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1.1 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 definitions and abbreviations are used herein:

Term:	Definition:
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
AOO	Anticipated Operational Occurrences
BAT	Best Available Techniques
CAS	Condenser Vacuum System
CS	Containment Structure
CVC	Chemical and Volume Control System
FA	Forward Action
FDP	Funded Decommissioning Programme
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GRW	Gaseous Radwaste System
HAW	Higher Activity Waste
HEPA	High Efficiency Particulate Air
HIC	High Integrity Container
HI-STORM UMAX	Holtec International Storage Module Underground MAXimum Safety
HI-TRAC	Holtec International TRAnsfer Cask
HLW	High Level Waste
HSE	Health and Safety Executive
HVAC	Heating, Ventilation and Air Conditioning
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
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LRW	Liquid Radwaste System
LT	Low Profile Transporter
MPC	Multi-Purpose Canister
NFWC	Non-Fuel Waste Canisters
NWS	Nuclear Waste Services
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PER	Preliminary Environmental Report
PPE	Personal Protective Equipment
PSL	Primary Sampling System
PSR	Preliminary Safety Report
PWR	Pressurised Water Reactor
QA	Quality Assurance
RAB	Reactor Auxiliary Building

Term:	Definition:
RCCA	Rod Cluster Control Assemblies
RCS	Reactor Coolant System
R&D	Research and Development
RGP	Relevant Good Practice
RMS	Radiation Monitoring System
RP	Requesting Party
RSR	Radioactive Substances Regulation
RWB	Radioactive Waste Building
RWMC	Radioactive Waste Management Case
SAPs	Safety Assessment Principles
SDD	System Design Description
SFA	Spent Fuel Assembly
SFAIRP	So Far As Is Reasonably Practicable
SFC	Spent Fuel Pool Cooling System
SFIS	Spent Fuel Interim Store
SFP	Spent Fuel Pool
SFSR	Spent Fuel Storage Rack
SGB	Steam Generator Blowdown System
SMR-300	Small Modular Reactor-300
SONGS	San Onofre Nuclear Generating Site
SRW	Solid Radwaste System
SSC	Structures, Systems and Components
SSEC	Safety, Security and Environment Case
UK	United Kingdom
US	United States
VCT	Volume Control Tank
VLLW	Very Low-Level Waste
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association

1.2 INTRODUCTION

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

1.2.1 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 New nuclear power plants: Generic Design Assessment guidance for Requesting Parties [2] and relevant principles in the Radioactive Substances Regulation (RSR) Generic Developed Principles [3].

1.2.2 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 the plant. A more detailed topic area scope is provided in HI-2240121, SMR-300 UK Generic Design Assessment GDA Scope [4].

The quantification of liquid and gaseous waste and the application of Best Available Techniques (BAT) in radioactive waste management are out of the scope of this chapter. The links to these topics are presented in this chapter. Additionally, the transportation of radioactive waste onsite and offsite is out of scope in this GDA as it is site-specific.

More details of the design and operations of radioactive waste management systems, spent fuel interim management and decommissioning are described in the Preliminary Safety Report (PSR) HI-2240344, PSR Part B Chapter 13 Radioactive Waste Management [5], HI-2240351, PSR Part B Chapter 24 Fuel Transport and Storage [6] and HI-2240355, PSR Part B Chapter 26 Decommissioning Approach [7], which avoids the repetition of similar topics across the safety case and environmental case.

1.2.3 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 provides the abbreviations and definitions used within this chapter.
- Sub-chapter 1.2 introduces the purpose, scope, interfaces, and assumptions of radioactive waste management arrangements.
- Sub-chapter 1.3 presents regulatory context, such as regulatory expectations and requirements, relevant RSR principles, codes and standards and lessons learnt from previous GDA projects, which are considered appropriately in the development of radioactive waste management arrangements.
- Sub-chapter 1.4 presents the radioactive waste principles for the development of radioactive waste management strategies and arrangements.
- Sub-chapter 1.5 presents the management of liquid, gaseous and solid radioactive waste, and spent fuel arising over the lifecycle of the plant.
- Sub-chapter 1.6 summarises this chapter.
- Sub-chapter 1.7 presents the references used in this chapter.
- Sub-chapter 1.8 contains the Appendix with a flow diagram of solid radioactive waste management.

1.2.4 Interfaces with Other SSEC Chapters

The chapters in the Safety, Security and Environment Case (SSEC) interfaced with this chapter are detailed in Table 1 below.

Table 1: Interfaces with other Chapters in the SSEC

SSEC	Interface
HI-2240361, Holtec SMR GDA PER Chapter 2 Quantification of Effluent Discharges and Limits [8]	This chapter presents the estimated quantities and limits, and radionuclides production mechanism of aqueous and gaseous effluents generated during plant normal operation, which contribute to underpin the radioactive waste management arrangements in PER Chapter 1.
HI-2240363, Holtec SMR GDA PER Chapter 4 Conventional Impact Assessment **[9]**	This chapter provides sustainability requirements that could be considered in the PER Chapter. This chapter also describes the radioactive aqueous discharges to surface water from the Liquid Radwaste System (LRW), which is described within PER Chapter 1.
HI-2240332, Holtec SMR GDA PSR Part A Chapter 1 Introduction **[10]**	This chapter provides the information required in the GDA process and the structure of the PER, which PER Chapter 1 should consider.
HI-2240333, Holtec SMR GDA PSR Part A Chapter 2 Generic Design and Site Characteristics **[1]**	This chapter introduces the main Structures, Systems and Components (SSCs) in the generic SMR-300 design, as well as the philosophy followed in the design which are considered in the conception of the radioactive waste management systems.
HI-2240335, Holtec SMR GDA PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance **[11]**	This chapter describes the safety management and quality assurance applied during the GDA process and its requirements, which are consistent across the PER, PSR and GSR.
HI-2240341, Holtec SMR GDA PSR Part B Chapter 10 Radiological Protection **[12]**	This chapter describes the radiological protection engineered features and general information relating to the source terms of radioactive waste, which underpin the development of radioactive waste management arrangement.
HI-2240342, Holtec SMR GDA PSR Part B Chapter 11 Environmental Protection **[13]**	This chapter summarises the PER chapters and BAT claims, including radioactive waste management arrangements.
HI-2240344, Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management **[5]**	This chapter provides the design and operations of radioactive waste management systems, which are summarised in the PER Chapter. Sign posting is made between this PER chapter and the PSR chapter in order to avoid duplication of significant amounts of information, where appropriate.
HI-2240352, Holtec SMR GDA PSR Part B Chapter 23 Reactor Chemistry **[14]**	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.
HI-2240351, Holtec SMR GDA PSR Part B Chapter 24 Fuel Transport and Storage **[6]**	This chapter describes the detailed design proposal of spent fuel management, which are summarised in PER Chapter 1.
HI-2240355, Holtec SMR GDA PSR Part B Chapter 26 Decommissioning Approach **[7]**	This chapter describes the detailed consideration for the decommissioning strategy and the design to facilitate decommissioning as well as the anticipated decommissioning wastes, which are also summarised in PER Chapter 1.

The interfaces between this chapter and other chapters within the SSEC will be continually reviewed, as other new chapters, e.g. Demonstration of BAT and Monitoring and Sampling, will be developed during the GDA. The BAT demonstration for the generic SMR-300 will be developed in line with HI-2240359, Approach and Application of the Demonstration of BAT [15] and GDA Scope [4], to indicate how the generation and disposal of radioactive waste will be prevented and minimised to reduce the impact on the members of the public and environment to As Low As Reasonably Achievable (ALARA). This BAT demonstration approach outlines the BAT methodology and relevant claims applied to radioactive waste management.

1.2.5 Assumptions

The following assumptions are made to underpin the radioactive waste management arrangements considering the 'Base Case' in The Energy Act 2008: Funded Decommissioning Programme Guidance for New Nuclear Power Stations [16].

1. The radioactive waste management systems are shared by the twin-units.

2. The regulations, codes and standards applied to radioactive waste management, decommissioning, and spent fuel management are those in force during the development of radioactive waste management arrangements.
3. Definitions of waste categories including low level waste (LLW), intermediate level waste (ILW) and high-level waste (HLW) will remain unchanged from those in current use in the United Kingdom (UK).
4. The ILW, HLW and spent fuel arising from operation and decommissioning will be stored on site until a Geological Disposal Facility (GDF) in the UK is available to accommodate these wastes.
5. The LLW arising during operation and decommissioning will be consigned to the LLW Repository site operating in West Cumbria or a successor facility for their management in line with the waste hierarchy and applying the current policy of diversion where possible.
6. Following BAT and ALARP assessment, the radioactive waste management systems will be used to treat radioactive waste arising during the decommissioning stage
7. The available techniques recognised by worldwide nuclear sector and/or similar sector at this stage are considered as ‘proof of concept’ to demonstrate that the process is capable of being implemented on the understanding that it might not be the final version.

1.3 REGULATORY CONTEXT

This sub-chapter describes the regulatory and GDA requirements to be considered during the development of radioactive waste management arrangements.

1.3.1 GDA Requirements

To guide the development of the environment case for a new reactor power plant in the UK, New nuclear power plants: Generic Design Assessment guidance for Requesting Parties [2] details the information required for the environment case for the whole GDA process. The key information relating to radioactive waste management arrangements that is required for a full GDA include:

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.*
- *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.*

Detailed description of Radioactive Waste Management Arrangements

- *Identifying the strategic considerations for radioactive waste management which underpin the design.*
- *A description of radioactive wastes and spent fuel arisings throughout the nuclear power plant's lifecycle, including sources of radioactivity and other matters affecting radioactive waste arisings – lifecycle includes commissioning and decommissioning.*
- *A description of the proposals for the management and disposal of all radioactive wastes, including solid, liquid and gaseous wastes and spent fuel, throughout the nuclear power plant's lifecycle – including commissioning, operation and decommissioning.*
- *A description of how the production, discharge and disposal of radioactive waste and spent fuel will be managed to protect the environment and optimise the protection of people.*

Quantification of Radioactive Waste Disposals

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.*

For combustible and other radioactive wastes, estimate the annual arisings and disposals during operation and give an indication of the likely arisings during decommissioning.

Radioactive wastes shall be identified in terms of their category (HLW, ILW, LLW, VLLW), physic-chemical characteristics and proposed disposal route (if any).

Quantification should be in terms of activity of important individual radionuclides and overall groupings of radionuclides (for example, total beta), together with mass or volume.

In order to undertake a meaningful assessment for the environment case in Step 2, the GDA guidance [2] also describes the regulatory requirements relevant to radioactive waste management arrangements to be prepared in preparation for Step 2. Table 2 below details where all relevant GDA information requirements are considered in the development of this chapter at this stage.

Table 2: Alignment Analysis between GDA Submissions and GDA Information Requirements for Step 2

GDA requirements for Step 2 Assessment	Information as part of GDA
Information on the source of radioactive waste arisings ('source term') in line with our joint regulatory interests with the Office for Nuclear Regulation (ONR) in the minimisation of radioactive waste and the management of Higher Activity Wastes (HAWs).	• This chapter, sub-chapter 1.5. gives an overview of the management of liquid, gaseous, solid, spent fuel and decommissioning waste streams and management • More information on 'source term' can be found in PSR Part B Chapter 10 Radiological Protection [12]. • A tier 2 report will also document the waste inventory
The quantities and types of radioactive waste (solid), including more challenging wastes, and spent fuel that are likely to arise during normal operations and in decommissioning.	• Liquid waste: This chapter, sub-chapter 1.5.1. • Gaseous waste: This chapter, sub-chapter 1.5.2. • Solid waste: This chapter, sub-chapter 1.5.3. • Spent fuel: This chapter, sub-chapter 1.5.4. • Decommissioning waste: This chapter, sub-chapter 1.5.5. • The quantities of aqueous and gaseous radioactive waste are presented in PER Chapter 2 [8]. • PSR Part B Chapter 26 [7] describes the wastes that are expected to be generated during decommissioning of the reactor. • PSR Part B Chapter 24 [6] describes the detailed design parameters of spent fuel management. • A tier 2 report will also document the waste inventory
A description of gaseous, liquid and solid waste management systems and their proposed operations.	• Liquid waste management systems: This chapter, sub-chapter 1.5.1. • Gaseous waste management systems: This chapter, sub-chapter 1.5.2. • Solid waste management systems: This chapter, sub-chapter 1.5.3. • More details on the designs and operations of gaseous, liquid and solid waste management systems are detailed in PSR Part B Chapter 13 [5].
Information on applicable Operational Experience (OPEX) and Relevant Good Practice (RGP) for radioactive waste management, decommissioning and the Spent Fuel Interim Store (SFIS)	• Information on RGP relating to radioactive waste management, decommissioning and the SFIS is presented in sub-chapters 1.3. • For the OPEX relevant to radioactive waste management, decommissioning and the SFIS, relevant information is provided in sub-chapter 1.4 and 1.5.

GDA requirements for Step 2 Assessment	Information as part of GDA
Disposability assessment on radioactive waste • a credible plan to obtain a view from Nuclear Waste Services (NWS) on the disposability of any solid radioactive waste arisings, including more challenging wastes and non-radiological hazardous substances arising across the reactor lifecycle. • the assessment of radioactive waste should address the waste form and any non-radioactive components that could have a bearing on its management and disposability. • during its engagement with NWS, the Requesting Party (RP) should identify any challenges the waste streams may present to the Waste Acceptance Criteria (WAC) for disposal facilities. • a credible plan to obtain a view from NWS on disposability of more challenging LLW arisings.	• This chapter, sub-chapter 1.4.9. gives an overview of this topic area and signposts to supporting documents
The RP's considerations at the design stage for meeting the joint regulators guidance on the decommissioning of nuclear sites and release from regulation.	• This chapter, sub-chapter 1.5.5. • PSR Part B Chapter 26 [7].

1.3.2 Radioactive Substances Regulation Principles

The Environment Agency 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 radioactive waste management arrangements, the key generic developed principles related to radioactive waste management are identified and considered appropriately. Table 3 below presents the principles which this chapter seeks to address. In the introduction to this chapter, the interfaces with other PER chapters, which address other generic developed principles, is provided.

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 (subchapter 1.4) presents the radioactive waste management arrangements, and principles that should be considered in the Integrated Waste Strategy (IWS) development. • The IWS will be developed to describe the overarching strategy of waste 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.	• Approach and application of BAT demonstration is detailed in 'Approach and Application of the Demonstration of BAT' [15] document. The demonstration of BAT for radioactive waste management will be produced and provided in line with the BAT approach. • BAT application and general information about design aspects to facilitate waste prevention and/or minimisation are discussed in sub-chapter 1.4.4 of this chapter.
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 of waste segregation are presented in sub-chapter 1.4.5 of this chapter. • Some information on specifics of radioactive waste segregation is presented in sub-chapter 1.5 of this chapter commensurate with design maturity at this time. • Further information on waste segregation will be presented in the IWS
RSMDP9 – Characterisation Radioactive substances should be characterised using BAT so as to facilitate their subsequent management, including waste disposal.	• The general requirements of waste characterisation are presented in sub-chapter 1.4.5 of this chapter. • Throughout sub-chapter 1.5 there are numerous mentions of waste characterisation of the various streams. More detail will be provided in step 2.
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 1.4.7 presents general requirements on interim storage of waste. • Sub-chapter 1.5.3.3.6 presents information on storage of solid radioactive waste and • 1.5.4.3 presents information on spent fuel interim storage • PSR Part B Chapter 13 [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 1.4.6 presents general requirements on waste processing. • Sub-chapter 1.5.1 to 1.5.5 presents information on processing 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 1.4.10 of this chapter. • More details about the management of records, safety case and environment case are presented in PSR Part A Chapter 4 [11].

RSR Principle	Information provided as part of GDA
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.	• Sub-chapter 1.4.9 of this chapter presents general requirements on waste disposability. • Based on Radioactive Waste Management Limited's (RWM) requirement, RWPR63-WI11, Preparation of an Expert View to support Step 2 of the Generic Design Assessment process [17], the RP will seek an Expert View from NWS on the packaging proposals of radioactive waste streams within Step 2.
Decommissioning Strategy - RSR guidance for nuclear sites undergoing decommissioning [18] 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 1.5.5 in this chapter presents information on decommissioning strategy. • More detail on decommissioning strategy is available in PSR Part B Chapter 26 Decommissioning Approach [7]. • Alongside PSR Chapter 26 a preliminary decommissioning strategy relevant to UK context shall be developed within Step 2
Design for Decommissioning [18] 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 1.5.5 of this chapter. • More detail on design for decommissioning is available in PSR Part B Chapter 26 [7].

1.3.3 Other Requirements related to Radioactive Waste Management

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

- Health and Safety at Work etc. Act 1974 [19].
- The Nuclear Installations Act 1965 [20].
- Environment Act 1995 [21].
- Ionising Radiations Regulations 2017 [22].
- The Environmental Permitting (England and Wales) Regulations 2016 (EPR16) [23].
- The Environmental Permitting (England and Wales) (Amendment) Regulations 2018 [24].
- The Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2018 [25].
- The Energy Act 2008: Funded Decommissioning Programme Guidance for New Nuclear Power Stations [16].
- UK Policy Framework for managing Radioactive Substances and Nuclear Decommissioning, May 2024 [26].
- CoRWM, Development of Small Modular Reactors and Advanced Modular Reactors – Implications for the Management of HAWs and Spent Fuel [27].

The sources of codes and standards 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 radioactive waste management arrangements. The main codes and standards, which are regarded as RGP, applied to the management of radioactive waste and spent fuel are listed below:

- IAEA, Predisposal Management of Radioactive Waste [28].
- IAEA, SSG-40, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors [29].
- The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites [30].

- UK Strategy for the Management of Solid LLW from the Nuclear Industry [31].
- Decommissioning of Nuclear Sites and release from Regulation [32].
- Industry Guidance – Interim Storage of HAW Packages – Integrated Approach [33].
- IAEA, No.SSG-15, Storage of Spent Nuclear Fuel [34].
- WENRA, Radioactive Waste Treatment and Conditioning Safety Reference Levels, 2018 [35]
- WENRA, Waste and Spent Fuel Storage Safety Reference Levels, Version 2.3, 2024 [36]

It is recognised that the ONR Safety Assessment Principles (SAPs) for Nuclear Facilities [37] is also deemed as RGP in the UK. Some key principles in SAPs, such as radioactive waste principles and decommissioning principle, will be considered alongside RSR principles in an integrated approach in the development of radioactive waste management arrangements and strategies during the 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 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 related to the design of the SSCs for the liquid, gaseous and solid radioactive waste systems are described in PSR Part B Chapter 13 [5].

1.3.4 Lessons Learnt

Relevant regulatory questions or issues raised during previous GDAs were reviewed, which provided more insight into the regulatory expectations to be met during the development of the radioactive waste management arrangements topic area. Concerns from previous GDAs were related to the development of the Disposability Assessment which supports this topic area. Key lessons learnt include:

- The requirement to engage with NWS to obtain their advice regarding the disposability of waste streams, which feeds into the development of radioactive waste management arrangements;
- The requirement to make any necessary updates to the submission in a timely manner to prevent delays to final submissions; and,
- The requirement to update regulators with progress, including any anticipated delays.

1.4 RADIOACTIVE WASTE MANAGEMENT PRINCIPLES AND STRATEGY

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

In line with the regulatory requirements in references [3], [37] and Basic Principles of Radioactive Waste Management [38], the waste producer should produce and maintain the radioactive waste management strategy for both initial and future waste management. This report will be continually developed to represent an overview on how the radioactive waste and spent fuel arising from the reactor lifecycle are managed in a safe, environmental and secure manner, which contribute to reducing the risks and optimising protection of workers, members of the public and the environment.

The following principles and requirements underpinning the development of the radioactive waste management arrangements are summarised appropriately from the RSR principles and RGP relevant to radioactive waste management, which are presented in the sub-chapters 1.3.2 and 1.3.3. All of these will feed into the development of the IWS, which will be developed in line with current UK legislation, policies and strategies, including overall policy aims on sustainable development.

1.4.1 General Radioactive Waste Management Principles

The key principles applied for radioactive waste management are drawn from the RGP and RSR generic developed principles presented in sub-chapter 1.3, 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 to products that are passively safe.
- Radioactive waste should be stored in line with good engineering practice and in a passively safety condition.
- The discharge or disposal of radioactive waste 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.
- Aspects to facilitate decommissioning should be considered in the design to minimise decommissioning waste.

These principles are applicable for the management of radioactive waste arising from the plant lifecycle and will support the radioactive waste management arrangement and strategies throughout the GDA process.

It is recognised that Outline Engineering Design Principles (EDPs) were developed and identified in the Holtec SMR GDA Fundamental Design Philosophy Report [39]. The report also provided a brief description of possible supporting sub-principles. The sub-principle relevant to environment protection will be fully developed by taking account of the above principles appropriately and will reflect the UK requirements and expectations for the design of a new facility.

1.4.2 Waste Hierarchy

The waste hierarchy, illustrated in Figure 1, forms a fundamental part of radioactive waste management principles and used as a framework for decision-making for all radioactive waste activities in the UK [30], [31]. Implementation of the waste hierarchy requires a systematic approach to prevent and minimise the generation of radioactive waste (both volume and radioactivity).

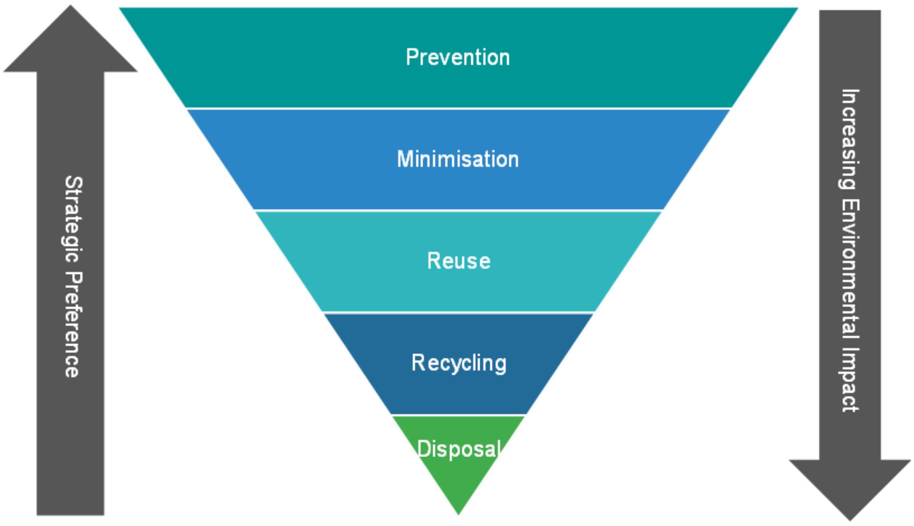

Figure 1: Waste Hierarchy

Waste hierarchy is a stepwise approach, which encourages selecting the options for waste management considering the following principles in order of priority:

1. Prevention: Creation of waste should be prevented, the highest level of the waste hierarchy.
2. Minimisation: Where wastes cannot be prevented, waste should be reduced at source as far as possible.
3. Reuse: Where appropriate, waste materials should be reused directly or after refurbishment.
4. Recycling: Where appropriate, waste materials should be recycled.
5. Disposal: Waste should only be disposed of when the above options are impossible.

In the application of the waste hierarchy, taking the best use of existing LLW management assets in the UK, including diversion routes such as incineration and metal recycling as well as the LLW disposal facility, should be considered appropriately to establish the most practicable management routes for radioactive waste by use of BAT, which contributes to minimising the radioactive waste to be finally disposed of and reduce the impacts to the public and environment, as well as achieving sustainable development of nuclear power in the UK.

1.4.3 Sustainability

In line with the requirements in The UK Policy Framework for Managing Radioactive Substances and Nuclear Decommissioning [26], the management of radioactive waste should consider internationally recognised best practices in sustainability and sustainable development, especially the United Nations' Sustainable Development Goals (SDGs) [40], which aims to protect the environment and the current and future generations. Sustainability is embedded into the founding 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.

In the development of the GDA environment case, the application of 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, environment and sustainable approach. This aligns with SDG 12 'Ensure Sustainable Consumption and Production Patterns' [40], particularly target 12.4, which focuses on the sound management of wastes throughout their lifecycle. The main aspects from the radioactive waste management perspective that will contribute to sustainable development in the generic SMR-300 include:

- The radioactive waste management will be justified by use of BAT as well as considering 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.

- In the optimisation process of radioactive waste management, all relevant competing factors, such as safety, technical feasibility, environment, and socio-economic benefits, etc., will be considered appropriately to give a single solution through the risk-informed decision-making approach. These criteria are aligned with the United Nations SDGs [40].

- Taking best use of existing and centralised off-site waste service infrastructures (including incineration, metallic waste recycling and super-compaction) or disposal facilities should be considered to select the practicable management route of each solid waste stream, that would provide a more sustainable or cost-effective solution in the development of radioactive waste management.

The RP respects the proximity principle in the management of radioactive waste, where pollution is practically reduced from the transportation of waste to off-site facilities, which contributes to the sustainable management of radioactive waste. Considering the nature of the GDA process, the proximity principle, which is identified as a sustainability opportunity for the management of radioactive waste, will be considered appropriately when the specific site is determined by the future operator at the site-specific stage.

Additionally, it is recognised that the future operator is required to have a Funded Decommissioning Programme (FDP) at the site-specific stage in line with the Energy Act 2008 [41] and FDP guidance [16]. This FDP ensures that operators have secure funding arrangements in place to meet the full costs of decommissioning, the management and disposal of hazardous waste, which will minimise the burden on current and future generations and contribute to the sustainable development of nuclear power in the UK.

1.4.4 Application of BAT and ALARP

Within the UK, the requirement to apply BAT is regarded as a fundamental environmental principle under EPR16 [23] and is to be applied through the effective application of radioactive substances management principles [3]. The regulatory expectations on the demonstration of BAT are also within the UK strategy for solid LLW management [31] and joint regulatory guidance on the management of higher activity radioactive wastes [30]. The application of BAT to the generic SMR-300 design will be appropriately carried out based on existing UK legislation and regimes as well as RGP and OPEX, so as to prevent and minimise the impacts to people and the environment.

The radioactive wastes arising from the lifecycle of the reactor are prevented and/or minimised appropriately at the source. Some design aspects contributing to the waste prevention and minimisation are considered in the design of the generic SMR-300 and are presented in HI-2240077, SMR-300 Plant Overview [42], such as (not an exhaustive list):

- Adopting high reliability and performance fuel to minimise fuel failure and fission products leakage.
- Adopting nominal 18-month refuelling cycle to minimise the generation of spent fuel [42].
- Simplifying the design to reduce the number of components.
- Selection of materials in and around cores to minimise the radioactive inventory.
- Control of reactor chemistry to preserve the integrity of the fuel, minimise impurities and the generation of corrosion products to be activated in the core and primary circuit.
- Systems that can be operated and maintained in an optimal way.

The following aspects are considered in the management of radioactive wastes to minimise their generation, discharge and disposal:

- Appropriate selection of materials of SSCs.
- Waste segregation and characterisation.
- Waste reuse and recycling.
- Waste conditioning and treatment techniques.
- Appropriate disposal routes.

More details regarding BAT are available in the Approach and Application of the Demonstration of BAT document [15]. The BAT demonstration for the generic SMR-300 will be developed in line with the BAT approach [15].

Like BAT, the requirement for risks to be As Low as Reasonably Practicable (ALARP) is a fundamental safety principle in the UK. The Health and Safety Executive (HSE) and ONR guidance generally use the term ALARP to express the legal duty of operators to continuously reduce risks SFAIRP. The terms SFAIRP and ALARP being synonymous in guidance documents.

For relevant risks to be judged reduced SFAIRP, 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 ALARP process in the generic SMR-300 is detailed in HI-2240125, ALARP Design Process document [43].

As required in the UK policy for radioactive substances management [26], the risk-informed approach is part of the overall decision-making process in radioactive waste management. The optimisation of radioactive waste management will be based on an integrated approach considering all relevant competing factors, which ensures the balance of principles of BAT and ALARP in the development of radioactive waste management to give a single solution through the risk-informed decision-making process.

1.4.5 Waste Characterisation and Segregation

Upon generation, radioactive waste will be segregated at various stages to facilitate appropriate processing and final discharges to the environment or disposal in off-site facilities. As part of characterisation, collecting and retaining information on non-radioactive properties is also vital. Segregation allows waste of similar characteristics to be collected together, which prevents the mixing of waste with different characteristics. Characterisation will provide information on waste properties, such as physical and chemical parameters, activity content and radionuclides, which underpin the risk-informed decision-making for the next step of radioactive waste management.

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 [44]:

“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, wastes should be segregated and characterised at the point of its generation and throughout the subsequent steps of radioactive waste management by considering and using BAT. Then, each waste stream will be treated, conditioned and stored more efficiently and effectively based on the characterisation information, which will contribute to minimising the discharge and disposal of radioactive waste.

1.4.6 Waste Processing

Where the radioactive effluents or material are not re-used or recycled and are unsuitable for permitted discharge, they will be processed as radioactive waste based on the waste information from the characterisation. Radioactive waste processing can either facilitate the recycling and reuse of waste, or it can produce treated or conditioned waste suitable for subsequent radioactive waste management, such as handling, storage, discharge, or disposal.

Radioactive waste processing often comprises one or more steps, including pre-treatment, treatment, and conditioning. During the processing of radioactive waste, either permanent facilities or mobile facilities could be selected to process radioactive waste, which depends on the decision-making of the design of radioactive waste management systems considering the principles of BAT and ALARP, as well as the waste hierarchy. Options for radioactive waste management can include "dilute and disperse", which involves the direct discharge of gaseous or aqueous radioactivity into the environment, or “concentrate and contain”, which involves trapping radioactivity in a solid concentrated form prior to storage and eventual disposal [26]. 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 [26]. As a result, it will be important to consider the principles of BAT and ALARP when selecting the most appropriate option. If releases are to be made to the environment, it should be noted that these releases are permitted and monitored.

The aqueous and gaseous radioactive waste should be treated to meet environmental discharge limits, and solid radioactive waste should be conditioned by approach techniques to produce the waste packages, which are suitable for onsite storage, and disposal or waste treatment in off-site facilities.

1.4.7 Waste Interim Storage

Based on the radioactive waste management requirement [31], after the LLW is packaged on site in line with relevant requirements of off-site waste service or disposal facility, the LLW packages should be shipped to these facilities swiftly, which contribute to minimising the accumulation of radioactive waste in the plant, so as to reduce radiological risks. The HAW and spent fuel will be subject to long-term storage in a safe and secure manner on site pending shipment to the UK GDF [30] [33]. The interim storage facilities to accommodate HAW and spent fuel for a new nuclear power plant should be designed, constructed, and operated in accordance with good engineering practice and NDA guidance [33].

The ILW/LLW boundary wastes, which contain short-lived radionuclides as opposed to those containing long-lived radionuclides, may be sent to an interim storage facility for long-term storage after being packaged in the waste processing facility. If these ILW/LLW boundary wastes decay to LLW during the period of long-term storage in the interim storage facility, they will be retrieved from the interim storage facility and sent to an off-site LLW facility for disposal to minimise the volume of ILW to be disposed of in the GDF.

1.4.8 Waste Discharge and Disposal

It is common practice in the UK, following treatment in a batch process through waste management systems, aqueous and gaseous radioactive waste will be recycled where possible based on sampling results to minimise the discharge of waste. If recycling is inappropriate, these wastes will be discharged to the environment via permitted discharge outlet. Discharge to the environment is regulated by the Environment Agency and will only be allowed under the environmental permitting system where requirements and limits on discharges and standard permit conditions apply. These are discussed in PER Chapter 2 Quantification of Effluent Discharges and Limits [8] and the approach to BAT document [15].

For the LLW, the disposal routes should be selected by using BAT as well as considering the waste hierarchy. These wastes should be transported to the off-site facilities for further waste treatment or final disposal in line with UK strategy for LLW management [31].

Packaged spent fuel and HAW will be safety and securely stored onsite before being transferred to a future GDF for final disposal based on the assumption in sub-chapter 1.2.5.

1.4.9 Waste Disposability Assessment

A disposability assessment is required for reactor new build projects to demonstrate that conditioned waste packages will be suitable and could be accepted in final disposal facilities in the UK [30]. It is also the regulator's expectation that the RP seeks advice from NWS regarding any risk to future disposability associated with expected waste arisings [17]. An Expert View process is to be carried out, which is essentially a preliminary opinion from NWS experts [17].

Based on the assumption in sub-chapter 1.2.5, LLW produced during the operating stages of the plant is expected to be consigned to the LLW Repository site (LLWR) or successor facility for treatment and disposal, in line with the waste hierarchy. As a result, there is a requirement to ensure that this waste is compliant with LLWR's or successor facility's WAC. Consequently, in this GDA, the RP will engage with NWS to carry out a qualitative disposability assessment and gain its views on operational LLW packaging proposals, as well as identifying any challenges presented by any waste streams.

Any HAW arisings, consisting of operational ILW, decommissioning ILW and spent fuel (SF), will undergo long-term storage on-site until a GDF becomes available in the UK. To comply with UK policy, it is required that any waste produced from the lifecycle of the reactor is suitable for disposal in a GDF. In this GDA, any significant risks or uncertainties concerning the wastes arising should be identified to allow the Expert Views process to progress [17].

The RP has already engaged with NWS to seek an Expert View on the disposability of radioactive waste streams.

Based on the developed IWS and outcomes from NWS Expert View, the Radioactive Waste Management Case (RWMC), which demonstrates the HAW and spent fuel can be managed in a manner to minimise the risks to workers, public and environment, will be developed in line with the Joint Guidance [30] at the site-specific stage.

1.4.10 Information and Records Management

The information with respect to the management and disposal of radioactive waste should be sufficiently recorded and maintained over the lifecycle of the plant under appropriate Quality Assurance (QA) arrangements, which contributes to facilitating the radioactive waste management, both now and in the future, and meeting the demands of all relevant stakeholders involved in radioactive waste management. In addition, information on history and provenance of waste can be a key input to the decision-making of radioactive waste management in the operational stage and decommissioning stage as discussed earlier.

All relevant documentation and information, such as environment case and safety case documentation, waste information, commitments, decision-making records, assumptions, and uncertainties, etc., should be sufficiently recorded and maintained by the appropriate information management system, which is to be developed at the site-specific stage. For more details about the documentation and information management, refer to PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance, [11].

The typical information for the radioactive waste management to be recorded includes (but not limited to), [3] [30]:

- Owner of radioactive waste.
- Generation points of radioactive waste.
- Characteristics of radioactive waste.
- Type and identifier of the waste package.
- Waste treatment and conditioning.
- Waste form and characterisation.
- Radioactive waste package storage.
- Records of waste package maintenance.
- Disposal records of radioactive waste.

In the GDA process, relevant radioactive waste information will be prepared and submitted to NWS for disposability Expert view in line with the NWS requirements [17].

Once the waste is planned to be consigned to off-site facilities, such as off-site waste service infrastructures or disposal facilities, 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 in order to maintain subsequent radioactive waste management in the off-site facilities.

1.5 RADIOACTIVE WASTE MANAGEMENT

This sub-chapter provides details on the radioactive waste to be generated during the lifecycle of the generic SMR-300, and how it will be processed and managed.

The generic SMR-300 design is based on proven technology and avoids first-of-a-kind engineering. The design draws on the OPEX and lessons learned from six decades of operating Pressurised Water Reactors (PWRs) [42]. Like other operating PWR fleets, it is expected that the following radioactive waste arisings from the lifecycle of the generic SMR-300 will be generated:

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

The following sub-chapters describes the source of these radioactive waste arisings from the plant operation and decommissioning, and how these radioactive wastes are managed in the generic SMR-300. More details of source term relating to radioactive waste are also presented in PSR Part B Chapter 10 [12].

The facilities within the plant which accommodate the radioactive waste management systems, for example, the Radioactive Waste Building (RWB), Reactor Auxiliary Building (RAB) and the dry spent fuel storage system (SFIS) are described within PSR Part A Chapter 2 [1].

Information provided on the radioactive waste systems in this revision of this chapter is commensurate to the design maturity at the time of writing. More detail on these systems is available in the System Design Descriptions (SDDs) released as part of the design reference.

1.5.1 Liquid Radioactive Effluent Management

Liquid effluent management has been designed in accordance with standard industry practice, including OPEX from PWRs. Liquid radioactive effluents are segregated appropriately based on characteristics, which facilitates the safe and effective management of these wastes, as well as reducing the amount of solid radioactive waste generated in the LRW.

1.5.1.1 Liquid Radioactive Waste

The LRW 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 also designed to protect plant personnel from radiation exposure and minimise radioactive releases to the environment.

The liquid radioactive wastes are segregated at source within the scope of the Radioactive Drain System (RDS), then co-collected in the LRW. Segregation and classification of waste is completed before processing within the RDS and Chemical and Volume Control System (CVC). This allows for more effective storage and processing of waste, which would contribute to minimising the quantity of solid waste produced by the LRW.

Waste arisings that are treated within the scope of the LRW include a mixture of drains from the RDS, RAB chemical drains from the RDS and CVC letdown.

The management of each category of liquid waste is described below. The designs and operation of the LRW can be found in PSR Part B Chapter 13 Radioactive Waste Management [5].

1.5.1.1.1 Liquid Radioactive Waste Management

The wastes collected within the LRW consist of potentially contaminated RDS floor drains and other wastes containing higher suspended solids. These wastes include the residual water transferred from the spent resin from the Solid Radwaste System (SRW), various potentially contaminated building RDS floor drains and sumps, and other miscellaneous drains.

RDS floor drains inside the containment and the potential spent fuel pool liner leakage are collected in the RDS containment floor sump. Wastes contained within the containment sumps are transferred to the waste tanks. Potentially contaminated building RDS floor drains and other miscellaneous waste in the RAB are sent directly to the waste tanks. Degasification occurs prior to entry into the LRW. Opportunities for further segregation will be investigated and considered in line with the requirement to use BAT.

Chemical wastes and detergent wastes are also produced throughout the plant, which include inputs from laboratories and other small volume sources. These wastes are also collected within the waste tanks. Provisions are included to transfer the tank contents to be processed through the LRW equipment. The chemical wastes may also be discharged if no processing is required or processed through a temporary mobile equipment skid. This ensures that waste will be treated and processed flexibly to minimise the impact of the release on the environment.

The processing equipment to be used for abatement is anticipated to include prefilter, activated carbon filter, ion exchange columns and after filter. Each filter and ion exchanger may be bypassed if it is not required for processing to extend resin life and add flexibility in operation and maintenance requirements, thereby reducing the amount of solid radioactive waste generated in the LRW. To allow bypassing, effluents would be monitored first to ensure activity levels are low enough. Within the LRW, there are flexible interface connections to a temporary mobile equipment skid for the processing or off-site shipment in case the waste is incompatible with the installed processing equipment.

1.5.1.1.2 Monitoring and Sampling of Liquid Radioactive Waste

The Primary Sampling System (PSL) in the plant allows for the in-processing collection of liquid and gaseous samples for laboratory analyses of chemical and radiochemical conditions of designated plant systems. Data from the analyses provide the required information to monitor plant, equipment and system performances, which may include an indication if something is not performing BAT.

The sampling of LRW involves the manual collection of samples directly from the source, where local sample connections to sources are available, which helps to reduce radiation exposures to the workers. There is also a continuous stream provided to the sampling instrument at the effluent monitoring tank sampling point to obtain a representative sample. The samples will be returned back to their system of origin as practical, so as to minimise the production of radioactive waste.

Based on the results from sampling, the tank contents 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 predetermined level in the discharge. Operator intervention is required to restart the release. When the waste is discharged, the flow rate is also monitored against limits to remain below concentration limits.

The effluent and waste tanks are equipped with a hydrogen monitor to detect the presence of explosive gases.

1.5.1.2 Degas Reactor Coolant Effluent

The letdown effluent from CVC effluent tanks due to the RCS heat up, boron concentration changes, and pressuriser (PZR) level reduction is directed the LRW after the hydrogen and fission gases are removed from the letdown effluent. The gases removed are sent to the Gaseous Radwaste System (GRW) for processing.

Similar to the processing of effluents discussed in sub-chapter 1.5.1.1.1, the processing equipment to be used for abatement is anticipated to include prefilter, activated carbon filter, ion exchange columns and after filter.

1.5.1.3 Steam Generator Blowdown Effluent

During plant operation, steam generator blowdown is normally accommodated and processed by the Steam Generator Blowdown System (SGB). The blowdown is directed to the main condenser via a heat exchanger. If radioactivity is detected in the steam generator blowdown line, which would indicate a steam generator tube leak or rupture, the blowdown will be isolated and managed. The management route for this effluent is subject to design development.

A steam generator blowdown radiation monitor is available, which monitors radioactivity in the liquid phase of the steam generator's secondary side in the event of a leak to the secondary system from the primary system. Presence of radioactivity, above a predetermined setpoint, detected by the monitor would indicate a leak, the SGB would be isolated, and then the operator will take action to redirect the blowdown to its management route. The design of the SGB will be presented in PSR Part B Chapter 1 [45].

1.5.2 Gaseous Radioactive Waste Management

1.5.2.1 Process Gaseous Effluent

During plant operation, radioactive gasses are generated within the reactor coolant system and transported with the reactor coolant. These gases collect in tanks (such as VCTs) containing the primary coolant; these radioactive gases include fission and activation products generated as a result of normal operation. The radionuclide production mechanism is documented in PER Chapter 2 [8] under sub-section 2.4.2.

Radioactive gases are flushed from these tanks by nitrogen to the GRW. This system provides holdup of the short-lived radionuclides to sufficiently decay before monitoring and discharging to atmosphere through the stack. Positive operator action is required to initiate any controlled discharge to the environment.

The processing equipment used to treat the waste gas arisings is in development as part of the generic SMR-300 design and further information will be provided as the design matures.

1.5.2.2 Gaseous Effluent from HVAC

Air from the radiologically controlled area and containment is extracted by the Heating, Ventilation and Air Conditioning (HVAC) systems. The origins of airborne radionuclides in these areas include residual contaminants in the spent fuel pool (such as tritiated water) and neutron activation of the air around the reactor pressure vessel.

The gaseous effluent collected by HVAC systems flow through exhaust filters (such as High Efficiency Particulate Air (HEPA)) to trap radioactive particulates, and the gaseous effluent are discharged to the atmosphere via a monitored release path.

More details on the HVAC systems can be found in HI-2240777, Holtec SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities [46].

1.5.2.3 Secondary Gaseous Effluent

In the abnormal event of a steam generator leak from the primary to the secondary side, some amount of reactor coolant is carried over to the secondary side where radioactive non-condensable gases 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 through the stack. Further information will be provided as the design of the generic SMR-300 matures.

1.5.3 Solid Radioactive Waste Management

1.5.3.1 Waste Arisings

The generic SMR-300 is an advanced and passive light water nuclear power plant with a design informed by decades of operating reactor experience and industry lessons-learned.

Like other operating PWRs, several types of solid radioactive waste and non-aqueous liquid waste are expected to be generated during the normal plant operation based on PWR OPEX, including:

a) Wet solid waste

Wet solid wastes consist of spent resin, filter bed media, filter cartridges and sludges from the bottom of tanks and sumps.

- Spent resin, generated from demineralisers of CVC and Spent Fuel Pool Cooling System (SFC), and LRW ion exchangers, which abate impurities and radioactivity from the reactor coolant and fuel pool coolant, respectively.
- Filter bed media, generated from LRW activated carbon filter, which abate impurities and radioactivity in the radioactive effluents.
- Filter cartridge, generated from filters of CVC, SFC, and LRW to be used to abate the impurity and radioactivity in the reactor coolant, fuel pool coolant and radioactive effluents, respectively.

b) Dry solid waste

Dry solid waste includes HVAC filters, Personal Protective Equipment (PPE), paper, cloth, wood, plastic, rubber, glass, and metal components that are potentially contaminated during the plant operation and maintenance.

c) Miscellaneous waste (including non-aqueous liquid waste)

Miscellaneous wastes consist of contaminated oily wastes and mixed wastes, which are typically generated from maintenance or decontamination of equipment.

d) Redundant in-core components

Redundant in-core components include those that are integral to Spent Fuel Assemblies (SFAs), such as Rod Cluster Control Assemblies (RCCAs), and other redundant in-core components (e.g. redundant in-core instrumentation).

1.5.3.2 Waste Categorisation

The development of the management route of wastes depends on a wide range of considerations such as the principles of BAT and ALARP, compliance with WACs of off-site waste service infrastructures, and the waste hierarchy. These aspects will be considered to ensure that each radioactive waste stream arising from the generic SMR-300 are managed efficiently and sufficiently in the UK.

In line with the *Basic Principles of Radioactive Waste Management* [38] and *Management of Radioactive Material and Radioactive Waste on Nuclear Licensed Sites* [30], the radioactive waste is categorised into different levels of waste for their sufficient and effective management in on-site and off-site facilities, as follows:

- **High Level Waste**
  Waste that is sufficiently radioactive that the decay heat significantly increases its temperature and the temperature of its surroundings. Typical characteristics of high-level waste are thermal power above about 2 kW/m^3 [38].
- **Intermediate Level Waste**
  Waste with radioactivity levels exceeding the upper boundaries for low-level wastes, but which does not require heating to be taken into account in the design of storage or disposal facilities. IAEA guidance is that ILW thermal power is below about 2 kW/m3 [38].
- **Low Level Waste**
  Low-level radioactive waste has a radioactive content not exceeding four giga-becquerels per tonne (GBq/t) of alpha activity or 12 GBq/t beta-gamma activity [38].
- **Very Low-Level Waste (VLLW)**
  VLLW is a sub-category of LLW. Low volume VLLW can be safely disposed of to an unspecified destination with municipal, commercial, or industrial waste, each 0.1 m^3 of waste containing less than 400 kilobecquerels (kBq) of total activity or single items containing less than 40 kBq of total activity. High Volume VLLW is defined as radioactive waste with maximum concentrations of four megabecquerels per tonne (MBq/te) of total activity which can be disposed of in specified landfill sites. For waste containing tritium, the concentration limit for tritium is 40 MBq/te. [26]

In order to make sure the radioactive waste generated in the lifecycle of reactor would be efficiently and sufficiently managed in the UK, each waste stream will be classified based on the above requirements, and more details about each waste inventory will be developed.

1.5.3.3 Solid Radioactive Waste Management

The management of each waste type is described below. More details of the design and operations of the SRW could be referred to PSR Part B Chapter 13 [5], a simplified process flow diagram illustrating the management of solid radioactive waste management is provided in Appendix A.

1.5.3.3.1 Spent Resin Management

The spent resin is generated from CVC, SFC, and LRW, and they are transferred by demineralised water to the spent resin tanks, which will have appropriate capacity to accommodate the spent resin for the radioactive 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 radioactivity, and identification of principal radionuclides and alpha emitters as well as their activities. After being sampled, the spent resin in the spent resin tank is transferred to a waste container, where the spent resin in spent resin tank is dewatered to remove the free water in the waste and improve the loading capacity of the waste container After being sealed, the waste package is decontaminated and stored onsite before being dispatched to a disposal facility.

For the filter bed media, it can be transferred to an empty spent resin tank or transferred directly to a waste container depending on plant needs, which is to be determined by the future operator. The management of filter bed media in the waste container is similar to the spent resin management. To minimise the production of secondary waste, the water removed from the waste package is returned to the spent resin tank to maintain water inventory. Based on the plant needs, this water can also be transferred to the LRW for processing.

It is recognised that the waste container (High Integrity Container (HIC)) used to package filter media in the generic SMR-300 reference design is different from the standardised containers to be used in the UK due to different radioactive waste disposal requirements between UK and United States (US). The review of options for the package of ILW spent resin will be undertaken as GDA progresses.

1.5.3.3.2 Spent Filter Management

The spent filter cartridges generated from filters of CVC, SFC, and LRW is changed by a shielded transfer cask, and then transferred to a temporary storage container in the RAB where it is sampled via the PSL and temporarily stored. Based on the sampling results, the filter cartridge is transferred to its final packaging container where it is dewatered and solidified or compacted, depending on processing requirements. Excess water is removed from the filter transfer cask and sent to the LRW for processing. After being sealed, the conditioned waste package is decontaminated, and stored onsite before being dispatched to a disposal facility.

1.5.3.3.3 Dry Solid Wastes Management

Dry solid wastes are collected near the generation point and transported to the RAB for storage and processing. Contaminated solid wastes are segregated based on contact dose rates to facilitate efficient packaging and for storage prior to processing, which aligns with the requirements of waste hierarchy.

Low-activity solid dry wastes, compactible and non-compactible, are placed into a single container.

Moderate-activity dry solid wastes are sorted to separate reusable, compactable, and no-compactable wastes. Reusable contaminated items are decontaminated and returned to the appropriate storage location. Compactable contaminated items are packaged, stored, and shipped offsite for compaction. Non-compactable wastes and hazardous wastes are packaged and stored for offsite shipment.

To reduce exposures to personnel, high-activity wastes are not sorted further, and are generally packaged for an offsite disposal facility.

1.5.3.3.4 Miscellaneous Waste Management

Radioactive oily wastes and mixed wastes are collected in storage containers and stored in the RAB for offsite shipment to an appropriate disposal facility.

1.5.3.3.5 Redundant In-core Components Management

Redundant in-core components will be stored within the Spent Fuel Storage Racks (SFSRs) within the Spent Fuel Pool (SFP) (there are designated cells for both SFAs and waste within the SFSRs). RCCAs will be packaged with SFAs within Multi-Purpose Canisters (MPCs) for interim storage in the Independent Spent Fuel Storage Installation (also known as an Interim Spent Fuel Storage Installation in the UK) (ISFSI) UMAX system; other redundant in-core components will be packaged within Non-Fuel Waste Canisters (NFWC) for interim storage in the ISFSI UMAX system. More information on the management of redundant in-core components will be presented in the “Spent Fuel Management Strategy” Report.

1.5.3.3.6 Storage of Radioactive Waste Prior to Offsite Shipment.

The SRW is designed to receive wastes at all times and during all phases of station operation. It has adequate capacity to handle waste resulting from all operating modes, shutdown modes, and AOO. In the event that offsite shipment is temporarily unavailable or delayed, the SRW provides sufficient storage capacity to accommodate packaged wastes based on the expected generation rate for 30 days. The buffer storage of waste packages is also beneficial to the decay of shorter-lived radionuclides and to accumulating sufficient wastes for offsite shipment.

Due to differences in radioactive waste disposal policies in the UK and US, the design of the Interim Storage Facility (ISF) for the radioactive waste in the generic SMR-300 has not been conducted yet. This is required to ensure that all ILW waste arisings can be safely stored on site prior to offsite shipment. The options review for the ISF, before final disposal at the site-specific phase, will be undertaken.

The redundant in-core components will be stored in the ISFSI UMAX system. More information can be found in sub-chapter 1.5.3.3.5 and sub-chapter 1.5.4.

1.5.4 Spent Fuel Management

1.5.4.1 Spent Fuel Arising

The fuel design in the generic SMR-300 uses existing, state-of-the-art PWR fuel technology. A widely used and proven fuel design has been selected by Holtec to ensure sufficient OPEX is available to minimise lead times and any necessary Research and Development (R&D) activities.

The generic SMR-300 uses standard uranium dioxide (UO_2) fuel with an average enrichment of 4.9% by weight and maximum enrichment of 5% by weight. Two types of rods - the fuel rods and guide tubes are used with the arrangement of 17×17 square lattice, each fuel rod consists 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 [42].

The generic SMR-300 is designed to operate on a nominal 18-month fuel cycle with approximately one third of the fuel assemblies in the core discharged every refuelling outage. Over an 80-year operating time, approximately 1600 SFA are expected to be discharged. For the parameters related to spent fuel, refer to PSR Part B Chapter 24 [6].

1.5.4.2 Spent Fuel Management Route

As discussed in sub-chapter 1.4.7, there is no availability of a disposal facility in the UK for spent fuel so far. The policy for spent fuel management in the UK is therefore to store the fuel on site until it can be disposed of in a future GDF. Management of spent fuel on site consists of two stages.

a) Short-term storage of spent fuel within the SFP

   The SFP is located inside the Containment Structure (CS), the capacity of the SFP is designed to accommodate discharged fuel for the requisite minimum cooling period prior to discharge into a dry storage system. Spent fuel remains in the SFP until the required cooling time for dry storage is achieved.

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

   After spent fuel loaded in the MPC are removed from the SFP, the MPC is processed, dried and sealed in the RAB, and the MPC will be transported to an onsite dry storage facility using the Holtec International Storage Module Underground MAXimum Safety (HI-STORM UMAX) system before the GDF is available.

It is expected that after the third refuelling outage the discharged SFA of the first cycle will be removed from the SFP and placed into underground dry storage in the HI-STORM UMAX system.

More details about spent fuel storage in SFP can be found in PSR Part B Chapter 24 [6]. The following sub-chapter briefly describes the management of spent fuel within an interim storage facility.

1.5.4.3 Spent Fuel Interim Storage

The spent fuel dry storage system is part of the integrated fuel management and on-site interim spent fuel storage utilising Holtec's HI-STORM UMAX (Figure 2), containing an optimised MPC. HI-STORM UMAX is an underground vertical ventilated module (VVM) dry spent fuel storage system.

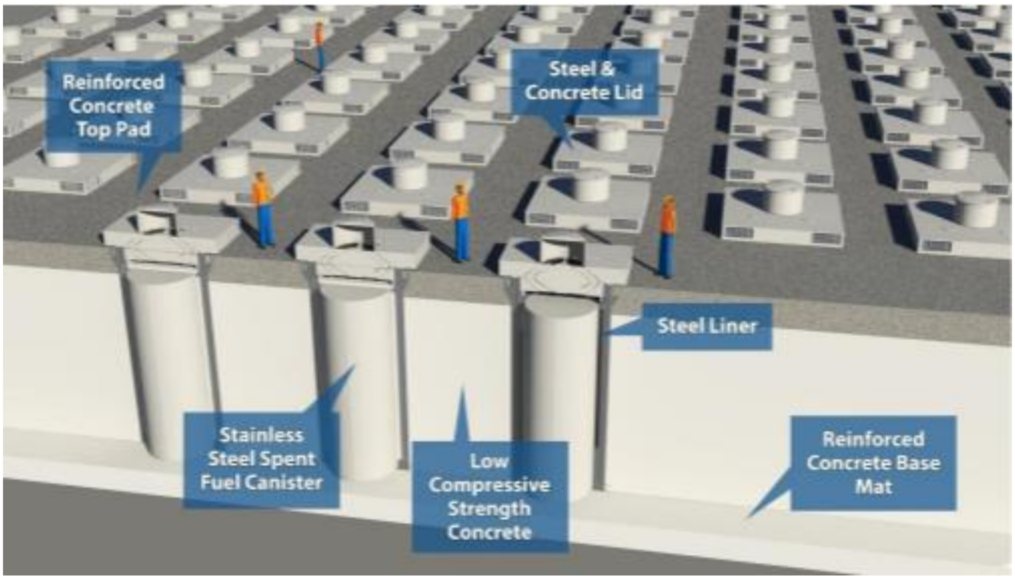

Figure 2: Holtec International HI-STORM UMAX System

Lifting, handling, processing, and transportation equipment is designed to efficiently move spent fuel from the SFP to the UMAX system. Dry storage operations performed during the refuelling outage involve the same Holtec International TRAnsfer Cask (HI-TRAC) that was used to bring in the new fuel and will move SFA into dry storage. The SFA within MPC are loaded into the HI-TRAC using the fuel handling bridge. The MPC is drained, dried, backfilled with inert gas and welded shut to provide a pressure vessel boundary as a containment/ confinement barrier for radioactivity both whilst on-site and during any subsequent off-site transport. When complete, the HI-TRAC is transferred to HI-STOR UMAX system for their long-term storage. At the dry storage facility, each HI-STORM UMAX VVM provides storage of an MPC in the vertical configuration inside a cylindrical cavity located entirely below the top-of-grade of the ISFSI. The entire inventory of spent fuel discharged over the life of the generic SMR-300 can be stored in less than 52 HI-STORM UMAX dry storage canisters per unit. On-site interim dry storage within the HI-STORM UMAX system is expected to be the storage means for spent nuclear fuel for at least the design life of the reactor. More details of the design and operation of spent fuel interim storage are presented in PSR Part B Chapter 24 [6]

Holtec dry storage systems benefit from many decades of continuous improvement and are the most widely used interim storage system globally, representing international RGP. Over 40 reactor sites use Holtec Low Profile Transporters (LTs) for cask transfers on-site. With over 2000 Holtec-designed spent fuel casks loaded to date, there is extensive OPEX available. The HI-STORM UMAX system represents the state-of-the-art in spent fuel dry storage systems. It is licensed by the NRC for generic use. The HI-STORM UMAX system is currently being deployed at a purpose built consolidated interim storage facility for spent fuel in New Mexico, USA (the HI-SAFE facility). To date over 103 MPCs have been safely loaded in HI-STORM UMAX systems, including at the San Onofre Nuclear Generating Site (SONGS), which is a power plant sited at a coastal location.

UK policy assumes that spent fuel will be re-packaged into NWS approved containers on-site, for transport to the GDF for disposal, following a required period of interim storage likely to be 100 years or more. To support the development of safety case and environment case for spent fuel, a spent fuel management strategy aligned with UK policy will be prepared, covering lifecycle management of spent fuel, any failed fuel and redundant in-core components. This will justify any deviations/ non-conformances with UK policy, strategy and regulatory frameworks, and will also describe alternative strategic options for spent fuel management.

1.5.5 Decommissioning Waste Management

According to IAEA General Safety Requirements Part 6, Decommissioning of Facilities [47], there are two possible decommissioning strategies:

a) Prompt dismantling, whereby decommissioning activities take place immediately after permanent shutdown.
Under this strategy, the equipment, structures, systems and components of a facility containing radioactive material are removed and/or decontaminated to a level that allows the facility to be released from regulatory control for unrestricted use or released with restrictions on its future use.
b) Deferred dismantling with varying periods of deferral that are in principle applicable for all facilities.
This strategy is intended to realise specific benefits such as radioactive decay which can reduce worker dose and radioactivity, and the volume of radioactive waste produced when decommissioning resumes. Under this strategy, after removal of the nuclear fuel from the facility (for nuclear installations), all or parts of a facility containing radioactive material is either processed or placed in such a condition that it can be kept in a safe and stable condition for varying time periods.

In the UK, entombment is not recognised as a planned decommissioning strategy [26], it is appropriate only under exceptional circumstances, for example, following a severe accident in line with IAEA requirements [47]. The decommissioning strategy development should be informed by the safety and environmental requirements, technical considerations and local conditions, such as the intended future use of the site. The considerations about decommissioning strategy are described in PSR Part B Chapter 26 Decommissioning Approach [7].

In order to prevent and/or minimise the generation of radioactive decommissioning waste, and reduce the impact of decommissioning activities on the workers, the public and environment, the following main design features facilitating decommissioning are identified in the design of 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.
- Radiological data and design information management to facilitate decommissioning.

It is recognised that above design features also are beneficial to the prevention and/or minimisation of the production of decommissioning waste. The detailed consideration on design for decommissioning are discussed in PSR Part B Chapter 26 Decommissioning Approach [7].

During the reactor decommissioning stage, various radioactive wastes will be unavoidably generated, especially in the process of decontamination and dismantling of SSCs. According to worldwide decommissioning OPEX, solid waste accounts for the largest part of decommissioning waste generated during the plant decommissioning stage, including:

- The decommissioning waste is the waste generated during dismantling activities, mainly including contaminated concrete and piping, and internal components.
- The secondary waste is typically generated during various decontamination and dismantling activities, e.g. decontamination of components, cutting of components, decommissioning waste treatment or flushing of contaminated systems. It typically consists of liquid waste, gaseous waste, spent ion exchange resins, spent filters, and miscellaneous solid waste.

Liquid and gaseous waste will be managed by mobile facilities or existing waste management systems, such LRW, GRW or HVAC systems, which will be determined by future operators taking account of the assessment of ALARP and BAT on existing systems, the requirements of radioactive waste treatment and disposal/discharge at the decommissioning stage.

Solid waste will be classified in terms of VLLW, LLW and ILW, and managed by existing solid waste or mobile facilities with the same approach as operational waste for suitable wastes based on the assumption in sub-chapter 1.2.5. Packaged VLLW and LLW will be sent to off-site facilities for treatment or final disposal by use of BAT as well as waste hierarchy. For packaged ILW, they will be stored on site if a GDF is not available in the decommissioning stage. The detailed information about decommissioning waste inventory will be developed considering the PWR OPEX.

1.6 SUMMARY

This chapter has presented the proposed arrangements for the management of radioactive waste and spent fuel arising over the lifecycle of the reactor, with due consideration of the appropriate RSR principles, GDA guidance and scope, which aims to meet regulatory expectations and requirements commensurate with the GDA scope.

Similar to other PWRs in operation, wastes arising from the generic SMR-300 are expected to include radioactive liquid, gaseous and solid wastes from 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 by providing details on the waste management systems.

As the GDA progresses, the radioactive waste management arrangements will be developed further for the purpose of a meaningful assessment of radioactive waste management arrangements. Additionally, it is recognised that the BAT demonstration will be undertaken to justify the radioactive waste management commensurate with GDA scope [4].

Next steps have been determined to ensure a meaningful GDA can be undertaken within this chapter, together with Forward Actions (FAs) for additional supporting documents to be completed to ensure all relevant GDA requirements can be met. FAs have been collated and are managed via the process described in HI-2240335, PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [11].

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1.8 LIST OF APPENDICES

Appendix A Simplified Flow Diagram of Solid Radioactive Waste Management