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ACRONYMS AND ABBREVIATIONS

The standard project glossary of terms, abbreviations, and plant systems is provided in HI-2240333, PSR Part A Chapter 2 General Design Aspects and Site Characteristics [1]. The following additional definitions and abbreviations are shown in Table 1:

Term	Definition
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AOO	Anticipated Operational Occurrences
BAT	Best Available Techniques
CAR	Commitments, Assumptions and Requirements
CAS	Condenser Vacuum System
CPO	Condensate Polisher System
CS	Containment Structure
CVC	Chemical and Volume Control System
DFC	Damaged Fuel Container
DRP	Design Reference Point
EA	Environment Agency
EPR16	Environmental Permitting (England and Wales) Regulations 2016
EPRI	Electric Power Research Institute
ENRMF	East Northants Resource Management Facility
FHISO	Full-Height ISO Container
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GRW	Gaseous Radwaste System
HEPA	High Efficiency Particulate Air
HHISO	Half-Height ISO Container
HIC	High Integrity Container
HI-STORM UMAX	Holtec International Storage Module Underground Maximum Safety
HI-TRAC	Holtec International Transfer Cask
HLW	High Level Waste
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
ISF	Interim Storage Facility
ISFSI	Independent Spent Fuel Storage Installation (also known as an Interim Spent Fuel Storage Installation in the UK)
IWS	Integrated Waste Strategy
LA-LLW	Lower Activity Low-Level Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LRW	Liquid Radwaste System
MPC	Multi-Purpose Canister
MSQA	Management of Safety and Quality Assurance
NDA	Nuclear Decommissioning Authority
NFW	Non-Fuel Waste
NFWC	Non-Fuel Waste Canister
NSD	Near Surface Disposal

Term	Definition
NWS	Nuclear Waste Services
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
PER	Preliminary Environmental Report
PPE	Personal Protective Equipment
PSL	Primary Sampling System
PSR	Preliminary Safety Report
PWR	Pressurised Water Reactor
QA	Quality Assurance
R&D	Research and Development
RAB	Reactor Auxiliary Building
RCA	Radiologically Controlled Area
RCCA	Rod Cluster Control Assemblies
RDS	Radioactive Drain System
RGP	Relevant Good Practice
RP	Requesting Party
RPV	Reactor Pressure Vessel
RSC	Robust Shielded Container
RSR	Radioactive Substances Regulation
RWM	Radioactive Waste Management
RWMA	Radioactive Waste Management Arrangements
RWMC	Radioactive Waste Management Case
SAPs	Safety Assessment Principles
SDG	Sustainable Development Goals
SFA	Spent Fuel Assembly
SFAIRP	So Far As Is Reasonably Practicable
SFP	Spent Fuel Pool
SFC	Spent Fuel Pool Cooling System
SFSR	Spent Fuel Storage Rack
SGB	Steam Generator Blowdown System
SGE	Steam Generator
SMR	Small Modular Reactor
SRW	Solid Radwaste System (also Solid Radiological Waste with reference to ENERCON waste inventories)
SSC	Structures, Systems and Components
SDD	System Design Description
SSEC	Safety, Security and Environmental Case
UK	United Kingdom
URD	Utility Requirements Document
US	United States
VCT	Volume Control Tank
VLLW	Very Low-Level Waste
VVM	Vertical Ventilated Module
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association

Term	Definition
WWS	Waste Water System

1.1 INTRODUCTION

This sub-chapter introduces the objectives, scope and structure of the Radioactive Waste Management Arrangements (RWMA) in the generic Small Modular Reactor (SMR)-300 Generic Design Assessment (GDA). Interfaces with other chapters and any assumptions made for the development of this chapter are also outlined.

1.1.1 Purpose

This chapter presents the management arrangements for solid, liquid and gaseous radioactive waste, and spent fuel arising over the lifecycle of the reactor, which aim to satisfy the information requirements in the Environment Agency's (EA) New nuclear power plants: Generic Design Assessment guidance for Requesting Parties [2] (RP) and relevant principles in the Radioactive Substances Regulation (RSR) Generic Developed Principles [3].

1.1.2 Scope

This chapter describes the management strategies and principles applicable for radioactive waste management, and presents the management arrangements of radioactive waste, covering liquid, gaseous and solid radioactive waste, and spent fuel arising during the operation and decommissioning of generic SMR-300. A more detailed topic area scope is provided in SMR-300 UK Generic Design Assessment Scope [4].

The quantification of liquid and gaseous waste and the application of Best Available Techniques (BAT) in radioactive waste management are not within this chapter's scope. The links to these topics are presented in this chapter. Additionally, the transportation of radioactive waste onsite and offsite is dependent on site-specific aspects, therefore, it is out of scope in this GDA.

The details of the design and operations of radioactive waste management systems, spent fuel management and decommissioning are described in the Preliminary Safety Report (PSR) PSR Part B Chapter 13 Radioactive Waste Management [5], PSR Part B Chapter 24 Fuel Transport and Storage [6] and PSR Part B Chapter 26 Decommissioning Approach [7], which avoids the repetition of similar topics across the safety case and environmental case.

1.1.3 Chapter Structure

This chapter is structured to provide information required for a meaningful GDA assessment. The main structure of this chapter consists of:

- Sub-chapter 1.1 introduces the purpose, scope, interfaces, and assumptions of RWMA.
- Sub-chapter 1.2 presents the regulatory context, such as regulatory expectations and requirements, relevant RSR principles, and codes and standards, which are considered appropriately in the development of RWMA.
- Sub-chapter 1.3 presents the radioactive waste principles and key considerations for the development of radioactive waste management strategies and arrangements.
- Sub-chapter 1.4 presents the management of liquid, gaseous and solid radioactive waste, and spent fuel arising over the lifecycle of the plant.
- Sub-chapter 1.5 presents the design considerations contributing to sustainability.
- Sub-chapter 1.6 summarises the requirements and the expert view of radioactive waste disposability.
- Sub-chapter 1.7 summarises this chapter.
- Sub-chapter 1.8 presents the references used in this chapter.

- Sub-chapter 1.9 presents the appendices, which include simplified flow diagrams illustrating liquid, gaseous and solid radioactive waste management.

1.1.4 Interfaces with Other SSEC Chapters

The chapters in the Safety, Security and Environmental Case (SSEC) interfacing with this chapter are shown in Table 1 below.

Table 1: Interfaces with Other Chapters in the SSEC

SSEC	Interface
Holtec SMR GDA Preliminary Environmental Report (PER) Chapter 2 Quantification of Effluent Discharges and Limits [8]	This chapter presents the estimated quantities, limits and radionuclide production mechanism of liquid and gaseous effluents generated during normal plant operation, which contribute to underpinning the RWMA in PER Chapter 1.
Holtec SMR GDA PER Chapter 4 Conventional Impact Assessment [9]	This chapter provides sustainability considerations that could be relevant to RWMA. It also describes the radioactive aqueous discharges to surface water from the Liquid Radwaste System (LRW), covered within PER Chapter 1.
Holtec SMR GDA PER Chapter 5 Monitoring and Sampling [10]	This chapter presents the sampling and monitoring arrangements for radioactive waste, which inform the decision-making for radioactive waste management in PER Chapter 1.
Holtec SMR GDA PER Chapter 6 Demonstration of BAT [11]	This chapter demonstrates how the generic SMR-300 design is capable of representing BAT, which includes the justification of prevention and/or minimisation of radioactive waste throughout lifecycle of SMR-300.
Holtec SMR GDA PSR Part A Chapter 1 Introduction [12]	This chapter provides the information required in the GDA process and the structure of the PER.
Holtec SMR GDA PSR Part A Chapter 2 Generic Design and Site Characteristics [1]	This chapter introduces the main Structures, Systems and Components (SSC) in the SMR-300 design, as well as the philosophy followed in the design which are considered in the conception of the radioactive waste management systems.
Holtec SMR GDA PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance (MSQA) [13]	This chapter describes the safety management and quality assurance applied during the GDA process and its requirements, which are consistent across the SSEC.
Holtec SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities [14]	This chapter presents the design information about auxiliary systems, and secondary circuit systems, which are relevant to radioactive waste management in PER Chapter 1 RWMA.
Holtec SMR GDA PSR Part B Chapter 10 Radiological Protection [15]	This chapter describes the radiological protection engineered features and general information relating to the source terms of radioactive waste, which underpin the development of RWMA.
Holtec SMR GDA PSR Part B Chapter 11 Environmental Protection [16]	This chapter summarises the PER chapters.
Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management [5] (RWM)	This chapter provides the design and operations of radioactive waste management systems, which are summarised in PER Chapter 1. Signposting is made between this PER Chapter 1 RWMA and the PSR Part B Chapter 13 RWM in order to avoid duplication of significant amounts of information, where appropriate.
Holtec SMR GDA PSR Part B Chapter 19 Mechanical Engineering [17]	This chapter provides the design information on the mechanical engineering design of SSCs, which is relevant to radioactive waste management and spent fuel management in PER Chapter 1 RWMA.
Holtec SMR GDA PSR Part B Chapter 20 Civil Engineering [18]	This chapter provides civil engineering design information in the generic SMR-300, which includes facilities containing radioactive waste management systems.
Holtec SMR GDA PSR Part B Chapter 23 Reactor Chemistry [19]	This chapter describes the reactor chemistry regime with focus on how the chemistry has been designed to minimise the radiological source term, which impacts the generation and management of radioactive waste and spent fuel.
Holtec SMR GDA PSR Part B Chapter 24 Fuel Transport and Storage [6]	This chapter describes the design proposal of spent fuel management, which are summarised in PER Chapter 1 RWMA. Signposting is made between PER Chapter 1 RWMA and the PSR Part B Chapter 24 Fuel Transport and Storage in order to avoid duplication of significant amounts of information, where appropriate.

SSEC	Interface
Holtec SMR GDA PSR Part B Chapter 26 Decommissioning Approach [7]	This chapter describes the decommissioning strategy, how the design facilitates decommissioning and the anticipated decommissioning wastes, which are also summarised in PER Chapter 1 RWMA. Signposting is made between PER Chapter 1 RWMA and the PSR Part B Chapter 26 Decommissioning Approach in order to avoid duplication of significant amounts of information, where appropriate.

1.1.5 Assumptions

The following assumptions are made to underpin the RWMA considering the 'Base Case' in The Energy Act 2008: Funded Decommissioning Programme Guidance for New Nuclear Power Stations [20].

1. The Intermediate Level Waste (ILW), High Level Waste (HLW) and spent fuel arising from operation and decommissioning will be disposed of at a Geological Disposal Facility (GDF) in the UK, when available to accommodate these wastes.
2. The LLW arising during operation and decommissioning will be consigned under the service framework of the Nuclear Waste Services (NWS) for their management in line with the waste hierarchy.

In addition to the assumptions outlined above, assumptions related to spent fuel storage and disposal are detailed in PSR Part B Chapter 24 Fuel Transport and Storage [6].

These assumptions have been recorded in the Commitments, Assumptions and Requirements (CAR) register, and will form part of the hand-over package post-GDA. These assumptions will be reviewed throughout the plant lifetime. If there are any changes to these assumptions, the implications on waste strategies will be assessed at the site-specific stage.

1.2 REGULATORY CONTEXT

This sub-chapter describes the regulatory and GDA requirements to be considered during the development of RWMA and highlights relevant policies, codes, standards and guidance.

1.2.1 GDA Requirements

To guide the development of the environment case for a new reactor power plant in the UK, the GDA guidance for RPs [2] details the information required for the environment case for the full GDA process. Table 2 below details where the full GDA information requirements relevant to RWMA are appropriately considered across the SSEC commensurate with the nature of GDA Step 2 and the maturity of generic SMR-300 design.

Table 2: Alignment Analysis between GDA Submissions and GDA Information Requirements relevant to RWMA

GDA requirements for Step 2 Assessment	Information as part of GDA
Detailed information about the design	
A technical description of the plants, systems and processes which have bearing on radioactive waste (solid, liquid and gaseous) generation, treatment, measurement, assessment and disposal.	• Sub-chapter 1.4 outlines the key SSCs that perform roles in radioactive waste management. • More detailed descriptions of SSCs are presented in PSR Part A Chapter 2 [1], and the Integrated Waste Strategy (IWS) [21].
Consideration of the potential for the creation of hazardous waste and the presence of hazardous substances and other pollutants in waste streams.	• Sub-chapter 1.4.4 describes the potential presence of hazardous substances and other pollutants in the solid radioactive waste streams based on Pressurised Water Reactor (PWR) Operational Experience (OPEX).
Assurance that the generic design is compatible with relevant UK approaches for management of radioactive wastes, decommissioning and long-term interim storage of spent fuel and final disposal of waste and spent fuel.	• Sub-chapters 1.2 and 1.3 present the UK radioactive waste management requirements and principles, which have been considered for radioactive waste management in the generic SMR-300. • Sub-chapter 1.4 presents the baseline strategies for the management of radioactive waste and spent fuel in line with the UK context. A commitment has been identified in sub-chapter 1.7 for the design challenge identified within GDA Step 2.
Detailed description of RWMA	
Identifying the strategic considerations for radioactive waste management which underpin the design.	• Sub-chapter 1.3 presents the requirements and principles of radioactive waste management, which have been considered in this chapter. • The IWS [21] provides more details regarding the strategic considerations for radioactive waste management.
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.	• Sub-chapter 1.4 describes the management of radioactive waste and spent fuel arising throughout the lifecycle of the generic SMR-300. • The waste inventories for operational and decommissioning wastes are presented in Calculation of SMR-300 Solid Radiological Waste (SRW) Inventories [22], and UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design [23], respectively.
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.	• Sub-chapter 1.4 describes the management arrangements of radioactive waste and spent fuel arising throughout the generic SMR-300's lifecycle. • The detailed management strategies are also presented in the IWS [21].
A description of how the production, discharge and disposal of radioactive waste and spent fuel will be managed to protect the environment and people.	• Sub-chapter 1.4 describes the management arrangements of radioactive waste and spent fuel arising throughout the generic SMR-300's lifecycle. • The detailed management strategies are also presented in the IWS [21].

<table>
<tr><th>GDA requirements for Step 2 Assessment</th><th>Information as part of GDA</th></tr>
<tr><td colspan="2">Quantification of radioactive waste disposals</td></tr>
<tr><td>Quantitative estimates of waste arisings for normal operation are required including:
• Arisings of combustible waste and disposals by on-site or off-site incineration.
• Arisings of other radioactive wastes – by category and disposal route (if any) – and spent fuel.</td><td rowspan="4">• Sub-chapter 1.4 presents the waste inventories relevant to operational and decommissioning wastes arising throughout the SMR-300's lifecycle.
• The detailed estimates of operational radioactive waste and decommissioning waste are presented in Calculation of SMR-300 Solid Radiological Waste (SRW) Inventories [22], and UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design [23], respectively.
• 'Quantification and Characteristics of Decommissioning Waste' has been identified in Sub-chapter 1.7 as future evidence (normal business task) and will be undertaken at the site-specific stage.</td></tr>
<tr><td>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.</td></tr>
<tr><td>The RP must identify wastes in terms of their:
• Category – HLW, ILW, LLW, Very Low Level Waste (VLLW).
• Physico-chemical characteristics.
• Proposed management and disposal route.</td></tr>
<tr><td>Quantify the activity of important individual radionuclides and overall groupings of radionuclides (for example, total beta), together with mass or volume.</td></tr>
</table>

1.2.2 Radioactive Substances Regulation Principles

The EA sets out the generic developed principles for radioactive substances [3] that aim to protect people and the environment from the harmful effects of ionising radiation, as well as aiming to protect and enhance the environment as a whole.

During the development of RWMA, the key generic developed principles related to radioactive waste management were considered appropriately. Table 3 presents the principles which this chapter seeks to address in GDA.

Table 3: Alignment Analysis between GDA Submissions and RSR Principles

RSR Principle	Information provided as part of GDA
RSMDP1 – Radioactive substances strategy A strategy should be produced for the management of all radioactive substances.	• This chapter presents the RWMA and principles that have been considered in the development of the IWS [21]. • The IWS [21] has been produced, which describes the overarching baseline strategies of waste management and spent fuel management in line with UK legislation, policies and strategies.
RSMDP3 – Use of BAT to minimise waste BAT 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.	• The prevention and justification of radioactive waste and spent fuel are discussed in Demonstration of BAT [11]. • BAT application and general information about design aspects to facilitate waste prevention and/or minimisation are discussed in sub-chapters 1.3.3 and 1.4.1 of this chapter, respectively.
RSMDP8 – Segregation of wastes BAT 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.	• The general requirements for waste segregation are presented in sub-chapter 1.3.5 of this chapter. • The descriptions of radioactive waste segregation are presented in sub-chapter 1.4 of this chapter.

RSR Principle	Information provided as part of GDA
RSMDP9 – Characterisation Radioactive substances should be characterised using BAT so as to facilitate their subsequent management, including waste disposal.	• The general requirements for waste characterisation are presented in sub-chapter 1.3.5 of this chapter. • The descriptions of radioactive waste characterisation are presented in sub-chapter 1.4 of this chapter.
RSMDP10 – Storage Radioactive substances should be stored using BAT so that their environmental risk and environmental impact are minimised and that subsequent management, including disposal is facilitated.	• Sub-chapter 1.3.7 presents the general requirements on storage of radioactive waste. • Sub-chapters 1.4.4.6.1 and 1.4.5.3 present information on storage of solid radioactive waste and spent fuel. • PSR Part B Chapter 13 RWM [5] also provides information on storage within the radioactive waste management systems.
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.	• Sub-chapter 1.3.6 presents the general requirements on waste processing. • Sub-chapters 1.4.2 to 1.4.5 presents information on processing or management proposals of radioactive waste and spent fuel.
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.	• Information and record management to be carried out is described in sub-chapter 1.3.9 of this chapter. • More details regarding record management including the management of the SSEC and transfer of GDA information to prospective operator are presented in PSR Part A Chapter 4 Lifecycle MSQA [13].
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.	• Based on Radioactive Waste Management Limited's requirement, RWPR63-WI11, Preparation of an Expert View to support Step 2 of the Generic Design Assessment process [24], the RP has sought an Expert View from NWS on the packaging proposals for radioactive waste streams. This is summarised in sub-chapter 1.6.
Decommissioning Strategy - RSR guidance for nuclear sites undergoing decommissioning [25] You need to prepare and maintain a decommissioning strategy for your site. Your decommissioning strategy should be integrated with other relevant strategies and plans.	• Sub-chapter 1.4.6 in this chapter presents information on the decommissioning strategy. • Decommissioning Strategy Assessment [26] has been produced for the generic SMR-300.
Design for Decommissioning [25] You must design your facilities using BAT so that they can be decommissioned in a way that protects the public and the environment from the radiation exposures from radioactive waste disposals.	• Design features to reduce the impact of decommissioning are outlined in sub-chapter 1.4.6 of this chapter. • More details regarding the design for decommissioning and relevant substantiation are discussed in the Decommissioning Strategy Assessment [26].

1.2.3 Other Requirements related to Radioactive Waste Management

The following key acts, legislation and policies are relevant to radioactive waste management:

- The Nuclear Installations Act 1965 [27].
- Health and Safety at Work etc. Act 1974 [28].
- Environment Act 1995 [29].
- The Energy Act 2008: Funded Decommissioning Programme Guidance for New Nuclear Power Stations [20].
- UK Strategy for Radioactive Discharges [30].
- The Environmental Permitting (England and Wales) Regulations 2016 (EPR16) [31].
- Ionising Radiations Regulations 2017 [32].

- The Environmental Permitting (England and Wales) (Amendment) Regulations 2018 [33].
- The Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2018 [34].
- UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning, May 2024 [35].

The sources of codes, standards and guidance relevant to radioactive waste management, including UK, International Atomic Energy Agency (IAEA) and Western European Nuclear Regulators Association (WENRA) are considered in the development of RWMA. The main codes, standards and guidance, which are regarded as Relevant Good Practice (RGP), applied to the management of radioactive waste and spent fuel are listed below:

- The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites [36].
- UK Strategy for the Management of Solid LLW from the Nuclear Industry [37].
- Decommissioning of Nuclear Sites and release from Regulation [38].
- Nuclear Decommissioning Authority (NDA), Industry Guidance – Interim Storage of Higher Activity Waste Packages – Integrated Approach [39].
- Electric Power Research Institute (EPRI) Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document (URD) [40].
- IAEA, Predisposal Management of Radioactive Waste, No. GSR Part 5 [41].
- IAEA, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, No. SSG-40 [42].
- IAEA, Storage of Spent Nuclear Fuel, No. SSG-15 [43].
- Nuclear Energy Agency, Decommissioning Considerations for New Nuclear Power Plants, NEA No. 6833 [44].
- WENRA, Radioactive Waste Treatment and Conditioning Safety Reference Levels, 2018 [45].
- WENRA, Waste and Spent Fuel Storage Safety Reference Levels, Version 2.3, 2024 [46].
- WENRA, Decommissioning Safety Reference Levels, version 2.3 [47].

Office for Nuclear Regulation's (ONR) Safety Assessment Principles (SAPs) for Nuclear Facilities [48] have been considered alongside the RSR principles for an integrated approach in the development of RWMA at GDA. The relevant SAPs include:

- 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 (SFAIRP).
- RW.4 Characterisation and segregation: Radioactive waste should be characterised and segregated to facilitate its subsequent safe and effective 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.
- DC.2 Decommissioning strategies: A decommissioning strategy should be prepared and maintained for each site and should be integrated with other relevant strategies.

The codes and standards applicable to the design of the SSCs for the liquid, gaseous and solid radioactive waste treatment systems are described in PSR Part B Chapter 13 RWM [5].

1.3 RADIOACTIVE WASTE MANAGEMENT PRINCIPLES AND STRATEGY

This sub-chapter outlines the general radioactive waste management principles to be applied to the radioactive waste management strategy in the generic SMR-300 design, and the key aspects to be considered for the development of this strategy.

The following principles and requirements underpinning the development of the RWMA and strategies are summarised appropriately from the RSR principles and RGP relevant to radioactive waste management, which are presented in sub-chapters 1.2.2 and 1.2.3.

The IWS [21] was developed in GDA to demonstrate the generic SMR-300 design is in line with UK legislation, policies and strategies, including overall policy aims on sustainable development. The IWS provides an overview of how radioactive waste and spent fuel arising from the reactor lifecycle are managed in a safe, environmentally sound and secure manner, which contributes to reducing radiological impacts of discharges and disposals of radioactive waste on people and the environment As Low As Reasonably Achievable (ALARA). The IWS must be maintained throughout the lifecycle of the plant, as such it will need to be updated beyond GDA timescales (see Table 9: Future Evidence).

1.3.1 General Radioactive Waste Management Principles

The key principles applied for radioactive waste management are derived appropriately from the RGP, RSR generic developed principles and ONR SAPs presented in sub-chapter 1.2, including:

- A waste management strategy should be in place for radioactive waste.
- Radioactive waste should be managed in a stepwise approach in line with principles of the waste hierarchy, as well as taking account of sustainability.
- The generation of radioactive waste should be prevented and where that is not possible, minimised by use of BAT.
- Radioactive waste should be segregated and characterised appropriately for subsequent effective management.
- Radioactive waste should be conditioned, as necessary, to produce a wasteform suitable for packaging that is passively safe to store.
- Radioactive waste should be stored in line with good engineering practice and in a passively safe condition.
- The disposal of radioactive waste by discharge or transfer to offsite premises should be minimised by use of BAT.
- Waste management information should be recorded and maintained to facilitate the radioactive waste management both currently and in the future.
- Design aspects to facilitate decommissioning should be considered to minimise decommissioning waste.

These principles are applicable for the management of radioactive waste arising from the plant lifecycle and have been considered in the RWMA and strategies.

1.3.2 Waste Hierarchy

The waste hierarchy, illustrated in Figure 1, is recognised as good practice in the UK for the management of radioactive waste through the UK Strategy for the Management of Solid Low Level Waste from the Nuclear Industry (2016) [37] and RSR Principle 2: Optimisation [49]. Additionally, it is used as a framework for decision-making in the management of radioactive waste in the UK [35].

Implementation of the waste hierarchy requires a systematic approach to prevent and minimise the generation of radioactive waste (both volume and radioactivity). As illustrated in Figure 1, the waste hierarchy encourages the adoption of options for managing wastes starting with those that have the least impact on the environment.

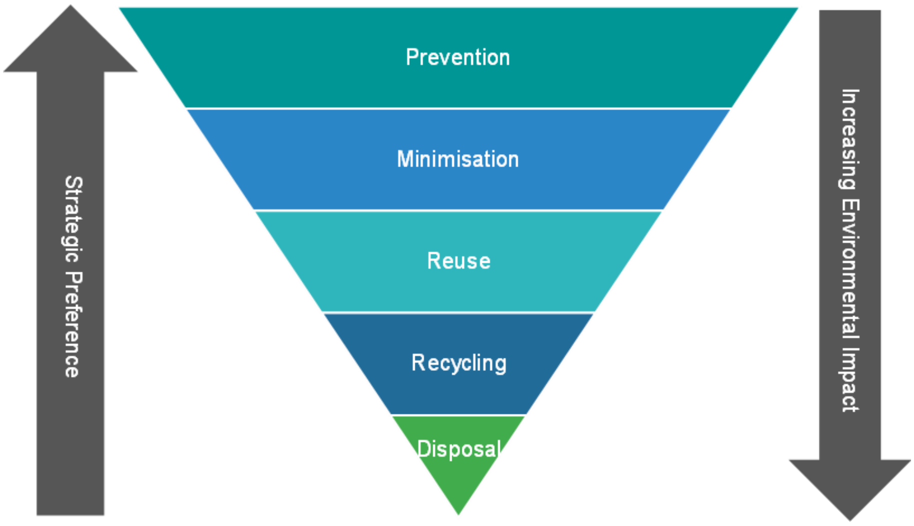

Figure 1: Waste Hierarchy

The general requirements to apply the waste hierarchy in order of priority [36]:

- Preventing the creation of waste where practicable.
- Minimising radioactive waste activity and volume through the appropriate design and operation of processes and equipment, and effective use of waste characterisation, sorting and segregation, volume reduction and surface contamination removal.
- Minimising quantities of radioactive waste requiring disposal through the adoption of decay storage, reuse, recycling or incineration.
- Selecting the optimum disposal route by use of BAT.

Options for waste management should be selected such that radiation exposures to workers and members of the public over the entire lifecycle of the waste are As Low As Reasonably Practicable (ALARP) [36], and such that the impacts of discharges and disposals of radioactive waste on the public and the environment are ALARA. As a result, the waste hierarchy should be applied such that there is a balance between a range of competing factors, such as nuclear safety, environment protection, security, cost and sustainability, which are discussed in sub-chapter 1.3.3.

1.3.3 Application of BAT and ALARP

Within the UK, the application of BAT is considered a fundamental concept under EPR16 [31] and RSR Principle 8 [49], and should be applied to prevent or minimise discharges and their impacts on the environment and people [35]. The UK context relevant to the demonstration of BAT is outlined within the UK Strategy for Solid LLW Management [37] and the joint regulatory guidance on The management of higher activity radioactive waste on nuclear licensed sites [36]. The application of BAT to the generic SMR-300 design will be appropriately undertaken in accordance with existing UK legislation and regulatory frameworks as well as RGP and OPEX, so as to prevent and minimise the impacts to people and the environment. The approach undertaken for the generic SMR-300, is presented in Holtec SMR-300 GDA Approach and Application of the Demonstration of BAT [50].

The requirement for risks to be ALARP is a fundamental safety principle defined in ONR Fundamental Principles of Safety Assessment [51]. For relevant risks to be deemed as reduced ALARP, it is necessary to demonstrate that the cost (in terms of money, time or effort) of reducing the risk further would be grossly disproportionate to the benefit gained. The approach for ALARP demonstration, which is applicable for the generic SMR-300, is presented in the ALARP Design Process [52].

The optioneering guidance for the generic SMR-300 GDA has been developed (SMR-300 GDA RSR-BAT Guidance [53] and SMR-300 UK GDA ALARP Guidance Document [54]) to ensure that decisions taken, with respect to the generic SMR-300, achieve an optimised solution that aligns with the regulatory principles of ALARP and BAT. The optimisation of radioactive waste management should consider all relevant competing factors, such as health, safety, environment, security, costs, sustainability, etc. This ensures that decision-making effectively balances the principles of BAT and ALARP in the development of radioactive waste management to provide an optimised solution through a risk-informed lifecycle approach.

1.3.4 Sustainability

In line with the approach set out in The UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning [35], the management of radioactive waste should consider internationally recognised best practices in sustainability and sustainable development, including the United Nations' Sustainable Development Goals (SDG) [55]. The SDGs aim to protect the environment and the current and future generations. Sustainability is embedded into the principles of radioactive waste management through the RSR principles, and the need to consider the full lifecycle of radioactive waste from generation to the final storage solution.

Application of the waste hierarchy and a risk-informed approach are recognised as key principles in the lifecycle of radioactive waste management, which ensure that the radioactive wastes are managed in a safe, secure and environmentally sustainable manner. This aligns with SDG 12 'Responsible consumption and production' [55], particularly target 12.4, which focuses on the sound management of wastes throughout their lifecycle.

1.3.5 Waste Characterisation and Segregation

To contribute to the effective application of the waste hierarchy, and thereby ensure effective waste management, characterisation of waste is required to obtain waste characterisation information. This characterisation information includes waste classification, physical and chemical parameters, activity content and radionuclides, which will help to inform decisions on the appropriate management and waste routing for waste streams.

To facilitate safe and effective waste management, segregation of generated waste based on characterisation is required. Segregation of waste involves the sorting and collection of wastes with similar characteristics, avoiding mixing wastes with different characteristics or properties that would prevent the use of an optimised management route. Segregated waste streams for the generic SMR-300 are described in the IWS [21].

Characterisation and segregation play a vital role in waste minimisation. According to the EPR permit condition 2.3.3 provided in the RSR permits for nuclear licensed sites: how to comply guidance [56]:

"The operator shall use the best available techniques to:

…

(b) characterise, sort and segregate solid and non-aqueous liquid radioactive wastes, to facilitate their disposal by optimised disposal routes;

…"

As a result, waste characterisation and segregation should take place as close to the point of generation as is reasonably practicable and throughout the subsequent radioactive waste management steps where necessary to demonstrate BAT. The lifetime impact of sorting and segregation of wastes will be considered to ensure that doses to workers are ALARP and to ensure that the waste management routes for all waste arising from the generic SMR-300 design demonstrates BAT.

The general approach to monitoring and sampling for radioactive waste is discussed in sub-chapter 1.4, and further details regarding monitoring and sampling arrangements are presented in PER Chapter 5 Monitoring and Sampling [10].

1.3.6 Waste Processing

Where radioactive effluents or materials are not re-used or recycled by the plant and are unsuitable for permitted site discharge, will be processed as radioactive waste based on the waste characteristics. The waste processing or conditioning can transform radioactive waste into a form that is suitable for subsequent management, such as handling, storage, discharge, or disposal. The processing of wastes can be conducted via permanently installed facilities, mobile facilities[1], or off-site facilities, considering the principles of BAT and ALARP, as well as worldwide OPEX.

Aqueous and gaseous radioactive waste will be treated to demonstrate BAT and meet RSR permit discharge limits. Solid and wet solid radioactive waste will be conditioned to produce waste packages that are suitable for on-site storage, and transfer to offsite premises for waste treatment or disposal, such as the GDF or LLW Repository.

[1] Examples of mobile facilities are provided in the IWS [21].

1.3.7 Waste Storage

In accordance with the UK Strategy for the Management of Solid LLW from the Nuclear Industry [37], after solid LLW is packaged on site in accordance with the Waste Acceptance Criteria (WAC) of the applicable off-site waste service or disposal facility, it should be swiftly transported to these facilities. This contributes to minimising the accumulation of radioactive waste in the plant and minimises radiological risks to workers and members of the public. Provisions for adequate buffer storage of LLW packages are necessary to accommodate for the potential unexpected unavailability of off-site waste services and disposal facilities, as well as the requirements for bulk transportation of LLW.

HLW, ILW and LLW that cannot currently be disposed of at existing disposal facilities, and spent fuel arising from the lifetime of the generic SMR-300 will be subject to long-term storage in a passively safe and secure manner on site pending shipment to the UK GDF [36] [39]. The interim storage facilities to accommodate these wastes, and spent fuel for a new nuclear power plant will be designed, constructed and operated in accordance with good engineering practice and should take into account NDA guidance [39].

ILW/LLW boundary wastes, which contain short-lived radionuclides as opposed to those containing long-lived radionuclides, can be consigned on a risk-informed basis to routes for lower activity wastes. This approach is subject to options balancing the principles of ALARP and BAT when these ILW/LLW boundary wastes decay to LLW during a period of decay in the ILW interim storage.

1.3.8 Waste Discharge and Disposal

Discharge or disposal is the final stage in the waste management lifecycle for waste that cannot be managed any further or higher up the waste hierarchy.

Discharges of aqueous and gaseous waste to the environment are regulated by the environment agencies and shall comply with the limits and conditions specified in permits granted by the environment agencies. Management of aqueous and gaseous waste can include "dilute and disperse", which involves the direct discharge of gaseous or aqueous radioactivity into the environment, or “concentrate and contain”, which involves collecting and accumulating radioactivity in a solid concentrated form prior to storage and subsequent disposal [35]. The preferred option in the UK is "concentrate and contain", but it is recognised that some releases to the environment are unavoidable, and therefore, this option may not always be reasonably practicable [35]. As a result, it will be important to consider the principles of BAT and ALARP when selecting the most practicable options for radioactive waste management.

Where available, disposal routes should be selected through the application of BAT and the waste hierarchy. The transport of waste to off-site facilities for further waste treatment or final disposal shall be undertaken in accordance with the UK strategy for LLW management [37].

The ultimate assessment of the disposability of lifetime radioactive waste and spent fuel arisings of the generic SMR-300 is conducted through the NWS Disposability Assessment. It was appropriate for a 2-Step GDA for NWS to submit its Expert View and provide an early assessment of the compatibility of the generic SMR-300’s waste arisings with UK geological disposal infrastructure requirements. The requirements and assessment outcome of NWS Expert View are outlined in sub-chapter 1.6.

1.3.9 Information and Records Management

Information regarding the management and disposal of radioactive waste should be recorded and maintained over the lifecycle of the plant under appropriate Quality Assurance (QA) arrangements. Information on waste history and provenance is a key input to the decision-making of radioactive waste management in the operational stage and decommissioning stage.

It is important to keep and manage information and records relating to radioactive wastes and associated facilities appropriately so that waste can continually be managed effectively to prevent or minimise impacts to the workers, public and the environment during the plant lifetime. The typical information for the radioactive waste management to be recorded includes (but not limited to) [57]:

- Owner of radioactive waste.
- Generation points of radioactive waste.
- Radionuclide fingerprint.
- Waste characterisation data.
- Type and identifier of the waste package.
- Waste treatment and conditioning.
- Wasteform and characterisation.
- Storage arrangements of radioactive waste packages.
- Records of waste package maintenance.
- Transport identified and conditions for the waste package.
- Disposability records of radioactive waste.

Within the GDA process, all relevant information related to radioactive waste management have been recorded and maintained in line with appropriate MSQA procedures, which are defined in PSR Part A Chapter 4 Lifecycle MSQA [13]. This information as well as GDA commitments, including those relating to radioactive waste management, will form part of any hand-over package to the future operator / licensee, as outlined in PSR Part A Chapter 4 Lifecycle MSQA [13].

When a waste consignment to an off-site premises (such as a disposal facility) is planned, the title to the radioactive waste will transfer from the waste producer to the off-site waste receiver(s). All relevant radioactive waste information and records will be provided to an off-site waste receiver to ensure the safe, environmentally protective and sustainable management of radioactive waste.

1.4 RADIOACTIVE WASTE MANAGEMENT

This sub-chapter provides details on the radioactive waste to be generated during the lifecycle of the SMR-300, and how it is managed in line with UK context to minimise their potential harmful effects on workers, the public and the environment.

The SMR-300 design is based on proven technology and avoids first-of-a-kind engineering. Like other operating PWR fleets, it is expected that the following radioactive waste arisings from the lifecycle of the SMR-300 will be generated:

- Operational liquid waste
- Operational gaseous waste
- Operational solid waste
- Spent fuel
- Decommissioning waste

The following sub-chapters describe the source of these radioactive waste arisings from plant operation and decommissioning, and how these radioactive wastes are managed in the SMR-300. More details on the source term relating to radioactive wastes are also presented in PSR Part B Chapter 10 [15].

The facilities and systems within the plant which accommodate radioactive waste management, for example the Containment Structure (CS), Reactor Auxiliary Building (RAB), the Independent Spent Fuel Storage Installation (ISFSI) and all relevant systems relevant to radioactive waste management are detailed within PSR Part A Chapter 2 [1] and summarised within the IWS [21]. Radioactive waste management systems will be shared by the twin unit reactors.

The overview of the management arrangements and strategies for radioactive waste and spent fuel arising from the generic SMR-300 lifetime is illustrated in Figure 2 (below) and detailed in the following sub-chapters.

It is recognised that the baseline strategies for the management of radioactive waste and spent fuel have been developed for the GDA purpose. However, at the site-specific stage, the baseline strategy will be assessed taking into account the principles of ALARP and BAT to select the most appropriate management and disposal routes. In order to advance the site-specific assessments on radioactive waste and spent fuel, a commitment and 'Future evidence' tasks have been identified and summarised in sub-chapter 1.7.

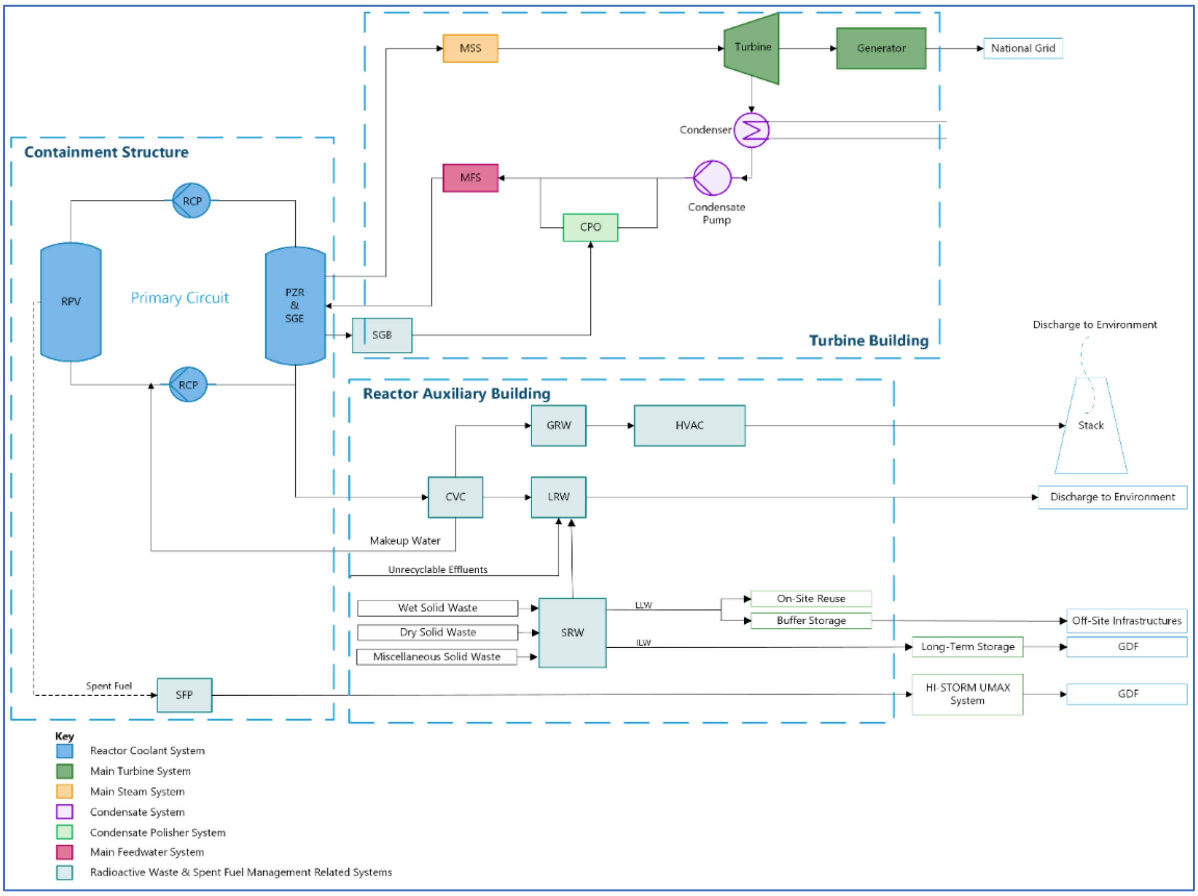

Figure 2: High Level Schematic of Radioactive Waste Management and Spent Fuel Management in the SMR-300

1.4.1 Prevention and Minimisation of Radioactive Waste

Generating radioactive waste is a largely unavoidable consequence of operating a nuclear reactor; however, the potentially harmful effects on workers, the public and the environment can be minimised with effective prevention and minimisation strategies. The waste hierarchy presented in sub-chapter 1.3.2 is deemed to be the fundamental principle for the management of waste generated in the generic SMR-300. The requirement to prevent and/or minimise radioactive waste is the highest priority in the waste hierarchy [78] and has been implemented in the generic SMR-300 lifecycle, including the design, construction, commissioning, operation and decommissioning stages.

In the current concept design stage of the generic SMR-300, a suite of design aspects contributing to the prevention and minimisation of waste have been considered. These include (not an exhaustive list):

- Adopting high-reliability and high-performance fuel cladding to minimise fuel failure and fission products leakage.
- Selection of materials and setting of impurity limits for those materials in and around the core to minimise their susceptibility to neutron activation and corrosion, and hence to minimise the radioactive inventory.

- Control of reactor chemistry to preserve the integrity of the fuel cladding, minimise impurities and the generation of corrosion products capable of being activated in the core and transported throughout the primary circuit.
- Minimising uncontrolled leakage of radioactive effluents (which is supported by leak detection and inspection).

A detailed argument of how the generic SMR-300 design enables the radioactive waste prevention and/or minimisation at source can be found in PER Chapter 6 Demonstration of BAT [11].

Where prevention and/or minimisation is not reasonably practicable, waste is managed by plant radioactive waste management systems and facilities, as summarised in the IWS [21]. The key management techniques applied to unavoidably generated waste include:

- Segregation and characterisation to facilitate subsequent safe and effective management.
- Recycling or reusing the waste where it is practicable. Where this is not reasonably practicable, the waste should be treated or conditioned via practicable techniques prior to discharge or disposal.
- Applying clearance and exemptions to enable some wastes to be characterised as out-of-scope waste where possible.
- Selecting the most practicable treatment technologies taking into account worldwide RGP and OPEX, as well as the global deployment strategy of a fleet of SMR-300s.
- Identifying and optimising the management of boundary waste, such as decay storage to reclassify the waste to minimise the wastes to be disposed of in the GDF.
- Where disposal routes are available, the prompt disposal of waste to minimise the accumulation on-site.
- Storage of HLW, ILW and spent fuel that currently cannot be disposed of at existing disposal facilities on-site in a passively safe condition until the GDF is available.
- Making best use of existing UK waste services and disposal facilities in the management of radioactive waste.
- Sampling and monitoring for final discharge of aqueous and gaseous wastes to ensure the discharges meet permitting limits.

1.4.2 Operational Liquid Radioactive Effluent Management

The liquid radioactive waste management strategy is to separately collect and process liquid effluents, applying the principles of ALARP and BAT to enable recycling where practicable and where unavoidable, discharging to the environment in compliance with permits.

It is good practice to segregate the effluents at source based on characteristics, which facilitates the safe and effective management of these wastes and reduces the amount of solid radioactive waste generated in the liquid radioactive waste management process. In line with UK RGP, the generic SMR-300 liquid radioactive effluents are segregated at source into:

- Borated, reactor quality effluent.
- Liquid radioactive wastes.
- Steam generator blowdown effluent.

The baseline management strategy for each liquid effluent is illustrated in Figure 4 in Appendix A. The overall strategy is to “concentrate and contain” (discussed in sub-chapter 1.3.8), which requires the processing of liquid waste to abate radionuclides prior to controlled discharge to the environment, subject to conditions and limits specified in the operator's environmental permit.

It should be noted that non-aqueous liquid waste (e.g. oily waste) is managed by the SRW (see sub-chapter 1.4.4.3).

1.4.2.1 Borated, Reactor Quality Effluent

Borated, reactor quality effluent is expected to make up the largest quantity of the effluent generated during normal operations of the generic SMR-300; for example, over the course of a fuel cycle, the reactor coolant boron concentration must be diluted to compensate for changes in reactivity. This produces reactor coolant that requires removal from the RCS. This is managed via the Chemical and Volume Control System (CVC), which has functions for effluent holdup, degassing and purification, to enable reuse of reactor quality water in the primary circuit.

The CVC letdown is purified and degassed. Purification is achieved using filtration and ion exchangers for the abatement of entrained and dissolved solids, respectively, which concentrates and contains contaminants to ensure that the CVC letdown can be reused as makeup water in the primary circuit. This contributes to minimising the volume of liquid effluent to be processed by the LRW. The processed effluent is collected in the CVC effluent holdup tanks, which have provisions for sampling to determine the most appropriate route for the tank contents by the prospective operator. This design is in line with the principles of the waste hierarchy, especially in complying with recycling and/or reuse to minimise the volume of radioactive waste arising from the generic SMR-300.

Based on typical PWR operation, effluent that is unsuitable for reuse is typically generated towards the end of the fuel cycle and is treated as liquid radioactive waste within LRW, which is discussed in sub-chapter 1.4.2.2.

1.4.2.2 Liquid Radioactive Waste

Radioactive liquid effluents that need to be processed will be managed as liquid radioactive waste by the LRW, which is designed to collect, treat, and release radioactive liquid waste generated in the plant during normal operation and Anticipated Operational Occurrences (AOO), including shutdown, refuelling, and maintenance. The LRW is designed to protect workers from radiation exposure and to minimise radioactive releases to the environment. Details on the design and operation of the LRW can be found in PSR Part B Chapter 13 Radioactive Waste Management [5] and System Design Description (SDD) for Liquid Radwaste System [58]. Waste arisings that are treated within the scope of the LRW include:

- Letdown effluent from the CVC holdup tanks, which comprises degassed reactor coolant effluent that is no longer suitable for reuse in the primary circuit.
- Residual water transferred from spent resins from the SRW.
- Floor drains within the Radiologically Controlled Area (RCA).
- Chemical drains within the RAB.
- Other miscellaneous drains, which typically consists of effluent generated through maintenance operations such as decontamination in the auxiliary building [59]. This waste stream will be defined further subject to further design definition.

Liquid wastes are segregated at source by the Radioactive Drain System (RDS) and CVC, and collected in the LRW for storage and processing via the abatement systems. Four waste holdup tanks are available, which provides the prospective operator the capability to temporarily store and segregate wastes of different characteristics if required. Effluent is sampled in the holdup tanks, upstream of abatement systems to determine its characteristics.

In line with the baseline strategy defined in the IWS [21], liquid radioactive waste will be processed by the abatement systems, including ion exchangers, pre-filters and after filters. For flexibility, the LRW has provisions to enable bypassing ion-exchangers and/or filters, if sampling results suggest that they are not required or suitable. This enables effective management of effluents, as well as extending the lifetime of filter bed media, such as filter cartridges or ion-exchange resins, which contributes to the minimisation of generation of solid radioactive waste from the LRW. Design provisions for flexible connections to enable the use of mobile processing units are incorporated in the LRW, particularly to manage any unexpected waste arisings that are incompatible with the permanently installed plant equipment. The use of mobile systems provide additional flexibility with lower overall costs (due to lower implementation costs), as well as adapting to changes in regulatory requirements. Examples of existing mobile treatment systems applied in the UK and internationally are provided in the IWS [21].

After processing, effluents are collected in the monitoring tanks for sampling and monitoring prior to discharge. Depending on the sampling results, the tank contents may either be discharged to the site outfall or returned to the holdup tanks for reprocessing.

It is recognised that there are viable alternative effluent abatement technologies, such as evaporators and reverse osmosis. These technologies may achieve in absolute terms an improved performance in separation of certain contaminants, but increase the cost and complexity of radioactive waste systems, in addition to creating new waste streams (e.g., aqueous concentrates) that would require further processing in the SRW system. Filtration and ion-exchange have been defined as the GDA baseline strategy for the abatement of radioactive liquid wastes generated by the generic SMR-300. At the site-specific stage an assessment of liquid waste treatment options will be are to be carried out to determine the abatement technology or combination of technologies that demonstrate BAT (see Table 9: Future Evidence).

1.4.2.2.1 Monitoring and Sampling of Liquid Radioactive Waste

The Primary Sampling System (PSL) enables on plant collection of liquid and gaseous samples for laboratory analyses of chemical and radiochemical conditions of designated systems. Data from the analyses provide the required information to monitor plant, equipment and system performances.

The sampling and monitoring arrangement for liquid radioactive combines both in-process and final sampling and monitoring. Grab samples are taken from LRW waste effluent holdup tanks, LRW containment sumps and LRW monitoring tanks while continuous radiation monitoring is installed on the discharge path from the LRW to the outfall. A recirculation line on the effluent holdup tanks and monitoring tanks facilitates the mixing of radioactive contents within the tanks to enable the collection of representative samples prior to subsequent processing or discharge. Where practicable, the sample purge volume will be returned back to its system of origin to minimise the production of radioactive waste.

Based on the sampling results, the contents within the monitoring tank are either discharged to the environment via discharge outlet or reprocessed. An effluent radiation monitor is present on the discharge line, which automatically terminates release to the environment upon detection of radiation above a setpoint level in the discharge. Operator intervention is required to restart the release. In the event of termination of a discharge, the tank contents will be recirculated to the LRW holdup tank for reprocessing.

More details regarding monitoring and sampling arrangements are presented in PER Chapter 5 Monitoring and Sampling [10].

1.4.2.3 Steam Generator Blowdown Effluent

Blowdown from the Steam Generator (SGE) is to be reused where practicable to minimise waste generation and reduce radiological impact on members of the public and the environment to ALARA. In normal operation the blowdown is transferred to the Condensate Polisher System (CPO) for processing and then reused as condensate in the secondary circuit.

In the event of any abnormal conditions, such as a SGE tube leak or rupture, the blowdown will be contaminated by primary coolant. Under such conditions, the SGB will be isolated and aligned to a drain connection in containment to attach temporary equipment for draining and collecting contaminated SGE water for treatment or disposal. Contaminated blowdown can be processed via mobile demineralisation equipment prior to discharge to the environment.

1.4.3 Operational Gaseous Radioactive Waste Management

Gaseous radioactive waste management for the generic SMR-300 ensures that each gaseous effluent is collected separately according to its characteristics to enable the subsequent processing via the most practicable techniques. This approach supports controlled discharge of the effluent, considering the principles of BAT and ALARP to minimise the harmful impacts on workers, members of the public and the environment.

In the generic SMR-300, gaseous radioactive effluent is segregated into:

- Primary gaseous effluent from the CVC holdup tanks and Volume Control Tanks (VCT).
- Gaseous effluent from Heating, Ventilation and Air Conditioning (HVAC) in the RCA.
- Secondary gaseous effluent from the SGE.

The baseline management strategy of each gaseous effluent, which is defined in the IWS [21], is illustrated in Figure 5 in Appendix B. The overall strategy is to segregate effluents at source for collection, followed by processing to minimise radioactivity prior to discharge via the main stack following sampling and monitoring. Further details on the management of individual waste streams are presented in the sub-chapters below.

1.4.3.1 Primary Gaseous Effluent

During plant operation, radioactive gases are generated within the reactor coolant system and transported with the reactor coolant. This gaseous effluent mainly consists of hydrogen and nitrogen, which act as carrier gases for the relatively small amounts of fission products like xenon and krypton, as well as activation products generated as the result of reactor normal operation, and is collected in tanks (such as VCT and CVC effluent holdup tanks) containing the primary coolant.

In line with the baseline strategy defined in the IWS [21], before shutdown and refuelling gaseous effluent is flushed from the VCTs by nitrogen to the Gaseous Radwaste System

(GRW), which is designed to collect, process, decay store and discharge gaseous radioactive waste generated from plant operations, including AOOs.

Once the effluent enters the GRW via the vent header, it undergoes compression for storage and moisture removal. The compressed gas is then collected in the decay tanks for holdup until short-lived radionuclides like xenon and krypton have decayed to levels that meet permitted discharge limits. To ensure that the short-lived radionuclides have decayed sufficiently, each decay tank has provisions for sampling and analysis of its contents before they are released into the environment. Once representative sampling confirms compliance with the permitted discharge limits, the processed gaseous effluent is transferred to the HVAC system for monitored and controlled release via the stack. If the gas meets operating requirements, it may be recycled to the effluent holdup tanks in the CVC to be used as cover gas to preclude air intrusion. The operating requirements and option to recycle gas will be determined by the prospective operator.

The design of the GRW considers the following requirements to reduce the impacts to workers and the members of the public ALARP, as well as reducing risks to the members of the public and the environment ALARA, which include:

- Controlling the concentration of oxygen and hydrogen to maintain a non-flammable atmospheric operating condition:
    - The operating pressure of the GRW is maintained at greater than atmospheric pressure to develop a non-flammable atmosphere, by maintaining an oxygen-free (<4% by volume) atmosphere.
    - Two redundant sets of oxygen and hydrogen analysers are provided to monitor gas composition and maintain a non-flammable atmosphere. If high oxygen levels are detected, there are functions for flushing and diluting the system with nitrogen to control the concentration of explosive gas.
- Design of SSCs to prevent and manage leakage of flammable and radioactive leakage
    - Welded connections are used for piping and components to the maximum extent practicable to prevent the leakage of radioactive gaseous waste. For example, flanged manways on the decay tanks will be seal welded or have an underlying seal welded diaphragm.
    - The use of stainless steel for metallic components in contact with the waste gas to prevent corrosion, which not only prevent and/or minimise the failure of components, but also will maintain and/or extend the design lifetime of components, which contributes to the minimisation the generation of solid radioactive waste during maintenance activities.
    - Leak rate will be within the limits specified in ANSI/ANS 55.4 [60], and testing provisions will be incorporated into the system design to enable periodic re-evaluation of leak rate of all active components in the GRW.
    - Detectors will be provided to monitor hydrogen leakage in compartments containing off-gas systems under pressure and where hydrogen leakage may occur.
    - For any leakages that are potentially flammable, ventilation systems will be activated to remove them in the compartment.
- Minimisation of the discharge to environment
    - The compressed gases are collected within decay tanks, which allow the sufficient decay of the short-lived radioisotopes (such as xenon and krypton) to ensure the discharge will be within the permitted discharge limits.

- Prior to discharge from the decay tanks, the gaseous content within the decay tanks is sampled and analysed to determine the activity levels and confirm they are within the permitted limits.
- The effluent radiation monitoring devices continuously monitor and record all gaseous radioactivity released from the GRW to the atmosphere via the main stack.

The design and operation of the GRW are presented in PSR Part B Chapter 13 RWM [5] and SDD for Gaseous Radwaste System [61].

It is recognised that there are other viable techniques for gaseous effluent treatment, such as charcoal delay beds. A comparison of PWR techniques for processing primary gaseous effluent is discussed in the IWS [21]. For the purpose of this GDA, the decay storage tank technology is defined as the baseline strategy for primary gaseous effluent management.

1.4.3.1.1 Monitoring and Sampling of Process Gaseous Effluent

Sampling within the GRW includes the manual collection of samples directly from GRW holdup tanks, where local sample connections to sources are available, rather than connections via pipework to the PSL. This helps to reduce radiation exposures to the workers ALARP. Two redundant sets of oxygen and hydrogen analysers are available to continuously monitor gas composition and ensure a non-flammable atmosphere is maintained. The decay tanks also have provisions for sampling to determine the radioactivity of the contents to ensure they are within the permitted discharge limits.

A radiation monitor is present on the discharge line, which automatically terminates release to the environment upon detection of radiation above a predetermined level in the discharge. Operator intervention is required to restart the release.

More details regarding monitoring and sampling arrangements will be presented in PER Chapter 5 Monitoring and Sampling [10].

1.4.3.2 Gaseous Effluent from HVAC

Air from the RCA and containment is extracted by the HVAC systems. The air is potentially radioactively contaminated by residual contaminants originating from the Spent Fuel Pool (SFP), and neutron activation of CS air around the reactor pressure vessel.

The gaseous effluent collected by HVAC systems flows through air filtration units (such as High Efficiency Particulate Air (HEPA) filters and charcoal adsorbers) to remove radioactive particulates and gases [62]. The resulting gaseous effluent is monitored and discharged to the environment via the main stack.

More details on the HVAC systems can be found in Holtec SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities [14].

1.4.3.3 Secondary Gaseous Effluent

In the abnormal event of a SGE tube leak, reactor water can be carried over to the secondary circuit. Radioisotopes (particularly tritium) from the primary coolant will come out of solution, mixing with non-condensable gases within the steam condenser, which can become contaminated. These gases are removed by the Condenser Vacuum System (CAS) and discharged to the HVAC system.

1.4.4 Operational Solid Radioactive Waste Management

The generic SMR-300 management strategy for operational solid radioactive wastes applies the waste hierarchy and takes into account the principles of ALARP and BAT. Waste management steps control and segregate generation at source to enable the most effective means of pre-treatment, treatment, conditioning, storage, and disposal, to minimise risk to workers, members of the public and environment.

Solid radioactive wastes expected to be generated through normal operations of the generic SMR-300 include:

- Wet solid wastes, which consist of spent resin, spent filter cartridges and filter bed media from radioactively contaminated systems.
- Dry solid wastes, which include HVAC filters, Personal Protective Equipment (PPE), paper, cloth, wood, plastic, rubber, glass, and metal components (e.g. valve parts, packing and tools) that are potentially contaminated.
- Miscellaneous solid wastes, which consist of mixed wastes that are defined as being both radioactive and hazardous (e.g. radioactive oily wastes that could be generated from maintenance or decontamination of equipment, and chemical wastes).
- Non-Fuel Waste (NFW) which consists of redundant activated items associated with the fuel assemblies and other in-core components.

The quantification and source term of operational solid radioactive waste are preliminary estimated in the Calculation of SMR-300 Solid Radiological Waste (SRW) Inventories [22]. The sources and categories of each waste stream are also summarised in Table 4.

Table 4: Summary of Operational Solid Radioactive Waste

Waste Stream		Source	Category
Wet Solid Wastes	Spent Resins and Filter Bed Media	Generated from CVC demineralisers, Spent Fuel Pool Cooling System (SFC) demineralisers, LRW demineralisers and CPO demineralisers. Filter bed media is generated from the LRW deep bed filters.	ILW
	Spent Resins	Generated from CPO demineralisers.	LLW
	Spent Filter Cartridges	Generated from the filters of CVC, SFC and LRW.	ILW
Dry Solid Wastes	Metallic Waste	Consists of HVAC filters PPE, paper, cloth, wood, plastic, rubber, glass, and metal components (e.g. valve parts, packing and tools) that are potentially contaminated during normal operations and outage conditions.	LLW
	Combustible Waste		LLW
	Non-Combustible and Compactable Waste		LLW
Miscellaneous Solid Wastes	Mixed Waste	Generated from the maintenance or decontamination of equipment in the LRW.	LLW
	Oily Waste		LLW
NFW	Rod Cluster Control Assemblies (RCCAs)	Activated, high dose rate redundant metallic components in the reactor core.	HLW/ILW
	Redundant Instrumentation		HLW/ILW

The baseline management strategies for the solid radioactive wastes, which are detailed in the IWS [21], are illustrated in Figure 6 in Appendix C. The management of each waste stream is presented in the following sub-chapters.

1.4.4.1 Wet Solid Wastes

Wet solid waste consists of spent resins, filter bed media, and filter cartridges. The management arrangements for these wastes are detailed below.

1.4.4.1.1 Spent Resin

The generic SMR-300 will generate both ILW and LLW spent resins. The characteristics of spent resins including filter bed media generated by the generic SMR-300 is summarised from the solid radioactive waste inventory report [22] and presented in Table 5.

Table 5: Description of Spent Resins

Parameter	Description
Waste source	ILW: Spent resins generated from CVC demineralisers, SFC demineralisers and LRW demineralisers. Filter bed media is generated from the LRW deep bed filters. LLW: CPO demineralisers.
Chemical and physical properties	Spent resins are spherical beads/ resin compounds. The properties of spent resin will be further defined at the site-specific stage. The filter bed media are wet granular carbon.
Waste classification at time of generation	ILW LLW
Annual arising from one generic SMR-300 reactor unit	[REDACTED]
Main radionuclides and radioactivity after 30-day cooldown	ILW • Main radionuclides: Cs-134, Cs-137, Co-58, Co-60, Ni-63, Zn-65 • [REDACTED] • [REDACTED] LLW • Main Radionuclides: Cs-134, Cs-137, Fe-55, Zn-65 • [REDACTED] • [REDACTED]

1.4.4.1.1.1 ILW Spent Resin

After generation, spent resin (including filter bed media from the CVC, SFC, and LRW) is transferred by demineralised water to the spent resin tanks, which will have appropriate capacity to accommodate the spent resin for the short-term decay before processing. The spent resin is processed on a batch-basis. When processing is desired, the spent resin in the tank is mixed by the resin mixing pump and resin transfer pump and sampled via the PSL to determine processing and package requirements. Sampling of the spent resin may include gross activity, and identification of principal radionuclides and alpha emitters as well as their activities. After sampling, spent resin in the spent resin tank is transferred to a waste container, where it is conditioned and packaged. The packaged waste will be sent to an interim storage facility for long-term storage, prior to dispatch to an off-site disposal facility.

At GDA, SMR-300 ILW Management Strategy: Options Assessment [63] describes two sets of viable options for the conditioning and packaging of ILW spent resin generated by the generic SMR-300:

- Robust Shielded Container (RSC) + Non-encapsulation (UK compliant option).
- High Integrity Container (HIC) + Non-encapsulation (United States (US) opportunity option).

"HIC + Non-encapsulation" is the approach in the SDD for SRW [64] within the GDA DRP [65]. The key benefit of using HIC is their large internal volume, which allows for a high packing fraction. This contributes to a reduction in the overall number of packages requiring disposal to a future GDF or Near Surface Disposal (NSD) facility. Non-encapsulation allows for the retrieval of waste, does not preclude other final disposal options within the GDA process and prevents any potential challenges with unstable cementitious encapsulation of borated resins. [REDACTED].

The RSC option is assessed as a UK-compliant and the baseline option, while the opportunity to invest in the novel waste management approach has not been foreclosed for post-GDA option studies. This is further discussed in the ILW management strategy [63]. A GDA Commitment has been identified that encompasses this planned work:

C_RWMA_078: Information dependent on site-specific factors will be required to meet regulatory expectations in establishing the strategies for ILW and LLW facilities. A Commitment is raised to undertake the following post-GDA activities to ensure site specific application:

a) Further quantification and categorisation of radioactive waste inventories.
b) Further down-selection of ILW management options, including container type e.g. RSCs or HICs.
c) Detailed design development of facilities for ILW storage and LLW handling.
d) Optimisation of the use of space allocated to RWM in the RAB or consideration of whether a dedicated facility is BAT.
e) Conduct further engagement with NWS for disposability assessment of ILW packages following down-selection of containers and further development of radioactive waste inventories.

1.4.4.1.1.2 LLW Spent Resin

Based on PWR management practices, two viable options were identified in the IWS [21]:

- Volume reduction, such as off-site incineration (HPR1000 practice).
- Encapsulation (Sizewell B and AP1000 practice).

LLW spent resins are combustible waste and can be incinerated at existing off-site facilities, provided waste packages meet the applicable WAC. This option reduces the final disposal volume.

Encapsulation of LLW spent resins is also a viable option; however, it entails additional costs. Implementing this approach would require use encapsulation equipment on site to solidify resin waste. Given the relatively low waste volume [REDACTED] generated annually, the costs are high to install or use mobile encapsulation equipment on site for this waste. Additionally, the encapsulation process is a volume expansion technique which will increase the disposal volume of waste, the complexity of its operation may potentially increase the radiation exposure to workers on site.

Based on the preliminary assessment, the baseline strategy for the management of LLW spent resins is to package them in a compliant container (e.g. 200 litre drum), and then ship off-site in bulk in an appropriate transport container (e.g. Full-Height ISO Container (FHISO), or Half-Height ISO Container (HHISO)) for incineration. Should the WAC for incineration not be met, encapsulation of these resins within a compliant container (e.g. 200 litre drum or HHISO) via a mobile encapsulation system and buffer storage before off-site disposal is practicable. The encapsulated waste form should have provisions for appropriate shielding to ensure radiation exposures to workers during buffer storage are reduced. A design challenge paper, ILW and LLW Facilities [66], has been produced, which highlights the key requirements for LLW management that would be considered at the site-specific stage.

1.4.4.1.2 Spent Filter Cartridges

The spent filter cartridges are replaced and then transferred to a dedicated area for their temporary storage or packaging using a shielded filter cask, where they are characterised via the PSL for subsequent processing. Based on the sampling results, the filter cartridge is transferred to its final packaging container before dispatch to a long-term storage facility.

Table 6: Description of Spent Filter Cartridges

Parameter	Description
Waste source	Generated from the filters of CVC, SFC and LRW.
Chemical and physical properties	Cartridges typically are pleated metallic cylinders. The types of cartridges will be defined at the site-specific stage.
Waste classification at time of generation	ILW
Annual Arising from one generic SMR-300 reactor unit	[REDACTED]
Main radionuclides and radioactivity after 30-day cooldown	Main radionuclides: Cs-134, Cs-137, Co-58, Co-60, Ni-63, Zn-65 [REDACTED]

The ILW Management Strategy: Options Assessment [63] provides a bounding case for the conditioning and packaging of ILW. Since the annual arising of spent filter cartridges is very low [REDACTED] the baseline strategy for ILW spent filter cartridges proposed in the IWS [21] is therefore similar to that for the low volume ILW spent resin arisings. ILW spent filter cartridges will be conditioned within an appropriate waste container (such as RSC or HIC) via a dewatering/ drying process, sealed, then decontaminated and stored prior to dispatch to the future GDF or Near Surface Disposal (NSD) facility . This also enables the same equipment to be used for both spent filter cartridges and spent resins, which contributes to reducing the capital and maintenance cost, as well as minimising future decommissioning waste arisings by using one plant.

1.4.4.2 Dry Solid Wastes

Dry solid wastes are generated as a result of operational and maintenance activities performed within the RCA and consists of any solid, dry material that becomes contaminated with radioactive material and is discarded as waste. The characteristics of dry solid wastes are summarised in Table 7.

These wastes typically have a lower specific activity and account for a substantial proportion of solid waste generated in the normal operation of a nuclear power plant. BAT and the waste hierarchy should be applied to the extent practicable to minimise the volume and activities of dry solid waste. For any LLW that is unavoidably generated, disposal should take place as soon as reasonably practicable, following the below steps:

Characterisation and Segregation

To facilitate subsequent safe and efficient management, dry solids are collected and preliminarily sorted based on their activity level at source. Non-radioactive wastes will be removed to the greatest extent possible to reduce the overall volume of radioactive wastes. Dry solid wastes undergo pretreatment in the RAB that includes sorting and segregation based on physical and chemical properties to enable planned treatment onsite or offsite.

Table 7: Description of Dry Solid Wastes

Parameter		Description
Waste source		Consists of HVAC filters PPE, paper, cloth, wood, plastic, rubber, glass, and metal components (e.g. valve parts, packing and tools) that are potentially contaminated during normal operations and outage conditions.
Chemical and physical properties		HVAC filters: Fibreglass/ metal, non-combustible PPE, rags and wipes: Paper, tape and textiles Failed equipment, tools and miscellaneous: Metallic parts.
Waste classification at time of generation		LLW
Annual arising from one generic SMR-300 reactor unit	Metallic waste	[REDACTED]
	Combustible waste	[REDACTED]
	Non-combustible & compactable waste	[REDACTED]
Main radionuclides and radioactivity after 30-day cooldown	Metallic waste	Main radionuclides: C-14, Co-60, I-129 [REDACTED]
	Combustible waste	Main radionuclides: C-14, Co-60, I-129 [REDACTED]
	Non-combustible & compactable waste	Main radionuclides: C-14, Co-60, I-129 [REDACTED]

Treatment and Disposal

Based on UK waste classifications, a variety of viable options for the management of LLW dry solid wastes have been identified. These options align with application of the waste hierarchy: the higher the level of the waste hierarchy that is applied in the treatment of waste, the more this will contribute to minimising the volume of radioactive waste to be disposed of, as well as reducing the environmental impact. Viable on-site or off-site options for the treatment of dry solid wastes have been identified in the IWS by applying NWS Waste Services guidance [67], including:

- **Reuse** – Some materials could be reused in operations and maintenance activities or for shielding purposes etc., where suitable opportunities arise, to avoid the need to consign them as waste. Examples include contaminated tools, which may require techniques such as decontamination prior to being reused.
- **Metal recycling** – If the reuse of metallic waste is not practicable after the application of decontamination techniques, they can be prepared for recycling off-site using surface treatment, such as abrasive cleaning, blasting, machining, milling, chemical cleaning, or water jetting. Metallic waste for treatment can be packaged in reusable packages (e.g. TC01R or TC02) and shipped off-site in bulk.
- **Incineration** – The volumes of radioactive wastes can be reduced through incineration, which involves the conversion of bulk combustible waste into radioactive ash and residue. Volume reduction of approximately 90% or more can be achieved [68]. Waste suitable for incineration can be packaged in a compliant container (e.g.

200 litre drum) and then shipped off-site in bulk in a transport container (e.g. FHISO/ HHISO) for incineration.

- **Compaction** – Volume reduction can also be achieved through compaction at either low pressure in drums or at high pressure into 'pucks' as used in the nuclear power industry. Plants generally use an off-site supercompaction service provided by vendors to make best use of available facilities. The waste could be packaged in a compliant container (e.g. 200 litre drum), and then shipped off-site in bulk in a transport container (e.g. FHISO/HHISO) for off-site supercompaction, which can achieve a volume reduction benefit usually in the range of 6:1 to 7:1.
- **Disposal of LLW** – LLW that is deemed unsuitable for management via the above options (e.g. does not meet the WAC for incineration) and meets the WAC of the Low-Level Waste Repository (LLWR) for vault disposal, would be conditioned and packaged in a compliant container (e.g. 200 litre drum or HHISO), and then transferred to the LLWR for disposal. Suitable VLLW, and Lower-Activity LLW (LA-LLW), could also be disposed at permitted landfill sites that can, under strict controls, accept this type of waste alongside non-radioactive waste, such as the East Northants Resource Management Facility (ENRMF) [69], where the above alternatives are not feasible.

Dry solid wastes in the SDD for Solid Radwaste System [64] have been segregated into categories such as reusable, compactable, and non-compactable waste. It is noted that some countries may not have incineration facilities available or may not accept waste incineration due to public sensitivity reasons [70]. As a result, dry solid wastes have not been further segregated in the generic SMR-300 design taking into account the global deployment of the generic SMR-300.

Further segregation to include combustible and non-combustible wastes can be considered to make best use of available options in the UK, such as off-site incineration. Therefore, sufficient space for characterisation and segregation, conditioning and buffer storage of dry solid wastes will be provided and justified in the generic SMR-300 design at the site-specific stage to allow for the adoption of practicable technologies, if required, which is discussed in the Design Challenge Paper [66].

1.4.4.3 Miscellaneous Wastes

The characteristics of miscellaneous waste are summarised from the Solid Radioactive Waste Inventory report [22] and presented in Table 8 (below).

Miscellaneous wastes generated from the generic SMR-300 are LLW and will therefore be managed via the appropriate LLW management route. Incineration has been identified as the most practicable option in the IWS [21], which would reduce the volume of the waste significantly. The waste can be packaged into a suitable container such as a 200 litre drum. Depending upon activity, waste would require overpacking in an IP2 rated ISO container for transportation purposes.

If these wastes do not meet the WAC for incineration, a potential option is absorption onto a suitable media and solidification of the waste via a mobile system and disposal at a suitable disposal facility such as the LLW disposal facility, based on waste characteristics.

Table 8: Description of Miscellaneous Wastes

Parameter	Description
Waste source	Consists of mixed wastes, which is defined as being both radioactive and hazardous, and radioactive oily wastes that are usually generated from the maintenance or decontamination of equipment.
Chemical and physical properties	Mixed waste: Uranyl compounds and any waste that is also considered to be toxic, ignitable, corrosive or reactive due to the chemical composition of the waste. Oily waste: Liquid oils
Waste classification at time of generation	LLW
Annual arising from one generic SMR-300 reactor unit	Mixed waste: [REDACTED] Oily waste: [REDACTED]
Main radionuclides and radioactivity after 30-day cooldown	Main radionuclides: C-14, Co-60, I-129 [REDACTED]

1.4.4.4 Boundary Wastes

Wastes that have a level of radioactivity close to the boundary between two waste categories, such as ILW/LLW or LLW/VLLW, are known as boundary wastes [35]. The potential option to manage boundary wastes, particularly those containing short-lived radionuclides, is via decay storage [39] until radioactivity reduces to LLW for ILW/LLW or VLLW for LLW/VLLW. This approach is described in The management of higher activity radioactive waste joint guidance [36], as a means of applying the waste hierarchy to optimise the disposal routes and minimise the volume of waste requiring final disposal.

Effective identification and decay storage of boundary wastes enable significant opportunities in waste management to be achieved. For example, the reclassification of waste will reduce costs associated with storage and disposal, reduce the footprint of interim waste storage facilities and lead to an early reduction of hazard reduction.

Based on a preliminary assessment of the expected operational waste streams arising from the generic SMR-300, ILW/LLW boundary wastes are expected to include the after-filter from the LRW, which is expected to decay to LLW approximately 18 months after generation at source. This boundary waste is to be managed similarly to the ILW filters that are discussed in sub-chapter 1.4.4.1.2, prior to storage in an interim storage facility. When this waste has decayed to LLW during the interim storage period, it will be retrieved from the interim storage facility and managed via the appropriate LLW management routes discussed in sub-chapter 1.4.4.2.

Any LLW/VLLW would be stored in a buffer storage area in the RAB or another suitable dedicated area in the plant with sufficient storage space, based on assessment of the capabilities in the existing RAB arrangements. LLW storage is discussed in sub-chapter 1.4.4.6.2 and in the design challenge paper on ILW and LLW facilities [66]. The bounding waste route for LLW/VLLW includes disposal at the LLWR or relevant diversion routes (see sub-chapter 1.4.4.2); with an opportunity to take advantage of permitted landfill sites, if the relevant WAC can be met.

1.4.4.5 Non-Fuel Waste

NFW includes activated, high dose rate redundant metallic components, such as redundant instrumentation. Rod Cluster Control Assemblies (RCCAs), also called control rod assemblies, are managed separately onsite with the spent fuel (see sub-chapter 1.4.5). It should be noted that the physical, chemical and radionuclide inventory of items that are classed as NFW is currently under development and will be confirmed at the site-specific stage.

At GDA, NFW packaging options derived from international OPEX were assessed in accordance with SMR-300 GDA RSR-BAT Guidance [53], the BAT option for NFW packaging options are presented in Non-Fuel Waste Packaging BAT Assessment Workshop Output Report [71]. The preferred BAT option identified to manage NFW is collection within the Spent Fuel Storage Rack (SFSR), prior to packaging in a NFWC for a dry storage campaign. The use of the NFWC for the dry storage of NFW in the Holtec International Storage Module Underground Maximum Safety HI-STORM UMAX system enables early hazard reduction, by transfer to passively safe dry storage conditions as soon as reasonably practicable upon accumulation of sufficient waste to efficiency fill a NFWC.

1.4.4.6 Storage of Radioactive Waste

1.4.4.6.1 Interim Storage

Due to the differences in radioactive waste disposal policies in the UK and US, the design of ILW Interim Storage Facility (ISF) has not been considered in the US Holtec Palisades SMR-300 design. Based on UK context relevant to radioactive waste disposal, particularly in the UK policy framework [35], interim storage facilities are required to ensure that HLW, ILW and LLW (that currently cannot be disposed of at existing LLW disposal facilities) are safely stored onsite prior to shipment to future GDF or Near Surface Disposal (NSD) facility.

A design challenge paper [66] has been produced to highlight this design gap and how it would lead to a prospective design change at the site-specific stage. For the 2-Step GDA, the ILW Management Strategy: Options Assessment [9] presented viable UK options for ILW interim storage, these were:

- RSCs stored in a shielded facility like the ISF at multiple Magnox (Nuclear Restoration Services) sites in the UK; and
- HICs stored in shielded storage units like Holtec International's HI-SAFE modules.

The preliminary assessment of the above viable options provides confidence that determining the BAT option can be addressed post-GDA. A GDA Commitment has been identified that encompasses this planned work:

C_RWMA_078: Information dependent on site-specific factors will be required to meet regulatory expectations in establishing the strategies for ILW and LLW facilities. A Commitment is raised to undertake the following post-GDA activities to ensure site specific application:

a) Further quantification and categorisation of radioactive waste inventories.
b) Further down-selection of ILW management options, including container type e.g. RSCs or HICs.
c) Detailed design development of facilities for ILW storage and LLW handling.
d) Optimisation of the use of space allocated to RWM in the RAB or consideration of whether a dedicated facility is BAT.
e) Conduct further engagement with NWS for disposability assessment of ILW packages following down-selection of containers and further development of radioactive waste inventories.

1.4.4.6.2 LLW Buffer Storage

The accumulation of radioactive waste in the generic SMR-300 design will be minimised to reduce the safety risk to workers when the appropriate disposal routes are available. However, prior to shipment of packaged LLW to off-site infrastructures, the packages need to be sent to the buffer storage area for temporary storage, which is subject to further design and assessment at the site-specific stage considering practicable factors, such as the availability of off-site waste services and the capacity of short-term waste storage for the purpose of economic bulk transportation.

The current design of the buffer storage capacity in the DRP [65] is compliant with PWR good practice specified in the EPRI URD [40]. However, this design doesn't consider sufficient footprint for the management of dry solid waste that should be developed in line with UK context. The design challenge paper [66] proposes two viable options, which require further assessment:

- A dedicated onsite LLW handling facility; and
- repurpose of existing RAB spaces and arrangements for LLW management.

Options will be assessed taking into account the principles of ALARP and BAT at the site-specific stage.

The design of buffer storage areas would need to enable storage of empty containers prior to use at fill stations, labelling and inspection of containers prior to use in creating waste packages. Sufficient space will also be needed to permit the decay storage of LLW/VLLW boundary waste and for laydown of waste package shipments prior to transfer to off-site premises for treatment or disposal.

1.4.5 Spent Fuel Management

The management strategy of spent fuel generated from the generic SMR-300 is presented in the Spent Fuel Management Strategy [72]. The below sub-chapters summarise the generation of spent fuel and the baseline management strategy at GDA.

1.4.5.1 Spent Fuel Arising

The generic SMR-300 utilises proven, state-of-the-art PWR fuel technology, supported by an established supply chain and OPEX. It adopts standard uranium dioxide (UO_2) fuel with an average enrichment of [REDACTED] by weight and maximum enrichment of [REDACTED] by weight. Two types of rods – the fuel rods and guide tubes are used with the arrangement of 17×17 square lattice. The fuel rods consist of high density ceramic UO_2 fuel pellets stacked within Zircaloy cladding that is evacuated, backfilled with helium, and sealed with Zircaloy end plugs welded on each end [73].

The SMR-300 is designed to operate on a nominal [REDACTED] fuel cycle with approximately one third of the fuel assemblies in the core discharged every refuelling outage. [REDACTED]. The parameters related to spent fuel are presented in PSR Part B Chapter 24 Fuel Transport and Storage [6].

1.4.5.2 Spent Fuel Management Route

The policy for spent fuel management in the UK is onsite storage in a passively safe form until it can be disposed of in a future GDF.

In line with above UK regulatory requirements, the generic SMR-300 baseline strategy for spent fuel management consists of:

a) Short-term storage of spent fuel within the SFP located inside the CS.

The capacity of the SFP is designed to accommodate discharged fuel for the requisite minimum cooling period (3 years) prior to transfer into a dry storage system. After the required cooling time for dry storage is achieved, SFAs are packaged in the Multi-Purpose Canister (MPC), which is then transferred for processing in the RAB before storage.

Any damaged fuel or fuel debris arising from the generic SMR-300 is managed in a similar baseline strategy, except it is packaged in a Damaged Fuel Container (DFC) located in designated cells in the MPC. It is also noted that damaged fuel may be subject to a longer cooling time in the SFP than SFAs prior to a dry fuel storage campaign.

b) Long-term interim storage of spent fuel within onsite dry storage facility.

After spent fuel loaded in the MPC is removed from the SFP, the MPC is processed, dried and sealed in the RAB, and then transported to an onsite dry storage facility before the GDF is available.

It is expected that after the fourth refuelling outage, the discharged SFA of the first cycle will be removed from the SFP and placed into the interim storage facility.

More details about spent fuel storage in the SFP and spent fuel management are presented in PSR Part B Chapter 24 Fuel Transport and Storage [6] as well as the Spent Fuel Management Strategy [72]. The following sub-chapter briefly describes the management of spent fuel within an interim storage facility in the generic SMR-300.

1.4.5.3 Spent Fuel Interim Storage

A range of viable interim storage options are identified in the Spent Fuel Management Strategy [72] based on worldwide OPEX. In order to yield a baseline strategy for the storage of spent fuel from the generic SMR-300, a preliminary screening exercise has been undertaken taking into account the relevant practicable criteria, such as compliance with UK legislation and policy, compatibility with the global deployment strategy of SMR-300 to yield a baseline strategy for spent fuel interim storage. The details regarding these considerations and the screening exercise are provided in the Spent Fuel Management Strategy [72], the baseline strategy is:

- Single wall MPC used for packaging SFAs.
- Single wall MPC with DFC used for packaging damaged fuel.
- Dry storage for SFAs and damaged fuel, using an MPC / dry fuel storage system, utilising a below ground vertical storage configuration Holtec International Storage Module Underground Maximum Safety (HI-STORM UMAX) ISFSI dry fuel storage system shown in Figure 3 and described below).

[REDACTED]

Figure 3: Holtec International HI-STORM UMAX System

The HI-STORM UMAX ISFSI is an underground Vertical Ventilated Module (VVM) dry fuel storage system with a service life of 100 years, which is consistent with the assumption in sub-chapter 1.1.5. It is estimated that the entire inventory of spent fuel discharged over the lifetime of one generic SMR-300 reactor unit can be stored in less than 54 HI-STORM UMAX dry storage canisters.

Dry storage operations for SFAs are performed during the refuelling outage and utilise the same Holtec International Transfer Cask (HI-TRAC) used for shielded transfer of new fuel. The SFA within MPC are loaded into the HI-TRAC using the fuel handling bridge crane. The MPC is drained, dried, backfilled with inert gas and welded shut to provide a pressure vessel boundary, this acts as a containment barrier to prevent leakage and escape of radioactivity. When complete, the HI-TRAC with MPC containing SFA is transferred to the ISFSI, and the MPC is downloaded into the VVM of the UMAX system for long-term storage. Each VVM provides storage of an MPC in the vertical configuration inside a cylindrical cavity located entirely below the top-of-grade of the ISFSI. More details of the design and operation of spent fuel interim storage are presented in PSR Part B Chapter 24 Fuel Transport and Storage [6].

This baseline strategy for spent fuel interim storage is suitable at GDA. At the site-specific stage, an assessment will be required to determine the preferred option that demonstrates BAT for spent fuel interim storage that takes into account site-specific factors (see Table 9: Future Evidence).

1.4.6 Decommissioning Waste Management

Decommissioning is the final phase of the lifecycle of a nuclear facility. At GDA, preliminary review of relevant viable decommissioning options were undertaken. The Holtec SMR-300 Decommissioning Strategy Assessment [26] concludes that immediate dismantling is preferred to enable a prompt decommissioning strategy for the generic SMR-300. This strategy aligns with the UK policy for nuclear decommissioning, which is to progress decommissioning at the earliest opportunity practicable [35], as this can reduce hazards and risks to workers, the member of the public and the environment. A Design for Decommissioning Justification Report will be developed beyond GDA timescales to establish an optimised decommissioning strategy, that takes into account the principles of ALARP and BAT at the site-specific stage (see Table 9: Future Evidence).

The generic SMR-300 design incorporates design provisions and features to facilitate safe and environmentally sound decommissioning at end of life. Designing for future decommissioning contributes to preventing and/or minimising the creation of radioactive waste, in terms of both volume and activity, to be disposed of, as well as ensuring radiological impacts to workers, members of the public and environment are ALARA during the decommissioning phase. The following design for decommissioning features (based on worldwide OPEX and RGP) are evidenced in the generic SMR-300:

- Reduction of the radiation source, such as fuel design, selection of materials, reduction of surface contamination.
- Plant layouts that limit the spread of contamination.
- Plant layouts that facilitate dismantling and decontamination of radioactive equipment.
- Simplification of waste management systems.
- Building and structure design.

More details regarding the design for decommissioning and relevant substantiation are discussed in the Holtec SMR-300 Decommissioning Strategy Assessment [26].

Like traditional PWRs, it is unavoidable that during the decommissioning stage of SMR-300, a range of radioactive wastes will be generated, especially in the process of decontamination and dismantling of SSCs. Radioactive decommissioning waste will be segregated and classified in terms of ILW, LLW, VLLW and/or waste that are out-of-scope from regulation under EPR16 Schedule 23. According to the OPEX presented in the IAEA report on Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities [74], the majority of materials arising from decommissioning activities are non-radioactive, with only approximately 3% classified as radioactive waste. Therefore, segregation at source will play a critical role in minimising the volume of decommissioning radioactive waste requiring treatment or disposal.

Given the generic SMR-300 design maturity and the ongoing development of source terms, a qualitative decommissioning inventory has been produced during Step 2 of the GDA. This inventory is based on UK RGP and existing PWR OPEX and is intended to provide an indicative overview of the expected waste streams. Details are provided in the UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design [23].

At the site-specific stage, a Decommissioning Waste Management Plan and a detailed quantification and characterisation of decommissioning waste streams will be developed and at the site-specific stage (see Table 9: Future Evidence). The Decommissioning Waste Management Plan will consider the proximity principle, to reduce the environmental impacts associated with the transportation of waste to offsite facilities.

Additionally, a Funded Decommissioning Plan will additionally be produced, to ensure the operator secures the funding arrangements to the meet the full costs of decommissioning and the management of any hazardous waste (see Table 9: Future Evidence).

The following sections describe the different types of decommissioning wastes anticipated and how these wastes will be managed appropriately in line with UK context.

1.4.6.1 Solid Decommissioning Waste Management

The waste hierarchy has been considered and will be implemented in decommissioning waste management. For solid radioactive wastes that are unavoidably generated, the baseline management strategy is to reuse or recycle components and materials, which will significantly reduce the amount or volume of wastes to be disposed of. Radioactive solid wastes which cannot be reused or recycled, will be conditioned and packaged by the appropriate processing technologies, based on the characteristics of the waste.

1.4.6.1.1 ILW Decommissioning Waste Management

According to the UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design [23], the ILW decommissioning wastes that are expected to be generated during the decontamination and dismantling activities include:

- Activated nuclear plant, such as Reactor Pressure Vessel (RPV) and in-core components.
- Contaminated components making up waste treatment systems and auxiliary systems, etc.
- Secondary waste generated during the decontamination operation and the SFP operation during decommissioning, such as spent resins and filters.
- Activated concrete and steel structures.

Where it is reasonably practicable, these wastes should be assessed as part of a risk-informed approach for the application of reclassification, e.g., to LLW, if possible, via techniques such as decontamination or decay storage, which allow ILW to be reclassified as LLW, which could contribute to reducing the volume of wastes to be disposed of as ILW, as well as exploring more appropriate management routes. If this is not feasible, volume reduction techniques should be used to minimise the volume of waste disposed of at off-site facilities.

After appropriate pre-treatment, wastes will be conditioned and packaged to meet GDF disposal requirements. UK OPEX on the conditioning and packaging of decommissioning waste informed the approach set out in the IWS [21] for managing generic SMR-300 decommissioning waste. Spent resins and filters generated during decommissioning can be conditioned and packaged in the same approach as described in sub-chapter 1.4.4.1. ILW such as activated concrete, RPV and core internals (excluding SFAs), could be immobilised with cementitious grout in a suitable container, such as a 4 m box or a 3 m^3 box.

Once packaged, the waste will be stored in a ILW interim storage facility discussed in sub-chapter 1.4.4.6.1, if the GDF is unavailable. Alternatively, for any less hazardous decommissioning ILW, disposal at a NSD facility is considered an opportunity in the future.

1.4.6.1.2 LLW and VLLW Decommissioning Waste Management

As is typical to PWRs, the generic SMR-300 will generate a variety of LLW and VLLW decommissioning wastes, such as auxiliary system components, contaminated concrete, piping, heat exchangers, SGEs, personal protection equipment, etc., is expected to be generated during the decommissioning of SMR-300. The details of these waste are presented in UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design [23] report.

Successful decontamination or decay storage of LLW and VLLW can result in wastes that are declassified to VLLW or out-of-scope, which would contribute to minimising waste sentenced to the LLW disposal facility for final disposal. Therefore, where it is reasonably practicable, these wastes could be reclassified via techniques such as decontamination and decay storage. These out-of-scope wastes will be managed in line with the principles of the waste hierarchy and regulations related to the management of non-radioactive wastes.

In line with the waste hierarchy, after pre-treatment, the decommissioning LLW and VLLW will be sorted and segregated further into different types of waste, such as metal waste, combustible waste, non-combustible and compactable waste, and non-combustible and non-compactable waste. Once conditioned and packaged in compliant containers (e.g. 200 L drum, HHISO or FHISO) in line with the WAC for off-site waste treatment or disposal facilities, wastes will be sent off-site for disposal or treatment based on their characteristics. Options to process and package decommissioning LLW wastes are similar to those discussed for operational LLW, discussed in Sub-chapter 1.4.4 . This will make best use of existing off-site facilities and will also reduce the accumulation of waste onsite for storage in line with RW.3 [48].

1.4.6.2 Liquid Decommissioning Waste Management

Liquid radioactive wastes are expected to be generated in the form of secondary wastes as a result of decontamination operations and flushing of contaminated systems. The liquid decommissioning waste will be managed by mobile facilities or the generic SMR-300 installed waste management systems, such as the LRW.

As outlined in PSR Part B Chapter 26 Decommissioning Approach [7] liquid waste will be processed by either the existing radioactive waste management systems or mobile equipment. Making use of existing treatment systems will contribute to reducing capital and maintenance costs, as well as simplifying the plant design, which will contribute to reducing solid decommissioning wastes. Furthermore, the LRW is designed to be flexible in terms of processing operations and has flexible connections, making it a potentially suitable option for the management of liquid wastes generated during decommissioning.

1.4.6.3 Gaseous Decommissioning Waste Management

It is expected that airborne radioactive particulates, and gases will be generated during decontamination and dismantling processes of generic SMR-300. The gaseous radioactive waste will be managed by mobile facilities or existing waste management systems, such as the GRW or HVAC systems.

As outlined in PSR Part B Chapter 26 Decommissioning Approach [7] gaseous decommissioning waste will be processed by either the existing radioactive waste management systems or mobile equipment. Making use of existing treatment systems will contribute to reducing capital and maintenance costs, as well as simplifying the plant design, which will contribute to reducing solid decommissioning wastes during the decommissioning stage. Based on the waste characteristics and plant requirements during the decommissioning of SMR-300, the mobile treatment facilities could also be employed to abate gaseous radioactive waste.

1.5 SUSTAINABILITY CONSIDERATIONS

The generic SMR-300 sustainability strategy (SMR-300 GDA Sustainability Strategy [75]) sets out the approach on how to demonstrate sustainability considerations in the design. The strategy is also forward looking on how the generic SMR-300 design can contribute towards sustainable development post-GDA.

The details on how sustainability has been considered in the management of radioactive waste and spent fuel in the generic SMR-300 GDA are summarised below, mainly including:

- Radioactive waste management will be justified by the application of BAT and the waste hierarchy principles to prevent and/or minimise the impacts of radioactive waste on the public and environment, so as to avoid burdening future generations.
- During the optimisation of RWMA, all relevant competing factors, such as safety, security, technical feasibility, environment, socio-economic benefits, etc., will be considered appropriately to provide a single solution through the risk-informed decision-making approach. These criteria are aligned with the United Nations SDGs [55] and the NDA Value Framework paper [76].
- Making best use of existing and centralised off-site waste service infrastructures (including incineration, metallic waste recycling and supercompaction) or disposal facilities to select the most practicable management route of each solid waste stream, and managing the waste as soon as reasonably practicable, would provide a more sustainable or cost-effective solution in the development of the generic SMR-300 waste management strategy.
- Flexible connections to mobile treatment systems in the generic SMR-300 waste management processes enables the adoption of innovation in waste management processes with an emphasis on minimising the volume and activity of waste to be discharged or disposed in the future.
- Consideration of design features to facilitate safe decommissioning of the nuclear facility in the future and prevent/minimise waste generation, which will contribute to achieving sustainability by restoring the site to a green field site, ensuring the net impact on the land is neutral.
- The fuel route and dry storage system design and operations make a significant contribution in supporting application of the waste management hierarchy by:
    - Avoiding and minimising the generation of wastes (including radioactive wastes).
    - Maximising re-use or recycling opportunities (e.g. reuse or recycling of MPCs and NFWCs).
    - Minimising the use of materials and resources (including water and energy).
    - Maximising opportunities for materials recycling and recovery (e.g. for redundant MPCs, if they are not to be reused).
    - Ensuring that potential long-term management options for spent fuel are not foreclosed e.g. reprocessing.

1.6 DISPOSABILITY ASSESSMENT

In the UK, a disposability assessment is required for reactor new build projects to demonstrate that conditioned radioactive waste packages will be suitable and could be accepted in final disposal facilities in the UK [2] [36]. At GDA Step 2, it was not appropriate to apply a standard Disposability Assessment due to the early stage in design of the proposals. An Expert View on disposability was instead applied by NWS to identify any inherent, unmitigated risks to disposability arising from a high-level review of the HLW, ILW and LLW, that currently cannot be disposed of at existing disposal facilities, streams and future plans for their management [24]. The NWS assessment has also included consideration of any risks associated with wastes that may sit around or below the boundary for HLW, ILW and LLW, that currently cannot be disposed of at existing disposal facilities, such as LLW Repository.

In compliance with the above requirements, the RP submitted, NWS Expert View Submission [77] to NWS for seeking an Expert View within GDA Step 2. NWS assessed the submission and provided their Expert View for the generic SMR-300 in GDA Step 2 Expert View on the Disposability of Wastes and Spent Fuel arising from the Holtec SMR-300 [78]. NWS concluded that in general the nature of the wastes and spent fuel from the generic SMR-300 are not significantly different to those which would arise from existing and planned PWRs, which they are already familiar with, giving confidence that a disposability case could be made.

[REDACTED] Holtec considers that direct disposal offers significant potential benefits in terms of safety, environmental performance, and long-term sustainability. As such, this approach may warrant consideration at a national strategic level by Government, to develop the infrastructure necessary to enable transport.

There are uncertainties in the Expert View assessment where further information will be required to support future disposability assessments. These uncertainties have been identified in the NWS Expert View [78] and will be addressed at the site-specific stage.

Beyond GDA timescales, the outcome of disposability assessments will support the development of the Radioactive Waste Management Case (RWMC) at the site-specific stage (see Table 9: Future Evidence). The RWMC will be developed in line with The management of higher activity radioactive waste joint guidance [36] and demonstrate ILW and spent fuel arising from the SMR-300 can be managed to minimise the risks to workers, member of public and the environment.

1.7 SUMMARY

This chapter presents the management arrangements for radioactive waste and spent fuel arising over the lifecycle of the reactor, with due consideration of the appropriate RSR principles, GDA guidance and scope, to meet regulatory expectations and requirements commensurate with the GDA scope, as well as the maturity of SMR-300 design.

Similar to traditional PWRs, wastes arising from the SMR-300 are expected to include radioactive liquid, gaseous and solid wastes from reactor operation and decommissioning, and spent fuel. This chapter provides details on each of the anticipated waste streams and how they are expected to be managed in line with UK regulations and waste management principles identified.

Suitable baseline strategies for the management of radioactive waste and spent fuel have been developed for a 2-Step GDA. However, it does not mean all other options have been foreclosed, the baseline strategies for the management of radioactive waste and spent fuel arising from the generic SMR-300 lifecycle will need assessment post-GDA to take into account site-specific factors for the determination of options that demonstrate BAT. Taking into account the design challenges discussed in this chapter, planned actions beyond GDA timescales have been captured within a GDA commitment:

C_RWMA_078: Information dependent on site-specific factors will be required to meet regulatory expectations in establishing the strategies for ILW and LLW facilities. A Commitment is raised to undertake the following post-GDA activities to ensure site specific application:

a) Further quantification and categorisation of radioactive waste inventories.
b) Further down-selection of ILW management options, including container type e.g. RSCs or HICs.
c) Detailed design development of facilities for ILW storage and LLW handling.
d) Optimisation of the use of space allocated to RWM in the RAB or consideration of whether a dedicated facility is BAT.
e) Conduct further engagement with NWS for disposability assessment of ILW packages following down-selection of containers and further development of radioactive waste inventories.

Beyond GDA, the management of radioactive waste and spent fuel arrangements will continue to develop in line with the developing maturity of the generic SMR-300 design, as well as site-specific requirements of nuclear site licensing and environment permits. The examples of future evidence identified in this chapter is listed in Table 9.

Table 9: Future Evidence

[REDACTED]

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1.9 LIST OF APPENDICES

Appendix A Simplified Flow Diagram of the Liquid Radioactive Waste Baseline Management Strategy

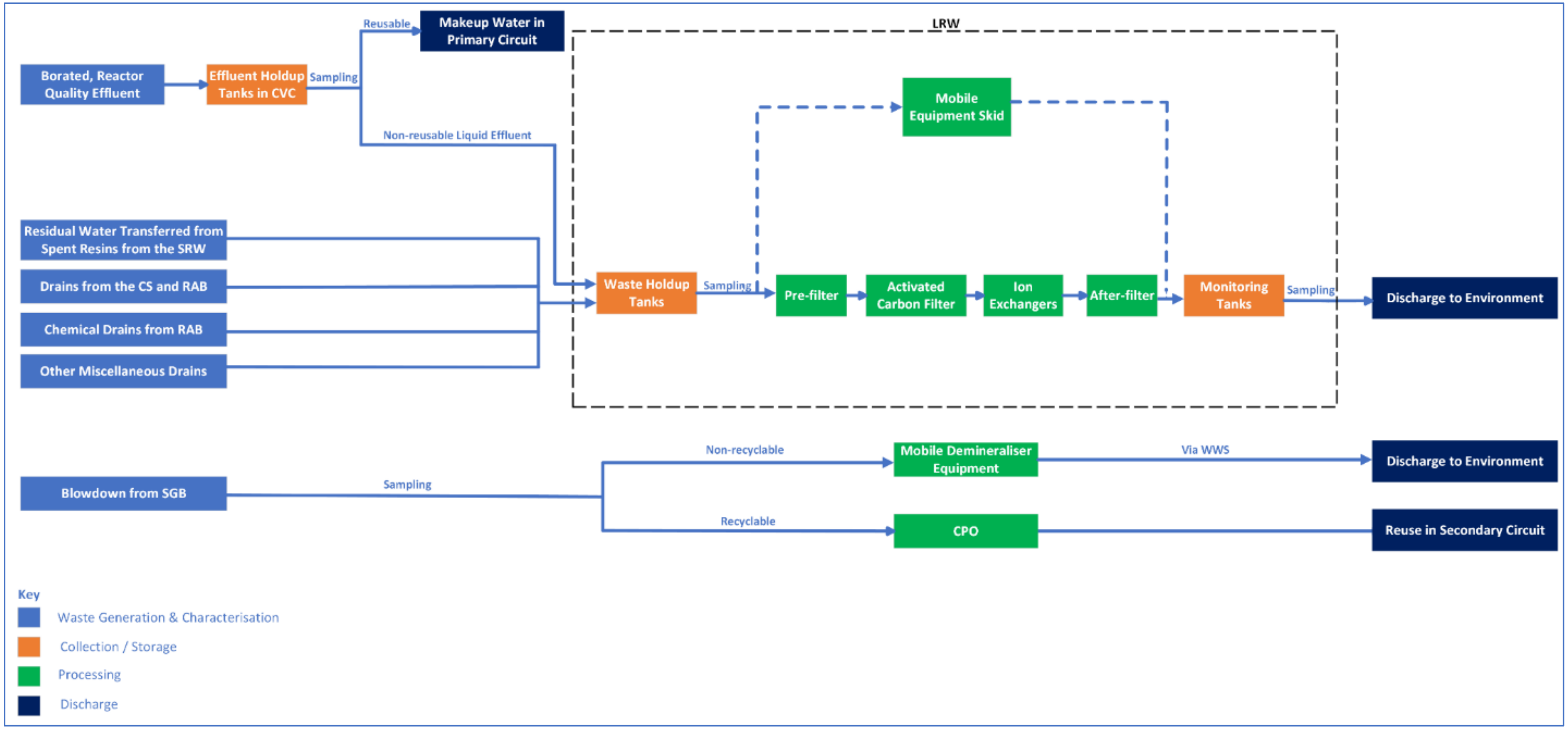

Figure 4: Simplified Flow Diagram of the Liquid Radioactive Waste Baseline Management Strategy

Appendix B Simplified Flow Diagram of the Gaseous Radioactive Waste Baseline Management Strategy

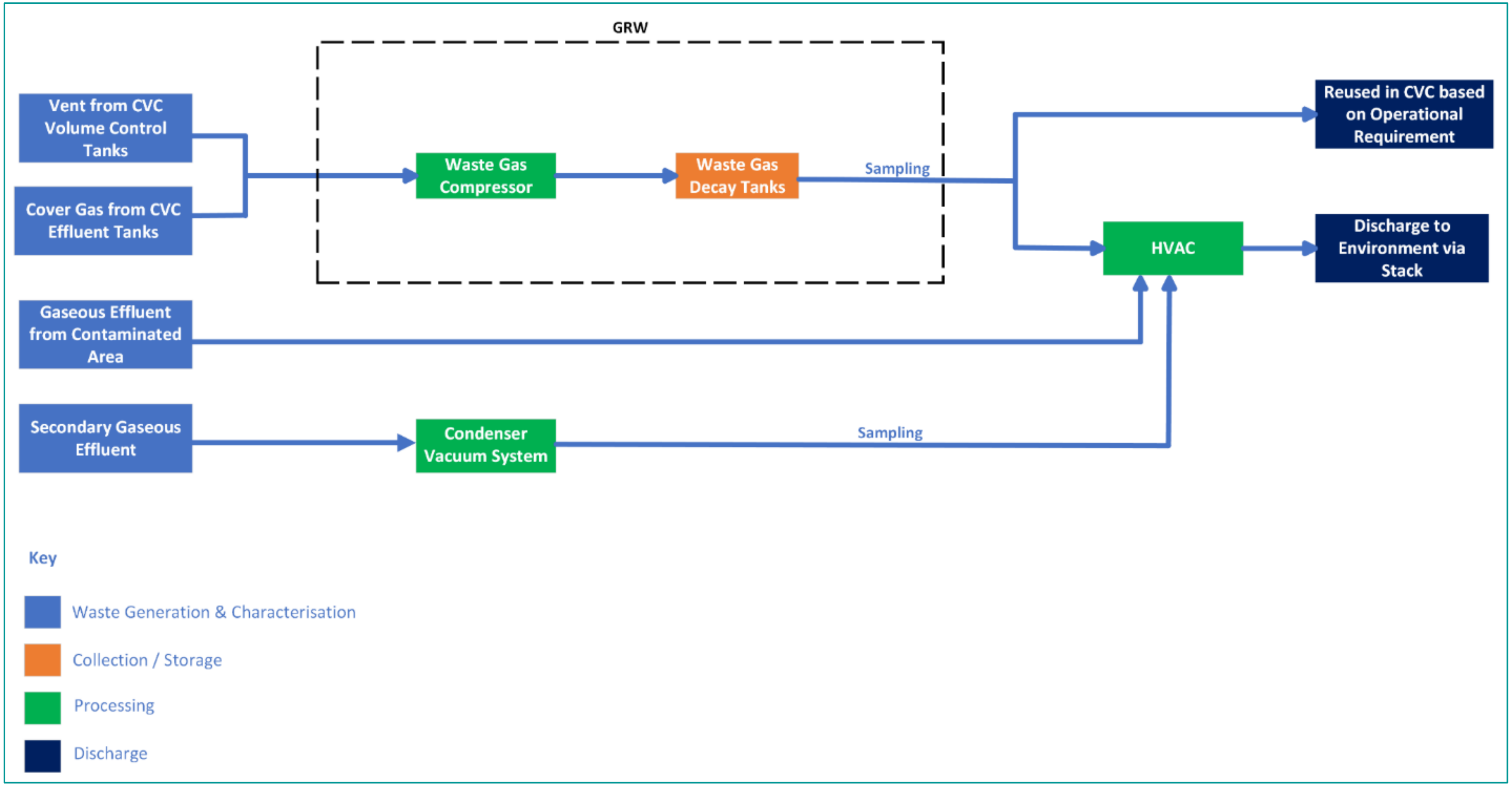

Figure 5: Simplified Flow Diagram of the Gaseous Radioactive Waste Baseline Management Strategy

Appendix C Simplified Flow Diagram of the Solid Radioactive Waste Baseline Management Strategy

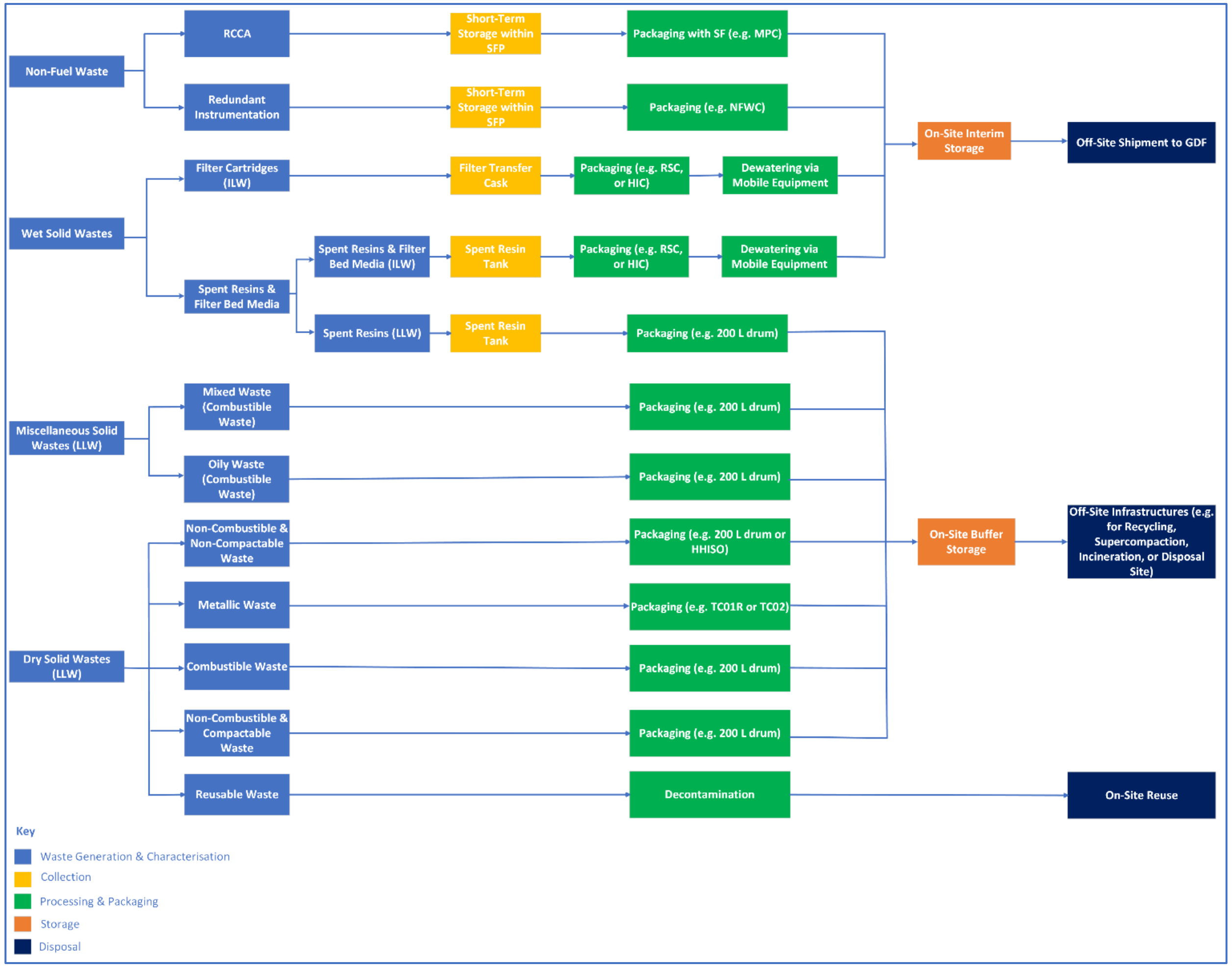

Figure 6: Simplified Flow Diagram of the Solid Radioactive Waste Baseline Management Strategy