of the system designs and waste management strategies and approaches (as outlined in Section 26.3) are still evolving and may be subject to change over the course of the ongoing evolving design of the RR SMR.

Current Best Estimates – All estimates of waste volumes (not provided in this document, but applicable to the IWS and other documents) and activities are based on preliminary best estimates and OPEX (from comparable PWR plants, adjusted for overall plant size).

Timing of Waste Processing – Radioactive wastes (including SF) will be processed upon arising (as allowed by cooling and decay) to allow segregation and minimise generation of orphan wastes.

Fuel Cycle Timing – The RR SMR will have 18-month fuel cycle and an operational lifetime of 60-years.

Optioneering Benchmark – A Technology Readiness Level (TRL) of 7 or less is the benchmark for waste system optioneering – technologies below this will not be included in FCD but where identified will not be foreclosed from future design.

26.4.11 Spent Fuel/High Level Wastes

SF will not undergo reprocessing and will be managed as radioactive waste.

All SF (including failed and damaged assemblies and NFCCs, including those co-located within SF assemblies, and separate items will be cooled in the SF pool prior to transfer to the interim SF store.

SF and NFCCs will be repackaged into containers suitable for transport and disposal to a GDF in an on-site facility (which won't be required until after the end of operations).

26.4.12 Solid Radioactive Waste

Off-site LLW treatment routes/disposal facilities will be available and will have sufficient capacity to accept all LLW from the RR SMR.

The UK national GDF will only be available to receive HAW packages after the decommissioning phase, so (separate) interim storage facilities for ILW and SF/NFCCs will be required pending a GDF being available.

26.4.13 Liquid Radioactive Waste

Minimal liquid effluent discharges will be required during normal operations (in line with minimal liquid discharge) but coolant bleed and discharge may be required in the event of fault conditions (e.g. fuel failure).

Effluent treatment will allow the recycling of effluent to the reactor or as demineralised makeup water (in line with the minimal liquid discharge).

There will not be an on-site laundry facility.

26.4.14 Gaseous Radioactive Waste

Fuel failures will impact activity concentrations of radionuclides, potentially resulting in a different operating mode to ensure enough recycle/hold-up of active waste gases prior to discharge.

26.5 Radioactive Waste Streams and Management Approaches

26.5.1 Overview

The following subsection provides an overview of the nature and origins of each waste stream, and the general approaches to management on a stream-by-stream basis. This information is primarily based on the RR SMR IWS [27].

The RR SMR comprises multiple waste treatment systems, which will be the origin of the majority of the radioactive waste streams described in the following subsections. These systems, which are outlined in Table 26.5-1, have a significant role in abating the radioactive waste arisings SFAIRP. Further details (including consideration of factors such as the hazardous properties of radioactive waste) are presented in Chapters 11 (Management of Radioactive Waste) and 25 (Detailed information about the design) of the E3S case.

Table 26.5-1 – Waste Systems Overview

System/Waste Stream	**Reference Designation System for Power Plants (RDS-PP) Identifier [9]**
Liquid Effluent	KNF
Gaseous Effluent	KPL
Drainage Effluent	KTA
Solid Waste	KMA (waste processing)
	KME (waste storage – Storage is for short term buffering, interim/longer term storage before dispatch to disposal, and decay storage)
Decontamination Effluent	FKA
Other Relevant Systems	
Wastewater Effluent	GM (drainage)
	GN (treatment)
Reactor Island Ventilation System	KL

[9] RDS-PP) is a standardised way of structuring SSCs in a form that allows them to be uniquely identified. RDS-PP identifiers in the form of trigrams are assigned to all the discrete systems making up the RR SMR. Further information on RDS-PP is provided in Chapter 1.

26.5.2 Spent Fuel and Non-Fuel Core Components

Spent Fuel

SF will be routinely produced from the generation of power by RR SMR units. The RR SMR reactor core comprises 121 fuel assemblies (which are made up of an array of rods/pins which contain the uranium fuel) when operating, which will be partially replaced (it is assumed that 40 will be replaced after their reactivity/power output has fallen below a defined level [10]) when the reactor is shut down and refuelled during refuelling outages (otherwise referred to as a 'cycle', which will occur every 18 months over the operation lifetime of the RR SMR) , and the assemblies removed from the core during these outages will be managed as SF.

During refuelling outages, the fuelling machine will extract SF assemblies from the Reactor Pressure Vessel (RPV), after which they are transferred to the SF pool where they undergo a cooling period, during which time the SF pool Cooling and Treatment system will remove decay heat from the assemblies, maintain the water quality and ensure adequate water coverage. After a cooling period sufficient for heat output from the assemblies to substantially reduce, the assemblies will be retrieved from the SF pool and packaged into steel canisters for long term storage in the dedicated dry SF Store. The transfer to the SF Store will be carried out by emplacing the steel canisters within transfer casks, which will be transferred into concrete overpacks for long term storage. Further details are presented in Chapter 9A (Auxiliary Systems) of the E3S case.

The SF assemblies will remain in storage for a prolonged period; this is because the earliest assumed/ planned opening date for the UK national GDF is in the 2040s [28]. Further, only ILW will be accepted initially, and the date at which SF will start to be accepted into the facility is currently uncertain, but will be well after the 2040s. The SF will also need to 'cool' such that its total levels of radioactivity and heat output meet GDF WAC (these have not yet been set, but are likely to be stringent). It is therefore assumed that SF will not be removed from the site until after the completion of the decommissioning phase.

The SF (potentially alongside other wastes) will be retained on site (in the SF Store, which hasn't yet been designed due to uncertainties over volumes and other underpinning data) after decommissioning works have removed most or all of the other main structures on site; there will be a prolonged quiescent period during which the only activities will be non-routine (e.g. maintenance, inspections (of the waste and associated infrastructure) and recladding of buildings). The SF will be retrieved when a GDF is able to accept it, and this phase will involve a re-mobilisation to site so that the Hot Cell building can be refurbished to allow repackaging of the SF into GDF-compliant disposal containers, followed by removal from site for disposal (and clearance of remaining structures on the site).

Figure 26.5-1 is the process flow for the management of SF; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of SF.

[10] A proportion of these SF assemblies are expected to be failed or damaged upon their arising (currently estimated at 16 per 1000, for failed assemblies – subject to review) and may require additional steps in their handling and management.

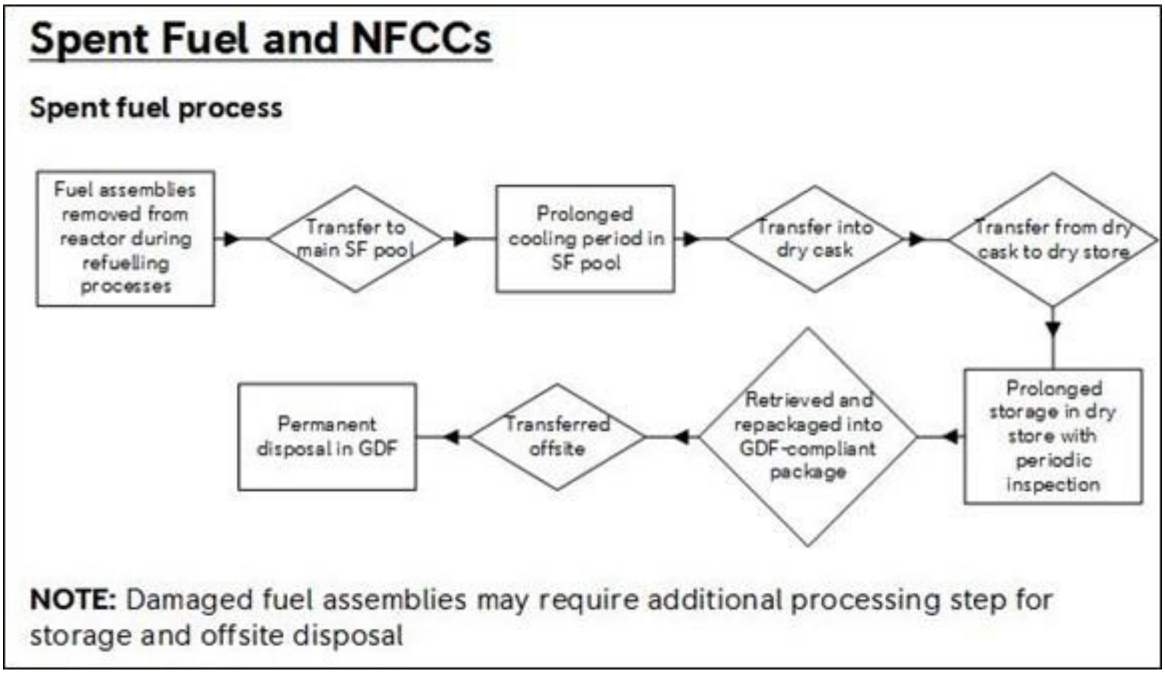

Figure 26.5-1 Spent Fuel Process Flow

Non-Fuel Core Components

NFCCs comprise a number of components and items that will be located in the RR SMR cores whilst they are operating; they are primarily Instrumentation and Control (I&C) components that perform safety and other operational functions. These items do not contain any fissile material and do not contribute to nuclear processes, but due to being located within the neutron field when the reactor is operating, they will become activated and will therefore require appropriate management via radioactive waste routes.

The following bullets describe the six components that make up the NFCC waste stream:

1. **Control rods** (the control rods are used to shut down or control reactivity in the core). Further details are presented in Chapter 4 (Reactor Systems (Fuel & Core)) of the E3S case).

2. **Thimble Plugs** (the thimble plugs are used to block coolant flow though empty locations in fuel assemblies and resemble control rods (though are shorter in length)).

3. **Fixed Neutron Sources** (the (primary/active) neutron sources are required for the first operational cycle but will not be required thereafter and will be removed).

4. **Self-Powered Neutron Detectors (SPNDs)** (these C&I components provide data on neutron fluxes in the core when it is operating, and function via activation of a metallic substrate).

5. **Core Outlet Thermocouple (COT)** Instrument Lances (the COTs measure the temperature of the coolant after having passed through the core).

6. **Ultrasonic Filters** (ultrasonic filters will be used to mobilise activity (crud and particulate) adhered to the fuel assemblies into the coolant (for removal by filtration)).

The waste categorisation of the different NFCCs varies significantly on the basis of variables including the materials that the items are constructed from and the extent of activation (which is a function of position and residence time in the reactor). The majority of the NFCC waste stream is anticipated to be ILW upon arising and will be managed in accordance with other dry solid ILW streams; the items that may be the exception to this are the SPNDs, and the management route for these may accordingly differ significantly.

The SPNDs are nuclear safety-related components that provide the reactor operators with data on crucial parameters such as neutron flux density, reactor transients and others. They contain quantities of a metallic 'activation substrate' that is intended to undergo activation when the reactor is operational, and the emitted radiation is used to generate a real-time (or near real-time) signal for the operators, the strength of which is proportional to the neutron conditions in the core. Different metals are suitable for use in SPNDs but have different performance characteristics in terms of sensitivity, response time and longevity, and also for waste management.

Cobalt-59 based SPNDs are the 'default choice' (from the nuclear safety perspective) for the SPND as it provides prompt response (minimal delay between neutron conditions and the signal), but these activate to Co-60; the high energy gamma emissions from this radionuclide produces SPNDs that are HLW (so require active heat management for a period of time) and are radiologically very hazardous. For this E3S Case revision, the Core Design team were making an operational assessment as to whether the performance of cobalt-based SPNDs will be required [11], or if SPNDs based on other metals (likely vanadium, but potentially others including hafnium and platinum) will provide sufficient safety margins for regulatory acceptance.

If vanadium (or another metal)-based SPNDs are used, they will be ILW upon arising and so can be managed in line with the other NFCC waste streams. If cobalt-based SPNDs are required then the waste stream will require management commensurate with their high-hazard nature, namely management through the fuel route envelope in line with SF assemblies. This means that the SPNDs will require a period of storage in pools (likely until they have decayed such that they have crossed the threshold from HLW to ILW and will no longer require active heat management) followed by transfer into suitable containers for long-term storage (in the SF store), and eventual repackaging for GDF disposal along with the SF.

Figure 26.5-2 presents the process flows for the management of NFCCs; these conceptually outline the process steps (handling, transfers, treatment and storage) that will take place as part of the management of HLW/ILW NFCCs.

[11] Potentially supplemented by additional in-core neutron detection/calibration instrumentation, namely Micro Pocket Fission Detectors (MPFDs) and aeroballs.

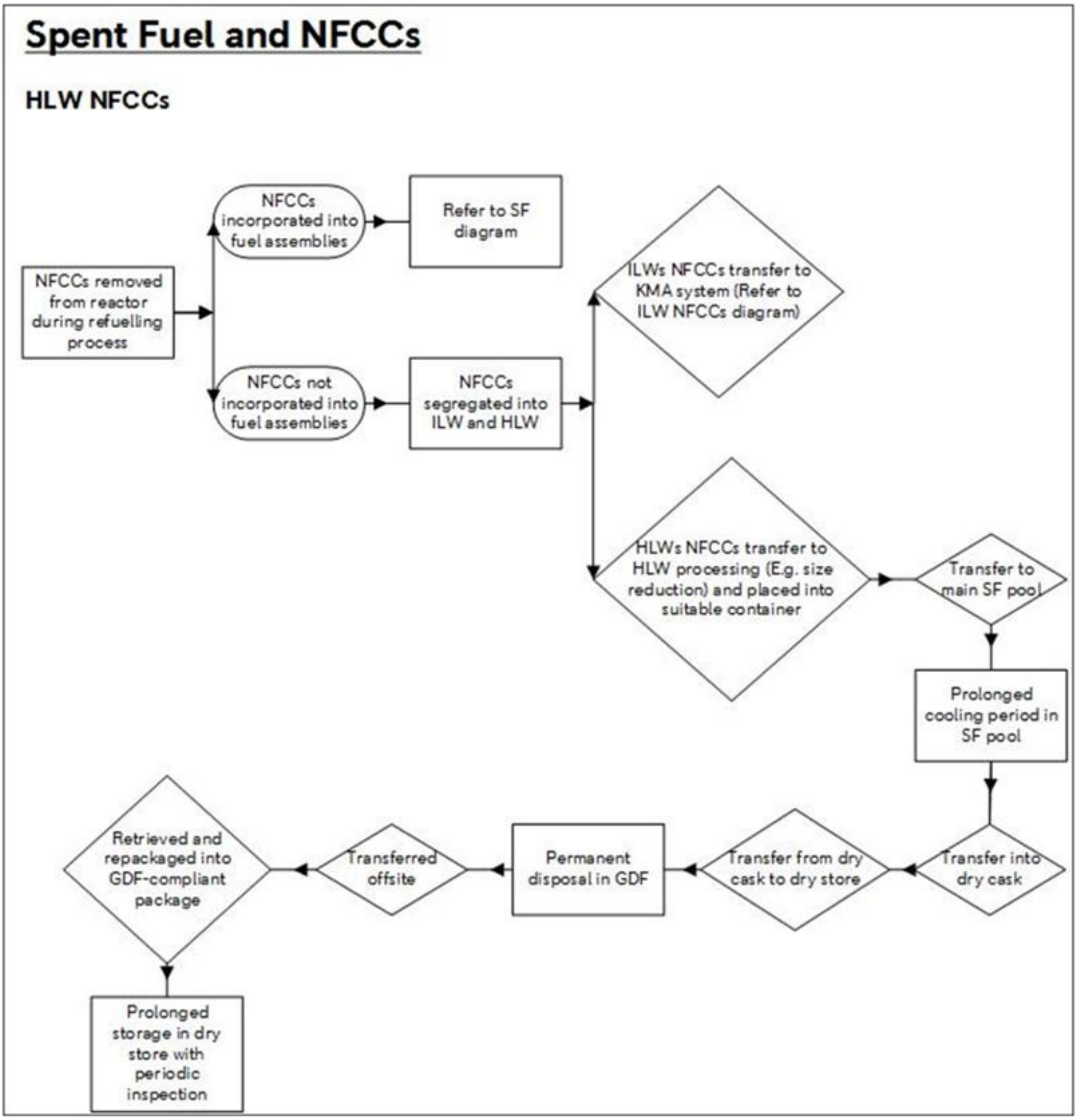

Figure 26.5-2 HLW NFCCs Process Flow

26.5.3 Solid Waste Management (HAW)

Solid wastes produced by the RR SMR during operations will be processed in the KMA system and stored (either for short term buffering or longer term storage for decay or awaiting the availability of offsite disposal routes) in the KME system, with KME20/30 comprising the ILW storage facilities. Wastes covered in this section are initially classed as HAW although after treatment may be classed differently.

Note that there are a number of arrangements and other aspects related to the management of wastes within the RR SMR [12]. These are not covered by this version of the RWMA (due to not having been defined) but will be described in detail in future issues of this document.

Dry Solid ILW

ILW NFCC Waste (Activated Metals Removed from the Reactor Core) – A proportion (or potentially all, if non-cobalt-based SPNDs are used) of the NFCC waste stream will comprise activated metals classified as ILW. These will be managed in accordance with the arrangements for Miscellaneous Operational Waste (see below), namely decay storage in suitable containers until the waste can be disposed of as LLW. Some NFCC components are expected to contain long-lived activation radionuclides (e.g. Ni-63) so are not suitable for decay storage, and will be cement encapsulated in appropriate thin-walled containers for storage until the disposal route to a GDF becomes available.

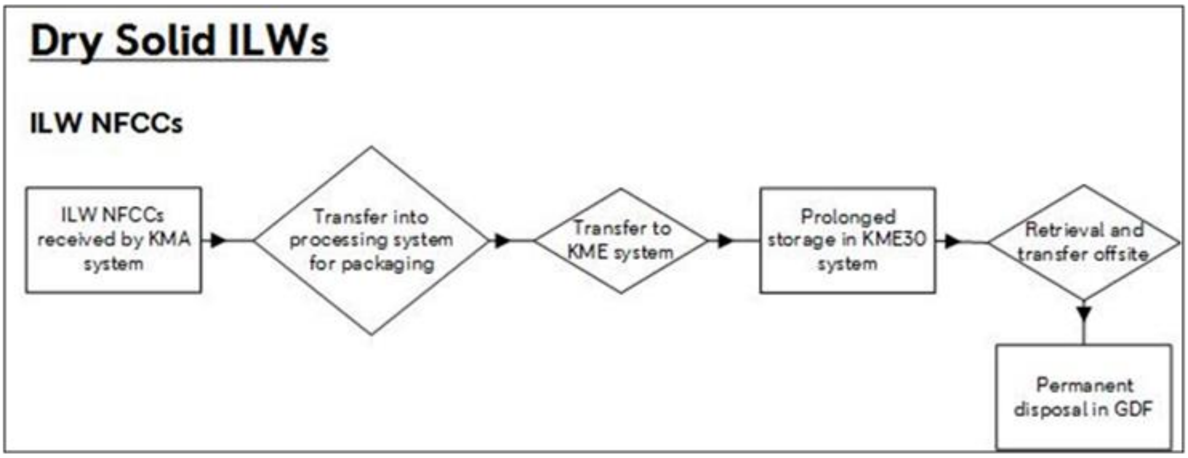

Figure 26.5-3 ILW NFCCs Process Flow

Filters – Filtration is required to remove particulate and other solid fines from multiple water circuits (the primary circuit/Chemical and Volume Control System, CVCS), the SF and refuelling pools (FPPS), and KNF), which is carried out using filter arrays located within the circuits. A decision was made [29] that back-washable (i.e. reusable) filters, rather than removable (i.e. disposable) cartridge filters, are the preferred filtration solution for the SMR. The primary waste stream from filtration will therefore be wet sludge from the filter back-washing process, but the filters (comprising the filter material and the housing) will have a finite operational life (estimated based on OPEX to be >10 years) and will require disposal after a certain number of saturation/backwashing cycles (the duration of use/number of filters requiring disposal per unit time is uncertain but the use of backwashable filters is estimated to reduce waste packages by 75% over a 10 year period [27]).

Figure 26.5-4 presents the process flow for the filters; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of filters.

[12] These arrangements will need to cover the following (note this may not be an exhaustive list): recording of local waste arisings; notification of transfers; handover protocols; composition; radioactive content and WAC aspects; contamination and surface doses; appropriateness of packaging; shielding considerations; handling equipment (accounting for weight and dose); and ALARP/BAT aspects.

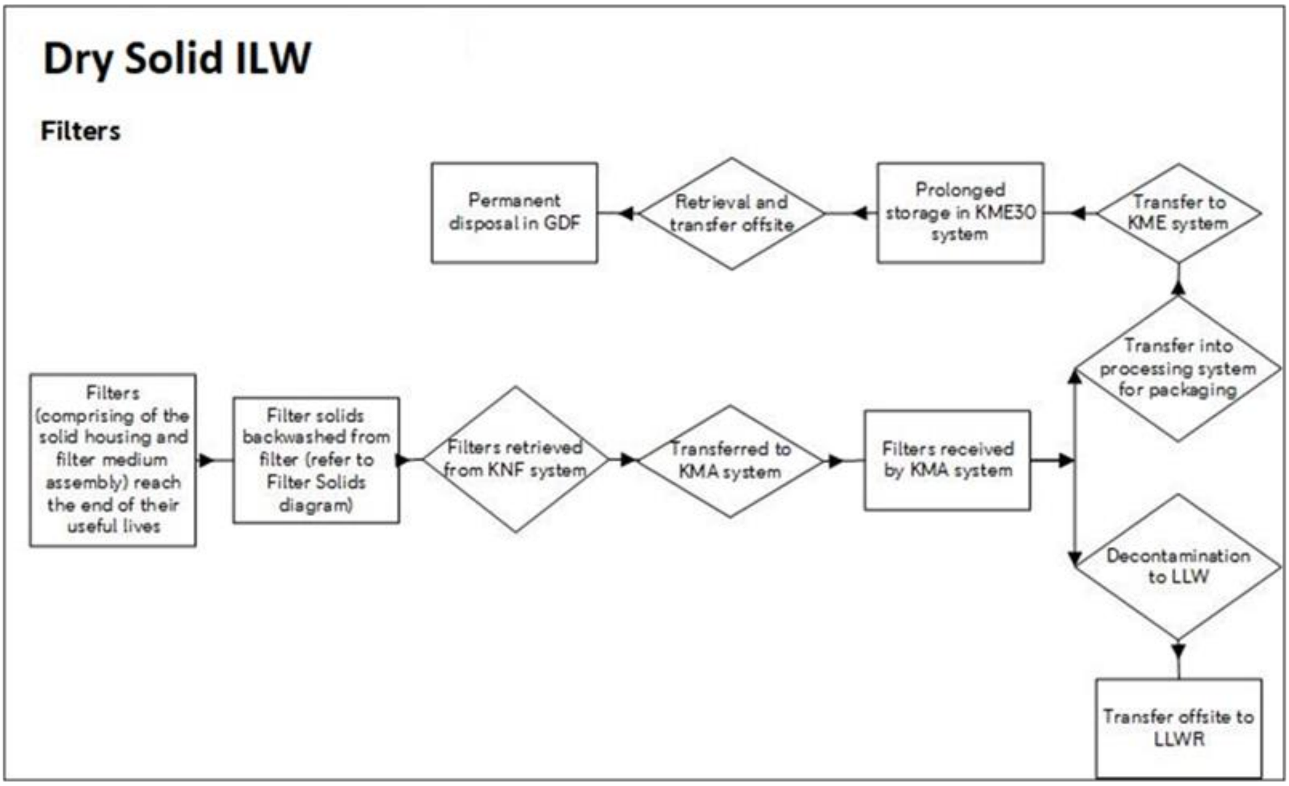

Figure 26.5-4 Filters Process Flow

Miscellaneous Operational Waste (Dry Active Waste (DAW)) – Miscellaneous Operational Waste (alternatively described as DAW) is a waste stream comprising contaminated items that will be generated primarily from routine maintenance operations undertaken during outages (e.g. removed plant components and materials such as tools, plastics, monitoring swabs and personal protective equipment etc.). As noted above, some ILW DAW items may be suitable to be decayed in containers until the waste can be managed as LLW, or may be decontaminated to below the LLW threshold in a suitable on-site facility. For items for which the activity cannot be reduced below the LLW threshold, management will be via cement encapsulation in appropriate thin-walled containers for storage until the disposal route to a GDF becomes available.

Figure 26.5-5 presents the process flow for DAW; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of DAW.

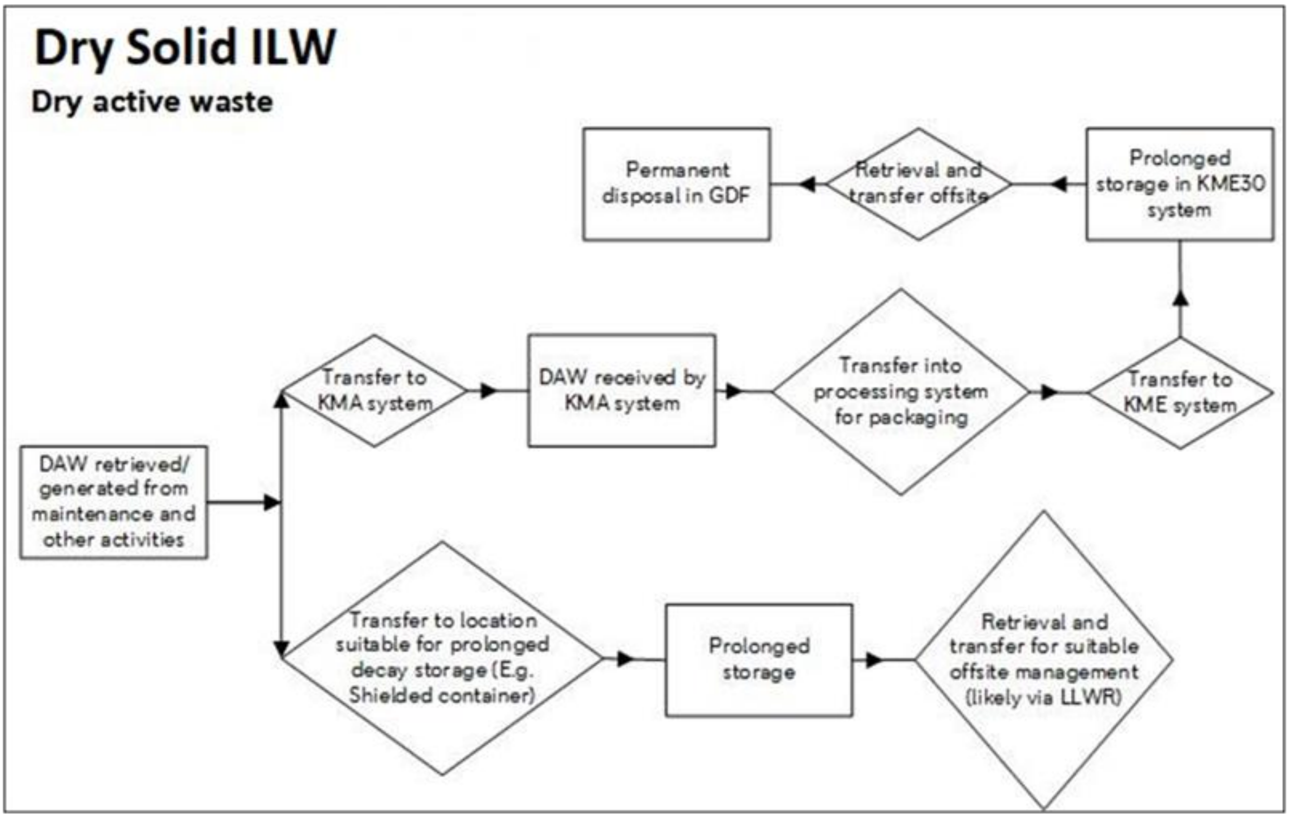

Figure 26.5-5 DAW Process Flow

Dry Boundary Wastes – For the filter and DAW streams it is expected that the waste will comprise a mixture of both ILW and LLW. In the case of the filters, the back-washed sludges will be either ILW or LLW, depending on the water circuit in question; this is described in detail below.

26.5.4 Solid Waste Management (LLW)

Dry Solid LLW

The following waste streams will be managed via KME10 (the LLW storage facilities) and the on-site LLW processing and treatment system, followed by management via suitable offsite facilities (LLWR and others) for onward management or disposal.

Steam Generator Blowdown System Filters – The Steam Generator Blowdown System (SGBS, on the secondary circuit) will incorporate an Electro-Deionisation (EDI) unit (for demineralisation), with pre/post cartridge filtration. The pre-filters are (conservatively) assumed to become LLW under normal operational conditions; under fault conditions (primarily a steam tube leak or rupture) these filters may be bypassed to ensure that they do not become contaminated with primary circuit radionuclides (effluents will likely be redirected to the KNF system in this event).

Gas Filters – Several different filtration systems will be employed for the management of off-gases from different systems. High Efficiency Particulate Air (HEPA) filters will be installed in multiple buildings and locations; these will require regular replacement and are anticipated to be LLW.

Charcoal Delay Beds – The KPL system will treat gaseous effluent from the Reactor Coolant System (RCS) and CVCS using charcoal delay beds for abatement of fission products - radioactivity will accumulate in the charcoal delay bed substrates such that they will need to be managed as radioactive waste. The Reactor Island (RI) Heating, Ventilation and Air Conditioning (HVAC) system will also incorporate charcoal iodine traps (in some locations). The delay/iodine traps beds in these systems will consist of activated charcoal that may require replacement, though OPEX indicates that these beds might be able to operate for the full 60-year operational life of the RR SMR. If replacement is required, it is anticipated that this material will be LLW, but could potentially (though it is unlikely, due to the short half-lives of relevant radionuclides) comprise ILW (e.g. in the event of a fault).

RO Membranes – RO is to be used in the treatment (after the filtration stage) of primary circuit water and spent liquid effluents, and the system will comprise multiple parallel trains of RO membranes. These will selectively remove ions, salts, colloids and particles (including radioactivity) and will also be self-cleaning (using crossflow operation). Accumulation of contaminants on the membranes is still anticipated to occur even with self and other cleaning, so are anticipated (especially the first membrane in the series) to be LLW upon arising when they are replaced.

Pool Skimmers – The pool skimmers will be used for the mechanical filtration of particulates floating on the surface of the SF and refuelling pools. The nature of these items was not defined for E3S Case Revision 1, but they are anticipated to become LLW due to the activity in the pools.

Metallic Waste – This stream encompasses metallic components (e.g. filter housings) that may have become surface contaminated during use, and are produced during maintenance and other works. Management routes such as metal melt (undertaken offsite via LLWR or other routes, following surface decontamination) may be appropriate for this waste stream.

Dry Solid LLW– Figure 26.5-6 is applicable to this waste stream. For DAW, LLW items (which will likely include items such as personal protective equipment) will be segregated (bagged and collected in bins) for transfer to the on-site LLW processing and treatment system followed by management via LLWR for onward management or disposal. A proportion of the DAW waste stream may also be VLLW, and will therefore be consigned to a suitable offsite facility for onward management or disposal no solid waste streams comprising only Very Low Level Waste (VLLW) are anticipated.

Figure 26.5-6 is the process flow for the dry solid LLW waste streams collectively; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management across all the streams,

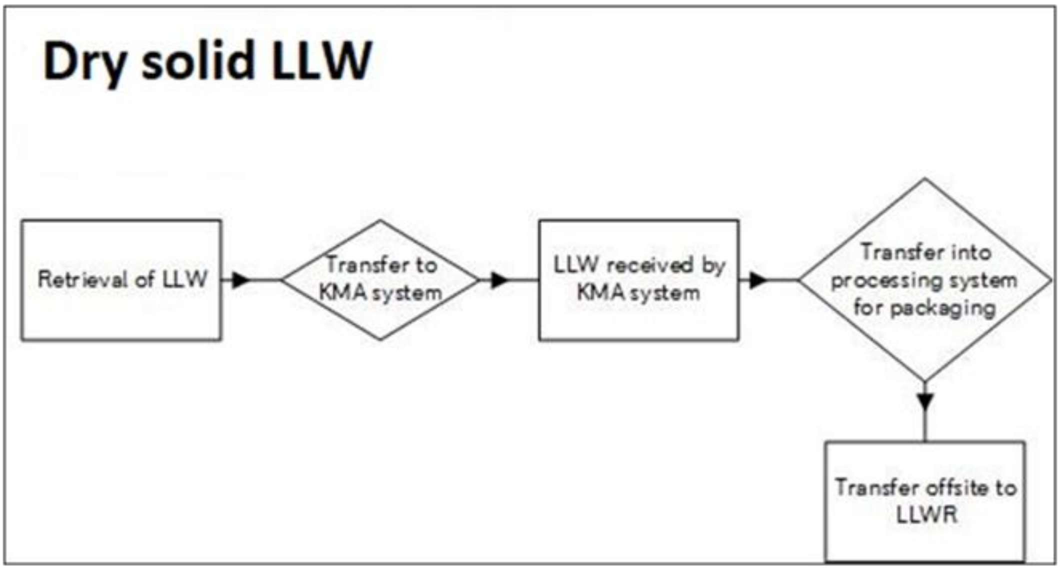

Figure 26.5-6 Solid Dry LLW Process Flow

26.5.5 Wet Solid Waste Management (HAW)

Bead Resin – Resin beds are used to demineralise (purify) water in the CVCS (three beds; duty, standby and cation), pond purification (FAL; two mixed beds) and spent liquid effluent treatment (KNF20) systems. The CVCS duty and cation beds are anticipated to reach saturation and require replacement at each 18-month refuelling outage cycle, and these, along with the FAL resins, are discharged by sluicing from the beds using process or demineralised water (and are transferred to KME20 via installed pipelines). The CVCS/FAL resins are anticipated to be ILW upon arising and will be managed through cement encapsulation in appropriate thin-walled containers for storage until the disposal route to a GDF becomes available. The KNF20 resins will be located downstream of the RO system (and are therefore primarily perform a 'polishing' function) and are anticipated to be LLW upon arising.

Figure 26.5-7 is the process flow for the bead resins; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of resins.

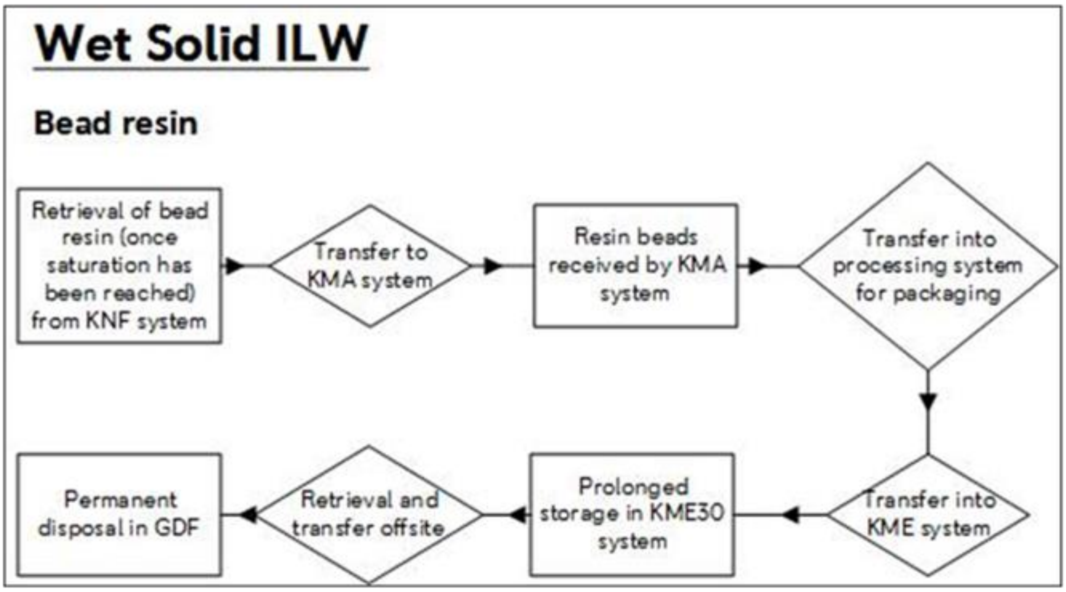

Figure 26.5-7 Bead Resin Process Flow

Concentrates – Spent liquid effluents (originating from e.g. active drains) are processed through a multi-stage system comprising the RO system, ion exchange, filtration and the evaporator. The concentrates waste stream will be produced from the RO system and the evaporator; retentate from the RO contains concentrated impurities separated from the effluent by the membrane, which is then sent to the evaporator for further concentration by water elimination (which achieves a significant volume reduction). The concentrate waste stream will be enriched in impurities including ions, colloid and salts and is expected to comprise ILW at the point of arising, but due to a low loading of activated particulate (due to filtration), is expected to be able to decay to LLW (which will be carried out in shielded tanks in the KME system). The decayed concentrates will likely be managed through cement encapsulation in appropriate thin-walled containers for management via LLWR, or alternatively could potentially be used as grout make up water for grouting of ILW waste streams (e.g. ILW bead resins).

Figure 26.5-8 is the process flow for the concentrates; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of concentrates.

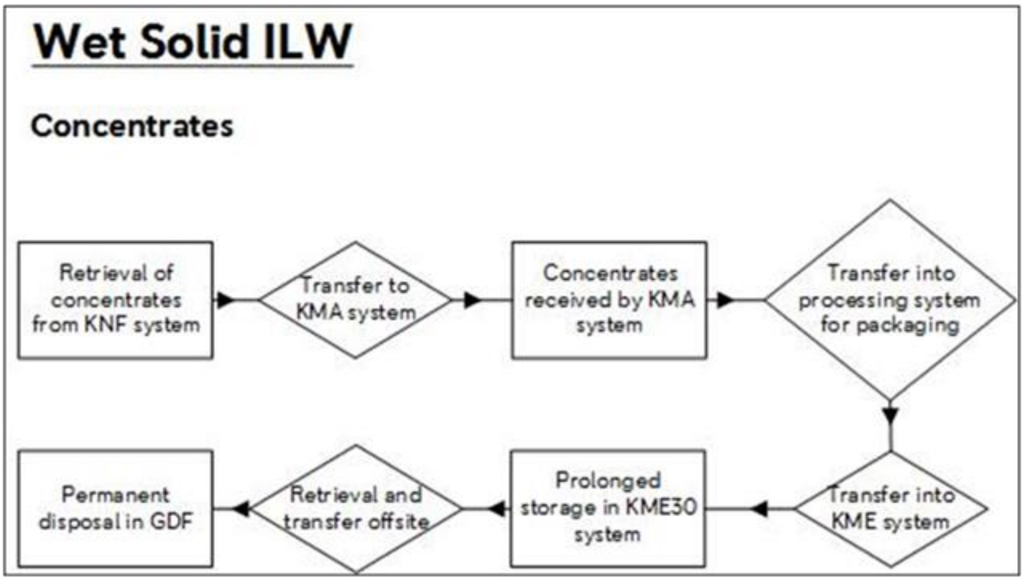

Figure 26.5-8 Concentrates Process Flow

Suspended Filter Solids – As noted above, a decision was made to use back-washable rather than removable cartridge filters on the liquid effluent systems (CVCS/FAL/KNF), which means that the primary waste stream from filtration will be a wet sludge filter back-washing process, but the filters themselves will also require disposal after a certain number of saturation/backwashing cycles the back-washing process will be undertaken (on one filter per system at each refuelling outage cycle) using a flushing system which is not fully developed for E3S Case Revision 1, but will produce a suspended particulate (sludge) waste stream. Following backwashing the sludge is transferred to the filter solids tank at which point excess water is decanted, which produces a slurry of water and solids. It is anticipated that the wet sludge from the liquid effluent systems will be ILW that will be managed through cement encapsulation in appropriate thin-walled containers for storage until the disposal route to ae GDF becomes available.

The SGBS EDI purifies the secondary circuit, but in the event of radioactivity entering the secondary circuit (i.e., from pinhole leaks) it is expected that radioactive material will collect in the brine from the EDI, which will be routed to the KNF system for treatment [30]. Therefore, filter solids will likely not require discharge from the secondary circuit to the KMA system.

Figure 26.5-9 is the process flow for the filter solids; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of filter solids.

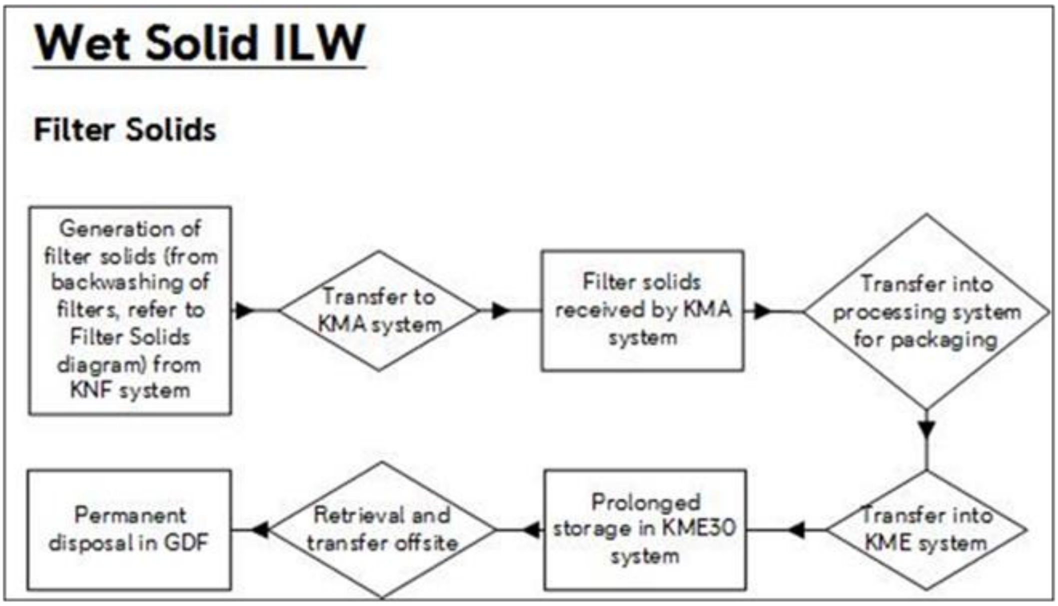

Figure 26.5-9 Filter Solids Process Flow

Wet Boundary Wastes – Miscellaneous sludges may be formed from complex mixtures of non-soluble matter through cumulative mechanisms in certain parts of the water circuits (e.g. tank sumps), and also from decontamination activities. Although the volume of these sludges is likely to be low, they will need to be removed by flushing at which point it would mostly be mitigated by the liquid effluent system (i.e. filtration, RO etc.) but where it forms a distinct waste stream it is anticipated to be primarily LLW, but may include ILW, and would therefore need to be managed on a case-by-case basis.

26.5.6 Wet Solid Waste Management (LLW)

No wet solid LLW arisings are anticipated from the RR SMR apart from boundary/decayed resins, concentrates and filter solids and miscellaneous sludges (See below).

Miscellaneous Sludges – This refers to sludges which are produced separately from the filter back-washing process described in Section 26.5.5; decontamination activities, along with the general presence of particulate and other impurities in different water circuits, could potentially cause sludges to accumulate in areas of low flow or stagnant flow (e.g. sumps, pipe elbows). Retrieval of this sludge is expected to result very low volumes during normal operations due to control, mitigation and prevention measures, and it is anticipated to be LLW.

26.5.7 Liquid Radioactive Effluent Management

Primary Circuit Effluents – These effluents originate from multiple sources (e.g. transfer of CVCS system effluents to the processing/treatment system, pressuriser bleeds during degassing) and are expected to contain low concentrations of contaminants (i.e. are ‘reactor grade’) during normal operations and are therefore suitable for direct recycling into the primary coolant loop after having been collected in storage tanks. In some circumstances, these effluents may fall outside the primary coolant Water Quality Specification (such as the effluents containing elevated tritium from fuel failure), and the effluents will be routed to the KNF20 system for treatment, or directed from the storage tanks into the monitoring and discharge system for offsite discharge.

Chemical Drain Effluents – These effluents originate from multiple source (e.g. effluents leaked/drained from the Nuclear Auxiliary Building, or lab samples from effluent testing) and contain higher concentrations of radioactivity and chemical contaminants. They are collected and sampled in separate tanks and treated on a by-batch basis via multiple stages of RO, ion exchange, evaporation and filtration to remove contaminants and reduce their volume. The treated effluent is transferred to the liquid effluent monitoring and discharge system tanks for sampling, at which point it will be either be recycled into the primary circuit (as coolant or service water) or directed [13] to offsite discharge (typically only if tritium is elevated).

Process Drain Effluents – These effluents primarily originate from maintenance operations and leaks/discharges from the RCS, and are expected to contain low to moderate radioactivity and chemical contaminants. These effluents will be collected, treated and reused/discharged in line with the Chemical Drain effluents.

Active Floor Drain Effluents – These effluents primarily originate from equipment draining and floor washing in the Radiological Control Area (RCA), and are expected to contain low radioactivity and chemical contaminants. These effluents will be collected, treated and reused/discharged in line with the Chemical Drain effluents.

Organic Liquid Wastes (Oils and Solvents) – Oils and solvents are used throughout the RCA (e.g. for lubrication and decontamination, respectively) and therefore have the potential to entrain radioactivity. These waste streams will be minimised as far as possible but have the potential if contaminated to form LLW, and will therefore need to be segregated and transferred to the LLW processing and treatment system for packaging and off-site management, for instance treatment/incineration.

Figure 26.5-10 is the process flow for oils and solvents; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management of oils and solvents.

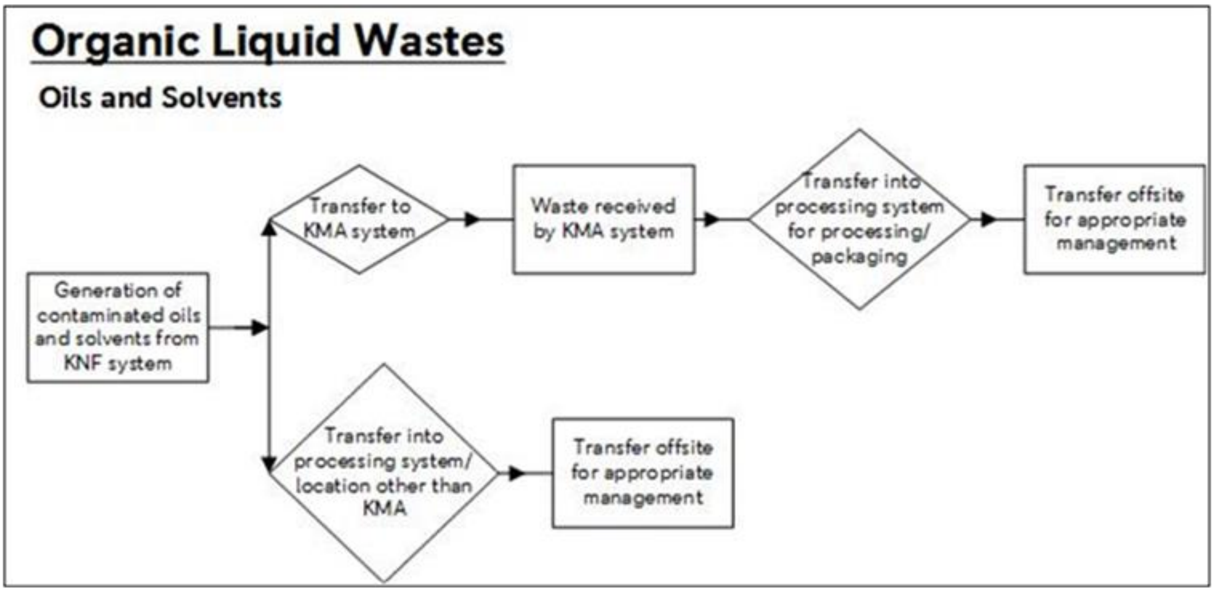

Figure 26.5-10 Oils and Solvents Process Flow

[13] A re-treatment step may be included prior to discharge, but this will not be routine.

Other Effluents – The other primary source of effluents is the secondary circuit, which may contain low concentrations of radioactivity under fault conditions (including expected events). Brine from the SGBS EDI is usually managed via the conventional wastewater system, but during fault conditions this may require alternative management. At PCD a decision on final option has not been decided but options being considered (given the chemical characteristics of the SGBS effluents) include direct offsite discharge, treatment and general (but not reactor water system) reuse and specialist treatment.

26.5.8 Gaseous Effluent Management

Primary Gaseous Effluent – The systems that handle primary circuit coolant will produce gaseous effluents containing radioactivity (fission and activation products including noble gases). These effluents are produced from the degassing of the coolant fluid and/or from gases that accumulate in tanks and vessels (i.e. in head spaces). These gaseous effluents are collected, dried (using cooling rather than desiccants), recombined (removal of hydrogen and oxygen) and potentially compressed (this will not be routinely required) before being passed through charcoal (activated carbon)-based beds to abate radioactivity via adsorption hold-up delay to permit decay. The gaseous effluents are then discharged to the environment via the stack (where monitoring is provided).

Ventilation Air – The HVAC systems servicing the RCA will manage gaseous effluents in the form of air with entrained radioactive airborne particulate (from the atmospheres of buildings containing contamination) and potentially iodine. The effluents are channelled through HEPA filters and charcoal-based iodine filters (on on-demand basis), and the abated gases are monitored and discharged to the environment via the stack.

Condenser Air Removal System (CARS) – CARS removes air from the condenser direct to the atmosphere. If there is a leak from the primary circuit to the secondary circuit, then leaked effluent is transported across the secondary circuit and non-condensable gases are eventually stripped by the (CARS)[MAJ] and discharged to the environment.

26.5.9 Decommissioning Wastes

The decommissioning phase of the RR SMR lifecycle will have an overall objective of transitioning the site from its operational state to an agreed end state. This will involve the progressive removal of hazards "giving due regard to security considerations, the safety of workers and the general public, and protecting the environment". All on- and off-site activities post-permanent reactor shutdown will form part of the 'Decommissioning Scope', which includes the following scope items [18].

1. Pre-closure planning;
2. Defueling and Post Operational Clean Out (POCO);
3. Reactor decommissioning;
4. ILW and SF storage;
5. Remobilisation for waste disposal;
6. Waste and SF disposal; and

7. Final site clearance and delicensing of site for re-use.

The Decommissioning Waste Management Plan (DWMP) is the document that will outline the expected waste categories and individual waste stream to be produced at decommissioning, and the approaches that will be applied for their management. Note this document was not available for this E3S Case revision , so the expected wastes are not outlined, but will be incorporated into future versions of this chapter.

Figure 26.5-11 is the process flow for the decommissioning waste streams collectively; this conceptually outlines the process steps (handling, transfers, treatment and storage) that will take place as part of the management across all the streams,

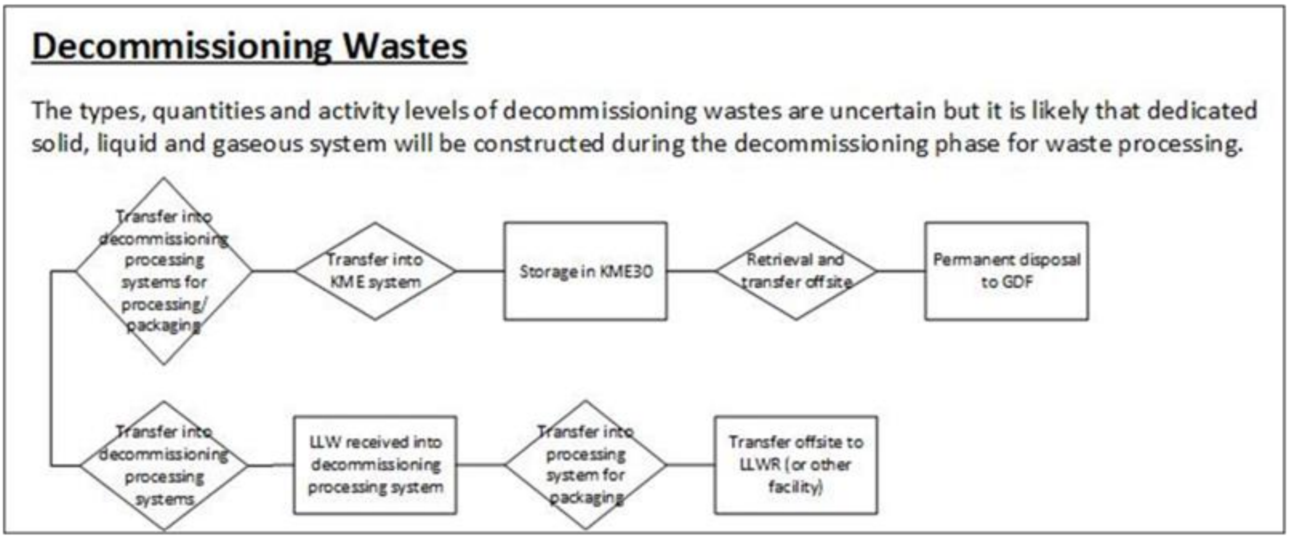

Figure 26.5-11 Decommissioning Waste Process Flow

26.5.10 Radioactive Waste Quantity Estimates

Table 26.5-2 provides an overview of expected/estimated annual solid and non-aqueous waste arisings from the RR SMR, along with the number of packages that will be produced, where this information was available [27]. Chapter 29 provides information on aqueous and gaseous waste arisings.

Table 26.5-2 - Summary of Solid and Non-Aqueous Annual Waste Volumes and Package Numbers

Waste Stream	Anticipated Waste Volume/year [14]	Anticipated Number of Packages/year
Dry Solid ILW		
Dry Active Waste (ILW)	0.3-0.7m^3	-
Spent Fuel		
SF Assemblies	29 assemblies (1708 assemblies over 60-year operational lifetime)	-
Dry Solid HLW		
NFCCs	-	-
Wet Solid ILW		
Resins	2.22m^3	8
Concentrates	1.46m^3	-
Suspended Filter Solids	0.8m^3	4
Sludges	No arisings expected	-
Dry Solid LLW		
Filters (Gas Treatment)	4.0m^3	144[15]
Membranes	0.8m^3	
Dry Active Waste (LLW)	25.0m^3	
Metallic Waste	3.0m^3	
LLW Operational Waste (Maintenance and replacement of materials in outage)	Not defined	217
Wet Solid LLW		
Resins	-	25
Concentrates	-	
Sludges	0.25m^3	8
Oils and Solvents	1.0m^3	

[14] The volumes are presented on an annual basis (or for the 18 month cycle where this is more applicable) rather than for the whole lifetime (with the exception of the SF assemblies). Arisings over the whole lifetime can be estimated based on extrapolations of these annual figures but will be subject to uncertainties, so are not explicitly presented in Table 26.5-2.

[15] 6 Backwashed filters, 7 RO membranes, 131 HEPA filters

26.6 Summary and Conclusions & Forward Action Plan

26.6.1 Summary and Conclusions

This RWMA document comprises Chapter 26 of the E3S case.

RWMA is primarily concerned with the management arrangements rather than physical processes and systems, noting however that the arrangements themselves will be focused on the systems that contain or create radioactive material (i.e. physical SSCs) in normal operations.

Given the early stage of the design process for the RR SMR, key assumptions relating to radioactive waste management assumptions have been made which will be reviewed and revised as design development progresses. These assumptions are broken down into project level assumptions (design evolution, current best estimates, timing of waste processing, fuel cycle timing and optioneering benchmarking), SF/HLW (reprocessing, cooling and packaging), solid radioactive waste (a GDF and other facilities will have sufficient capacity), liquid radioactive waste (discharges will be reduced as far as possible through the minimal liquid discharge philosophy) and gaseous radioactive waste (fuel failures will impact activity concentrations).

The key aspects of the regulatory/legislative context of the RWMA are as follows:

1. The RSR define a number of Environmental Principles, 11 of which are directly application to radioactive waste must therefore be taken into account in the RWMA.

2. The ONR SAPs provide a framework for regulators and guidance to designers and duty-holders regarding the content of safety cases and the application of ALARP/ALARA to reduce risk SFAIRP. These requirements are captured through seven principles which cover different aspects of radioactive waste management.

3. The GDA guidance to RPs [21] outlines the requirements, expectations and content for each of the steps and submissions in support of the GDA process.

The lifecycle of the RR SMR comprises the following phases: Planning and Design; Site Preparations and Clearance; Construction; Commissioning and Operation; and Reactor Decommissioning. Key site features are RI; Turbine Island (TI); Cooling Water Island (CWI); Balance of Plant (BoP); Electrical Control and Instrumentation (EC&I); and Civils and Infrastructure. The waste streams that the RR SMR will produce are broken into the following categories: SF/NFCCs; Dry Solid ILW/LLW; Wet Solid ILW/LLW; Liquid Radioactive Effluents; Gaseous Radioactive Effluents; and Decommissioning Wastes.

The key aspects of the radioactive waste strategy, principles and arrangements are as follows:

1. The Waste Hierarchy is a system for ranking and prioritising waste management options and approaches such that environmental impacts are minimised, and is outlined in The Waste (England and Wales) Regulations 2011 [19] and applied to radioactive waste management through the NDA 'LLW Strategy' [31] and RSR2 [20]. It is incorporated into radioactive waste decision making for RR SMR via Key Design Objective 5, which is used in quantitative options assessment.

2. BAT will underpin all operational aspects of the RR SMR and will therefore also be applied to radioactive waste management. The requirement for BAT is defined in 'Approach for the

Demonstration of Optimisation through the Application of BAT' [23], and for RR SMR application is captured in the BAT Claims (four of which apply directly to radioactive waste management) and 'Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles' [22]. Application of BAT will be based on the Claims, Argument, Evidence (CAE) model and will be combined with the Pugh Matrix for complex decisions.

3. ALARP will be applied to all aspects of the SMR lifecycle stages to ensure that the risks to people from exposure to ionising radiation are tolerable and reduced as low as is reasonably practicable. The regulators advise that ALARP should provide clear conclusion of no further feasible actions, apply RGP, and apply a process to select options and assess risk. The requirement to demonstrate and apply ALARP is outlined in the 'Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles' [22] and the 'Literature Review of ALARP Principles and Process' documents [32].

4. 'Disposability Assessment' can refer to separate but related processes, one which is led by Rolls-Royce SMR Ltd, and another which is led by NWS in response to an application for an LoC for a waste stream; the term 'Disposability Case' will be applied to the design process to minimise scope for confusion. For E3S Case Revision 1, the outline structure of the RR SMR 'Disposability Case' had been informally accepted, and when issued this will comprise the first step towards obtaining LoC for all of the HAW waste streams to be produced by the RR SMR.

5. Waste package records will need to be produced for all waste packaged in the RR SMR, and the NWS requirement for this is captured in the 'Waste Package Data and Information Recording Requirements' document. For E3S Case Revision 1, initial discussions have taken place but formal proposals for capturing and recording data will be endorsed as part of the LoC process (see above), but the general requirements to capture data as waste is being packaged are understood.

Risks identified as applying to the waste management strategy and arrangements are that new treatment and waste routes may be required (given that waste volumes and activities are currently based on estimations), reuse of effluents may not be possible (as achievable decontamination factors and water specifications are assumed) and waste management facility capacities could be challenged (if multiple SMRs are deployed). Opportunities identified are that there might not be a requirement for an evaporator (if assumptions for VRFs are exceeded) and OPEX/equipment/technique sharing could be enabled by multiple SMR deployment (UK and/or international).

Overall, the RR SMR was at PCD stage of design development, and the RWMA have accordingly been developed as far as this has allowed. Ongoing future development, particularly around understanding of waste streams (primarily inventory and volume), system and engineering design, waste processing and packaging approaches, offsite management (particularly development of the Disposability Case and later the LoC) and management approaches for radioactive waste will allow assumptions and risks to be reduced and opportunities to be realised, and therefore for the RWMA to be further developed.

The following subsection outlines the Forward Action Plan that identifies the main gaps in the RWMA at the time of PCD, and the steps, events and milestones that will allow these gaps to be addressed and the RWMA to undergo future updates.

26.6.2 Assumptions & Commitments on Future Permit Holders / Dutyholders

The intention is that the E3S Case will capture assumptions and commitments for future permit holders/dutyholders/licensees. Environmental assumptions and commitments for permit holders have not been formally captured at this stage in the process, but will be included in future revisions of the GER.

26.6.3 Forward Action Plan

Table 26.6-1 provides a summary of the Forward Actions that will enable and underpin future update of the RWMA. Further work will be undertaken to update the RWMA based on RR SMR design definition at the Reference Design 7.

The primary focus of the Forward Actions (FA) in Table 26.6-1 is to ensure that the E3S case demonstrates that the RR SMR will be compliant with BAT, ALARP and Secure By Design principles, and meet key objectives and assessment criteria. The FA will also address the GDA requirements described in Section 26.1.6.

Table 26.6-1 - List of Forward Actions

ID	Description	Required for
FA1	Incorporate new information from issue of RD7.	RD7
FA2	Address identified project level assumptions (as design development progresses).	GER Revision 2
FA3	Address identified waste-specific assumptions (as design development progresses).	GER Revision 2
FA4	Incorporate new information from issue of Disposability Case (including for Waste Package Records).	GER Revision 2
FA5	Incorporate new information from issue of Mass and Activity Balance (MAB) calculations (waste inventories and volumes) and update to IWS.	GER Revision 2
FA6	Incorporate new information from issue of DWMP.	GER Revision 2
FA7	Address identified risks (as design development progresses).	GER Revision 2
FA8	Address identified opportunities (as design development progresses).	GER Revision 2

26.7 Key Supporting Documentation

26.7.1 Key Supporting Documentation

The following paragraphs provide additional detail and context (i.e. the type of information they contain and their timelines for production, where applicable) for the key supporting documents (noting that this is not an exhaustive list of references, but rather a description of the most important).

Integrated Waste Strategy – This document outlines the over-arching and high-level strategy for the management of wastes of the RR SMR, covering all lifecycle stages and for both normal and fault conditions. It covers both radioactive and conventional wastes in solid, liquid, and gaseous form, along with materials that have the potential to become waste at future lifecycle stages, provides descriptions of the systems that produce and handle the wastes, and provides approximate volumes and inventories for the radioactive materials. Due to the ongoing development of the Final Concept Definition (FCD) the IWS will undergo future updates, reviews and reissues at appropriate stages in the design process to ensure that it stays current and consistent with the design, technology, policy and regulatory developments and background [27].

Design for 'X' Requirements – This document will provide the strategic considerations that underpin and which must be accounted for in design. The 'X' refers to the different systems that this document can be applied to; for radioactive waste management this document applied primarily to factors including regulatory context, requirements for offsite disposal, and interfaces with other systems (note the information was not available for E3S Case Revision 1 but will be fully referenced in future versions of this document).

Decommissioning Strategy – This document outlines the high-level approach for RR SMR decommissioning through definition of the seven phases comprising decommissioning, and presentation of the underpinning (based on a Pugh Matrix and BAT assessment) for the decommissioning strategy decision. It also outlines the time for decommissioning from end of generations through to final site end state [18].

Solid Operation Waste Identification (SOWI) – This document identifies all of the operational waste streams that are expected to arise from the RR SMR. Estimates of activities/volumes had been made in the Reference Design 3 baseline based on scaling of other Pressurised Water Reactor (PWR) data, and the latest version of the SOWI builds on this with a wider range of OPEX. This latest version also updates the total number of waste streams/raw volumes and highlights potential future waste streams [30].

Decommissioning Waste Management Plan – This document will provide the high-level underpinning, feasibility and approach, and technical basis for the decommissioning and dismantling of the reactor system and associated plant, along with estimates of the liability costs for the undertaking of this work (note this document was not available for E3S Case Revision 1, but will be fully referenced in future versions of this document).

Radioactive Waste Management Case Signpost Document – This document will capture, summarise and provide signposting to the documentation and references that will contribute to the Radioactive Waste Management Case (note this document was not available for this E3S Case Revision 1, but will be fully referenced in future versions of this document).

GDA Disposability Case – This document (which will be for HAW; a separate assessment will be carried out for LLW) will outline the proposed waste packaging approaches (along with underpinning information) for full range of RR SMR waste streams. This document will be submitted to and appraised by NWS in support of the Disposability Case that is carried out during GDA (related to but separate from the Disposability Assessment carried by NWS; see Section 26.4.3) (note this document was not available for E3S Case Revision 1 but will be fully referenced in future versions of this document).

Interim storage arrangements for ILW & SF – Separate documents will be produced to describe the arrangements (and supporting systems) that will be implemented at the RR SMR for the interim storage (i.e. until offsite disposal can be undertaken) of SF (and potentially HLW) and ILW generated during the operational and decommissioning phases. These will cover: system description and interfaces; design, performance, environment, safety and safeguards summary; installation, commissioning and maintenance requirements; description of design risks and issues; and identification of further work (note this document was not available for this E3S Case Revision 1, but will be fully referenced in future versions of this document).

Approach for the Demonstration of Optimisation through Application of BAT – This document provides a description of how BAT can be proportionately approached, demonstrated, and applied for the RR SMR through the application of guidance and OPEX; a more complete description will be provided in Chapter 27 of the E3S case [23].

26.8 References

[1] Environment Agency, Natural Resources Wales and Office for Nuclear Regulation, “New nuclear power plants: Generic Design Assessment guidance for Requesting Parties,” 2019.

[2] Department for Environment, Food and Rural Affairs, “Policy for the Long-Term Management of Solid Low-Level Radioactive Waste in the United Kingdom,” 2007.

[3] Department of Energy and Climate Change, “UK Strategy for the Management of Solid Low-Level Radioactive Waste from the Nuclear Industry,” 2016.

[4] Department of Energy and Climate Change, “UK Strategy for Radioactive Discharges,” 2009.

[5] Department of Energy and Climate Change, “Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment,” 2009.

[6] Department for Business, Energy and Industrial Strategy, “Implementing geological disposal – working with communities: long term management of higher activity radioactive waste,” 2018.

[7] Welsh Government, “Welsh Government Policy on the Management and Disposal of Higher Activity Radioactive Waste,” 2015.

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[9] Gov.uk, “The Environmental Permitting (England and Wales) Regulations 2016,” 2016.

[10] Environment Agency, “Guidance: Radioactive substances regulation (RSR): objective and principles,” December 2021. [Online]. Available: https://www.gov.uk/government/publications/radioactive-substances-regulation-rsr-objective-and-principles.

[11] Environment Agency, “Regulatory Guidance Series RSR 1: Radioactive Substances Regulation – Environmental Principles (Version 2),” 2010.

[12] HM-Government, “Health and Safety at Work etc. Act 1974,” 1974.

[13] HM-Government, “Energy Act 2013,” 2013.

[14] HM-Government, “Nuclear Installations Act 1965,” 1965.

[15] HM-Government, “The Ionising Radiations Regulations 2017,” 2017.

[16] Office for Nuclear Regulation, Natural Resources Wales, SEPA and Environment Agency, “Basic principles of radioactive waste management, An introduction to the management of higher activity radioactive waste on nuclear licensed sites(Revision 2),” 2015.

[17] Office for Nuclear Regulation, “Safety Assessment Principles for Nuclear Facilities,” 2020.

[18] RR Report, SMR0004048/001, “SMR Decommissioning Strategy,” February 2023.

[19] HM-Government, “The Waste (England and Wales) Regulations 2011,” 2011.

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26.9 Acronyms and Abbreviations

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
BoP	Balance of Plant
CAE	Claims, Argument, Evidence
CBA	Cost Benefit Analysis
CDF	Core Damage Frequency
COT	Core Outlet Thermocouple
CVCS	Chemical and Volume Control System
CWI	Cooling Water Island
DAW	Dry Active Waste
DR	Definition Review
DRP	Design Reference Point
DWMP	Decommissioning Waste Management Plan
E3S	Environment, Safety, Security and Safeguards
EA(s)	Environmental Agency(ies)
EC&I	Electrical Control & Instrumentation
EDI	Electro-Deionisation
EPR16	Environmental Permitting Regulation 2016
ESFs	Engineered Safety Features
FA	Forward Action
FCD	Final Concept Definition
FCM	Filter Change Machine
FMA	Function Means Analysis
FSFs	Fundamental Safety Functions
GB	Great Britain
GDA	Generic Design Assessment

GDF	Geological Disposal Facility
GDP	Generic Developed Principles
GER	Generic Environment Report
HAW	Higher Activity Waste
HASW74	Health and Safety At Work etc. Act 1974
HEPA	High Efficiency Particulate Air
HLSFs	High Level Safety Features
HLW	High Level Waste
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
ILW	Intermediate Level Waste
IRR17	Ionising Radiations Regulations 2017
IWS	Integrated Waste Strategy
KDO	Key Design Objectives
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoC	Letter of Compliance
MAB	Mass and Activity Balance
MPFDs	Micro Pocket Fission Detectors
NDA	Nuclear Decommissioning Authority
NFCC	Non-Fuel Core Component
NIA65	Nuclear Installations Act 1965
NPP	Nuclear Power Plant
NRW	Natural Resources Wales
NWS	Nuclear Waste Services
O&M	Operations and Maintenance
ONR	Office for Nuclear Regulation

OPEX	Operating Experience
OSPAR	Oslo and Paris
PCD	Preliminary Concept Definition
POCO	Post Operational Clear Out
PPE	Personal Protective Equipment
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
RCA	Radiologically Controlled Area
RCS	Reactor Coolant System
RDS-PP	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RI	Reactor Island
RO	Reverse Osmosis
RP	Requesting Party
RR	Rolls-Royce
RSR	Radioactive Substances Regulation
RWMA	Radioactive Waste Management Arrangements
SAPs	Safety Assessment Principles
SF	Spent Fuel
SFAIRP	So Far As Is Reasonably Practicable
SGBS	Steam Generator Blowdown System
SMR	Small Modular Reactor
SOD	System Outline Description
SOWI	Solid Operation Waste Identification
SPND	Self-Powered Neutron Detector
SSC	Structures, Systems and Components
SQEP	Suitably Qualified and Experienced Person
TAGs	Technical Assessment Guides
TBC	To Be Confirmed
TI	Turbine Island
TRL	Technology Readiness Level

UK	United Kingdom
VLLW	Very Low Level Waste
VRF	Volume Reduction Factor
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association