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6.1 ACRONYMS AND ABBREVIATIONS

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

Table 1: Acronyms and Abbreviations

Term	Definition
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ANS	American Nuclear Society
ANSI	American National Standards Institute
AOO	Anticipated Operational Occurrence
AR	Annular Reservoir
BAT	Best Available Techniques
BATC	BAT Conclusions
BREEAM	Buildings Research Establishment Environmental Assessment Method
BREF	BAT reference document
BS	British Standards
CAE	Claims, Arguments and Evidence
CAR	Commitments, Assumptions, Requirements
CBV	Containment Ventilation System
CCTV	Closed-Circuit Television
CEC	Cavity Enclosure Container
CES	Containment Enclosure System
CFR	Code Federal Regulations
CGC	Combustible Gas Control System
CIV	Containment Isolation Valve
CLDP	Contaminated land and groundwater generic developed principles
Co	Cobalt
COMAH	Control of Major Accident Hazards
CRS	Circulating Water System
Cs	Caesium
CS	Containment Structure
CVC	Chemical and Volume Control System
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DFC	Damaged Fuel Container
DPUC	Dose Per Unit Concentration
DPUR	Dose Per Unit Release
DRP	Design Reference Point
DWMP	Decommissioning Waste Management Plan
DWS	Demineralised Water Transfer System
EA	Environment Agency
EIMT	Examination, Inspection, Maintenance and Testing
ELV	Emission Limit Values
EN	European Stanards

Term	Definition
ENDP	Engineering generic developed principles
EPF	Environmental Protection Function
EPM	Environmental Protection Measure
EPR16	Environmental Permitting (England and Wales) Regulations 2016
EPRI	Electric Power Research Institute
ERICA	Environmental Risk from Ionising Radiation Contaminants: Assessment and Management
EU	European Union
F-gas	Fluorinated gas
FDP	Funded Decommissioning Plan
FHISO	Full-Height International Organization for Standardization Container
FSAR	Final Safety Analysis Report
GALE	Gaseous And Liquid Effluents
GDA	Generic Design Assessment
GDC	General Design Criteria
GDF	Geological Disposal Facility
GDP	Generic Developed Principles
GDT	Gas Decay Tank
GRR	Guidance on Requirements for Release
GRW	Gaseous Radwaste System
GSD	Generic Site Description
GSE	Generic Site Envelope
HEPA	High Efficiency Particulate Air
HHISO	Half-Height International Organization for Standardization Container
HI-STAR	Holtec International Storage, Transport & Repository
HI-STORM	Holtec International Storage Module
HI-TRAC	Holtec International Transport Cask
HIC	High Integrity Container
HRGS	High Resolution Gamma Spectroscopy
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IB	Intermediate Building
ICS	Industrial Cooling System
IEC	International Electrotechnical Commission
IED	Industrial Emissions Directive
ILW	Intermediate Level Waste
IRAT2	Initial Radiological Assessment Tool 2
ISF	Intermediate Storage Facility
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance
ISO	International Organization for Standardization
IWS	Integrated Waste Strategy
Li	Lithium
LLW	Low Level Waste
LOOP	Loss Of Off-site Power
LRW	Liquid Radwaste System
MCERTS	Monitoring Certification Scheme

Term	Definition
MCPD	Medium Combustion Plant Directive
MOU	Memorandum Of Understanding
MPC	Multi-Purpose Canister
MSQA	Management of Safety and Quality Assurance
N/A	Not Applicable
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NFW	Non-Fuel Waste
NFWC	Non-Fuel Waste Container
NI	Nuclear Island
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
NWS	Nuclear Waste Services
ODS	Ozone Depleting Substances
OPEX	Operational Experience
P&ID	Piping & Instrumentation Diagram
PCER	Pre-Construction Environmental Report
PCMWS	Passive Core Make Up Water System
PCSR	Pre-Construction Safety Report
PER	Preliminary Environmental Report
PSL	Primary Sampling System
PSR	Preliminary Safety Report
PST	Primary Source Term
PWR	Pressurised Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
QA	Quality Assurance
QAM	Quality Assurance Manual
QEDL	Quantification of Effluent Discharges and Limits
RAB	Reactor Auxiliary Building
RCCA	Rod Cluster Control Assembly
RCS	Reactor Coolant System
RCV	Radiologically Controlled Area HVAC System
RDS	Radioactive Drain System
RGP	Relevant Good Practice
RIA	Radiological Impact Assessment
RMS	Radiation Monitoring System
RP	Requesting Party
RPV	Reactor Pressure Vessel
RPDP	Radiological Protection of People and the Environment Developed Principle
RSC	Robust Shielded Container
RSMDP	Radioactive Substances Management Developed Principles
RSR	Radioactive Substances Regulation
RWB	Radioactive Waste Building
RWMA	Radioactive Waste Management Arrangements
RWMC	Radioactive Waste Management Case
SAP	Safety Assessment Principle

Term	Definition
SDD	System Design Description
SDH	Secondary Decay Heat
SDHRS	Secondary Decay Heat Removal System
SFA	Spent Fuel Assembly
SFC	Spent Fuel Pool Cooling System
SFP	Spent Fuel Pool
SFSR	Spent Fuel Storage Racks
SGE	Steam Generator
SMR-300	Small Modular Reactor-300
SRW	Solid Radwaste System
SSA	Secondary Source Assembly
SSC	Structures, Systems and Components
SSEC	Safety, Security and Environment Case
SWESC	Site-Wide Environmental Safety Case
SWS	Service Water System
TAG	Technical Assessment Guides
UK	United Kingdom
UMAX	Underground Maximum Capacity
URD	Utility Requirements Document
US	United States
U.S.NRC	United States Nuclear Regulatory Commission
VCT	Volume Control Tank
VLLW	Very Low Level Waste
VVM	Vertical Ventilated Module
WAC	Waste Acceptance Criteria
WMP	Waste Management Plan
Zn	Zinc

6.2 INTRODUCTION

6.2.1 Purpose

The Fundamental Purpose of the Generic Design Assessment (GDA) Safety, Security and Environment Case (SSEC) is to demonstrate that the generic Small Modular Reactor (SMR)-300 can be constructed, commissioned, operated, and decommissioned on a generic site in the United Kingdom (UK) to fulfil the future licensee's legal duties to be safe, secure and protect people and the environment.

The Fundamental Purpose is achieved through the Fundamental Objectives of the Preliminary Environmental Report (PER) and Preliminary Safety Report (PSR). The objectives are to summarise the environmental and safety standards and criteria that are being applied and the management system and organisation through which this is being achieved, together with the associated Claims, Arguments and Evidence (CAE) structure.

In accordance with this intent, this chapter provides the demonstration of BAT for the generic SMR-300 in order to ensure the radiological risks to people As Low As Reasonably Achievable (ALARA). This chapter follows the CAE model which provides a transparent framework for the demonstration of BAT. The CAE model is well-established in the UK and is routinely used in the development of safety and environmental cases for nuclear facilities [2].

6.2.2 Scope

Within this chapter, the fundamental aspects focussed on in the demonstration of BAT in the generic SMR-300 are:

1. Prevent the unnecessary creation of radioactive wastes and/or discharges.
2. Minimise the quantity and activity of any radioactive wastes and/or discharges created.
3. Minimise the impacts of radioactive wastes and/or discharges on people and the environment.

Deciding what can reasonably be achieved must take into account the environmental, social and economic factors associated with the activity creating the exposure [3], therefore, the approach to BAT will consider a number of attributes in addition to these three fundamental aspects.

Claims are presented in this chapter on conventional impacts in the interest of completeness, but recognising the different approach taken in the conventional environmental protection. For more information on conventional environmental aspects, see PER Chapter 4 Conventional Impact Assessment [4].

The regulatory context for BAT is presented in the Approach and Application to the Demonstration of BAT [5] which is also summarised in sub-chapter 6.4 of this chapter. Approach and Application to the Demonstration of BAT [5] also includes a detailed discussion on the scope of BAT, recognising for example that it applies across the whole lifetime of the plant and to normal operations including expected events.

The BAT methodology and proportionate optioneering process is detailed in the SMR-300 GDA RSR-BAT Guidance [6] and is summarised in sub-chapter 6.5 of this chapter.

Recognising that sites for this GDA are in England and Wales, this chapter is focused on the requirements of the Environment Agency (EA) and Natural Resources Wales (NRW) (referred to as the environment agencies).

6.2.3 Chapter Structure

This chapter is structured to provide information required for a meaningful GDA assessment and to help demonstrate the application of BAT to the generic SMR-300. The main structure of this chapter consists of:

- Sub-chapter 6.1: provides the abbreviations and definitions.
- Sub-chapter 6.2: introduces the scope, chapter structure, interfaces with other SSEC chapters and assumptions.
- Sub-chapter 6.3: outlines the generic SMR-300 design in order to provide the context of the relevant SSCs.
- Sub-chapter 6.4: presents the regulatory context, including regulatory expectations and requirements as well as key legislative and regulatory documents.
- Sub-chapter 6.5: presents the BAT methodology and optimisation process that have been developed for the generic SMR-300.
- Sub-chapter 6.6: sets out the structure of the CAE and introduces this chapters claims.
- Sub-chapter 6.7: presents the arguments and evidence for the demonstration of BAT under Claim 3: Regulatory Principles and Requirements.
- Sub-chapter 6.8: presents the arguments and evidence for the demonstration of BAT under Claim 4: Environmental Protection.
- Sub-chapter 6.9: provides a summary of the document including the CAE which demonstrate the generic SMR-300 uses BAT.
- Sub-chapter 6.10: provides a list of reference material used within the document.
- Sub-chapter 6.11: includes relevant appendices.

6.2.4 Interfaces with other SSEC Chapters

The chapters in the PER and PSR that interface with this chapter and a brief description of that chapter are detailed in Table 2 below.

Table 2: Interfaces with other chapters

SSEC Chapter	Interface
PER Chapter 1 Radioactive Waste Management Arrangements [7] (RWMA)	This chapter presents the management arrangements and strategy for radioactive waste and spent fuel arising over the lifecycle of the plant.
PER Chapter 2 Quantification of Effluent Discharges and Limits [8] (QEDL)	This chapter presents the estimated quantities and indicative limits of liquid and gaseous effluents discharged during normal operation.
PER Chapter 3 Radiological Impact Assessment [9] (RIA)	This chapter presents the methods and data for assessing the prospective societal and environmental dose impact from discharges, of gaseous and aqueous-liquid effluents.
PER Chapter 4 Conventional Impact Assessment [4]	This chapter presents conventional aspects of the generic SMR-300 design which have the potential to result in conventional environmental impacts. This chapter also takes into consideration sustainability.
PER Chapter 5 Monitoring and Sampling [10]	This chapter presents information relating to monitoring and sampling arrangements, techniques, and systems for measuring and assessing discharges and disposals of radioactive waste for the generic SMR-300.
PSR Part A Chapter 1 Introduction [11]	This chapter provides the introductory information required for the GDA process including the structure of the PER.

SSEC Chapter	Interface
PSR Part A Chapter 2 Generic Design and Site Characteristics [1]	This chapter presents general description of the facilities in the reference design. It also sets out the principles and approach used in selecting the codes and standards used for the SMR-300 that contribute to development of the PER.
PSR Part A Chapter 3 Claims, Arguments and Evidence [12]	This chapter summarises the CAE, which includes high-level claims that the PER should substantiated in the GDA process.
PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [13]	This chapter describes safety management and quality assurance applied during the GDA process and its requirements, which are suitable for the development of the environment case.
PSR Part A Chapter 5 Summary of ALARP and SSEC [14]	This chapter presents the demonstration that risks outlined within the PSR are reduced to As Low As Reasonably Practicable (ALARP), significant design decisions have appropriately considered ALARP.
PSR Part B Chapter 2 Reactor Fuel and Core [15]	This chapter presents information on the reactor fuel and core design of the generic SMR-300 design, which include relevant design aspects contributing to the development of the environment case, e.g. BAT demonstration.
PSR Part B Chapter 5 Reactor Supporting Facilities [16]	This chapter provides design information on auxiliary systems, Steam and Power Conversion Systems, and Heating, Ventilation and Air Conditioning (HVAC) systems of the SMR-300 design, which include relevant design aspects contributing to the development of environment case, e.g. BAT demonstration, RWMA, and monitoring and sampling.
PSR Part B Chapter 9 Conduction of Operations [17]	This chapter is focussed on the operational phase of the generic SMR-300 and discusses the Examination, Inspection, Maintenance and Testing (EIMT) programme.
PSR Part B Chapter 10 Radiological Protection [18]	This chapter provides a description on the source term of radioactive waste generated by the generic SMR-300, which contribute to the development of the environment case, e.g. RWMA, QEDL, and RIA.
PSR Part B Chapter 13 Radioactive Waste Management [19]	This chapter describes the design and operations of liquid, gaseous and solid radioactive waste treatment systems for the generic SMR-300, which include relevant design aspects contributing to the development of the environment case, e.g. BAT demonstration, and RWMA.
PSR Part B Chapter 19 Mechanical Engineering [20]	This chapter presents design information about the mechanical engineering design of SSCs, which include relevant design aspects contributing to the development of the environment case, e.g. BAT demonstration, and RWMA.
PSR Part B Chapter 23 Reactor Chemistry [21]	This chapter describes the reactor chemistry regime with focus on how the selected chemistry regimes have been designed to align to state of the art water chemistry programmes which minimise radiological source term and ensure controlled retention of radioactivity. This inherently contributes to the development of the environment case.
PSR Part B Chapter 24 Fuel Transport and Storage / Spent Fuel Management [22]	This chapter provides the design information about the generic SMR-300 fuel transport and storage arrangements. SSCs involved in fuel transport and storage and Operational Experience (OPEX) on the handling and storage of spent fuel, which contribute to the development of the environment case, e.g. BAT demonstration and RWMA.
PSR Part B Chapter 25 Construction and Commissioning [23]	This chapter outlines the intent in developing a generic SMR-300 construction and commissioning programme.
PSR Part B Chapter 26 Decommissioning Approach [24]	This chapter describes the detailed consideration for the decommissioning strategy and the design to facilitate decommissioning as well as the anticipated decommissioning wastes, which contribute to the development of the environment case, e.g. BAT demonstration.

6.2.5 Assumptions

General assumptions in the management of BAT are captured in the Holtec SMR-300 GDA Approach and Application to the Demonstration of BAT [5].

6.3 OVERVIEW OF GENERIC SMR-300

The generic SMR-300 is a two-loop Pressurised Water Reactor (PWR) with forced circulation in normal operation. The design has two cold legs each with a vertically mounted Reactor Coolant Pump, two hot legs, and a single once-through Steam Generator (SGE) with an integral pressuriser stacked on top of the SGE. The plant design is simplified relative to operating plants and incorporates passive and robust safety systems.

Detailed descriptions of the generic SMR-300 are also available in PSR Part A Chapter 2 General Design Aspects and Site Characteristics [1] and the generic SMR-300 Plant Overview [25].

For the purpose of this GDA, a twin-unit configuration is proposed for the generic site [1]. This twin-unit arrangement enables shared buildings and systems, a more compact footprint, and a reduced overall cost of the plant on a per MWe basis, as compared to single unit configurations [26]. The SMR-300 offers at least 300 MWe net electrical power and is designed for 80 years of operation [25].

The GDA scope comprises operations within the Nuclear Island (NI) and the on-site fuel store. It includes the following buildings [1]:

- Containment Enclosure Structure (CES).
- Containment Structure (CS).
- Reactor Auxiliary Building (RAB).
- Intermediate Building (IB).
- Independent Spent Fuel Storage Installation (ISFSI)

Holtec's objective is to design, develop and build SMR-300s with a mindset that weighs the lifecycle cost against the need to control the risks of SMR-300 deployment across multiple sites worldwide, whilst ensuring the fundamental safety and security of the design [27].

Detailed descriptions of the generic SMR-300 are available in PSR Part A Chapter 2 General Design Aspects and Site Characteristics [1] and the generic SMR-300 Plant Overview [25].

6.4 REGULATORY CONTEXT

This sub-chapter provides an overview of the legislative and regulatory framework relating to the use of BAT, alongside other important sources of information, including regulatory guidance and permit conditions covering Radioactive Substances Regulation (RSR) activities. A more comprehensive overview of the UK regulatory regime is set out in the Approach and Application to the Demonstration of BAT [5].

6.4.1 GDA Requirements

The New Nuclear Power Plants: Generic Design Assessment Guidance for Requesting Parties [28] provides guidance by the Office for Nuclear Regulation (ONR) and EA on public and environmental protection arrangements for new Nuclear Power Plants (NPP). The guidance refers to the development of an environment case to help a Requesting Party (RP) to demonstrate regulatory requirements have been met and BAT has been used to prevent and/or minimise harm to the public and the environment. The two key objectives of the environment case are to:

- Outline how the nuclear power plant design meet regulatory requirements and expectations.
- Demonstrate the use of BAT to prevent or minimise harm to the public and the environment in the design.

GDA Guidance for Requesting Parties [28] outlines information the RP must provide to the environment agencies to complete an assessment of the PER. Table 3 below details where the full GDA information requirements relevant to BAT are appropriately considered across the SSEC.

Table 3: Alignment Analysis between GDA Submissions and GDA Information Requirements Directly Relevant to BAT

GDA Requirements for Step 2 Assessment	Information as Part of GDA
The RP's approach and methodology for determining BAT to prevent or minimise radioactive wastes and their impact during the lifecycle of the plant – design, construction, commissioning, operation and decommissioning.	Holtec SMR-300 GDA Approach and Application to the Demonstration of BAT [5].
Worked examples demonstrating the BAT approach and methodology sufficient to provide confidence that any fundamental concerns should be identified in Step 2.	Worked examples produced in accordance with the RP's approach as set out SMR-300 GDA RSR-BAT Guidance [6] include: • Non-Fuel waste Packaging BAT Workshop Output Report [29]. • Holtec SMR-300 GDA BAT Statement – Li Enrichment [30].
Establishing the methodology used for identifying BAT and making sure they are used in the design.	Approach and Application to the Demonstration of BAT [5] for the approach to demonstrating BAT, SMR-300 GDA RSR-BAT Guidance [6] for more details on optioneering methodology and proportionality and Design Management [31] for information on how optioneering is performed during design changes).
A description of the optimisation process used to identify and justify that the proposed techniques are BAT	Holtec SMR-300 GDA Approach and Application to the Demonstration of BAT [5] and SMR-300 GDA RSR-BAT Guidance [6].

GDA Requirements for Step 2 Assessment	Information as Part of GDA
The justifications for each of the techniques that have been identified as BAT. The justifications for how each of the techniques have been implemented or will be implemented in the design so that they are BAT.	Justifications for techniques are set out in the Arguments and Sub-Arguments in this Chapter.
The RP must demonstrate that their proposals represent BAT for monitoring and confirm that the sensitivity is sufficient to: • Readily demonstrate compliance with the proposed limits. • Meet the levels of detection specified in 2004/2/Euratom, which we consider to be good practice.	PER Chapter 2 QEDL [8] presents the effluent limits. PER Chapter 5 Monitoring and Sampling [10] presents the demonstration of meeting required levels of detection. This chapter presents a summarised BAT position in Argument 4.7-A1: Parameters to be Monitored.

6.4.2 Radioactive Substances Regulation and Principles

6.4.2.1 Radioactive Substances Regulation: Objective and Principles

The EA sets out the RSR fundamental objective and regulatory principles that are taken into account in their regulatory duties [3]. The three RSR overarching principles relating to BAT are:

- Principle 2: Optimisation.
- Principle 7: Lifetime Planning for Radioactive Substances.
- Principle 8: BAT.

6.4.2.2 Radioactive Substances Regulation: Generic Developed Principles

The RSR: Generic Developed Principles (RSR: GDP) [32] build upon the overarching aims of the RSR as set out in the RSR: Objective and Principles [3] and specify the EA's expectations from those holding an RSR permit. BAT is a common theme throughout the RSR: GDP. Within the GDPs there are over 25 references to BAT, which highlights the importance put on BAT as a theme. It is particularly a focus within:

- Radioactive Substances Management Developed Principles (RSMDP) [33].
- Radiological Protection of People and the Environment Developed Principles (RPDP).
- Engineering Developed Principles (ENDP) [34].
- Contaminated Land and Groundwater Developed Principles (CLDP) [35].

It should be noted that the RSR: GDP on Decommissioning was withdrawn in May 2024. The principles have been replaced by the Guidance for Nuclear Sites undergoing Decommissioning which are also relevant to the demonstration of BAT [36].

6.4.3 Environmental Permitting (England and Wales) Regulations

The Environmental Permitting (England and Wales) Regulations 2016 (as amended) [37] (EPR16) provide the environment agencies the legal basis from which to regulate activities related to radioactive substances. They cover all wastes (conventional and radioactive) and emissions (aqueous and gaseous discharge to the environment) and include the generation of radioactive wastes and their disposal to a permitted site.

The requirement to ensure doses to the public and population as a whole resulting from radioactive waste disposal activities are kept ALARA is set out in Schedule 23 Part 4 of the EPR16 [37].

prospective operators of nuclear facilities must obtain a radioactive substances activity permit under EPR16, from the relevant environment agency (the EA or NRW) before keeping, using or disposing of radioactive materials or waste. RSR activity permits contain conditions that specify the use of BAT [38].

6.5 BAT METHODOLOGY AND OPTIMISATION PROCESS

The RP has incorporated an integrated approach to optioneering. Conventional safety, costs, technology and radiological hazards are considered alongside the environment within a systematic optimisation process to ensure a BAT option is reached, which meets all legislative requirements and aims to address conflicts via collaboration [6].

For the generic SMR-300, the following approaches have been undertaken to demonstrate BAT:

- **Claims, Arguments and Evidence Approach** (sub-chapter 6.5.1) – Provides a systematic, evidence-based approach for substantiating claims made regarding the environmental performance of the design. It provides a transparent framework for the demonstration of BAT in the design of NPPs involving the assembly of coherent and robust arguments.
- **Options appraisal approach** (sub-chapter 6.5.2) – Employed to support the CAE approach for assessments where there are clear alternatives that can be compared against each other in order to readily determine what is optimal. Optioneering can be used to consider a number of aspects or attributes in conjunction, for example environment, safety, radiation protection etc. The approach for the generic SMR-300 is set out in SMR-300 GDA RSR-BAT Guidance [6].

6.5.1 Claims, Arguments and Evidence Approach

The CAE model is applied in the development of the Chapter 6 for the generic SMR-300. All claims and arguments were developed by the RSR-BAT Topic Lead, in consultation with specialist topic areas. Arguments and evidence will evolve with the maturity of the design beyond GDA.

A breakdown of the RP's CAE for the entirety of the SSEC can be found in PSR Part A Chapter 3 Claims, Arguments and Evidence [12] whilst a breakdown of the CAE for the PER can be found within this document, a route map is presented in Appendix A.

6.5.1.1 Claims

Each claim is a clear true / false statement or assertion with respect to the intent of the generic SMR-300. Claims were derived based on demonstrating compliance with RSR permit conditions or environmental principles that need to be taken into account to apply BAT. Claims must be supported by one or more arguments.

6.5.1.2 Arguments

Arguments provide the reasoning as to why a claim is satisfied. They are a series of robust justifications which are presented to validate a claim, and typically involves identification of design features and functionality that support a claim. Each argument draws the evidence together into a 'story'.

Arguments are expressed in a level of detail that is commensurate with the relevant generic SMR-300 system's design maturity. Attributes of an argument include, but are not limited to the following:

- An outline of the context or issue that explores why it is important to the application of BAT.
- Discussion on how relevant features of the generic SMR-300 contribute to delivering high levels of performance in environmental protection.
- Statements that clearly articulate what has been demonstrated.

6.5.1.3 Evidence

Evidence presents the facts, information or data that is used to demonstrate that the supporting arguments made for each claim are appropriately substantiated. Evidence shall be presented to an appropriate granularity so that it can be readily examined and challenged where necessary in accordance with the requirement for transparency in the identification of BAT. Evidence sections in this chapter signpost out to source materials which may originate from Holtec Britain or Holtec International.

Through engagement with the EA requirements for a meaningful 2-Step GDA assessment were discussed. We recognise the BAT demonstration will continue to develop as design maturity develops and this is discussed more under argument 3.2-A4-SA3 on Future Evidence.

Figure 1 illustrates the CAE philosophy where a claim about the design is made and the evidence can be listed to show why this claim is substantiated. The argument then links the claim and argument together to state why (or argue) that the evidence substantiates the claim.

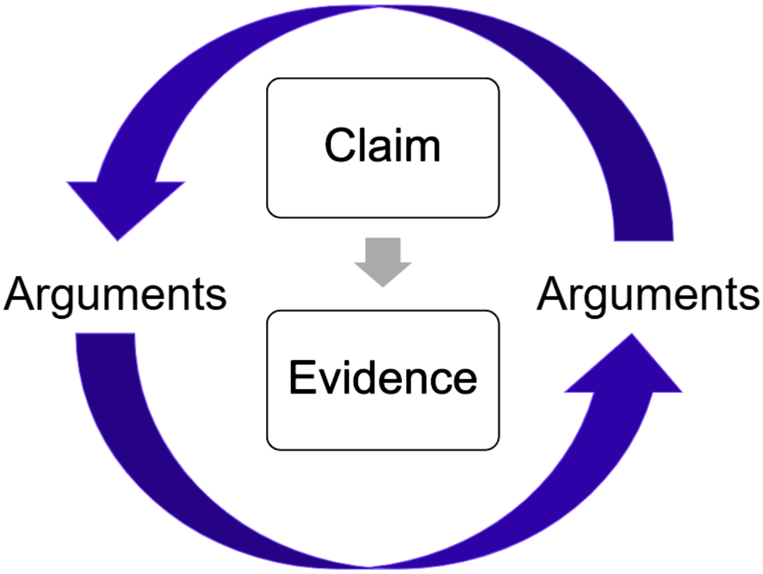

Figure 1: CAE Philosophy

6.5.2 Options Appraisal Approach

Figure 2 below presents the RP's approach to applying BAT optioneering to the generic SMR-300 design. The full BAT optioneering methodology is described in the SMR-300 GDA RSR-BAT Guidance [6] and is applied with consideration to the SMR-300 UK GDA ALARP Guidance Document [39] and the GDA SMR-300 Design Stability Toolkit [27], in order to ensure an aligned approach to safety and environmental optimisation.

SMR-300 GDA RSR-BAT Guidance [6] was applied during GDA to produce the following worked examples:

- Non-Fuel Waste Packaging BAT Workshop Output report [29], supported by Workshop Briefing Pack [40].
- Holtec SMR-300 GDA BAT Statement – Li Enrichment [30].

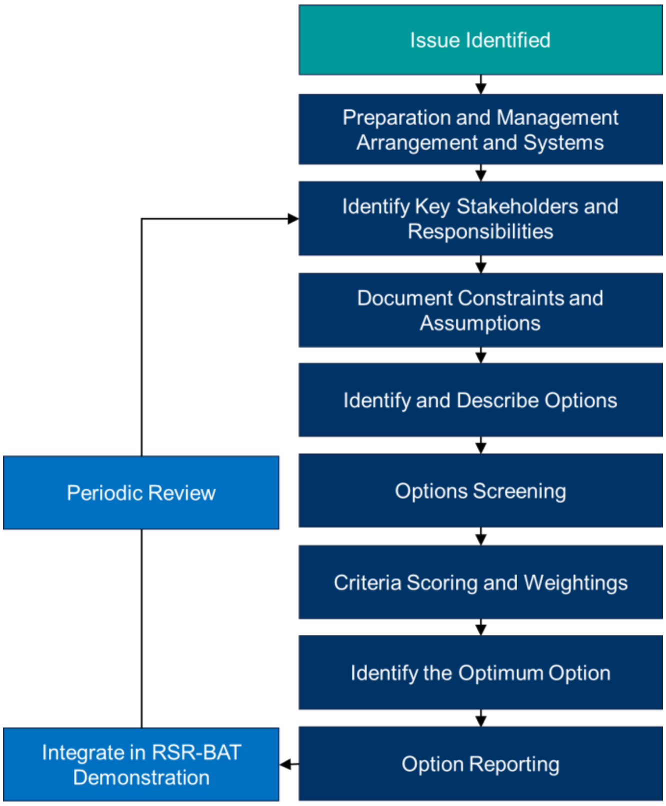

Figure 2: Methodology for Determining, Implementing and Maintaining BAT

6.6 DEMONSTRATION OF CLAIMS

The following sub-chapters 6.7 and 6.8 present the claims, arguments and evidence established to demonstrate BAT and optimisation in the generic SMR-300 design for the PER, as part of the wider SSEC.

The overarching claims for the generic SMR-300 SSEC are presented in Holtec SMR-300 GDA PSR Part A Chapter Claims, Arguments & Evidence [14].

This PER chapter covers the level one and level two claims (referred to as sub-claims) presented in Table 4 below. In total there are nine sub-claims that have been developed to comply with the legislative requirements and consider regulatory expectations as set out in the UK regulatory regime and requirements of any future RSR environmental permit.

Table 4: PER Claims and Sub-Claims

Claim Title and Description	Sub-claim Number	Sub-claim Title and Description
Claim 3: Environmental Principles Environmental principles are implemented such that the generic Holtec SMR-300 design meets the Environmental Objective.	**Claim 3.1**	**Regulatory Principles and Requirements** The generic Holtec SMR-300 design identifies relevant regulatory principles and requirements to meet the Environmental Objective.
	Claim 3.2	**Full Lifecycle Assessment** The generic Holtec SMR-300 Environment Case addresses relevant regulatory principles and requirements across the entire reactor lifecycle.
Claim 4: Environmental Protection The generic Holtec SMR-300 design is developed so far as is reasonably achievable to provide optimal protection of people and the environment.	**Claim 4.1**	**Generation of Radioactive Wastes** The generation of all radioactive wastes is prevented where achievable, or otherwise minimised.
	Claim 4.2	**Quantity of Radioactive Wastes** Where prevention is not possible, the mass and/or volume of radioactive wastes, including discharges, disposals and transfers to other premises is minimised.
	Claim 4.3	**Activity of Radioactive Wastes** The activity of radioactive wastes from discharges, disposals and releases to the environment is minimised.
	Claim 4.4	**Impacts of Radioactive Wastes** The impacts of radioactive wastes including discharges and disposals from the generic SMR-300 have been minimised. Radiation doses to any individual member of the public and the population as a whole are as low as reasonably achievable. Non-human species are adequately protected against exposures to ionising radiation.
	Claim 4.5	**Non-Radioactive Aspects of Radioactive Wastes** Potentially adverse non-radiological impacts of radioactive wastes are precluded or, where this is not possible minimised.
	Claim 4.6	**Conventional and Non-Radioactive Impacts** Conventional environmental impacts from the generic SMR-300 are in compliance with all relevant legislation, taking into account BAT reference documents (BREFs) where relevant.
	Claim 4.7	**Monitoring and Sampling** The Generic SMR-300 includes appropriate monitoring and sampling arrangements for measuring and assessing discharges, disposals and transfers to other premises of radioactive waste to demonstrate compliance with the proposed limits and provide an indication of plant performance.

BAT arguments and sub-arguments (where appropriate) support each sub-claim and are followed by evidence (illustrated in Figure 3 below) that has been gathered during the GDA and considered commensurate with generic SMR-300's design maturity and the requirements of a 2-Step GDA.

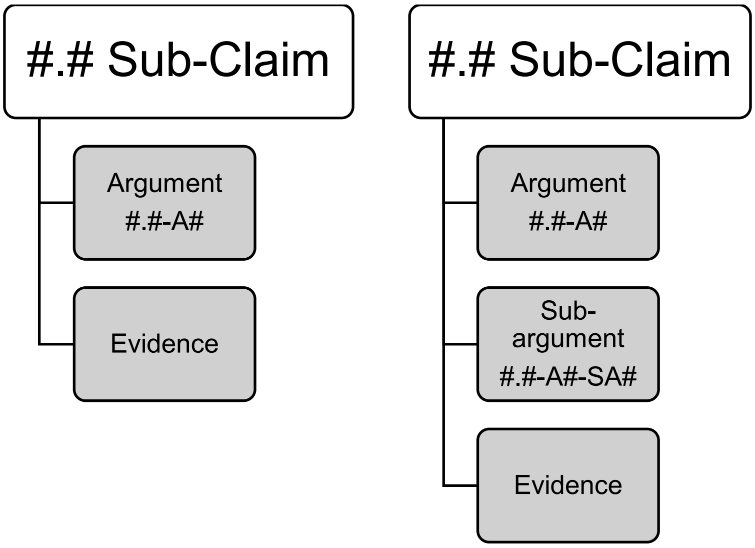

Figure 3: Presentation of CAE in this Chapter

Sub-chapters have adopted a hierarchical structure to aid navigation of the CAE. The hierarchy of the PER CAE can be followed by looking at the relevant headings and numbering system for ease of reference (i.e., 4.1-A1-SA1 indicates that this sits within Claim 4.1, under argument one and sub-argument one). The PER CAE is also presented pictorially in figures at the beginning of each claim or argument. See Figure 4 below for an example of this style of figure.

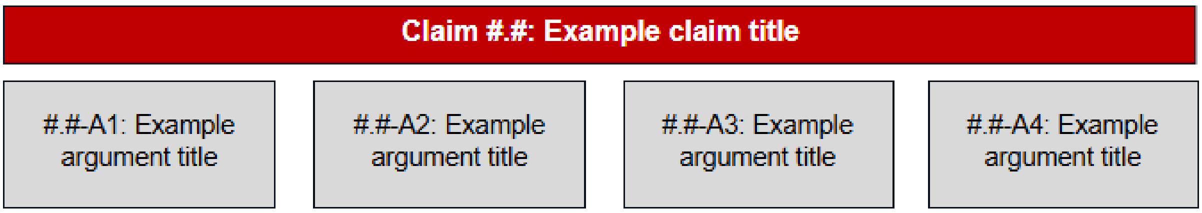

Figure 4: Example Claim and Argument Decomposition Figure

6.7 CLAIM 3: ENVIRONMENTAL PRINCIPLES

Claim 3: Environmental Principles *Environmental principles are implemented such that the Holtec Generic SMR-300 design meets the Environmental Objective.*

The Fundamental Objective of the PER, is presented in PSR Part A Chapter 1 [11]:

"The PER presents the environmental standards, criteria and management arrangements to provide confidence that the design, construction, operation and decommissioning of the generic SMR-300 will protect people and the environment from harm and will apply Best Available Techniques and incorporate relevant good practice and operating experience."

6.7.1 Claim 3.1 Regulatory Principles and Requirements

Claim 3.1: Regulatory Principles and Requirements *The Generic SMR-300 design identifies relevant regulatory principles and requirements to meet the Environmental Objective.*

Under the EPR16 [37] the relevant environment agency is responsible for granting an RSR permit to a prospective NPP operator. During the GDA process, NPP designers and development organisations can utilise the suite of available RSR guidance in preparing the PER, which then becomes the foundation for developing the Pre-Construction Environmental Report (PCER) at the site-specific stage when an RSR permit can be applied for. Arguments under Claim 3.1 have, therefore, been structured recognising the key documented information on RSR regime.

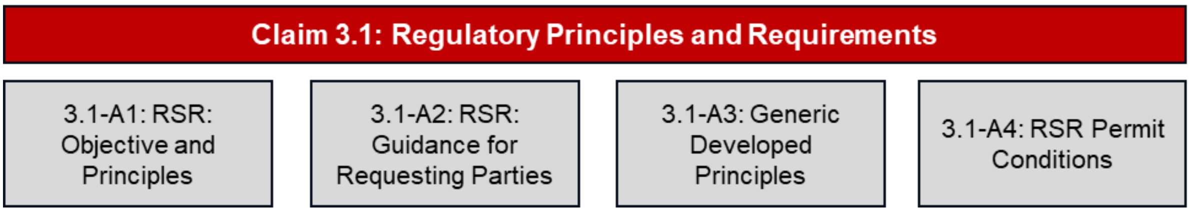

Figure 5: Summary CAE Tree for Claim 3.1: Regulatory Principles and Requirements.

6.7.1.1 Argument 3.1-A1: RSR: Objective and Principles

Argument 3.1-A1: RSR: Objective and Principles
The Requesting Party understands the requirements set out in the RSR: Objective and Principles and has developed management arrangements to deliver the desired outcomes.

RSR: Objective and Principles [3] details the fundamental objective and a set of regulatory principles that are taken into account when the environment agency carry out their work in reviewing and authorising RSR permits. The need for a specific RSR objective arises because the regulation of radioactive substances is different to other aspects of environmental regulation.

Within the SMR-300 GDA process, the RSR objective specified in RSR: Objective and Principles [3] has been incorporated into Fundamental Objective of the PER (see sub-chapter 6.7) to guide the development of the PER.

The RSR objective and fundamental principles informed the top-level direction of the RP's approach in the GDA process [28] and align to the strategic commitments and values established in its Environmental Policy [41].

6.7.1.1.1 Evidence for 3.1-A1: RSR: Objective and Principles

- **Holtec SMR GDA PSR Part A Chapter 1 Introduction** [11] – The PER Fundamental Objective is consistent with the RSR Objective [3] to "*protect people and the environment from the harmful effects of ionising radiation, now and in the future*".
- **Holtec Britain Environmental Policy** [41] – Proposes the use of nuclear power to provide low carbon power to protect the health, environment and economic well-being of communities, which is consistent with the objective of enhancing the environment as a whole.
- **Holtec SMR GDA PER Approach and Application to the Demonstration of BAT** [5] – Principles 2 and 8 are explicitly recognised in the introduction to this chapter and discussed further within this document.
- **SMR-300 GDA RSR-BAT Guidance** [6] – Describes how to implement environmental optimisation and takes into account principles 2 and 8.

6.7.1.2 Argument 3.1-A2: Guidance for Requesting Parties

Argument 3.1-A2: Guidance for Requesting Parties *The Requesting Party understands the requirements set out in the Guidance for Requesting Parties and has incorporated these into the Safety, Security and Environment Case.*

To guide the development of the environment case in GDA, New nuclear power plants: Generic Design Assessment guidance for Requesting Parties [28] details the information required for a GDA environment case, which includes the aspects below:

- General information about the RP and the design.
- Description of the RP's management arrangements and responsibilities.
- Detailed information about the design.
- Detailed description of radioactive waste management arrangements.
- Quantification of radioactive waste disposals.
- Sampling arrangements, techniques and systems for measuring and assessing discharges and disposals of radioactive waste.
- Prospective radiological assessment at the proposed limits for discharges and for any on-site incineration.
- Information relating to other environmental regulations.

Within the generic SMR-300 GDA process, information requirements for GDA were incorporated within the SSEC for a meaningful fundamental assessment.

It is recognised that completing a 2-Step GDA will result in particular information requirements being unfulfilled by the PER, see Argument 3.2-A4-SA3 Future Evidence for more information.

6.7.1.2.1 Evidence for 3.2-A2 Guidance for Requesting Parties

- **PER chapters** – Each chapter contains a 'Regulatory Context sub-chapter which presents the information requirements for RPs relevant to the topic area and addressed within the chapter.
    - PER Chapter 1 RWMA [7]
    - PER Chapter 2 QEDL [8]
    - PER Chapter 3 RIA [9]
    - PER Chapter 5 Monitoring and Sampling [10]
- **Holtec SMR-300 GDA PSR Part B Chapter 11 Environmental Protection** [42] – Presents the mapping of the information requirements for RPs against the applicable PER submission.
- **Holtec SMR GDA PER Approach and Application to the Demonstration of BAT** [5] – Summarises the RP's understanding of this guidance and the requirements there-in for BAT.

6.7.1.3 Argument 3.1-A3: RSR: Generic Developed Principles

Argument 3.1-A2: RSR: Generic Developed Principles *The Requesting Party understands the requirements set out in the RSR: GDPs and has considered these in the Safety, Security and Environment Case.*

The RSR: GDP [32] build upon the overarching RSR objectives and principles [3] and specify the EA's expectations from those holding or applying for an RSR permit [33]. The RSR: GDP apply to specific topics set out within the RSR regime, such as emergency preparedness, contaminated land and radiation protection. The environmental agencies expect RSR permit operators to implement recognised standards and practices such as BAT to optimise systems and strategies.

The generic developed principles were consulted during the generation of the SSEC. Some principles are not relevant at this lifecycle phase, where they are relevant they are built into the PER.

6.7.1.3.1 Evidence for 3.1-A3 RSR: Generic Developed Principles

- **Holtec SMR GDA PER Approach and Application to the Demonstration of BAT** [5] – The RSR principles applicable to BAT demonstration for the generic SMR-300 are detailed in Table 5.
- **Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management** [43] – Relevant radioactive waste management generic developed principles were considered in the production of that chapter.
- **Holtec SMR GDA PSR Part B Chapter 24 Fuel Transport and Storage** [22] – Table 14 presents the generic developed principles relevant to that chapter.
- **Holtec SMR GDA PSR Part B Chapter 26 Decommissioning Approach** [24] – The decommissioning generic developed principles were withdrawn in 2024 and replaced with RSR guidance for nuclear sites undergoing decommissioning, which was referred to the production of this chapter.
- **PER chapters** – Generic developed principles relevant to each environmental topic are presented in the following:
  - PER Chapter 1 RWMA [7].
  - PER Chapter 2 QEDL [8].
  - PER Chapter 3 RIA [9].
  - PER Chapter 5 Monitoring and Sampling [10].

6.7.1.4 Argument 3.1-A4: RSR Permit Conditions

Argument 3.1-A4: RSR Permit Conditions *The Requesting Party understands the requirements set out in the standard RSR Permit Conditions and is cognisant of these in the developing design and organisational capability.*

The EPR16 [37] require nuclear facilities to be permitted by the relevant environmental agency, before conducting activities that involve radioactive substances. To meet the obligations in protecting the environment and public from ionising radiation and the use of BAT in waste management, the environment agencies impose RSR permit conditions on the operator of a NPP.

RSR permit conditions are directly applicable to operators. The RP recognises that an RSR permit is a pre-requisite to operating a SMR-300 in England or Wales and has used the RSR permit conditions, along with the Objectives and Principles and Generic Developed Principles in developing the PER for the generic SMR-300.

The EA's RSR Permit for Nuclear Licensed Sites: How to Comply [38] explains the standard permit conditions related to receiving and disposing of radioactive waste from nuclear sites. This document alongside permits for NPPs under construction were used in order to inform the definition of the arguments presented in this chapter.

6.7.1.4.1 Evidence for 3.1- A4: RSR Permit Conditions

- **Holtec SMR GDA PER Approach and Application to the Demonstration of BAT** [5] – Presents the RSR permit conditions directly related to BAT.
- **SMR-300 GDA RSR-BAT Guidance** [6] – The RSR permit conditions informed the development of optioneering criteria in this document.
- **Holtec SMR-300 GDA Environmental Protection Functions Report** [44] – Presents the RP's GDA Environmental Protection Functions (EPFs). The core intent of those EPFs can be traced to the RSR permit conditions, specifically the control of operations 2.3.4, 2.3.5 and 2.3.6 [38].

6.7.2 Claim 3.2 Full Lifecycle Assessment

Claim 3.2: Full Lifecycle Assessment *The Generic SMR-300 Environment Case addresses relevant regulatory principles and requirements across the entire reactor lifecycle.*

BAT applies across the full lifecycle of a nuclear facility and must be considered in design, construction, commissioning, operation and decommissioning phases (shown in Figure 6 below).

What is considered BAT for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

Focus is applied during a 2-Step GDA to the development of a concept design and key decision making. A balance must be struck in presenting an optimised generic design. Early foreclosure of options in design features and methods of operation that are irreversible before site-specific factors are taken into account should be avoided, if they are fundamental to the demonstration of BAT for the PCER. The overarching strategy for development of the SSEC is presented in PSR Part A Chapter 4 [13].

Figure 6: Reactor Lifecycle Phases

This claim is also cognisant of Condition 1.1.3 of the standard RSR environmental permit [38] which states that:

> *"The operator shall maintain a waste management plan and a site-wide environmental safety case, which together demonstrate throughout the lifecycle of the regulated facility, how the:*
>
> *(a) production and disposal of radioactive waste is managed to protect the environment and to optimise the protection of people;*
>
> *(b) disposability of radioactive waste that will require disposal on or from the premises is assured;*
>
> *(c) public and the environment are protected from the non-radiological hazards of disposals of radioactive waste; and*
>
> *(d) premises will be brought to a condition at which it can be released from regulation under this permit."*

This claim also relates to the GDA guidance for requesting parties, in which it is stated that the approach for BAT should be used to *"prevent or minimise radioactive wastes and their impact during the lifecycle of the plant – design, construction, commissioning, operation and decommissioning"* [28].

RSMDP3 [33] – use of BAT to minimise waste, states the following:

- Processes creating, handling, treating and storing radioactive materials should be chosen so as to prevent or minimise the production of waste over the complete lifecycle of the facility.
- Optimisation should be demonstrated through options studies, particularly for new or changing facilities.
- Processes producing radioactive waste should be reviewed at intervals, to identify opportunities to minimise waste production.

PSR Part A Chapter 4 [13] presents the arrangements for the lifecycle Management of Safety and Quality Assurance (MSQA) for the generic SMR-300. They comprise design and quality control arrangements that allow safety, security, safeguards and environmental protection matters to be managed [13]. Further information on the whole lifecycle aspect of BAT can be found in the Approach and Application to the Demonstration of BAT [5].

6.7.2.1 Argument 3.2-A1: Design Management

Argument 3.2-A1: Design Management *The Generic SMR-300 complies with relevant regulatory principles and requirements and applies BAT during the design phase of the reactor lifecycle.*

The generic SMR-300 is the UK GDA design based on Holtec Palisades SMR-300 that will be deployed in the United States (US) on Lake Michigan. Holtec Palisades SMR-300 is designed to meet a prescriptive regulatory regime as defined by the US Nuclear Regulatory Commission (U.S.NRC).

During the course of GDA, the RP has conducted reviews of the generic SMR-300 design to establish conformity to applicable codes and standards and to determine the status of compliance against UK requirements and international good practices.

The RP has established processes to facilitate the identification and management of areas in the design that potentially pose challenge if UK context requirements are not taken into account in the detailed development of the design.

To support the demonstration of Argument 3.2-A1, it has been decomposed into four sub-arguments covering:

- Modularisation – A SMR design involves a higher degree of modularisation compared to larger PWRs.
- Innovation and novel design features – A SMR design brings the opportunity to introduce innovations that provide a safety or environmental protection benefit.
- Design integrity – How the design requirements and changes are presented and managed during the lifecycle of SMR-300.
- Codes and standards – Demonstrating an appreciation of the correct codes and standards that the design complies with is the foundation of applying for regulatory approval.

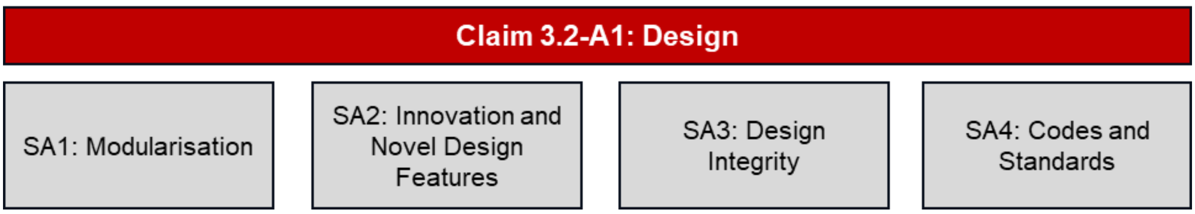

Figure 7: Summary CAE Tree for 3.2-A1 Design

6.7.2.1.1 Argument 3.2-A1-SA1 Modularisation

Argument 3.2-A1-SA1: Modularisation *The Generic SMR-300's modular design aspects minimise the generation and impacts of radioactive wastes and present wider holistic benefits.*

A modular design has the ability to fabricate major components in a factory environment and transport to the point of use can contribute to minimisation of waste and has potentially wider holistic benefits via the following aspects:

- Modularisation leads to increased quality due to controlled manufacturing and construction [45].
- Factory production of sub-assemblies provides enhanced opportunities for applying circular economy principles to manage wastes and materials. At the factory site there is greater available knowledge of material specifications, clearer traceability of a material's origin and closer proximity to the fabricator or manufacturer than at a construction site, which enables higher retention of material value and functionality.
- Comparably shorter build programmes than standard construction techniques that reduce secondary waste and wider environmental impacts during construction.
- Ease of decommissioning, with disassembly broadly being the reverse of assembly of the plant.

The generic SMR-300 design utilises Steel-Concrete modular construction for the CES. Furthermore, the design and construction of other structures, such as the RAB, may also evolve to utilise modular construction. PSR Part B Chapter 20 Civil Engineering [46] discusses the CES design methodology of the Steel-Concrete modular concept will not be available within the GDA timeframes but will be developed further post-GDA for a GDA commitment.

For the current stage of the design of the generic SMR-300 it has not been possible to characterise in detail the environmental impacts of modularisation, development of the design will provide the opportunity to identify how modular design supports the demonstration of BAT.

6.7.2.1.1.1 Evidence for 3.2-A1-SA1- Modularisation

- **Holtec SMR GDA PSR Part B Chapter 20 Civil Engineering** [46] – Discusses the modular construction of the SMR-300 CES, particularly under Claim 2.2.11.1-A3.
- **SMR-300 Top Level Plant Design Requirements** [47] – Describes design philosophy and sets out the requirement for prefabrication, preassembly and modularisation to be used to the maximum extent practical.
- **SMR-300 GDA Design Stability Toolkit** [27] – Describes the holistic benefits that can be realised by a modular design.
- **Future Evidence: Appraisal of Modularisation and its Environmental Impacts** – Assessment of relevant environmental aspects and impacts of a modular design through the lifecycle of the plant.
- **GDA Commitment: C_Civi_012** – Raised to develop the design methodology of the SMR-300 steel-concrete modular concept using guidance from relevant nuclear-specific US codes and standards, coupled with physical testing and numerical analysis.

6.7.2.1.2 Argument 3.2-A1-SA2 Innovation and Novel Design Features

Argument 3.2-A1-SA2: Innovation and Novel Design features

The Generic SMR-300 includes novel design aspects which comply with relevant regulatory principles and requirements and minimise the generation and impacts of radioactive wastes.

The SMR-300 design includes features which are novel compared to existing PWRs, they include:

- **Annular Reservoir (AR)** – The containment of the SMR-300 is designed to remain intact and sealed during all postulated events, and to reject its internal energy to the large body of water surrounding the containment structure. The AR is a large body of demineralised water that fills part of the interspace between the CES and the CS. Its purpose is to serve as the 'ultimate' heatsink for decay heat either through the Secondary Decay Heat Removal System (SDH) Heat Exchangers or through the containment walls. During normal operation the SDH Heat Exchangers contain coolant free from radioactive contamination, in the event of leakage into the AR it would not result in the generation of radioactive effluent requiring processing. The chemistry of the water in the AR is controlled to prevent biological growth and corrosion [48].
- **Siting of the Spent Fuel Pool (SFP) within the CS** – This feature provides robust protection of the fuel during all normal and accident conditions, which in turn has a benefit for the containment of radioactive materials and the generation of radioactive waste [46].

The generic SMR-300 design incorporates the following innovations in approach and technology.

- **Partially embedded below grade build** – a significant portion of the reactor building is partially embedded below grade for enhanced safety and security. The design methodologies will adopt tried-and-tested civil engineering approaches for the construction of the reactor building with focus on the below grade external walls and basemat [46].
- **Use of Metamic in Spent Fuel Storage Racks (SFSR)** – Metamic is neutron absorber material consisting of aluminium/boron carbide composite on a aluminium structure. It is selected for use SFSR in the SFP. The choice of metamic eliminates a potential source of the impurity silica which has been historically associated with use of Boraflex [21].
- **Heavy Reflector** (also referred to as the neutron reflector) – In-core component of the SMR core design that reduces neutron leakage by reflecting neutrons back into the core, enhancing fuel efficiency and reducing irradiation embrittlement of the Reactor Pressure Vessel (RPV) wall. The design and application of in-core components performing similar functions as the SMR-300 heavy reflector include:
    - **Westinghouse neutron shield pads** – Attenuate fast neutrons that would otherwise excessively irradiate and embrittle the RPV's walls. The pads are made of 304 stainless steel and 2.7 to 2.8 inches thick [49].
    - **UK EPR (originally known as European Pressurised Water Reactors) heavy reflector** – The core is radially surrounded by a heavy reflector made of thick steel slabs, whose function is to reflect the neutrons which escape the core back

towards the fuel assemblies. The heavy reflector will become waste during decommissioning[1] [50]; however, it is considered that this is offset by benefits in fuel efficiencies [51].

6.7.2.1.2.1 Evidence for 3.2-A1-SA2 Innovation and Novel Design Features

- **SDD for Passive Core Cooling System** [52] – Describes the SDH cooling the primary circuit by transferring heat from the SGE to the AR via the SDH Heat Exchanger.
- **General Arrangement of Containment Structure Internals for SMR-300** [53] – Presents the location of the SFP adjacent the RPV and within the protection of the CS.
- **Containment Structure System Based View** [54] – Provides supplemental justification of the robustness of the design of the AR and CS.
- **Holtec SMR-300 GDA Passive Systems Report** [55] – The Passive Systems Report describes the passive safety features incorporated in the SMR-300 design and signposts to where their justification resides in the PSR.
- **Future Evidence: Further Substantiation of the Use of Metamic in the SFP** – This will include consideration on whether boric acid levels in the SFP could be reduced as a consequence of the use of metamic.

6.7.2.1.3 Argument 3.2-A1-SA3 Design Integrity

Argument 3.2-A1-SA3: Design Integrity *The Generic SMR-300 design is based on a defined design reference point and has a clear mechanism for assessing and making design changes thereafter.*

It is considered best practice that a reference configuration is used as the basis for each safety, security and environment report production phase, particularly in the early lifecycle phases, to ensure there is a consistent and coherent approach to the maturity of evidence against which the safety of the plant is justified [56]. At GDA, a Design Reference Point (DRP) [57] was set. Further details on the DRP used for GDA Step 2 is provided in PSR Chapter A2 [1] and information on future DRPs beyond GDA is provided in PSR Part A Chapter 4 [13].

[REDACTED]

The RP has implemented a pragmatic and holistic approach to optimisation which builds on the design that is developing in the US. Design development to the DRP is controlled by the RP through application of the Design Management [31] process. This sets out a gated process which can identify:

- Design challenges – Identified risks to design stability of the generic SMR-300.
- Prospective design changes – Changes impacting the future design that fall outside the DRP.

---

[1] The UK EPR heavy reflector is designed to be dismantled in sections for decommissioning. Detailed decommissioning arrangements that cover the SMR-300 heavy reflector will be available post-GDA as described in Argument 3.2-A3-SA1 Decommissioning.

The BAT Suitable Qualified and Experienced Person in the RP reviews design challenges and changes as part of the Design Management [31] process. Design challenges have been raised in the following areas that directly interface with BAT:

- Sufficient provisions for independent sampling and the design of Monitoring and sampling equipment can represent BAT, see PER Chapter 5 Monitoring and Sampling [10] and Argument 4.7-A2-SA2: Aqueous Final Discharge Monitoring and Sampling; and
- Differences between US and UK radioactive waste disposal routes and containers, see PER Chapter 1 RWMA [7] and Argument 4.2-A3-SA2 Radioactive Waste Management Processes and Facilities.

[REDACTED]

6.7.2.1.3.1 Evidence for 3.2-A1-SA3 Design Integrity

- **Holtec SMR-300 Through-Life Safety, Security and Environmental Case (SSEC) Strategy** [57] – Presents the strategy for the development of the SSEC through Step 2 and is forward looking with through-life requirements.
- **Design Management** [31] – Process describing how design challenges are raised and may become design changes.
- **SMR-300 GDA Design Stability Toolkit** [27] – Provides additional guidance on how to assess design challenges and changes
- **GDA Design Reference Point** [56] – Lists the design documentation that has been formally captured in the DRP for GDA.
- **Design Reference Point and GDA Scope Change Proposal No 1** [58] – Presents the proposed change in establishing a new DRP baseline that incorporates updated RAB design information and removes information on the Radioactive Waste Building in response to the relocation of radioactive waste processing systems to the RAB.
- **Future Evidence: Site-specific SMR-300 design management and configuration control Process** – Prospective arrangement to identify, log and manage proposed changes to the configured SMR-300 design at the site-specific stage.
- **Future Evidence: RSR-BAT Case Management and Amendment Process** – Prospective arrangement for identifying and managing changes or updates to BAT Case Arguments and Evidence that arise during the site-specific stage.

6.7.2.1.4 Argument 3.2-A1-SA4: Codes and Standards

Argument 3.2-A1-SA4: Codes and Standards *The Generic SMR-300 is based on Codes, Standards and regulatory expectations which represent good practice that is relevant to the deployment of the SMR-300 in the UK.*

Codes and standards form the foundations for a design to meet regulatory expectations. Meaning that if a design adheres to the relevant codes and standards during development, it can contribute to the demonstration that regulatory requirements or expectations are met.

Due to the SMR-300 being designed in the US under U.S.NRC regulations and US codes and standards, extensive work has been carried out to compare them to equivalent UK and international requirements. This allows justifications to be made as to why relevant US codes, standards and regulatory expectations can satisfy the UK context requirements.

Overall, relevant codes, standards and regulatory expectations are addressed in the design of the generic SMR-300. For the most part there is good alignment between adopted codes, standards and methodologies for the generic SMR-300 design and UK context expectations of good practice.

[REDACTED]

6.7.2.1.4.1 Evidence for 3.2-A1-SA4 Codes and Standards

- **Mechanical Codes and Standards Report** [59].
- **Codes and Standards Applicability Report for Civil Engineering** [60].
- **UK Gap Analysis of SMR-300 Design Philosophy Against Chemistry Codes and Standards** [61].
- **UK-US Radiological Protection Regulatory Framework Comparison** [62].
- **SMR-300 SSG Compliance Report** [63] – Compares the SMR-300 design and associated safety case with clauses in the International Atomic Energy Agency (IAEA) Specific Safety Guide SSG-52 [64].
- **UK / US Regulatory Framework Principles Report** [65].
- **GDA Step 1 Codes And Standards Report** [66].

6.7.2.2 Argument 3.2-A2: Construction, Commissioning and Operations

Argument 3.2-A2: Construction, Commissioning and Operations *The Generic SMR-300 complies with relevant regulatory principles and requirements and is forward looking with regards to the use of BAT to optimise the construction, commissioning and operation phases of the reactor lifecycle.*

These lifecycle phases after the design phase of the generic SMR-300 are crucial in applying BAT. The quality assurance process plays an important role in this phase demonstrating aspects of design are implemented using BAT.

EIMT performed during the operational phase will have a large impact on the prevention and minimisation of radioactive waste. The identification of EPFs and Environmental Protection Measures (EPMs) will be performed to ensure this vital equipment is identified.

This argument is split into three sub-arguments as depicted in Figure 8 below.

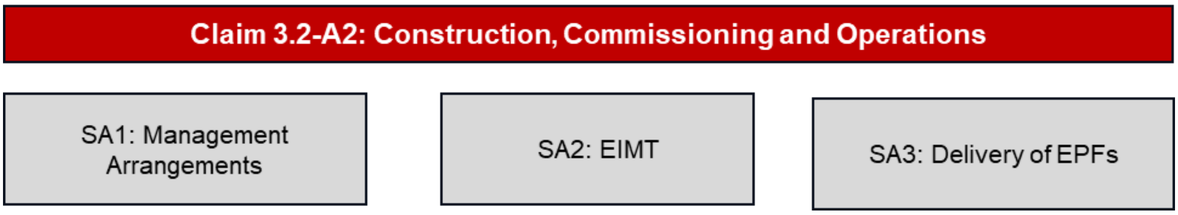

Figure 8: Summary CAE Tree for 3.2-A2 Construction, Commissioning and Operations

6.7.2.2.1 Argument 3.2-A2-SA1 Management Arrangements

Argument 3.2-A2-SA1: Management Arrangements *The Holtec Generic SMR-300 construction, commissioning, and operations phases incorporate systems and procedures to minimise the generation, activity and impacts of radioactive wastes*

It is important to incorporate BAT not only in operational phases but also within construction, and commissioning phases of the SMR-300's lifecycle to prevent the generation of unnecessary wastes before plant start-up.

PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [13] demonstrates that the RP has appropriate MSQA arrangements to deliver a UK site-specific SMR-300 project, including arrangements for the development of a detailed design and SSEC.

6.7.2.2.1.1 Construction

Holtec SMR GDA PSR Part B Chapter 25 Construction and Commissioning Approach [23] provides information on aspects which support waste prevention and minimisation for example:

- The generic SMR-300 uses standardised component sizes, types, and installation where it is considered BAT to allow for streamlined construction, maintenance, and operations. Off-the-shelf components as opposed to special-order/design components are utilised to the maximum extent practical. Off-the-shelf components means OPEX will be available and can be used to inform waste estimates and prevent waste generation where possible.
- Provisions for simplification and facilitation of construction and startup include provisions of good material handling and crane access and adequate space for construction activities, as well as provision for temporary construction buildings and equipment. Maximising off-site fabrication also reduces impacts on people and the environment by minimising the time spent around hazardous work areas.

6.7.2.2.1.2 Commissioning

Optimisation during commissioning will mainly focus on the following areas:

- Testing of SSCs and associated equipment to ensure the plant is functioning as intended.

- Trail of management arrangements to demonstrate that the plants management systems are effective and fit for purpose.
- Start-up and shutdown of the reactor core.
- Maintenance of plant performance including relevant EIMT considerations.
- Periodic reviews for further optimisation and use of BAT through the reactor lifecycle.

Ill-conceived commissioning, start-up and shutdown procedures of the reactor can increase the generation corrosion products (such as iron, nickel and cobalt) within the primary circuit. Specific procedures will be developed beyond the GDA that will plan the testing of SSCs to demonstrate that they meet their intended requirements before operation.

6.7.2.2.1.3 Operations

Plant operations have a critical role in the generation, volume and activity of radioactive wastes and their associated impacts on people and the environment and therefore should be optimised through the use of BAT. There are a number of measures integrated into the generic SMR-300 design which minimise the generation of radioactive wastes during operations.

Operating procedures will be produced at the site-specific stage to ensure start-up, shutdown operations follow procedures. The SMR-300 has a design life of at least 80 years [47], as such periodic reviews will be held to identify if further optimisation can be implemented in any part of the operation.

6.7.2.2.1.4 Evidence for 3.2-A2-SA1 Management Arrangements

- **SMR-300 GDA RSR-BAT Guidance** [6] – Scope of application extends across the whole lifecycle.
- **Future Evidence: Commissioning, start-up and shutdown procedures** – Developed to incorporate measures to minimise the corrosion of reactor internals and the consequential generation of activation products and production of radioactive waste.
- **Future Evidence: Commissioning Program** – To establish steps to test and operate equipment to ensure performance meets design intent. The programme will be developed and refined through design [23]. It will follow IAEA Commissioning Guidelines [67].
- **Future Evidence: Technical Specifications** – Produced to establish and communicate BAT requirements to operate equipment.

6.7.2.2.2 Argument 3.2-A2-SA2 Examination, Inspection, Maintenance and testing of SSC

Argument 3.2-A2-SA2: Examination, Inspection, Maintenance and testing of SSC *The Generic SMR-300 ensures that equipment is fit for purpose and specified to allow for ease of maintenance, timely replacement and other Examination Inspection Maintenance and Testing requirements to reduce the generation and impacts of radioactive wastes.*

The application and demonstration of BAT includes management regimes to ensure competence and efficiency of the plant. This includes carrying out EIMT activities across all stages in the lifecycle of a facility. It is important to identify and determine specialised management arrangements i.e., the EIMT schedule.

Applying BAT to EIMT arrangements can minimise the generation of radioactive wastes over the SMR-300's lifetime. The EIMT programme can be optimised using BAT by ensuring:

- The design of the generic SMR-300 is simple so that operations are streamlined for all modes of operation and eliminates the need for EIMT where possible.
- Materials used within SSCs and the plant as a whole are designed to be durable (for more information see Argument for 4.1-A1-SA4 Material Selection and Surface Finish).
- Equipment that could wear out is replaceable.
- SSCs are accessible to allow for appropriate examination, inspection and maintenance to support through-life reliability.
- Appropriate testing can take place and performance is properly monitored and mitigation actions (such as replacement) can take place if required.
- Confined spaces requiring routine entry for maintenance and inspection of equipment and components shall be minimised by design.

6.7.2.2.2.1 Evidence for 3.2-A2-SA2 Examination, Inspection, Maintenance and testing of SSC

- **PSR Part B Chapter 9 Description of Operational Aspects and Conduct of Operations** [17] – Provides the overall approach to EIMT for the generic SMR-300. It is acknowledged that the EIMT programme for the plant is expected to be defined as the design develops during the site-specific stage.
- **SMR-300 Top Level Plant Design Requirements** [47] – Sets out requirements covering the design of maintenance, testing and inspection aspects of the generic SMR-300. The requirements set out in this document align with the intent of Electric Power Research Institute (EPRI) Utility Requirements Document (URD) [68] and translate into SMR-300 objectives such as: "*Access provisions to equipment and components requiring routine maintenance and inspection shall consider human factors and operational experience*."
- **Future Evidence: EIMT Programme** – Will present the SSC and EIMT activities necessary to maintain through-life reliability of SMR-300 SSC.

6.7.2.2.3 Argument 3.2-A2-SA3 Delivery of Environmental Protection Functions

Argument 3.2-A2-SA3: Delivery of Environmental Protection Functions *The generic SMR-300 ensures that equipment in the design is identified as having an Environment Protection Function and in addition those which provide an Environment Protection Measure. Appropriate arrangements are made for these items.*

EPFs are applied to identify the SSC (or referred to as EPM) required to prevent and / or minimise radiological impacts to people and the environment, and therefore help identify and deliver plant performance that demonstrates BAT. The Best Available Techniques (BAT) for the Management of the Generation and Disposal of Radioactive Wastes Good Practice Guide [2] includes guidance on the maintenance of equipment needed to demonstrate BAT.

Where appropriate, existing EPFs for a facility may need to be taken into account in the determination of BAT. ENDP4 [34] makes clear the expectations for EPFs including their performance in normal and fault conditions. RSR: Objective and Principles Guidance [3] indicates that the process to identify BAT should be initiated when modifications to functions are proposed or expected. Prevention of unintended modifications to SSC fulfilling EPFs is crucial to the prevention and minimisation of radioactive waste, therefore, there is a strong link between BAT and the identification of EPFs.

The identification of EPFs provide the following benefits in environmental protection:

- They aid in the identification of SSCs which prevent the production of radioactive wastes, minimise the volume and activity of radioactive wastes or minimise the impacts of discharges on people and the environment.
- They aid in the identification of SSCs which require additional management requirements and arrangements to fulfil their intended purpose of environmental protection (i.e. EIMT, human factors etc.).
- They can indicate the SSCs which may require further design measures and 'lines of defence' / defence-in-depth due to their critical role in environmental protection.

It is acknowledged that the identification of site-specific EPFs will be completed during post-GDA timescales. However, it is important to identify EPFs and EPMs at the earliest opportunity in a NPP's lifecycle, to ensure appropriate codes and standards are applied in the design and construction and SSC that are EPMs are taken into account in the NPP EIMT schedule and asset management system.

6.7.2.2.3.1 Evidence 3.2-A2-SA3 Delivery of Environmental Protection Functions

- **The Holtec SMR-300 GDA Environmental Protection Functions and Measures Identification Methodology** [69] – Outlines the approach the RP will take in identifying SSCs classified as EPMs as they fulfil an EPF.
- **Holtec SMR-300 GDA Environmental Protection Functions Report** [44] – Presents the EPF framework for the generic SMR-300 and the EPFs at GDA.
- **Holtec SMR-300 GDA Pilot Identification of Environmental Protection Measures Study Report** [70] – Provides demonstration that generic SMR-300 EPFs can be used to identify EPM for a selected system (the LRW was studied).
- **Future Evidence: Site-Specific SMR-300 Environmental Protection Functions Report** – Presents the full list of EPFs for the SMR-300 by taking into account site-specific SSC not designed at GDA.
- **Future Evidence: Environmental Protection Measure Repository** – Stores information on the Environmental SSC and methods of operation that deliver EPFs.
- **Future Evidence: Environmental SSC Integration Strategy** – Will set out how decisions on Environmental SSC will inform procurement and through-life management arrangements (e.g. EIMT programme) to ensure adequate implementation of environmental protection in the operating plant.
- **Future Evidence: EIMT Programme** – Will present the SSC and EIMT activities necessary to maintain through-life reliability of SMR-300 Environmental SSC.
- **Future Evidence: Human Factors Assessments of Environmental Protection Measures** – A systematic determination of human actions important to plant

environmental protection performance. Human Reliability Assessments will be undertaken where appropriate, to determine the reliability and risks of tasks.

6.7.2.3 Argument 3.2-A3: End of Life Considerations

Argument 3.2-A3: End of Life Considerations *The Generic SMR-300 addresses relevant regulatory principles and requirements and uses BAT to optimise the decommissioning and end of life phases of the reactor lifecycle.*

At the end of operation the generic SMR-300 will enter a post operational clean out and decommissioning phase. The ONR, under licence condition 35 sets a number of requirements for decommissioning nuclear facilities [71].

The aim of the decommissioning phase is to transition the site to the agreed end state and achieve the two key milestones of: nuclear site delicensing and surrender of environmental permits. This will involve optimising decommissioning activities to minimise waste generation, conventional and radiological.

Decommissioning and site clean up can result in large volumes of waste being generated, it is therefore important that waste minimisation is a consideration in these activities.

Argument 3.2-A3 is further broken down into two sub-arguments which discuss decommissioning and the release from radioactive substances regulation as depicted in Figure 9 below.

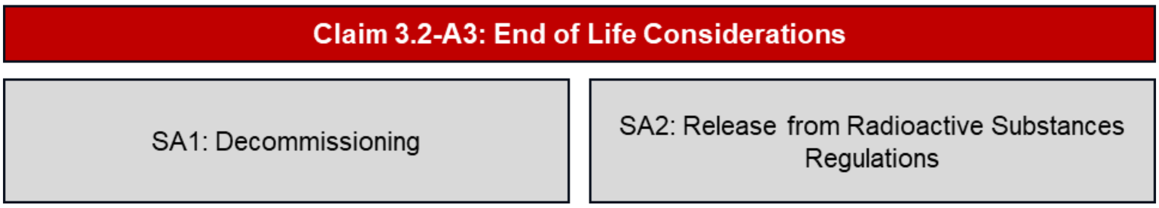

Figure 9: Summary CAE Tree for 3.2-A3 End of Life Considerations

6.7.2.3.1 Argument 3.2-A3-SA1 Decommissioning

Argument 3.2-A3-SA1: Decommissioning *The Generic SMR-300 addresses relevant regulatory principles and requirements and minimises waste generated and environmental impacts during the decommissioning phase of the reactor lifecycle.*

A key stage for optimisation of decommissioning is during the design of the generic SMR-300. Another is towards the end of operation when the decommissioning plans and strategy are being updated and finalised.

The requirements for decommissioning during GDA are derived from three main areas:

- EA RSR guidance for sites undergoing decommissioning [36].
- ONR Safety Assessment Principles (SAPs) [72] and Technical Assessment Guide on decommissioning [73].
- ONR New Nuclear Power Plants: Generic Design Assessment Technical Guidance [74].

As decommissioning is an area of joint regulation, PSR Part B Chapter 26 Decommissioning Approach [24] presents safety case claims, arguments and evidence to demonstrate compliance with the ONR Nuclear Liabilities Requirements on decommissioning. Requirements from both regulators would be taken into consideration to find an optimised solution, see Argument 3.2-A4-SA2 Holistic Optimisation.

EA decommissioning guidance [75] and RSMDPs [33] require decommissioning to align with BAT expectations. Key decisions regarding decommissioning would be subject to BAT appraisal using SMR-300 GDA RSR-BAT Guidance [6].

Guidance on the Funded Decommissioning Programme (FDP) for New Nuclear Power Stations [76] identifies decommissioning arrangements that are required at the PCSR and PCER stage. These arrangements require detailed design information over post-GDA timescales to produce and have been captured as future evidence.

During GDA, the RP has formulated decommissioning arrangements and strategies based on available information that provide credible evidence the generic SMR-300 demonstrates a design for decommissioning approach. The intent being that the design is built to facilitate decommissioning. Post-GDA, further development and future evidence can ensure that BAT is used at the time of decommissioning to minimise waste generation and environmental impacts.

6.7.2.3.1.1 Evidence for 3.2-A3-SA1 Decommissioning

- **The Decommissioning Strategy Assessment** [77] – Presents evidence of features in the generic SMR-300 that demonstrate design for decommissioning evidence.
- **SMR-160 Design Standard for Decommissioning** [78] – Sets a prompt decommissioning strategy and identifies design engineering features to facilitate dismantling and decontamination. This design standard is relevant underpinning to the generic SMR-300 design as it evolved from the SMR-160 design.
- **UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design** [79] – Provides qualitative information on the solid radioactive wastes generated during the decommissioning phase.
- **SMR-300 Top Level Plant Design Requirements** [47] – Specifies that future decommissioning and dismantling activities are considered in the SMR-300 design.
- **SMR-300 GDA RSR-BAT Guidance** [6] – Describes the importance of considering the full lifecycle in carrying out BAT appraisals.
- **Future Evidence: Design for Decommissioning Justification Report** – Provides underpinning evidence of safety and environmental optimisation of SMR-300 SSCs and plant layout to support the demonstration that risks have been reduced ALARP and represent BAT in decommissioning.

- **Future Evidence: Decommissioning Waste Management Plan (DWMP)** – Intended to meet the Guiding Factors set out in UK Government Guidance [76] and to provide sequencing of decommissioning of SSC.
- **Future Evidence: Quantified Decommissioning Waste Inventory** – An updated inventory presenting estimated quantities of decommissioning wastes.
- **Future Evidence: FDP** – Sets out how adequate funding is in place to support the full scope of decommissioning activities. The FDP comprises the DWMP and Funded Arrangements Plan.

GDA Commitment: C_Deco_079 – Performs a comparative assessment of the preferred prompt strategy against a deferred strategy. This will integrate considerations from a quantitative decommissioning inventory and identify enduring SSCs and plant equipment required for decommissioning that will require maintenance beyond the plant's operational period.

6.7.2.3.2 Argument 3.2-A3-SA2 Release from Radioactive Substances Regulation

Argument 3.2-A3-SA2: Release from Radioactive Substances Regulation *The Requesting Party has made preparations so that the site can be released from radioactive substances regulation while applying BAT when all activities involving the management of radioactive waste have ceased.*

The environment agencies will agree to release a nuclear site from RSR permitting if they are satisfied that radioactive waste disposal has ended and that site conditions can ensure people and the environment are protected [80].

Like the decommissioning phase site clean up can result in large amounts of waste being generated which contain only small amounts of radioactivity, therefore optimisation is crucial.

The Guidance on Requirements for Release (GRR) [81], outline guidance for operators planning decommissioning and clean up. The main requirements are:

- Produce a Waste Management Plan (WMP).
- Produce a Site-Wide Environmental Safety Case (SWESC).
- Use optimisation in decision making.
- Site conditions meet standards for protection of people and the environment, now and into the future.

The SWESC and WMP will be jointly reviewed by the applicable environment agency and the ONR to assess their adequacy to meet regulatory expectations. This ensures that radioactive waste management and land quality management of the site over its lifetime complies with both sets of regulatory requirements. This should ensure that the site achieves a condition that complies with the environment agencies' requirements, both before and after the site is released from RSR, and with relevant ONR nuclear safety requirements for the duration of the nuclear site licence [82].

At the time of environmental permit surrender there is also likely the requirement for de-licensing of the nuclear site. The main condition to surrender a nuclear licence is to satisfy the ONR that there is no danger from ionising radiation from anything on site. This is granted under the Nuclear Installations Act 1965 [83], demonstrating the need for close collaboration by the regulators in this area. Presently, there is no direct statutory link between release from RSR and the ONR de-licensing process [81]. However, there is a Memorandum of Understanding (MOU) between the EA and ONR on regulation.

Although these tasks are concerned with the release from regulation at the end of the reactor's lifecycle the compilation of documents begins well before this phase. As can be seen below some preparation towards these requirements has already begun where as some work is not appropriate at this design phase and is identified as future evidence.

6.7.2.3.2.1 Evidence for 3.2-A3-SA2 Release from Radioactive Substances Regulation

- **Decommissioning Waste Inventory for the Generic SMR-300 Design** [79] – Provides qualitative information on the solid radioactive wastes generated during the decommissioning phase.
- **Calculation of the SMR-300 Solid Radiological Waste Inventories** [84] – Presents waste volume calculations per year for the SMR-300 and applies UK waste categorisation and classification definitions. The document describes the calculation method.
- **Estimate of the SMR-300 Gaseous and Liquid Effluent releases using the PWR-GALE3.2 Code** [85] – Presents the calculation method and estimation of GBq per year for liquid and gaseous wastes.
- **Future Evidence: Site Wide Environmental Safety Case** – Creation of the SWESC is out of scope of GDA. The arrangement would be the responsibility of the permit holder and required to support permit surrender.

6.7.2.4 Argument 3.2-A4: Through-Life Considerations

Argument 3.2-A4: Through-Life Considerations *The Generic SMR-300 addresses relevant regulatory principles and requirements and takes into account through-life considerations which will impact BAT as it develops over the lifecycle of the reactor.*

During the plant's operational lifetime it is possible that the optimal option may change due to advancements in engineering or changes in industry or regulatory guidance. The RP are aware of this and have therefore developed guidance and management arrangements to account for these circumstances.

This argument has been split into three sub-arguments as depicted in Figure 10 below.

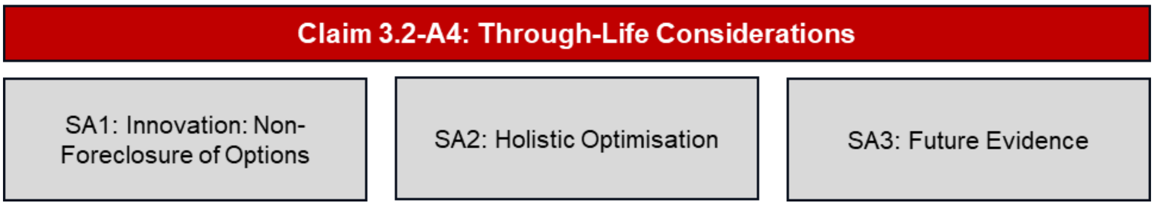

Figure 10: Summary CAE Tree for 3.2-A4 Through Life Considerations

6.7.2.4.1 Argument 3.2-A4-SA1 Innovation: Non-Foreclosure of Options

Argument 3.2-A4-SA1: Innovation: Non-Foreclosure of Options *The Generic SMR-300 recognises that BAT will change over time through advancements in legislation, technology and scientific understandings and includes appropriate procedures and mechanisms to review BAT and allow for advancement and avoid the pre-emptive foreclosure of options.*

BAT within the UK nuclear industry will change with time, both as a result of technological developments, design changes and in light of policy, regulatory and societal shifts. As such, the generic SMR-300 design has been developed with consideration of the benefits of non-foreclosure of options to allow for changes and to utilise possible advancements, where advantageous.

The RP's approach to demonstrating BAT is through the use of the CAE model and options assessments ('optioneering'). The RP's SMR-300 RSR-BAT Guidance [6] outlines the criteria for identifying options during optioneering. Where optioneering is identified as suitable and in line with a proportional approach, options generation shall be used to allow for innovation and will not foreclose options.

The Integrated Waste Strategy (IWS) [86] for the generic SMR-300 outlines a number of areas where options have not been foreclosed at the current stage of developed including:

- Strategy for Intermediate Level Waste (ILW) Spent Resins, Low Level Waste (LLW) Spent Resins and ILW Filter Cartridges – A baseline strategy has been developed for the identified processing, conditioning and packaging. None of the viable options foreclosed at this stage.
- Mobile treatment – The opportunity to use mobile treatment to process various waste streams to enable the adoption of modern and innovative technologies as they become readily available, in line the BAT.
- LLW disposal – LLW assumed to be consigned for treatment and disposal to Nuclear Waste Services (NWS) but other facilities providing similar waste services are not foreclosed.

SMR-300 ILW Management Strategy: Options Assessment [87] seeks to demonstrate that suitable solutions are available whilst not performing full BAT optioneering options. It identifies packaging options to allow for future international OPEX and possible future changes in UK Government policy:

- Spent Fuel – non-foreclosure of the opportunity option of direct disposal of spent fuel in a Multi-Purpose Canister (MPC)-37 transported in the HI-STAR 190 Type B transport package.
- NFW – non-foreclosure of the opportunity option of disposal in a Non-Fuel Waste Canister (NFWC), transported in a HI-STAR 190 Type B(U) transport package.
- ILW – non-foreclosure of the opportunity options of disposal in a High Integrity Container (HIC), assumed to be the AVANTech RadSafe™ Container 160 (ARC-160), transported in a HI-STAR 190 Type B(U) transport package.

6.7.2.4.1.1 Evidence for 3.2-A4-SA1 Innovation: Non-Foreclosure of Options

- **SMR-300 GDA RSR-BAT Guidance** [6] – Specifically accounts for innovation and non-foreclosure of options.
- **ILW Management Strategy: Options Assessment** [87] – Evaluates a number of credible waste packaging options for consideration.
- **Future Evidence: Long Lead Item Packages** – Presents environmental requirements and justifications for equipment that have a long lead time in manufacture and procurement.

6.7.2.4.2 Argument 3.2-A4-SA2 Holistic Optimisation

Argument 3.2-A4-SA2: Holistic Optimisation *The Generic SMR-300 recognises the need to balance between requirements under separate regulatory regimes to identify an optimum position and includes appropriate procedures and mechanisms to manage their requirements and allow for holistic optimisation.*

The approach for BAT demonstration, which is applicable for the generic SMR-300, is presented in HI-2240359, Approach and Application of the Demonstration of BAT [65]. This GDA step 1 tier 2 deliverable recognises the potential conflict between disciplines, for example between BAT and ALARP.

During the GDA process, the optioneering guidance for the generic SMR-300 GDA [6] has been developed to ensure that decisions taken, with respect to the generic SMR-300, achieve optimum solutions through a risk-informed lifecycle approach considering all relevant competing factors, such as safety, environment, security, costs, sustainability, etc, that aligns with the regulatory principles of ALARP and BAT. To support this approach, the RP will need to establish and maintain suitable levels of BAT knowledge and an understanding of the interfaces with design management and engineering disciplines.

For potential differences identified between the reference design and UK regulatory requirements these differences should be managed in line with the Design Management [31] process. Where the issue concerns both environmental and nuclear safety optimisation both the SMR-300 RSR-BAT Guidance [6] and the SMR-300 UK GDA ALARP Guidance Document [39] will be applied in seeking the optimised solution.

6.7.2.4.2.1 Evidence for Argument 3.2-A4-SA2 Holistic Optimisation

- **Design Management** [31] – Process establishes requirements for both ALARP and BAT optioneering for the justification of applicable design changes or design challenges.
- **SMR-300 GDA RSR BAT Guidance** [6] – Outlines holistic optioneering criteria to identify BAT.
- **SMR-300 GDA ALARP Guidance** [39] – Sets the requirement to include representatives of environmental protection and engineering disciplines when performing optioneering, in order to identify and manage potential conflicts between ALARP and BAT.
- **Holtec SMR GDA PER Approach and Application to the Demonstration of BAT** [5] – Establishes the intention to integrate BAT into a wider holistic optioneering process.
- **Holtec SMR GDA PSR A5 Summary of ALARP and SSEC** [14] – Describes the interfaces between BAT and ALARP and provides a top level approach to how optioneering can be conducted.
- **Non-Fuel Waste Packaging BAT Assessment Workshop Output Report** [88] – A detailed BAT Assessment (GDA worked example) for non-fuel waste packaging applying criteria within the SMR-300 RSR-BAT Guidance [6].
- **Holtec SMR-300 GDA BAT Statement - Li Enrichment** [30] – A proportionate BAT appraisal (GDA worked example) on the use of enriched lithium in the design undertaken in accordance with the SMR-300 RSR-BAT Guidance [6].
- **SMR-300 ILW Management Strategy: Options Assessment** [87] – Qualitative assessment of the options available for the management of ILW has been undertaken considering a range of criteria including safety, environment, security, technical, regulatory.
- **Holtec SMR-300 GDA BAT Statement - Prospective Design Change CES & CS** [89] – BAT study developed to support the CES prospective design change undertaken in accordance with SMR-300 RSR-BAT Guidance [6].
- **Future Evidence: BAT Training** – Development and provision of BAT training to suitable internal interested parties and key stakeholders in design management and engineering teams.

6.7.2.4.3 Argument 3.2-A4-SA3 Future Evidence

Argument 3.2-A4-SA3: Future Evidence *Beyond the GDA timescale, the demonstration of BAT for the Generic SMR-300 will continue to develop in line with the developing design and organisational maturity, as well as the requirements of environment permits.*

It is recognised that this chapter does not represent the complete demonstration of BAT for a future operating SMR-300 at a UK site, but represents a demonstration of BAT commensurate for a generic design. Throughout this chapter, as well as presenting available evidence as part of the CAE structure, evidence items are also recognised as 'future evidence'. This is intended to support the continued development of the BAT case.

As well as future evidence, which represents a business as usual activity or development of the demonstration BAT within a project, throughout Step 2 of the GDA Commitments are identified.

A GDA Commitment is a stated intent or undertaking made by the RP that affects the SMR-300 design intended for deployment to a UK site. GDA Commitments are not raised where the need for future work is considered to be 'normal business' i.e. where there will be resolution as part of the normal staged design / SSEC development [13].

GDA Commitments within the SSEC are formally recorded on the UK GDA - Commitments, Assumptions and Requirements Register [90]. No GDA Commitments have been specifically identified within the BAT topic area. GDA Commitments from other topic areas that interface with BAT are listed in Table 5 below and recognised in the applicable BAT argument. More information on GDA Commitments and their context can be found in their respective SSEC chapter.

Table 5: Commitments Interfacing with BAT

Reference	Chapter
C_Mech_028	Holtec SMR GDA PSR Part B Chapter 19 Mechanical Engineering [20]
C_Civi_012	Holtec SMR GDA PSR Part B Chapter 20 Civil Engineering
C_RWMA_078	Holtec SMR GDA PER Chapter 1 Radioactive Waste Management Arrangements [7]
C_Deco_079	Holtec SMR GDA PSR Part B Chapter 26 Decommissioning Approach [24]
C_QEDL_100	Holtec SMR GDA PER Chapter 2 Quantification of Effluent Discharges and Limits [8]
C_QEDL_101	Holtec SMR GDA PER Chapter 2 Quantification of Effluent Discharges and Limits [8]
C_Moni_119	Holtec SMR GDA PER Chapter 5 Monitoring and Sampling [10]
C_Fuel_128	Holtec SMR GDA PSR Part B Chapter 2 Reactor Fuel and Core [15]

6.7.2.4.3.1 Evidence 3.2-A4-SA3 Future Evidence

- **Holtec SMR-300 Generic Design Assessment Capturing and Managing Commitments, Assumptions and Requirements** [91] – Sets out the process for identifying, writing and managing GDA Commitments.
- **UK GDA - Commitments, Assumptions and Requirements Register** [90] – Contains the list of SSEC GDA Commitments.

6.8 CLAIM 4: ENVIRONMENTAL PROTECTION

Claim 4: Environmental Protection

The Generic Holtec SMR-300 design is developed so far as is reasonably achievable to provide optimal protection of people and the environment.

6.8.1 Claim 4.1 Generation of Radioactive Wastes

Claim 4.1: Generation of Radioactive Wastes

The generation of all radioactive wastes is prevented where achievable, or otherwise minimised.

The design of the plant includes all practical measures to protect the environment during normal operation and to mitigate the consequences of an accident. The design contains provisions to control, treat, and monitor releases to the environment and strives to minimise the generation of radioactive waste [47]. Focus has been applied to eliminate radioactive waste at source, and where elimination has not been practicable, the activity and quantity of radioactive waste has been minimised, as this is the most effective approach to minimise the environmental impacts and risks to members of the public.

The arguments presented in support of this sub-claim are considered to demonstrate compliance with the requirements set out under RSR permit condition 2.3.1 [38], which states:

"The operator shall use the best available techniques to minimise the activity of radioactive waste produced on the premises that will require to disposed of on or from the premises."

This sub-claim relates to the GDA regulatory guidance for RPs and the principles for RSR which states that the optimisation process for BAT should be used to *"prevent the unnecessary creation of radioactive waste or discharges"* [3].

The development of the generic SMR-300 has incorporated the application of BAT to prevent and / or minimise the generation of radioactive wastes. To demonstrate the minimisation of radioactive waste generation, two arguments are presented:

1. Argument 4.1-A1: Design for the Reduction of Waste Generation.
2. Argument 4.1-A2: Optimisation of Reactor Chemistry.

Features of the generic SMR-300 particularly important to this claim include:

- The design of fuel assemblies and control rods.
- The design of reactor core, primary circuit and fuel cycle.
- Materials selection and surface treatment of plant SSCs.
- Development of the regime proposed to manage reactor chemistry, pH and impurity control.

6.8.1.1 Argument 4.1-A1: Design for the Reduction of Waste Generation

Argument 4.1-A1: Design for the Reduction of Waste Generation *The Generic SMR-300 is designed to prevent or where that is not possible, minimise the generation of radioactive wastes at source from fission and activation products in the Primary Circuit and SSC exposed to neutron radiation*

The generation, build-up and discharge of radioactive wastes throughout the plant lifetime is undesirable due to the potentially harmful effects on workers, the public and the environment from exposure to radiation. Consequently, the prevention and minimisation of radioactive waste has been considered in across plant lifecycle phases (design, construction, commissioning, operation and decommissioning). Where waste prevention is not reasonably practicable, various systems and facilities providing the safe, environmentally protective and sustainable management of these wastes are considered in the radioactive waste management of the generic SMR-300 GDA. These are discussed under Claim 4.4 Impacts of Radioactive Wastes.

Design aspects which contribute to the prevention and minimisation of waste at source include, but are not limited to:

- Adopting proven high-reliability, safety enhanced and robust fuel to minimise fuel failure and fission product leakage.
- Selection of materials in and around the core to minimise its susceptibility to neutron activation, chemical degradation and corrosion, and hence to minimise the radioactive inventory.
- Designing plant layout with consideration for waste minimisation, ease of maintenance and minimisation of public doses.

This argument has been split into five sub-arguments as depicted in Figure 11 below.

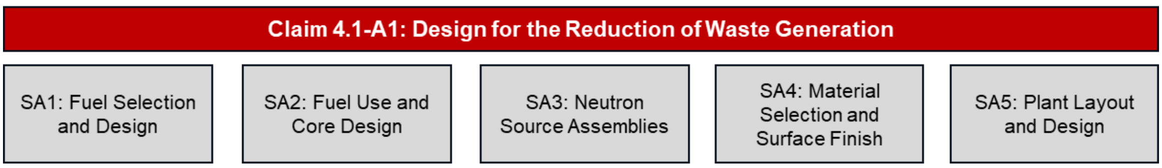

Figure 11: Summary CAE Tree for 4.1-A1 Design for the Reduction of Waste Generation

6.8.1.1.1 Argument 4.1-A1-SA1 Fuel Selection and Design

Argument 4.1-A1-SA1: Fuel Selection and Design *The Generic SMR-300 fuel and fuel assemblies are designed, manufactured and selected to minimise the generation or release of fission products in the primary coolant and the generation of radioactive wastes.*

The selection of fuel design is one of the most important decisions made for the generic SMR-300 as it is the fundamental source term for all radioactive waste within the reactor. The fuel generates radioactive waste via the following mechanisms:

- Directly as a result of fission during operation, over time creating spent fuel and fission products.
- Through fission products leaking into the primary circuit and causing contamination.
- Irradiating SSC such as the in-core components or the RPV and causing activation of these materials.

To minimise the generation of waste, the fuel is designed with the following considerations:

- The Rod Cluster Control Assemblies (RCCAs) and Control Rod Drive Mechanisms to be used in the generic SMR-300 are of a standard Framatome design that are used in other PWRs. These components have previously undergone extensive testing and design substantiation, and their use in PWR cores is supported by extensive OPEX.
- Cladding design that has minimal corrosion and leakage, and high reliability.
- Fuel rods are designed by Framatome to optimally sit in the GAIA fuel assembly.
- Enrichment selected for the core design is chosen to minimise radioactive waste.
- The core has been designed with fixed burnable poisons.
- The fuel is manufactured in an efficient process that limits the production of radioactive waste during production.
- Designed for no fuel failures during normal operation.

Several areas around fuel and core design play a role in minimising the generation and release of radioactive waste. The main points are summarised below:

- The fuel assembly and control rod components are designed to conform within the acceptance criteria in section 4.2 of NUREG-0800 [92] (for more information see Holtec SMR GDA PSR Part B Chapter 2 Reactor Fuel and Core [15]).
- Use of gadolinia as an integral burnable absorber within the fuel assemblies and soluble boron ensures optimal core activity, minimising unnecessary production of spent fuel and activated products from core peaking.
- Fuel pellets go through testing and inspection to maintain optimal chemical properties and minimise contaminant introduction.
- The higher the fuel integrity, the less radioactive material available to be released into the surrounding equipment and potentially cause contamination. This minimises the generation of radioactive waste. The generic SMR-300 will use fuel assemblies with a design informed by extensive operational experience. Containment is also a primary

safety function of the fuel assemblies. The ALARP demonstration involves substantiating the fuel clad integrity. (see Holtec SMR GDA PSR Part B Chapter 2 Reactor Fuel and Core [15]).

6.8.1.1.1.1 Evidence for 4.1-A1-SA1 Fuel Selection and Design

- **Primary Chemistry Strategic Plan** [93] – Preliminary calculation demonstrating that the core design is estimated to be [REDACTED]. This indicates a low risk of excessive corrosion product deposition on the fuel assemblies. Minimisation of crud generation in this way minimises activated corrosion products that may deposit elsewhere in the primary circuit and connected auxiliary systems.
- **Applicability of Framatome Fuel Methods for Holtec Fuel** [94] – Reports NRC approved codes and standards used to evaluate performance of the Holtec SMR-300 fuel design.
- **SMR-160 Fuel Assembly Material Corrosion Evaluation** [95] – Zircaloy-M5 alloy will be used in fuel cladding as it is deemed the best material by the study conducted. Use of Zircaloy-M5 alloy will limit the release of radionuclides into the system, which will minimise decommissioning wastes. It will also reduce the activation of the cladding itself.
- **Holtec SMR-300 GDA Nuclear Design Basis** [96] – Covers technical aspects of the fuel and core design. It compares the design against the derived safety limits and highlights ALARP considerations. Whilst the technical information does not directly contribute to demonstrating the minimisation of waste generation, it does highlight how core operation will be safe and controlled, contributing to high fuel integrity which effects waste generation.
- **Holtec SMR-300 GDA Fuel Design Criteria and Limits** [97] – Summarises key requirements and acceptance criteria associated with the design of the fuel, RCCAs and neutron sources. Many of the fuel and core criteria listed within this document are widely applied internationally and are based on fuel vendor validation and operational experience. Observation of these limits will contribute to fuel integrity and therefore prevent generation of radioactive waste.
- **Future Evidence: Fuel Manufacturing Surveillance and Inspections Reports** – Provided at a time closer to when fuel assemblies will be manufactured.
- **Future Evidence: Fuel reliability Supporting Information** – Comprises fuel vendor fuel assembly analysis under transient conditions, detailed fuel assembly design measures preventing damage by debris, fuel cladding design and fuel manufacturer's specifications.

6.8.1.1.2 Argument 4.1-A1-SA2 Fuel Use and Core Design

Argument 4.1-A1-SA2: Fuel Use and Core Design *The Generic SMR-300 fuel and design of the reactor core ensure reliable and efficient power generation, optimised fuel burnup and cycle length and reduce the generation of radioactive wastes.*

The design and operation of the reactor plays an important role in utilising the chosen fuel to minimise the generation of radioactive waste.

The operation of the generic SMR-300 utilises available OPEX and RGP to ensure that the power generation is safe and reliable and considers BAT to ensure waste generation is prevented or minimised.

Key factors that have been considered to minimise the generation of radioactive waste during reactor core design are: size, shape and assembly design of the core as this affects power control, fuel burnup and neutron leakage rates.

The heavy reflector reduces neutron leakage leading to fuel efficiency, and reduces irradiation embrittlement of the RPV (discussed in Argument 3.2-A1-SA2 Innovation and Novel Design Features).

The generic SMR-300 heavy reflector will be made of stainless steel and will comply with the requirements described in Argument for 4.1-A1-SA4 Material Selection and Surface Finish to minimise impurities which would lead to activation within the steel [24].

Neutron leakage has also been considered within the context of irradiation damage to the reactor vessel. Fuel utilisation, leakage, power peaking and vessel integrity are interrelated factors which have been taken into account during the core design development. This optimisation work has focused on minimising the size of the fresh fuel batch, enrichments and vessel damage while ensuring other design limits remain satisfied with positive margin. The preferred loading pattern scheme was selected because it is considered to strike an acceptable balance between fuel utilisation, leakage and power peaking [96].

Key factors that have been considered to minimise the generation of radioactive waste during reactor operation are: the fuel cycle length, fuel burn up, fresh fuel batch sizes, operational parameters and chemistry controls. The main points are summarised below:

- During operation conditions are adjusted to obtain optimum conditions, maintaining fuel and cladding integrity, minimising release of radioactive material into the core.
- Requirements relating to fuel and core components are established which define the safe envelope of operation. The core is designed and optimised to meet these parameters whilst meeting the stated objective power output. The fuel cycle is optimised to align with the selected fuel enrichment level, achieving the required burnup while allowing further adjustment using reactor poisons. This ensures an optimal balance between spent fuel and fission product generation and the desired reactor performance.
- Cycle length and number of discharge fuel assemblies have been selected to reduce the batch size (number of discarded fuel assemblies at the end of each cycle). [REDACTED]. This would have positive implications for fuel utilisation and environmental considerations.
- Procedure followed correctly will ensure desired operation and shutdown of all systems minimising any risks in these areas. This will maintain minimised generation of radioactive waste.
- Some aspects of reactor chemistry also contribute to this argument. For example, the chemical control of reactor coolant, SFP and supporting auxiliaries is coherent with the fuel cladding and assembly design which supports its continued integrity during operation and after. The minimisation of impurities, addition of hydrogen and control of the pH are the main ways in which loss of fuel integrity is minimised by chemistry control. See Argument 4.1-A2: Optimisation of Reactor Chemistry for more information on reactor chemistry.

6.8.1.1.2.1 Evidence for 4.1-A1-SA2 Fuel Use and Core Design

- **Holtec SMR-300 GDA Nuclear Design Basis** [96] – Discusses fuel management and batching and how a balance can be achieved between meeting all objectives including the generation of waste. Also includes technical details on neutron reflector material and models, the reflector will become waste at end of life.
- **Overview of Holtec SMR-300 Fuel Design and Core Components** [98] – Presents core design decisions related to fuel and core. OPEX is also presented on fuel use. Information is presented on reactor monitoring instrumentation. By monitoring the conditions within the core observations can be made as to whether it is operating at optimum conditions.
- **Holtec SMR-300 GDA Fuel Design Criteria and Limits** [97] – Summarises key requirements and acceptance criteria associated with the design of the fuel, RCCAs and neutron sources. Many of the fuel and core criteria listed within this document are widely applied internationally and are based on fuel vendor validation and operational experience. Observation of these limits will contribute to fuel integrity and therefore prevent generation of radioactive waste.
- **Holtec SMR-300 GDA Thermal and Mechanical Design Basis** [99] – Presents the methodology and scope for demonstrating the integrity of the fuel assembly and core components under both mechanical and thermal loads provide confidence that there are no fundamental shortfalls in the design of the SMR-300 fuel and core system.
- **Holtec SMR-300 GDA SMR-300 SSG-52 Compliance Report** [63] – Presents a review of SMR-300 design against the specific safety guide SSG-52 demonstrating that the design is broadly compliant with this best practice.
- **Future Evidence: Fuel Surveillance Programme** – Arrangement intended to ensure design basis and safety criteria are met. This will limit fuel failure and therefore minimise release of radioactive material into system
- **Future Evidence: Detailed Core Design and Optimisation** – Work will comprise flow control, burnable poisons and core configuration and geometry.
- **GDA Commitment: C_Fuel_128** – Core design and optimisation work undertaken for the SMR-300 has identified that the gadolinium-doped fuel rod average burnup exceeds the limit applied by Holtec (fuel vendor limit) if operated conservatively. A Commitment is raised to progress to completion the optioneering undertaken to address this topic in accordance with the Design Management process (HPP-3295-0017-R1.0).

6.8.1.1.3 Argument 4.1-A1-SA3 Neutron Source Assemblies

Argument 4.1-A1-SA3: Neutron Source Assemblies *The Generic SMR-300 ensures that neutron source assemblies are managed during start-up to minimise the generation of radioactive wastes.*

Start up sources are required to initiate a stable chain reaction in a nuclear reactor. The purpose of the primary sources is to provide a minimum detectable neutron flux level at the source range detectors for the initial core and to allow monitoring of the change in core multiplication factor during fuel loading and approach to criticality. Secondary sources provide the same function for subsequent cycles of operation but differ from primary sources in that they require activation prior to use.

Use of a secondary source has impact on the generation of waste over the reactor lifetime. A typical secondary source is made from Antimony and Beryllium (^{9}Be-^{124}Sb) and is activated in the core in order to generate a source of neutrons for detection by the source range detectors, during core-build. The decay chain also includes a statistical chance to generate H-3 (tritium). This is a less significant cause of radioactive waste generation than other sources in the primary circuit, but it is notable.

[REDACTED]

6.8.1.1.3.1 Evidence for 4.1-A1-SA6 Neutron Source Assemblies

- **Holtec SMR-300, GDA Nuclear Design Basis** [96] – [REDACTED]
- **Future Evidence: Secondary Neutron Source Optimisation** – Undertake an appraisal of the radiological impacts and waste arisings of viable secondary neutron source types.

6.8.1.1.4 Argument for 4.1-A1-SA4 Material Selection and Surface Finish

Argument 4.1-A1-SA4: Material Selection and Surface Finish *The Generic SMR-300 incorporates appropriately selected materials in the Primary Circuit to prevent the creation, transportation and deposition of contamination and minimise the generation of radioactive wastes and subsequently the volume and/or activity.*

The material selection of the generic SMR-300 has a large impact on the generation of waste over the reactor lifetime. Key considerations include:

- Materials with a low potential for activation from neutron irradiation.
- Materials selected to minimise corrosion to maximise service life of SSC. Minimising corrosion products also results in less crud buildup and activation within the core.

Selection of materials in the RCS is made according to relevant codes and standards, such as those by EPRI. Codes and standards are created using the most up to date research and OPEX, giving design and construction companies a universal methodology to follow.

Corrosion resistant materials (such as stainless steels and nickel-based alloys) chosen for the primary circuit and interfacing systems of the SMR-300 align with RGP [21]. Primary circuit and Nuclear Island auxiliaries will be procured to an appropriate surface roughness. This will be further defined as the design progresses.

The Design Standard for Radiation Protection [100] identifies a number of material selection features which support waste minimisation, for example:

- Materials exposed to neutron radiation will be made from materials that are resistant to activation, chemical degradation, and corrosion resistant.
- The materials selection of fuel cladding, and compliance with OPEX from traditional PWRs will contribute to ensuring the structural integrity of the fuel assemblies in the SMR-300.

- Minimisation of the creation of crud by selecting adequate materials and selection of materials to minimise Co-58 and Co-60 activation products which constitute substantial radiation sources in crud. Zinc is to be injected into the RCS in line with international good practice to reduce accumulation of these radionuclides on internal pipe surfaces.
- Use of smooth materials been selected or consideration given to coating inner surfaces to reduce plate out.
- The use of coating or material selection to allow easy decontamination in radioactive material handling areas.

6.8.1.1.4.1 Evidence for 4.1-A1-SA4 Material Selection and Surface Finish

- **Design Specification for the SMR-300 Steam Generator** [101] – Specifies that cobalt percentages have been minimised in SGE tubes to minimise activated cobalt generation. Includes provisions for chemical cleaning of the SGE if required. This capability in the design will, if required, result in an increased lifetime of operation of the SGE.
- **Spent Fuel Pool Cooling System Requirements, Open Items, and Interface Requirements Notebook** [102] – Equipment and piping in contact with borated water between SFP connections is stainless steel. Further specified are chemical control limits for the SFP. This has the same benefits stated for stainless steel above, in that corrosion is minimised.
- **SMR-300 Design Standard for Radiation Protection** [100] – Includes considerations on material selection and the nature of radiation and the shielding property of the materials (the degree of scattering, production of secondary radiation, activation, absorption).
- **Overview of Holtec SMR-300 Fuel Design and Core Components** [98] – Presents the materials used for various fuel assembly and RCCA components. Also discusses the codes and standards used in material selection and how non-destructive examination will be used in section 7.8.
- **Future Evidence: Procurement Specifications** – To support the communication of material requirements (e.g. impurity limits and surface finish) to suppliers for procured components.

6.8.1.1.5 Argument 4.1-A1-SA5 Plant Layout and Design

Argument 4.1-A1-SA5: Plant Layout and Design *The Generic SMR-300 plant layout supports an optimised EIMT schedule and minimised public doses*

The generic SMR-300 design layout decisions are guided by codes and standards, and they are informed from operational, radiological, construction, and maintenance experience that comes from the technical governance of large industrial/electrical generating plant. Layout practices and design considerations for Light Water Reactors used in the US, due to the history of the design, development and deployment of this technology, are generally considered to represent good practice that is relevant to the deployment of the SMR-300 in the UK.

With regards to BAT, the plant layout can influence waste minimisation through its impact on the EIMT schedule as well as the minimisation of radiological impacts. Decisions regarding component location, site plot plan and shielding can affect public doses.

Design Standard for Radiation Protection [100] discusses the concept of optimisation and its application to both workers and the public. It stipulates the following aspects related to plant layout:

- Arrangement of plant to minimise offsite doses from direct radiation.
- Shielding of plant including the ISFSI to minimise offsite doses from direct radiation.
- Controlling access of unauthorised persons within the exclusion area boundary.
- Storing active solid wastes in a manner that minimises direct exposures.

On a granular level, good layout design provides safe and easy access to SSCs for maintenance and waste management activities. Supporting regular maintenance contributes to the minimisation of the generation of radioactive waste. Standard permit condition 2.3.4 [38] requires NPP operators to maintain systems and equipment which:

- Produce radioactive waste requiring disposal.
- Minimise, monitor and measure radioactive waste discharged to the environment.
- Minimise, measure and assess the radiological impact of waste discharged to the environment.

The Equipment and Piping Layout Guidelines for Ensuring Radiation Exposures ALARA [103] includes the requirement to improve the accessibility of components requiring periodic maintenance or in-service inspections within design measures. It also discusses the requirement to reduce the frequency of servicing in order to maintain doses ALARP. Holistic optioneering is discussed in Argument 3.2-A4-SA2 Holistic Optimisation.

Equipment and Piping Layout Guidelines [103] cover the following engineering aspects that support environmentally optimal plant design:

- Routing piping systems containing radioactive materials away from clean piping systems.
- Piping expected to contain significant radiation sources should be adequately shielded.
- Piping carrying radioactive fluid should not be buried in concrete or underground, as it is difficult to inspect to ensure no significant degradation of the piping is present.
- Piping systems containing radioactive fluids should be designed to reduce accumulation of radioactive materials: avoiding the creation of stagnant legs and applying sloping pipe runs.
- The design features that enable control leaked fluid to be collected such as sumps and drip pans piped to floor drains routed to the liquid radioactive waste system.
- Locate major equipment containing highly concentrated radioactivity in shielded cubicles/compartments.
- Locate equipment and components (pumps, valves, instruments etc.) requiring more frequent maintenance or operations outside the shield wall of the major equipment containing highly concentrated radioactivity.

Further details on layout in relation to minimising the spread of contamination and appropriate radiological zoning can be found in Argument 4.2-A2-SA4 Transfer of Radioactivity.

Housing the SFP within the CS results in a smaller overall footprint for the pool and removes the requirement for a separate fuel handling building. This substantially reduces the use of construction materials for the generic SMR-300. The use of one RAB for a twin unit design also reduces the overall number of buildings and therefore reduces the required amount of construction materials.

At the current design stage, there is insufficient information to carry out a comprehensive assessment of direct doses to the public; however, a preliminary assessment of the dose received by a local resident family from storage of spent fuel in the ISFSI and direct radiation from the reactor cores at power are summarised in PER Chapter 3 RIA [11].

6.8.1.1.5.1 Evidence for 4.1-A1-SA5 Plant Layout and Design

- **SMR-300 Design Standard for Radiation Protection** [100] – Sets out the design features to protect plant personnel and members of the public.
- **Holtec SMR GDA PER Chapter 3 Radiological Impact Assessment** [11] – Summarises direct dose assessments.
- **Holtec SMR-300 Shielding Design Basis** [104] – Presents methodology, assumptions and calculated dose rates from preliminary shielding calculations.
- **Dose Management Strategy** [105] – Presents zoning philosophy and shielding strategy.
- **Equipment and Piping Layout Guidelines for Ensuring Radiation Exposures ALARA** [103] – Presents a number of aspects contributing to BAT as described above.
- **Future Evidence: Shielding Design and Calculations** – Further design work on the shielding will be performed as part of business as usual as the design matures.
- **Future Evidence: Direct Dose Assessment** – A comprehensive direct radiation assessment will be carried out once shielding assessment data is available for a selected site and spent fuel storage facility designed.
- **Future Evidence: Site-Specific Plot Plan** – Provides the layout of buildings and infrastructure for the SMR-300 and associated activities.
- **Future Evidence: Updated Source Terms** – As design maturity increases source terms used for dose rate calculations will become more accurate.

6.8.1.2 Argument 4.1-A2: Optimisation of Reactor Chemistry

Argument 4.1-A2: Optimisation of Reactor Chemistry *The Generic SMR-300 ensures that reactor chemistry is optimised to prevent or minimise the generation of contamination and radioactive wastes.*

Reactor chemistry of the primary circuit in the generic SMR-300 plays an important role in the safety of the reactor and how much radioactive waste it generates throughout its lifetime.

Argument 4.1-A2 can be further broken down into three sub-arguments, as depicted in Figure 12 below. Each sub-argument focusing on an area where waste generation can be minimised.

Together the evidence in the sub-arguments will show that the reactor chemistry is controlled optimally to minimise radioactive waste generation.

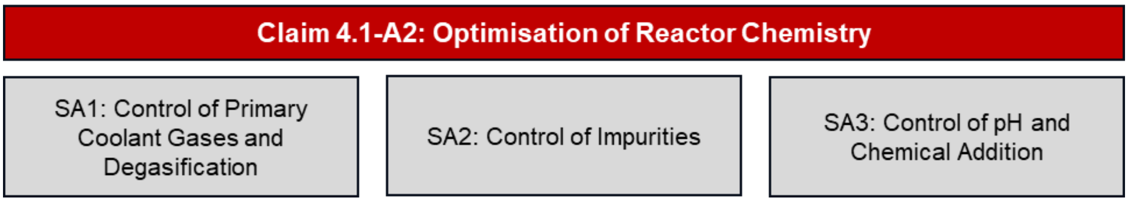

Figure 12: Summary CAE Tree for 4.1-A2 Optimisation of Reactor Chemistry

6.8.1.2.1 Argument 4.1-A2-SA1 Control of Primary Coolant Gases and Degasification

Argument 4.1-A2-SA1: Control of Primary Coolant Gases and Degasification *The Generic SMR-300 has appropriate gaseous control systems and procedures to minimise the generation of radioactive wastes at source by eliminating radiolysis products in coolant and through retention of fission product gasses in fuel rods*

The control of gas levels in the primary coolant plays an important role in safety and minimising corrosion. It also minimises the amount of time activatable gaseous species are exposed to neutron flux.

The generic SMR-300 incorporates design features and systems for the control of gaseous species in the primary circuit. These systems manage gases produced through radiation-coolant interactions and radiolysis of water, ensuring the effective containment of fission product gases within the fuel system.

Within the reactor core, radiolysis of water occurs due to the exposure of coolant to gamma (and to an extent, neutron) radiation, resulting in the generation of hydrogen, oxygen, and reactive oxygen species such as oxygen radicals. These oxidising species present a threat to the structural integrity of core internals through corrosion. A positive inventory of hydrogen is actively maintained in the primary coolant. This hydrogen recombines with oxidising species to re-form water, thereby reducing the electrochemical potential of the system and suppressing corrosive degradation mechanisms.

This chemical control strategy minimises the generation of corrosion products by oxidative processes, many of which would otherwise become activated and require subsequent removal from primary coolant. This lessens the demand on purification systems, including the Chemical and Volume Control System (CVC) ion exchange resins. As a result, resin lifetime is improved, and the volume of secondary radioactive waste from resin disposal is reduced.

Gaseous waste generation is also minimised by the retention of fission product gases within the fuel rods. Fission gases are unavoidably generated during reactor operation as a by-product of nuclear fission. However, these gases are typically contained within the fuel pellet and the narrow fuel-clad gap. The fuel cladding serves as the primary barrier preventing the migration of these gases into the reactor coolant. The SMR-300 design ensures the integrity of fuel cladding through material selection and primary chemistry control.

By maintaining the structural integrity of the fuel envelope, the release of radioactive gases into the primary circuit is minimised, which in turn reduces the generation of radioactive wastes. This lessens the output to gaseous waste systems, thus reducing the quantity of radioactive gas disposal.

6.8.1.2.1.1 Evidence for 4.1-A2-SA1 Control of Primary Coolant Gases and Degasification

- **PSR Part B Chapter 23 Reactor Chemistry** [21], discusses how hydrogen can be injected and dissolved into the primary coolant and the capability of the CVC for degasification of gaseous species in the reactor coolant system via the Volume Control Tank (VCT).
- **Future Evidence:** Commissioning, Start-up and Shutdown Procedures, chemistry can have a large influence on the generation of waste at source therefore chemistry commissioning procedures are particularly noted as requiring BAT input.

6.8.1.2.2 Argument 4.1-A2-SA2 Control of Impurities

Argument 4.1-A2-SA2: Control of Impurities *The Generic SMR-300 has appropriate filtration and purification systems to prevent the generation of radioactive wastes at source by controlling impurities and reducing crud deposition.*

Effective control of impurities and reduction of crud generation / deposition is essential for minimising the generation of radioactive waste at source. This is achieved through a combination of design features that limit impurity ingress and purification systems that maintain coolant quality. By managing impurities, the SMR-300 reduces corrosions rates, improves plant component longevity (particularly filters and resins) and minimises the generation of solid and liquid waste.

Control of Impurities

The SMR-300 limits impurity ingress to the RCS (which potentially could occur from other interfacing systems or contaminated makeup). The high-purity Demineralised Water Transfer System (DWS) provides coolant makeup, ensuring only trace levels of particulate or ionic contaminants are introduced. The selection of corrosion resistant materials further limits the release of corrosion products into the RCS and minimises in-situ impurity generation. Impurities are limited to values which align with international good practice.

In the event of impurity ingress, the SMR-300 is equipped to remove contaminants efficiently with the filtration and purification systems. This includes cation and mixed-bed mineralisers, a deborating bed and reactor coolant filters. By reducing the impurity load and suppressing corrosion at source, the purification systems experience lower throughput demands, resulting in an extended service life of filters and ion exchanges. This in turn, reduces the volume of secondary waste arisings. Similarly the Spent Fuel Cooling system (SFC) includes demineralisers in order to limit the impurities in the SFP.

Limiting Crud

The SMR-300 chemistry regime also minimises the generation and deposition of corrosion and wear products (crud) that may accumulate in the core. Crud results from the corrosion of internal components and is exacerbated by the presence of impurities (normally from other interfacing systems or contaminated makeup). The SMR-300 mitigates crud generation through hydrogen addition, pH optimisation and impurity suppression. This limits the availability of material to deposit on fuel cladding surfaces, limiting activation and future corrosion on the area onto which crud is deposited.

Minimisation of crud also reduces the burden on plant purification systems that are responsible for removing particulates from the coolant. As with the control of impurities, the limitation of crud will result in less frequent filter and resin replacement and thus minimises the generation of secondary waste.

6.8.1.2.2.1 Evidence for 4.1-A2-SA2 Control of Impurities

- **SMR-300 Primary Water Chemistry Strategic Plan** [106] – Provides justification for the downselected primary chemistry regime of the SMR-300, including the selection of materials that minimise generation of radionuclides through minimising corrosion.
- **SDD for CVC** [107] – Describes the crud minimisation measures: hydrogen addition, pH optimisation and impurity suppression.
- **SDD for SFC** [108] – Describes maintaining water quality to reduce impurities and the use of a demineraliser with a filter.
- **SDD for RCS** [109] – States that a water chemistry program will be established to control corrosion.
- **PSR Part B Chapter 23 Reactor Chemistry** [21] – Describes:
  - The DWS makeup for the RCS.
  - The main coolant purification system: cation demineraliser, a deborating bed demineraliser, mixed bed demineralisers and reactor coolant filters and how they maintain the reactor coolant purity, suspended solids and activity levels.
- **Future Evidence: Commissioning and Testing Performance Results for Purification Systems** – Will be developed and used in order to validate plant performance.

6.8.1.2.3 Argument 4.1-A2-SA3 Control of pH and Chemical Addition

Argument 4.1-A2-SA3: Control of pH and Chemical Addition *The Generic SMR-300 has an appropriate pH strategy and chemical addition programme to prevent the generation of radioactive wastes at source by reducing cladding and RCS structural material corrosion.*

Primary coolant pH plays an important role in dictating the rate of corrosion and therefore the availability of corrosion products to become activated within the system. It also affects the rate of fuel cladding corrosion. Effective pH control directly reduces the amount of corrosion products that may become activated, be deposited as crud, or require downstream filtration. This contributes to the minimisation of radioactive waste generation.

Chemistry control features that contribute to pH control and corrosion minimisation include:

- The pH in the RCS is controlled by coordinating lithium hydroxide with boron concentration. Boron, in the form of boric acid, is added for reactivity control and lithium hydroxide, a strong base, is used to generate a net alkaline pH.
- The quantity of boron required is reduced through the use of RCCAs and in-core burnable poisons. Tritium is generated through a minor reaction pathway of the neutronic absorption of boron. By minimising the quantity of boron required, the amount of tritium generated is minimised.

Chemical additives are selected and managed to avoid introducing elements that could increase radioactive waste production:

- Lithium hydroxide used for pH control is isotopically enriched in Li-7, thereby avoiding the $^{6}Li(n,\alpha)^{3}H$ reaction, which would contribute to tritium generation.
- Zinc injection is used to minimise the deposition of cobalt radionuclides onto RCS pipework. Zinc is added in the form of depleted zinc acetate, which is depleted in ^{64}Zn to minimise activation via $^{64}Zn(n,\gamma)^{65}Zn$, which produces radioactive Zn-65.
- Hydrogen injection is employed to maintain conditions that limit radiolysis of water, as discussed in Argument 4.1-A2-SA1 Control of Primary Coolant Gases and Degasification.
- The coolant water used in both the RCS and CVC is deoxygenated, high purity water, with a high pH to promote the formation of a stable metal oxide passivating layer, thereby reducing corrosion of system components.

The instrumentation, monitoring and materials selection of the SMR-300 ensure conditions are maintained that minimise the potential for corrosion:

- The Primary Sampling System (PSL) enables regular monitoring of coolant chemistry, during all modes of operation, including pH and impurity levels. This supports informed and effective chemical additions to maintain optimal chemistry conditions.
- The selection of corrosion and activation resistant materials for core components limits the potential for radioactive waste generation. Further information can be found in Argument for 4.1-A1-SA4 Material Selection and Surface Finish.
- Regular reviews of source terms, as they develop, comparing generation with other PWRs and industry benchmarks provides evidence of the application of BAT in minimising the generation of radioactive waste.

6.8.1.2.3.1 Evidence for 4.1-A2-SA3 Control of pH and Chemical Addition

- **PSR Part B Chapter 23 Reactor Chemistry** [21] – Discusses pH control and chemical addition in several key area that will contribute to the minimisation of radioactive waste generation.
- **Position Paper on SMR-300 Plant Demineralized Water Treatment Systems Output Quality Considerations and Requirements** [110] – Evaluates the currently available industry recommendations for deionized water chemistry specifications and provides a basis for the recommendations on the make-up water for the RCS.

- **SMR-300 Primary Water Chemistry Strategic Plan** [106] – Provides justification for the down selected primary chemistry regime of the SMR-300.
- **SMR-160 Fuel Assembly Material Corrosion Evaluation** [95] – Evaluates the materials corrosion evaluation, given the nominal operating conditions.
- **SMR-300 Nuclear Island Minimalization Strategy of Activity Generation and Accumulation** [111] – Outlines generation of activated products can how they can be minimised through the selection of materials.
- **Evaluation of SMR-300 Calculated Source Terms Against Publicly Available Information** [112] – Provides a comparison of the SMR-300 source terms against other relevant PWRs.
- **SMR-300 Design Standard for Radiation Protection** [100] – Proposes minimisation of corrosion products via control of coolant chemistry.
- **Future Evidence: Commissioning Strategy** – Chemistry can have a large influence on the generation of waste at source therefore chemistry commissioning procedures are particularly noted as requiring BAT input.

6.8.2 Claim 4.2 Quantity of Radioactive Wastes

Claim 4.2: Quantity of Radioactive Wastes *Where prevention is not possible, the mass and/or volume of radioactive wastes, including discharges, disposals and transfers to other premises is minimised.*

As stated in Claim 4.1 (sub-chapter 6.8.1), the RP has prioritised prevention of radioactive waste generation at source, recognising this as the most effective means of reducing the radiological and environmental impact on people and the environment. While some radiological waste generation is unavoidable through the reactor lifecycle, the design of the generic SMR-300 has incorporated features and strategies that minimise the quantity (mass and / or volume) of radioactive waste requiring subsequent management and permitted disposal.

The arguments presented in support of this claim are intended to demonstrate compliance with the requirements set out under Condition 2.3.2 (b) of the standard RSR environmental permit [38] which requires:

"The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to minimise the volume of radioactive waste disposed of by transfer to other premises" [38].

This claim also relates to the regulatory GDA guidance for RPs, in which it is stated that the optimisation process for BAT should be used to minimise *"(in terms of mass and volume) solid and non-aqueous liquid radioactive wastes and spent fuel"* [28]. Developed principle RSMDP3 [33] also states *"BAT should be used to ensure that production of waste is prevented and where that is not practicable minimised with regard to activity and quantity".*

In line with these expectations, the design of the generic SMR-300 has incorporated the application of BAT so as to prevent and / or minimise the mass and / or volume of radioactive wastes. Management arrangements and design aspects considered in the generic SMR-300 to minimise the mass and / or volume of radioactive wastes are categorised into three broad arguments:

1. Management of Fuel (sub-chapter 6.8.2.1).
2. Containment Systems (sub-chapter 6.8.2.2).
3. Radioactive Waste Management Lifecycle (sub-chapter 6.8.2.3).

Features of the generic SMR-300 particularly important to this claim include:

- The management arrangements for New, Spent and Damaged Fuel including its receipt, inspection, transport and handling.
- Design of containment systems and related equipment (i.e., Non-Fuel Waste Container).
- Measures to limit the transfer of radioactivity including designation of zones and barriers.
- Development of waste inventories.
- Development of optimal waste management techniques, facilities and disposal routes.

6.8.2.1 Argument 4.2-A1: Management of Fuel

Argument 4.2-A1: Management of Fuel *The Generic SMR-300 has appropriate systems and procedures to allow optimised management of fuel both new and used.*

The safe, effective management of both new and used fuel in the generic SMR-300 through the fuel lifecycle in a manner that prevents contamination and maintains fuel integrity will support the demonstration of BAT. New fuel will require controls to prevent contamination and avoid operational incidents, while spent fuel introduces high radiological risk and requires systems for containment and handling to maintain fuel integrity and limit radiological releases.

Fuel management can be broken down into two separate sub-arguments as depicted in Figure 13 below.

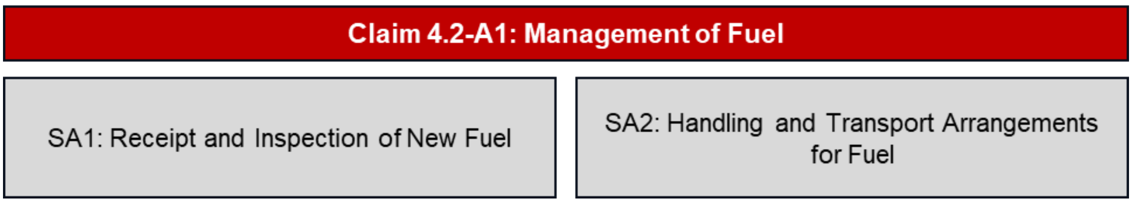

Figure 13: Summary CAE Tree for 4.2-A1 Management of Fuel

6.8.2.1.1 Argument 4.2-A1-SA1 Receipt and Inspection of New Fuel

Argument 4.2-A1-SA1: Receipt and Inspection of New Fuel *The Generic SMR-300 ensures that New Fuel Assemblies can be appropriately received and inspected to protect people and the environment and minimise the volume of radioactive wastes generated.*

New fuel assemblies must be managed with care to avoid the potential of contamination or damaged that could result in future radioactive waste arisings. If mis-managed during receipt or inspections, the volume of radioactive waste could be increased due to the following reasons:

- Physical damage to the fuel assemblies - inspection of new fuel and fuel throughout its lifetime is important to show that the cladding integrity has not failed. This could results in fuel, fission products and fission gases being released unknowingly, increasing the volume of radioactive waste present in the contaminated system.
- Increase in defects to fuel - failure to detect pre-existing defects in the fuel could result in its introduction to the core, increasing the likelihood of fuel failure during operation and leading to primary circuit contamination and increased resin/filter waste.

The generic SMR-300 fuel management systems and strategy are designed so that BAT is demonstrated and shows the volume of radioactive waste is minimised during the receipt and inspection of fuel. BAT is demonstrated in the following areas:

- The fuel has systems in place so that it can be inspected during receipt, operation, refuelling outages, SFP storage and interim storage.
- There are appropriate information management systems in place to record all inspection results so the operator is appropriately informed and can make the correct fuel management decisions.

New fuel assemblies are received individually and transferred into the designated inspection area within the RAB where they are inspected prior to storage in the New Fuel Storage Rack in the New Fuel Vault [22]. This process enables early detection of any defects, foreign material, or mechanical damage that could compromise fuel integrity, preventing potential contamination of downstream systems or fuel failures during operation.

During reactor operation and refuelling, the generic SMR-300 employs monitoring techniques such as RCS sampling, fuel sipping, and Closed-Circuit Television (CCTV) inspection to identify damaged fuel assemblies. If fuel failure is detected during handling or storage, assemblies can be returned to the SFP for safe management as damaged fuel, minimising contamination and unnecessary radioactive waste generation. This inspection programme allows spent fuel to be repackaged at a later date to a NWS approved container. The strategy available means there is no foreclosure of long-term management options for spent fuel and NFW, meaning the BAT container option can be selected.

There is the capability to undertake external MPC or Non-Fuel Waste Container (NFWC) inspections at the ISFSI [22]. This will help capture any degradation and potential leakage, helping to keep radioactive waste volume minimised by catching any leaks before they occur.

6.8.2.1.1.1 Evidence for 4.2-A1-SA1 Receipt and Inspection of New Fuel

- **PSR Part B Chapter 24 Fuel Transport and Storage** [22] – Provides an overview of the fuel transport and storage route including the transfer of new fuel to the reactor and the inspection of new fuel assemblies.
- **SMR-160 Fuel Handling and Storage** [113] – Defines the fuel handling and management strategy for the SMR-160 used as a basis for the SMR-300 strategy.
- **Holtec SMR-300 GDA Fuel Design Criteria and Limits** [97] – Summarises key requirements and acceptance criteria associated with the design of the fuel, RCCAs and neutron sources to be used within the SMR-300 core.
- **PSR Part B Chapter 9 Conduct of Operations** [17] – Provides a high-level summary of SMR-300 refuelling operations.
- **Future Evidence: New Fuel Management Procedure** – Will specify receipt and inspection procedures for new fuel in order to ensure fuel meets requirements before loading.

6.8.2.1.2 Argument 4.2-A1-SA2 Handling and Transport Arrangements for Fuel

Argument 4.2-A1-SA2: Handling and Transport Arrangements for Fuel *The Generic SMR-300 ensures that New, Damaged and Spent Fuel Assemblies can be appropriately handled and transported, including before and after loading/unloading of the reactor core, to reduce the volume of radioactive waste generated.*

Appropriate systems for the management of new, damaged and spent waste, from initial receipt through to interim storage reduces the risk of fuel damage during handling and transport operations. This will reduce the number of events that may damage cladding and release fission products or gases, leading to the creation of radioactive waste and the need for subsequent clean-up and management.

Key design features of the SMR-300 that support BAT include:

- The use of a modern well document PWR fuel supported by well-established handling methods reduces the risk of fuel assembly damage during handling and transfer operations. This contributes to maintaining fuel cladding integrity and reduces the number of failed assemblies over the reactor lifecycle, therefore decreasing the volume of radioactive waste.
- The SMR-300 has a simplified and fully integrated refuelling route. This minimises the potential for fuel damage and release of fission products. The SFP is located within the containment structure, eliminating the need for fuel elevator, fuel handling building or fuel canal, typically required in conventional PWRs. This reduces the potential for contamination across the wet fuel route and decreases complexity of decommissioning with fewer structures becoming contaminated and requiring decommissioning.
- The SMR-300 has a small volume SFP design for shorter-term wet storage. Spent fuel assemblies are transferred to dry storage after [REDACTED] years (less than typical PWRs), reducing the operational demand on SFP filtration and resin systems and thereby reducing secondary waste arisings [22].

- The SMR-300 utilises an efficient, simplified passive dry storage using the Holtec's proprietary HI-STORM UMAX[2] system. The HI-STORM UMAX and associated MPCs have been engineered for long-term integrity and can function as the final disposal package in a Geological Disposal Facility (GDF), subject to acceptance criteria [114]. This would eliminate a major handling step, reducing future processing risks and potential waste arisings. The early storage of spent fuel in the HI-STORM UMAX system eliminates further generation of wastes associated with operation and decommissioning of wet storage systems and allows for further decay while a final waste disposal site is determined.
- The design and loading processes for the MPC, Damaged Fuel Container (DFC), and NFWC include features that reduce the potential for internal contamination. For example, inflatable seals and elastomeric gaskets isolate the MPC from SFP water during loading, while coated surfaces on the HI-TRAC (transfer cask) simplify decontamination. Containers can be reused or subject to metals recycling following the retrieval of their contents, supporting application of the waste hierarchy and minimising the generation of secondary wastes [22]. Non-encapsulated storage of Non-Fuel Waste (NFW) removes the need for materials for grout reagents and ensures items are readily retrievable and avoid foreclosure of future management options for any suitable material.
- Similar NFW components are grouped together in pre-fabricated boxes within the NFWC, facilitating future waste handling. This approach helps to reduce cross-contamination and simplifies the identification and routing of wastes, further reducing volume of radioactive waste [88].
- The base pad, fence, and peripheral utility structures will require no special handling after the last Vertical Ventilation Module (VVM)[3] is removed [115], as no contamination is expected to be present.

6.8.2.1.2.1 Evidence for 4.2-A1-SA2: Handling and Transport Arrangements for Fuel

- **PSR Part B Chapter 24 Fuel Transport and Storage** [22] – Provides an overview of the fuel transport and storage route encompassing the unloading of spent fuel from the reactor core, the transfer in a MPC, handling and storage through to downloading and sealing in a VVM of the HI-STORM UMAX.
- **Holtec SMR-300 GDA - Non-Fuel Waste Packaging BAT Workshop Output Report (worked example**) [29] – Underpins the selection of the NFWC as the preferred option. This takes into account radioactive waste generation and transport of all the options.
- **Spent Fuel Management Strategy** [116] – Prior to disposal to the GDF, strategic opportunities involving the offsite transport of the MPC containing spent fuel are identified. The MPC is designed to be transportable in a HI-STAR overpack and is not required to be unloaded prior to shipment offsite.
- **Holtec SMR-300 GD Fuel Design Criteria and Limits** [97] – Shipping and handling loads on the fuel assembly shall remain below the specified limits presented in this report. This support fuel integrity and therefore minimisation of waste.

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[2] Holtec International Storage Module (HI-STORM) Underground Maximum Capacity (UMAX).

[3] VVM provides for storage of an MPC in the vertical configuration inside a cylindrical cavity located entirely below the top-of-grade of the ISFSI.

- **PSR Part B Chapter 9 Conduct of Operations** [17] – Describes fuel route, transport and storage operations consistent with current design maturity.
- **System Design Description for the Spent Fuel Cooling System** [22] – Defines the design description and functional requirements of the SMR-300 SFC, which ensures safe heat removal and containment boundary integrity for spent fuel assemblies during wet storage.
- **SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities** [16] – Provides the systems functions and a system description of the SFC.
- **Spent Fuel Pool Cooling System Regulatory Compliance Report** [117] – Details how the SMR-160 Spent Fuel Pool Cooling System meets the requirements of US regulators.
- **SMR-160 Fuel Handling and Storage** [113] – Defines the fuel handling and management strategy for the SMR-160 used as a basis for the SMR-300 strategy.
- **Future Evidence: New Fuel Management Procedure** – Will set out the handling arrangements for new fuel in order to ensure the integrity of fuel is maintained during handling and that contamination is minimised, therefore reducing the quantity of radioactive waste produced.
- **Future Evidence: Spent Fuel and Damaged Fuel Management Procedures** – Will set out the handling arrangements for spent fuel and damaged fuel and controls during operations which minimise the potential for generation of secondary waste in these operations.

6.8.2.2 Argument 4.2-A2: Containment Systems

Argument 4.2-A2: Containment Systems *The Generic SMR-300 includes appropriate containment and leak detection systems to confine radioactivity to protect people and the environment and reduce the volume or mass of radioactive wastes.*

This argument addresses how the generic SMR-300 applies the principle of 'concentrate and contain' which underpins radioactive waste management. Effective containment of radioactive materials within their intended systems and vessels is essential, both for radiation protection and to minimise the generation of unintended and unnecessary secondary waste. If loss of containment does occur, timely detection and secondary containment (such as in a bund or sump) will be in place to reduce the radiological impact and avoid waste proliferation.

This argument has similarities with claim 2.2.16 in the PSR *"SSCs which support the safe management and storage of radioactive waste are designed to ensure safety functions and measures are delivered and radiation exposure and release of radioactivity are minimised ALARP."*. The focus here is specific to the application of BAT, in line with environmental permitting requirements.

This argument is broken down into six separate sub-arguments as depicted in Figure 14 below.

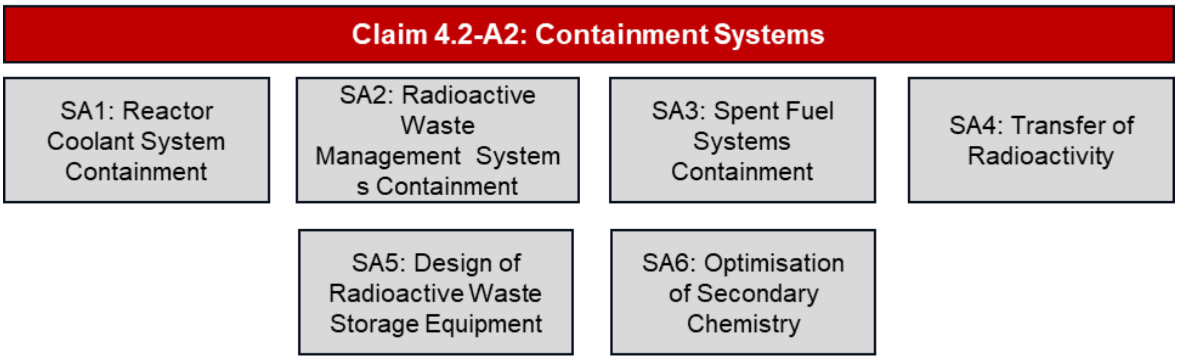

Figure 14: Summary CAE Tree for 4.2-A2 Containment Systems

6.8.2.2.1 Argument 4.2-A2-SA1 Reactor Coolant System Containment

Argument 4.2-A2-SA1: Reactor Coolant System Containment *The Generic SMR-300 reactor coolant system is designed to ensure radioactive substances are appropriately contained so as to prevent the spread of contamination and degradation of barriers against leakage to the environment.*

The generic SMR-300 primary circuit has been designed with containment features that prevent the spread of contamination and minimise leakage into the surrounding substructures and environment. The SSCs demonstrate the 'defence in depth' approach with the following barriers to radiological release:

- Fuel matrix.
- Fuel rod cladding.
- Reactor coolant circuit.
- Reactor containment structure.

The generic SMR-300 containment structure consists of multiple physical barriers. This includes the Containment Structure (CS), a Seismic Category I structure that acts as an essentially leak-tight barrier to contain fission and activation product releases from the reactor coolant pressure boundary. The RPV, Reactor Coolant System (RCS), SFP and associated SSCs are contained with the CS and each contribute to the integrity of the containments system.

These barriers are supported by engineered features that limit the potential for leaks or failures during all modes of operation.

Key features of the generic SMR-300 design that support effective primary circuit containment include:

- Materials selected for their resistance to corrosion and radiation damage – See Argument for 4.1-A1-SA4 Material Selection and Surface Finish.
- Primary circuit chemistry control – To maintain the integrity of both fuel cladding and reactor pressure boundary, the SMR-300 employs rigorous chemistry control to minimise corrosion.
- Leak-tight containment structure and primary circuit equipment – High-integrity welds/isolation valves to minimise leaks.
- Containment Ventilation System (CBV) – The CBV performs a containment isolation function to maintain the containment pressure boundary and prevent uncontrolled egress of radioactivity into the environment.

To complement these design features, proven diagnostic monitoring techniques shall be used for leak detection [47]. This will provide an early warning of potential breaches or degradation in containment.

The design of the generic SMR-300 primary circuit containment systems prevents the dispersal of radioactive substances within the facility and environment which reduces the need for secondary decontamination systems and their associated secondary wastes.

6.8.2.2.1.1 Evidence for 4.2-A2-SA1: Reactor Coolant System Containment

- **SMR-300 Primary Water Chemistry Strategic Plan** [106] – Provides an evaluation of the susceptibility of SMR-300 RCS materials (austenitic stainless steel to Primary Water Stress Corrosion Cracking (PWSCC) and general corrosion.
- **Stress Corrosion Cracking in Light Water Reactors: Good Practices and Lessons Learned** [118] – Provides a demonstration that SMR-300 design and material aligns to international good practice.
- **SMR-300 Nuclear Island Minimalization Strategy of Activity Generation and Accumulation** [111] – Provides an overview of the use of hydrogen peroxide and dedicated crud burst beds for chemistry control during transients. Outlines the plant-specific operation to produce a controlled forced oxidation strategy. This will allow for a controlled release of corrosion products, to be captured by ion exchange.
- **SDD for CBV** [119] – Provides a description of how the CBV performs a containment isolation function (including vacuum relief) and how airborne radioactivity and releases to environment are managed.
- **SDD for RMS** [120] – Includes the detection of coolant system leakage as a non-safety function.
- **SDD for RCS** [109] – Includes confinement of radioactive material as a safety function.
- **Containment Structure System Based View** [121] – Provides a holistic view of the integrity of the containment structure and the role engineered safety features play in maintaining a secure structure.
- [REDACTED]

6.8.2.2.2 Argument 4.2-A2-SA2 Radioactive Waste Management Systems Containment

Argument 4.2-A2-SA2: Radioactive Waste Management Systems Containment

The Generic SMR-300 solid, liquid and gaseous waste systems are designed to ensure radioactive substances are appropriately contained so as to prevent the spread of contamination and degradation of barriers against leakage to the environment.

The generic SMR-300 design incorporates a suitable design of SSCs for all radioactive waste management systems to ensure containment is maintained and the spread of activity is minimised. This is critical to reduce the overall volume and mass of radioactive waste and maintain protection of the environment. The following discussion outlines how each of the systems have been designed, taking due cognisance of BAT, to perform the containment function.

Each of the LRW, GRW and SRW have been designed in accordance with internationally recognised codes and standards including ANSI/ANS-55.6 [122][4] and the EPRI URD [123]. These codes and standards outline key features intended to minimise the potential for loss of containment to the environment.

The key points contributing to the demonstration of containment in these systems are summarised for each system below:

- The LRW has the following design features which contribute to ensuring containment of the liquid wastes:
    - Berms are required on all tanks that have the potential to contain or are designed to contain radioactive liquids. This will contain leakage in the event of a line or tank failure.
    - All berms shall have a minimum holding capacity for containment of 110% of the tank volume.
    - Equipment and piping shall be designed to minimise leaks to comply with 10 CFR 20.1406 and RG 4.21 [124] which mandates the minimisation of contamination.
    - The LRW will be designed to preclude gravity flow from the systems to the environment. This is in line with EPRI requirements [123] and eliminates unplanned or unmonitored releases via gravity or siphon flow.
    - Tanks and equipment are designed in accordance with ANSI/ANS 55.6 [122].
- The GRW has the following design features which contribute to ensuring containment of the gaseous wastes:
    - The pressure relief devices on the GRW equipment shall be piped into the building exhaust ventilation system to provide an additional means for monitored containment. This is a requirement laid out within ANSI/ANS-55.4 [125].
    - The piping and equipment for the GRW has been designed to minimise the potential for leakage from the system. This includes design features such as use

[4] ANSI/ANS American National Standards Institute/American Nuclear Society

of welding on the piping where practicable, and selection of valves and equipment to minimise the potential for leakage.

- The SRW has the following design features which contribute to ensuring containment of the solid wastes:
  - The design of the filter transfer vehicle will be developed to ensure that leakage during the transporting of a filter assembly is prevented.
  - The number of penetrations on the waste containers shall be minimised to minimise the potential number of leak paths. While the specific conditioning equipment is yet to be defined, ensuring this requirement is in the design from this early stage will lead to reduced leak paths going forward.
  - The design shall take into consideration the potential buildup of concentrates within the cleanout and flushing connection. All connections between concentrates and flush-water systems shall have a positive means of preventing the backflow of concentrates into flush-water systems [126].
  - Pumps should have wear-resistant mechanical seals to minimise the leakage of radioactive liquids [126].

These design features demonstrate that the radioactive waste management systems have been designed to ensure that the wastes are appropriately contained, such that the spread of contamination is minimised, and environmental boundaries are not degraded.

6.8.2.2.2.1 Evidence for 4.2-A2-SA2: Radioactive Waste Management Systems Containment

- **PSR Part B Chapter 13 Radioactive Waste Management** [43] – Presents key design features of the radioactive waste management systems, containment of waste and environmental protective barriers. It also presents a number of codes and standards used in the design and described in the arguments above which contribute to the minimisation of radioactive waste.
- **SDD for Solid Radwaste System** [127] (SRW) – Provides a system description of the SRW for wet, dry and miscellaneous solid waste. The includes the functional requirements and design basis to maintain containment and minimise leakage.
- **SDD for Liquid Radwaste System** [128] (LRW) – Provides a system description of the LRW, including the functional requirements and design basis to maintain containment and minimise leakage.
- **SDD for Gaseous Radwaste System** [129] (GRW) – Provides a system description of the GRW, including the functional requirements and design basis to maintain containment and minimise leakage.
- **SMR-300 Top Level Plant Design Requirements** [47] – Outlines the requirements to have multiple physical barriers to radiological releases and defines the requirements for containment performance.

6.8.2.2.3 Argument 4.2-A2-SA3 Spent Fuel Systems Containment

Argument 4.2-A2-SA3: Spent Fuel Systems Containment

The Generic SMR-300 includes appropriate containment systems to prevent the escape of radioactivity when storing, transporting and handling spent fuel so as to prevent the spread of contamination and degradation of barriers against leakage to the environment.

The generic SMR-300 minimises the escape of radioactivity and contamination at each stage of the spent fuel transport and storage route, The generic SMR-300 applies a defence-in-depth philosophy, implementing a combination of radiological barriers and containment systems (fuel cladding reactor coolant pressure boundary, and the containment structure). The integrity of the radiological barriers prevent or limit the release of radioactivity.

Table 6 below summarises the stages of the spent fuel transport and storage route along with the associated containment measures that prevent release of activity.

Table 6 - Spent Fuel Transport Route and Containment Features

Spent Fuel Route Phase	Containment
The transfer of spent fuel from the reactor core into the SFP.	Conducted within the containment structure. Fuel integrity is preserved, and the containment structure serves as a robust physical barrier [130].
The cooling of spent fuel within the SFP.	The SFC ensures containment integrity by employing Containment Isolation Valves (CIVs) that limit leakage in the event of pipe failure. CIV design complies with 10 CFR 50, GDC 56 [131]. Redundant valves provide defence-in-depth.
The transfer of spent fuel from the SFP to the Fuel Handling Areas.	Spent Fuel Assemblies (SFAs) are submerged in the MPC in the SFP before transfer. SFAs remain in MPCs within a HI-TRAC transfer cask during transfer. Containment is provided by the water-filled MPC cavity and isolation by inflatable and elastomeric seals.
The processing/drying in preparation for dry storage and transfer to dry storage.	During processing, the MPC functions as a sealed confinement boundary. It is subjected to helium leak testing and weld inspections to verify integrity. The design is consistent with U.S.NRC ISG-8 guidance, ensuring that confinement failure is non-credible.
The final dry interim storage in the passively safe HI-STORM UMAX system.	Spent fuel is stored in the HI-STORM UMAX system, an underground, passively safe storage solution. The MPC provides the primary confinement boundary, with UMAX overpacks offering shielding and further containment.

Lifting, handling, processing and transportation equipment is designed to efficiently move spent fuel from the SFP to the UMAX system at the on-site ISFSI.

6.8.2.2.3.1 Multi-Purpose Canister and HI-TRAC

The MPC is a seal welded enclosure which provides the confinement boundary. The MPC confinement boundary is defined by the MPC baseplate, MPC shell, MPC lid, closure ring, port cover plates, and associated welds. The annular area between the MPC outer surface and the HI-TRAC inner surface can be isolated to minimise the potential for surface contamination of the MPC by spent fuel pool water during wet loading operations.

The HI-TRAC transfer cask provides shielding to maintain occupational exposures ALARA in accordance with 10 CFR 20, while also maintaining the maximum load on the plant's crane hook below the rated capacity of the crane.

6.8.2.2.3.2 Spent Fuel Pool

The SFC has two containment penetrations. CIVs minimise leakage from penetrating piping. In the case of a break outside the containment, redundant isolation valves provide 'defence in depth' by ensuring containment isolation.

Spent fuel is transferred from the SFP to the passively safe storage conditions of the ISFSI as soon as reasonable practicable. This strategy minimises the accumulation of SFAs within the reactor building and ensures that only a low source term is maintained within the SFP [22].

Collection of any leakage from the SFP is routed via the Radioactive Drain System (RDS) to the LRW where abatement systems minimise discharge to the environment [113]. Should a leak occur, leak chases would be expected for the SFP liner to enable the rate and location of leakage through it to be monitored, noting that details for the RDS are not yet available [22].

6.8.2.2.3.3 HI-STORM UMAX

Spent fuel is stored within the Holtec's proprietary HI-STORM UMAX dry storage system, a proven mature system that has been in-service at power station sites since 2015. It is licensed by the U.S.NRC for generic use in the US.

MPC design meets the guidance in ISG-8 so that leakage of radiological matter from the confinement boundary is non-credible. The underground location of the VVMs significantly reduces the radiation from the ISFSI at the site boundary compared to an aboveground cask [115].

Contamination on the outside of the MPC from the fuel pool water is minimised by preventing contact and decontamination. An inflatable seal in the annular gap between the MPC and HI-TRAC, and the elastomer seal in the HI-TRAC bottom lid prevent the fuel pool water from contacting the exterior of the MPC and interior of the HI-TRAC while submerged for fuel loading.

6.8.2.2.3.4 Evidence 4.2-A2-SA3 Spent Fuel Containment Systems

- **PSR Part B Chapter 24: Fuel Transport and Storage** [22] – Provides an overview of the fuel transport and storage route encompassing the unloading of spent fuel from the reactor core, the transfer in a MPC, handling and storage through to downloading and sealing in a VVM of the HI-STORM UMAX.
- **SDD for SFC** [108] – Defines the function requirements and design basis for the SFC, providing cooling, cleanup and maintenance of water quality within specified chemistry, radioactivity and clarity limits.
- **SMR-300 Acceptance Criteria for Deterministic Safety Analysis** [132] – Provides a summary of the acceptance criteria to maintain the integrity of the radiological containment barriers and allowable radiological consequences if those barriers fail.
- **Design Specification for the Containment Structure** [130] – Provides a definition of the functional, performance and safety requirements that form the basis of design of the SMR-300 Containment Structure.
- **SMR-300 UK GDA Spent Fuel Management Strategy** [116] – Establishes a compliant baseline strategy for spent fuel management for the generic SMR-300.
- **Future Evidence: Final Safety Analysis Report (FSAR) for the HI-STORM UMAX System** – The scope and level of detail for the justification during GDA Step 2

fundamental assessment of the UMAX system was reduced (outlined in UK GDA [DC08] Design Challenge - Reduction in GDA Scope for the HI-STORM UMAX System [133]). The scope that was removed at GDA represents future evidence for the site-specific stage.

6.8.2.2.4 Argument 4.2-A2-SA4 Transfer of Radioactivity

Argument 4.2-A2-SA4: Transfer of Radioactivity *The Generic SMR-300 employs barriers, zones and other mechanisms to ensure the uncontrolled transfer of radioactivity between areas is minimised.*

The generic SMR-300 minimises the transfer of radioactivity through the design of layout, plant systems and procedures and controls. Contamination control is implemented into the design through design specifications that must be implemented across all relevant systems. While some of these measures, such as procedural controls, will be developed and refined at the site-specific stage of development, the design requirements developed at this stage ensure the generic SMR-300 design will meet regulatory expectations in radioactivity and contamination control. These requirements support a key safety claim in PSR Part B Chapter 10 Radiation Protection [18] and contribute to demonstrating that worker dose is ALARP and the waste arisings are minimised.

ALARP is achieved through the integration of radiological protection principles into the design. Many of these protective design features also contribute to the minimisation of radioactive waste. Key examples include the minimisation of source terms, optimisation of shielding design, minimisation of activation products, and strategic facility design / layout, including systems such as HVAC.

A baseline radiation zoning scheme has been introduced in the SMR-300 Design Standard for Radiation Protection [100]. Zones will be established in conjunction with plant layout such that the personnel layout of the zones is designed such that personnel do not have to pass through higher radiation zones to access lower radiation zones. Movement between zones will be controlled by a combination of physical barriers, contamination controls and procedural controls. Washing facilities shall be provided where contamination is likely such that contamination can be removed to avoid spread Sufficient space should be provided so that cross contamination between personnel is avoided.

Zoning forms a key safety claim in PSR Part B Chapter 10 "*Radiation zoning ensures access to and between Controlled and Supervised Areas will be suitably controlled to minimise exposures to ALARP and prevent the spread of radioactive material*." [18]. This zoning ensures the appropriate controls are put in place such as access barriers, PPE and shielding.

The approach to contamination control is to ensure air flows from areas of low contamination to areas of high contamination. Airflow in the ventilation system will be such that the pressure in a region of lower airborne contamination levels is higher than the pressure in a region of potentially higher contamination levels to minimise the spread of contamination minimising solid radioactive waste generation. The pressure of rooms located in controlled areas will be maintained below atmospheric to prevent radioactive releases into the atmosphere during operation minimising gaseous waste discharges.

The Radiation Protection Design Standard [100] also discusses the use of ventilation systems featuring blowers, High Efficiency Particulate Air (HEPA) filters, and activated charcoal filters to control local airborne contaminants.

Design specifications for the CS [130] and RAB [134] specify design requirements that will help minimise the transfer of radioactivity. As the design requirements capture the needs of all topic areas the design requirements amalgamate all topic needs. Relevant design requirements that contribute to the minimisation of radioactivity transfer are areas such as HVAC requirements, radiological and shielding requirements and layout requirements.

6.8.2.2.4.1 Evidence 4.2-A2-SA4 Transfer of Radioactivity

- **SMR-300 Design Standard for Radiation Protection** [100] – Discusses zoning, barriers, HVAC and PPE requirements which all contribute towards preventing the spread of contamination and therefore minimisation of waste. Includes the requirements for washing and clothing facilities.
- **PSR Part B Chapter 10 Radiation Protection** [18] – Proposes zoning schemes to classify External Radiation Controlled Areas and Contamination Controlled Areas. The designation of areas is based on existing UK practice from operational (and decommissioning) reactor sites. Also discusses the applicable aspects of the design specifications of the CS and RAB that contribute to radiation protection and contamination control.
- **Design Specification for the Containment Structure** [130] – Specify design requirements that will help minimise the transfer of radioactivity namely the CS is designed to provide a leak-tight barrier against the uncontrolled release of radioactivity in all operational states and design basis conditions, throughout the life of the plant.
- **Design Specification for the RAB** [134] – Specify design requirements that will help minimise the transfer of radioactivity namely:
  - Radiation zoning and access control.
  - Remotely operated process and instrumentation controls.
  - Isolation and decontamination of substantial radiation sources.
  - Minimisation of accumulation of radioactive materials in resin and sludge treatment systems, etc.
- **SDD for RMS** [120] – Includes non-safety functions relating to contamination control.
- **Holtec SMR GDA PSR Part B Chapter 20 Civil Engineering** [46] – Provides discussion on the functions of the CS.
- **Equipment and Piping Layout Guidelines for Ensuring Radiation Exposures ALARA** [103] – Includes features which contribute to the minimisation of the spread of radioactive contamination such as providing adequate space for maintenance, not routing pipes buried in concrete such that it is difficult to inspect for degradation and having isolation systems in place of systems which contain substantial radiation sources.
- **Future Evidence: Zoning and Barrier Layout** – Work will continue in developing and refining the layout plans as room and shielding design maturity increases.

6.8.2.2.5 Argument 4.2-A2-SA5 Design of Radioactive Waste Storage Equipment

Argument 4.2-A2-SA5: Design of Radioactive Waste Storage Equipment The Generic SMR-300 includes containers and other storage equipment to minimise the uncontrolled spread of activity and therefore volumes and mass of radioactive wastes.

The generic SMR-300 design is still to finalise the waste packages for its different waste arisings, BAT appraisals will be carried out at the site-specific stage to identify the optimal waste container for each waste stream. This sub-argument only covers the containers used for LLW and ILW. Spent fuel storage containers are not within the scope of this argument and are covered within Argument 4.2-A2-SA3 Spent Fuel Systems Containment.

While the design does not confirm the final waste containers for the different waste streams, the following discussion covers the baseline for the waste containers to provide confidence that all waste arisings will be stored within appropriately designed containers to prevent the uncontrolled spread of activity and therefore volumes of radioactive waste.

6.8.2.2.5.1 VLLW and LLW Containers

Very Low Level Waste (VLLW) and LLW arisings from the operation and decommissioning of the Generic SMR-300 are anticipated to arise from many different sources. The IWS [86] provides the baseline strategy for the management of operational and decommissioning LLW streams and outlines that the container options for these wastes is likely to be 200 litre drums before being transported off-site in a suitable transport container such as a Half-Height ISO (HHISO) or Full-Height ISO (FHISO). Miscellaneous oily or mixed wastes are assumed to be LLW and therefore will be managed via the appropriate LLW management route. As with all other waste arisings, the optimal container selection for these miscellaneous wastes will be confirmed at a later design phase, taking cognisance of the principles of BAT, ALARP and the application of the waste hierarchy.

6.8.2.2.5.2 ILW Containers

The majority of operational ILW waste arisings are foreseen to come from spent ion exchange resin and spent filter cartridges. It is assumed that HICs are to be used for the storage of ILW resins and cartridges arising from the operation of the generic SMR-300 [127]. HICs are commonly used within the US for the storage of spent resin and filter media; however, there is a known difference between the US and UK regulatory regime such that interim on-site storage of these wastes is not required due to a difference in the waste classification scheme. This results in the waste being packaged into the HICs and shipped off site for disposal rather than storing it on-site until a disposal route becomes available such as a GDF. Because of the UK requirement for long term on-site storage, the containers are required to be more robust than the HIC.

During Step 2 a high-level options assessment [87] was conducted on the different viable packaging solutions for operational ILW. This assessment utilised the Nuclear Decommissioning Authority (NDA) Value Framework [135] to appraise a UK and US option for the packaging and storage of ILW on site. The US option presented was storage of the ILW in a HIC before storing those HICs in a HI-SAFE module to meet the additional performance requirements of the package. The UK option selected was storage of the ILW within a Robust Shielded Container (RSC) prior to on-site storage in a lightly shielded Intermediate Storage Facility (ISF). The assessment does not constitute full BAT and ALARP optioneering at this stage; however, it does provide confidence that there are no anticipated operational ILW streams which cannot be safely containerised utilising NWS approved containers. As aforementioned, this assessment is a high-level options assessment and full, detailed BAT and ALARP optioneering is required to be carried out at a later design phase to confirm the most optimal container for the packaging and storage of operational ILW. This process will also be conducted for all decommissioning ILW to ensure the optimum container solution is selected.

6.8.2.2.5.3 Evidence for Argument 4.2-A2-SA5: Design of Radioactive Waste Storage Equipment

- **Integrated Waste Strategy** [86] – Identifies the baseline strategy for each waste stream arising from the generic SMR-300.
- **SMR-300 ILW Management Strategy: Options Assessment** [87] – Provides a comparative assessment of UK and US packaging solutions to understand the strengths and weaknesses of each option.
- **Future Evidence: Waste Storage and Packaging Optioneering** – The IWS provides confidence that all wastes can be packaged into a suitably robust and effective container, full BAT and ALARP optioneering is required post-GDA to confirm packaging options.
- **Future Evidence: Letters of Compliance** – Further engagement with NWS and Letter of Compliance (LoC) submissions to support endorsement of the radioactive waste management strategy through disposability assessment.

6.8.2.2.6 Argument 4.2-A2-SA6 Optimisation of Secondary Chemistry

Argument 4.2-A2-SA6: Optimisation of Secondary Chemistry *The design of Generic SMR-300 ensures that secondary chemistry is optimised to maintain integrity of SGE tubing and the Secondary Circuit.*

In the SGE there is an interface between the primary and secondary circuits, optimisation of secondary circuit chemistry maintains minimal corrosion and wear in the secondary coolant system which serves two functions:

- Minimises degradation of the secondary barrier to radioactivity release, so no primary coolant leaks into the secondary circuit contaminating it and ensures optimal heat transfer is maintained.
- Minimises degradation of structures in the secondary system and associated auxiliary systems of the turbine island, so that they last their required lifetime. This also supports the first function by reducing the delivery of corrosion products in feedwater delivered to the SGE, which in turn further reduces corrosion of the secondary barrier.

The generic SMR-300 maintains optimal secondary chemistry through the control of impurities, chemical addition, and pH. This demonstrates BAT by maintaining the secondary barrier to radioactivity release which stops the secondary coolant becoming contaminated and increasing the volume of radioactive waste. There is also the benefit that secondary chemistry control minimises the amount of conventional waste as SSCs do not degrade and need to be replaced as often.

An amine will be introduced to maintain pH and a reducing agent will be used, both of which help ensure corrosion is minimised. Hydrazine, the reducing agent, is added because it reacts with the oxygen in the system, stopping it from causing corrosion to the surrounding materials. This helps maintain a reducing environment which minimises the formation of corrosive species. Hydrazine undergoes thermal breakdown to ammonia which helps maintain the elevated pH in the circuit. This aligns with the selected amine for pH control which also produces ammonia as a thermal breakdown by-product. A Deaerator is used to remove oxygen from the feedwater supply to help reduce corrosive oxidising conditions in the main feedwater system and SGE.

6.8.2.2.6.1 Evidence for 4.2-A2-SA6: Optimisation of Secondary Chemistry

- PSR Part B Chapter 23 Chemistry [21] – Presents the secondary chemistry operating regime for SMR-300 with technical justification based on empirical data, industry recommendations, and operating experience. Summarises design information from:
- SMR-300 Secondary Water Chemistry Strategic Plan [136] – Provides a basis for the operating chemistry regime for the SMR-300 secondary water.
- SMR-300 Closed Cooling Water Chemistry Strategic Plan [137] – Provides an overview of the operating chemistry regime for the SMR-300 closed cooling water systems.
- Future Evidence: Commissioning, Start-up and Shutdown Procedures – Chemistry can have a large influence on the generation of waste at source therefore chemistry commissioning procedures are particularly noted as requiring BAT input.

6.8.2.3 Argument 4.2-A3: Radioactive Waste Management Lifecycle

Argument 4.2-A3: Radioactive Waste Management Lifecycle *The Generic SMR-300 ensures that its radioactive waste management arrangements are optimised throughout the waste lifecycle and appropriate considerations concerning capacity and acceptance criteria to other premises have been taken into account.*

Effective management of radioactive waste across the waste lifecycle will facilitate the minimisation of the quantity of radioactive waste arisings. This aligns with the requirement for lifetime planning for radioactive substances outlined within RSR Principle 7 "*Radioactive substances should be managed throughout their lifetime to make sure people and the environment are protected both now and in the future*" [3]. It also supports several of the generic developed principles [33], including:

- RSMDP1 – radioactive substances strategy
- RSMDP3 – use of BAT to minimise waste
- RSMDP8 – segregation of wastes
- RSMDP9 – characterisation.

This argument interfaces closely with the Radioactive Waste Management Arrangements topic area, detailed in PER Chapter 1 RWMA [7] and demonstrates how the principles of BAT and the waste hierarchy have been integrated into the generic SMR-300 design and lifecycle planning.

The application of the waste hierarchy and suitable planning, arrangements and facilities for management of radioactive wastes is essential in order to demonstrate the application of BAT throughout the entire radioactive waste management lifecycle. This argument is further decomposed into two sub-arguments:

- SA1: Waste Inventory
- SA2: Waste Management Techniques and Facilities

Figure 15: Summary CAE Tree for 4.2-A3 Radioactive Waste Management Lifecycle

6.8.2.3.1 Argument 4.2-A3-SA1 Waste Inventory

Argument 4.2-A3-SA1: Waste Inventory *The Generic SMR-300 has undertaken appropriate calculations to define and estimate waste volumes which fully take into account operating experience from existing nuclear plants that uses comparable PWR technology.*

The two radioactive waste inventories developed for the SMR-300 design during Step 2 are appropriate for the level of maturity of the design and are in line with regulatory requirements as outlined in GDA Guidance for Requesting Parties [28].

GDA Guidance for Requesting Parties [28] specifies that the environment case should include:

- 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
- Category – High Level Waste, ILW, LLW, VLLW.
- Physico-chemical characteristics.
- Proposed management and disposal route.

The operational and decommissioning radioactive waste inventories have been developed separately as they have well understood differences in the characteristics and provenance of radioactive wastes generated during the two phases. The operational waste inventory is split between the calculation of solid waste [84] and the calculation of liquid and gaseous discharges [85].

The operational waste inventory has been developed using appropriate input data and calculational methods. It estimates the volume and specific activity of solid radioactive waste that a single SMR-300 unit will generate. The level of detail and accuracy of the calculation is suitable for the current state of development. Limitation on the calculations have been identified and inputs and assumptions highlighted that will require verification as the design progresses.

Neutron and gamma source terms, decay heat values, and quantities of radionuclides have been calculated with the TRITON and ORIGAMI / ORIGEN sequences of the SCALE 6.2.1 code package [138]. While the source term is not part of the DRP it has been used to allow for indicative demonstration of waste classification which is suitable for step 2 of this GDA. The source term will be developed further at the site-specific licensing phase.

The decommissioning waste inventory benchmarks the generic SMR-300 design against similar nuclear power plants and considers the differences in waste processing systems that could result in differences in waste streams when decommissioned [79]. Table 8 of the Decommissioning Waste Inventory summarises the qualitative inventory of decommissioning wastes, their likely material type and estimated waste category. At the site-specific stage, the development of a decommissioning plan will enable the production of a quantitative decommissioning waste inventory.

The Decommissioning Waste Inventory comprises of a qualitative indicative data on the SMR-300 based on the OPEX gathered from similar PWR designs.

Waste classification was determined based on the maximum calculated activity values or, where this is unavailable, based on relevant industry experience of the classification of such or similar components.

6.8.2.3.1.1 Evidence for 4.2-A3-SA1: Waste Inventory

- **SMR-300 Source Terms** [138] – Outlines the methodology for the calculation of source terms. Source Terms will continue to develop with design maturity.
- **Decommissioning Waste Inventory for the Generic SMR-300 Design** – Provides qualitative information on the solid radioactive wastes generated during the decommissioning phase.
- **Calculation of the SMR-300 Solid Radiological Waste Inventories** [84] – Presents waste volume calculations per year for the SMR-300 and applies UK waste categorisation and classification definitions. The document describes the calculation method.
- **Estimate of the SMR-300 Gaseous and Liquid Effluent releases using the PWR-GALE3.2 Code** [85] – Presents the calculation method and estimation of GBq per year for liquid and gaseous wastes.
- **Future Evidence: Quantitative Decommissioning Waste Inventory** – This document will present calculations on the quantity of wastes expected to be generated from decommissioning the SMR-300.

6.8.2.3.2 Argument 4.2-A3-SA2 Radioactive Waste Management Processes and Facilities

Argument 4.2-A3-SA2: Radioactive Waste Management Processes and Facilities

The Generic SMR-300 waste management facilities are designed to allow for optimised waste management techniques.

The design of the generic SMR-300 waste management facilities incorporates SSCs that enable sorting, segregation and conditioning of radioactive waste as close to the point of generation as reasonably practicable. This supports the application of the waste hierarchy and ensures the most appropriate treatment/disposal route is selected based on the waste's radiological and physical characteristics.

The generic SMR-300 waste management facilities are designed to be compatible with mobile treatment and conditioning system facilities such that additional processing may be selected if determined to be the most practicable options when taking into consideration ALARP and BAT and other holistic factors. Waste management facilities are configured to enable this flexibility.

[REDACTED]

In recognition of the differences between the approach to radioactive waste management in the US and the UK a design challenge paper was been raised [139].

Key design features of the generic SMR-300 waste management facilities allow for the following waste management techniques:

6.8.2.3.2.1 Waste Characterisation

The generic SMR-300 waste management facilities are designed to allow for comprehensive and optimised characterisation of radioactive waste. The facility incorporates dedicated areas and equipment for waste monitoring, sampling and analysis.

6.8.2.3.2.2 Waste Segregation

Waste management handling facilities will enable solid radioactive waste to be sorted by activity into waste category and by physical form in accordance with regulatory thresholds and Waste Acceptance Criteria (WAC) of disposal sites. Sufficient space and appropriate sorting equipment will be provided to ensure safe and efficient segregation in the RAB as the design progresses to the detailed stages.

For liquid wastes, SSCs have been developed to separately collect and process liquid effluents considering the principle of BAT to enable environmentally acceptable discharge. Liquid waste streams are segregated through dedicated collection sumps to avoid the mixing of wastes with different characteristics. Liquid wastes are segregated at source within the scope of RDS and CVC, and then collected in the LRW waste holdup tanks for storage and processing via the abatement systems following sampling and monitoring.

Gaseous effluent is segregated at source, then processed to remove the main radionuclides to the maximum extent practicable.

6.8.2.3.2.3 Waste Processing, Treatment & Conditioning

The generic SMR-300 waste management facilities enable the efficient processing and conditioning of radioactive waste into forms suitable for safe and compliant handling, storage, discharge or disposal. Facilities are configured to ensure flexibility through permanently installed systems, mobile treatment units or via integration with off-site processing facilities.

Aqueous and gaseous radwaste systems enable optimal treatment to meet environmental permitted discharge limits. Options are available to further refine effluent should it be deemed preferable, considering the principles of BAT and ALARP, as well as worldwide OPEX. Further information on liquid and gaseous waste management can be found in Argument 4.3-A1-SA1 Liquid Effluent Management.

The SRW allows for solid wastes to be processed and/or conditioned into packages that meet the WAC of disposal facilities. The flexibility in solid waste processing within the design allows for application of the optimal management strategy for the waste. The SRW will make best use of UK off-site waste volume reduction facilities, where it is reasonably practicable, e.g. recycling of metallic waste, incineration of combustible waste, supercompaction of compactable waste. Pre-treatment, such as cutting, decontamination, drying or dewatering, which is contingent on the requirements of subsequent treatment of each solid waste stream will be considered, where feasible, in the management of dry solid waste.

The SFC removes dissolved radionuclides from the SFP water using demineralisers and limits the activity of aqueous waste that may require discharge or further treatment. The SFC utilises two parallel demineralisers to maximise ion exchange capacity and provide optimal process flexibility during operation which reduces secondary waste arisings [108].

Miscellaneous oily and mixed wastes are expected to be LLW and will be managed via the appropriate LLW management route. The most practicable option is incineration at an off-site incinerator, which would reduce the volume of the waste significantly. If oily wastes do not meet the WAC for incineration, a potential option is absorption onto a suitable media and solidification of the waste oil via a mobile system and disposal at a suitable disposal facility such as the LLW disposal facility, based on waste characteristics [86].

6.8.2.3.2.4 Waste Packaging

The packaging stage can affect the quantity of radioactive waste generated via a number of factors. The volume within waste containers should be used efficiently such that the least number of containers are used.

6.8.2.3.2.5 Waste Storage

Waste that currently cannot 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 interim storage in a robust, passively safe manner on site pending shipment to the UK GDF.

The SRW for wet solid wastes incorporates features that allow for the radioactive decay to enable the potential change in categorisation of some ILW streams and to reduce operator dose [127]. Two spent resin tanks are provided to collect, and store spent resins and filter bed material form contaminated systems. This provides hold capacity to allow for the radioactive decay prior to processing. Consistent with RGP and OPEX, this approach does not require the mechanical or chemical waste treatment and therefore does not generate secondary wastes.

ILW/LLW boundary wastes which contain short-lived radionuclides as opposed to those containing long-lived radionuclides, can be consigned on a risk-informed approach to routes for lower activity wastes. This option is subject to 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.

There is a GDA Commitment (**C_RWMA_078**) to undertake additional work into developing the design for the facilities required for ILW storage and LLW handling to ensure they are designed to facilitate the application of optimal waste management strategies.

6.8.2.3.2.6 Waste Discharge

The Generic SMR-300 liquid and gaseous radwaste systems are design to allow for the controlled discharge of gaseous and aqueous radioactive wastes. Key features of the GRW allow for the compressed decay storage and/or reuse of gas to be used as cover gases before release to atmosphere. The LRW facility design supports the preferred ‘concentrate and contain’ approach wherever possible.

6.8.2.3.2.7 Timely disposal

The generic SMR-300 is designed so that wastes can be disposed off-site in a timely manner.

There is the requirement under standard permit condition 2.3.2(c) to:

“dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public.” [38]

This approach is consistent with the ONR’s regulatory expectations [72] to minimise waste accumulation and to process and store waste in a passively safe condition as soon as possible.

Timely disposal offers BAT benefits by reducing the potential for repackaging due to changes in waste acceptance criteria, maintaining up-to-date characterisation data to avoid misconsignment, and ensuring container integrity is not compromised. Radiological impacts are also reduced by limiting the duration waste is held in temporary storage.

Timely disposal of solid waste from SMR-300 is achieved by:

- Determining an accurate waste inventory (see Argument 4.2-A3-SA1 Waste Inventory)
- The provision of sufficient characterisation facilities in design for the waste (see Argument 4.4-A4-SA1: Characterisation and Segregation).
- Using established waste routes and eliminating orphan or problematic waste (see Argument 4.4-A4-SA3).

GDA Commitment **C_RWMA_078** establishes that design development on the facilities for ILW storage and LLW handling will be carried out to ensure site specific application is satisfactory.

6.8.2.3.2.8 Evidence 4.2-A3-SA2 Radioactive Waste Management Processes and Facilities

- **Integrated Waste Strategy** [86] – Presents a baseline strategy for the characterisation, segregation, processing, storage and subsequent discharge for all anticipated waste streams arising from the generic SMR-300.
- **SDD for SRW** [127] – Presents the SRW design features incorporated minimise the potentially harmful effects on workers, the public and the environment.
- **SMR-300 UK GDA Spent Fuel Management Strategy** [116] – Provides a baseline strategy for the management of spent fuel.
- **Part B PSR Chapter 24 Fuel Transport and Storage** [22] – Outlines the features present within the design of the spent fuel management systems which contribute towards substantiation of this argument.
- **SDD for SFC** [22] – Defines functional requirements of the system.
- **NWS Expert View Submission** [140] – Provision of radioactive waste stream information for review by NWS.
- **Calculation of SMR-300 Solid Radiological Waste (SRW) Inventories** [84] – Presents the operational waste streams for the generic SMR-300.
- **UK GDA Decommissioning Waste Inventory for the Generic SMR-300 Design** [79] – Presents qualitative descriptions of waste streams expected to be generated when decommissioning the generic SMR-300.
- **Future Evidence: Quantitative Decommissioning Waste Inventory** – This document will present calculations on the quantity of wastes expected to be generated from decommissioning the SMR-300.
- **GDA Commitment: C_RWMA_078** – Undertake additional work into developing the design for the facilities required for ILW storage and LLW handling to ensure they are designed to facilitate the application of optimal waste management strategies.

6.8.3 Claim 4.3 Activity of Radioactive Wastes

Claim 4.3: Activity of Radioactive Wastes *The activity of radioactive wastes from discharges to the environment and disposals is minimised.*

The development of the design of the generic SMR-300 has incorporated the application of BAT so as to minimise the activity of radioactive waste to reduce the impact on members of the public and environment ALARA. As set out in Claim 4.1, it is critical to prevent the generation of radioactive wastes at source as the most effective means by which to avoid environmental impacts. However, the generation of radioactive wastes is inevitable over the course of the lifetime of the plant and the reduction of radioactivity, in discharges and releases particularly, is required to minimise impacts on people and the environment.

The arguments presented in support of this claim are considered to demonstrate compliance with the requirements set out under condition 2.3.2 (a) of the standard RSR environmental permit [38] which states that:

"The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to: minimise the activity of gaseous and aqueous radioactive waste disposed by discharge to the environment".

Permit condition 2.3.3 is also discussed in the liquid waste sub-argument made under this claim:

"The operator shall use the best available techniques to:

(a) exclude all entrained solids, gases and non-aqueous liquids from radioactive aqueous waste prior to discharge to the environment;

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

(c) remove suspended solids from radioactive waste oil prior to incineration."

This claim also relates to the regulatory GDA guidance for RPs, in which it is stated that the optimisation process for BAT should be used to minimise *"(in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes"* [28].

In addition the generic developed principles for Radioactive Substances Regulations [33] RSMDP3, RSMDP5, RSMDP7, RSMDP15 and relevant decommissioning guidance [36].

The development of the generic SMR-300 has incorporated the application of BAT so as to prevent and / or minimise the activity of radioactive wastes. Features of the generic SMR-300 particularly important to this claim include:

- Abatement and treatment techniques and systems.
- Functions provided by radioactive waste systems.

Only one argument is made against this claim, but that argument is split into sub-arguments which face each main system in the design.

6.8.3.1 Argument 4.3-A1: Radioactive Waste Management Arrangements

Argument 4.3-A1: Radioactive Waste Management Arrangements *The Generic SMR-300 includes appropriate radioactive waste management, abatement arrangements to reduce the activity of radioactive wastes before discharge, disposal or release.*

Demonstration that the Generic SMR-300 design adequately incorporates features to reduce the activity of radioactive wastes prior to environmental discharge or disposal to ensure that both personnel and the environment are protected is fundamental to the overall environmental protection substantiation.

This argument has been further decomposed into two sub-arguments as depicted in Figure 16 and outlined below:

- SA1: Liquid Waste - Demonstration that the generic SMR-300 has the capability to appropriately manage liquid radioactive wastes and adequately reduce their activity before discharge.

- SA2: Gaseous Waste - Demonstration that the generic SMR-300 has the capability to appropriately manage gaseous radioactive wastes and adequately reduce their activity before discharge.

The sub-arguments and evidence provided demonstrate that appropriate radioactive waste management, abatement and storage arrangements are present in the generic SMR-300 design to protect people and the environment and reduce the activity of radioactive wastes.

Figure 16: Summary CAE Tree for 4.3-A1 Radioactive Waste Management Arrangements

6.8.3.1.1 Argument 4.3-A1-SA1 Liquid Effluent Management

Argument 4.3-A1-SA1: Liquid Effluent Management *The Generic SMR-300 will utilise radioactive waste processing systems featuring ion exchange resins to reduce the radioactivity of aqueous effluent discharged to the outfall.*

The LRW, collects, treats and discharges radioactive liquid waste generated by the SMR-300 using BAT. The LRW consists of waste holdup tanks which store liquid waste until processing occurs. A prefilter, activated carbon filter, three ion exchangers, and an after-filter are used, as needed, to process the wastes. Liquid waste SSCs will effectively utilise the regulatory preferred use of ‘concentrate and contain’ for radioactive waste over ‘dilute and disperse’.

It incorporates relevant codes of practise (such those outlined to by EPRI) and the U.S.NRC regulations. The LRW design ensures the requirements in the EA’s Radioactive Substances Management Developed Principles (RSMDPs) [33], as well as ONR SAPs [72] and Technical Assessment Guides (TAGs) are met.

The LRW baseline uses a combination of abatement techniques (filters and ion exchange media) to remove isotopes both in suspension and solution. Filtration and ion exchange are used widely in combination across the nuclear industry and are recognised in the American Nuclear Society (ANS) for Liquid Radioactive Waste Processing System for Light Water Reactor Plants document [122] and NDA good practice guidance [141]. These abatement techniques ensure that the activity of the liquid radioactive waste is reduced sufficiently such that it can be safely discharged to the environment.

The ion exchangers may be selectively loaded with resin, depending on plant conditions and waste needs. The order of the last two ion exchangers can be interchanged to provide complete usage of the ion exchange resin. This optimises resin utilisation and minimises solid waste generation.

The LRW Piping and Instrumentation Diagram (P&ID) [142] outlines how liquid effluent shall be segregated at source by routing to designated collection sumps and tanks using subsystems, hoses, or catch containments to manage each of the following waste categories: low conductivity waste, borated waste, high conductivity waste, chemical wastes, detergent wastes, non-contaminated wastes. Liquid wastes shall be segregated before processing, with each batch of liquid waste being characterised before processing and the appropriate treatment route being selected for the processing of each waste stream – dependent on its characteristics. This avoids the mixing of different waste streams (e.g. lightly contaminated liquid, heavily contaminated liquid, chemically contaminated liquid) and avoids undesired or premature blinding of resins and filters.

The LRW System contains two effluent holdup tanks sized to collect and store the waste inputs until enough is collected for batch processing [128]. If waste collected in the effluent holdup tanks is not compatible with the installed plant equipment based on sampling, connections for mobile equipment are provided for processing or preparation for offsite transport. This allows for use of the latest technology available so that the most efficient systems may be used [128]. This baseline strategy, outlined in the Integrated Waste Strategy [86] is in accordance with international good practice, such as ANSI / ANS-40.37 [143]. Tanks in the LRW system have been designed as vertical cylinders with internal pump suction piping at the low points of the tank. This minimises the formation of sludge at the bottoms of the tanks, in line with the EPRI URD. The contents of the waste holdup and monitoring tanks are recirculated by their respective pumps, contributing to the minimisation of deposition.

The use of temporary mobile equipment additionally allows for the flexible use of other alternative techniques, when required. Mobile system such as evaporators and Reverse Osmosis membranes at may improve separation of contaminants but also increase the complexity of radioactive waste systems and create new waste streams that would require further processing in SRW [86].

Particulate material from the liquid waste management system shall be removed through the combination of coarse pre-filters, charcoal bed filters, ion exchange filters and post demineralization particulate filters [100].

6.8.3.1.1.1 Evidence for 4.2-A1-SA1: Liquid Effluent Management

- **SDD for LRW** [128] – Provides the design features which demonstrate that the system adequately reduces the activity of radioactive wastes and minimises the overall volume of waste discharged to the environment.
- **PER Chapter 5 Monitoring and Sampling** [10] – Further detail surrounding the sampling and monitoring arrangements for liquid effluents arising including prevention of discharge if levels are above permitted limits.
- **Integrated Waste Strategy** [116] – Identifies the baseline waste management strategy for all liquid radioactive waste arisings. The strategy selected for the LRW has applied the waste hierarchy to reduce activity of the liquid waste, minimise the volume of waste being released to the environment and minimise the generation of secondary solid wastes.
- **Design Standard for Radiation Protection** [100] – Introduces the requirement for particulate filtration in the LRW.

- **Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management** [19] – Describes the LRW and presents the codes and standards used in the design of the LRW.
- **Future Evidence: Liquid Waste Management BAT Options Appraisal** – Demonstration of environmental optimisation of the storage and abatement options for liquid radioactive waste.

6.8.3.1.2 Argument 4.3-A1-SA2 Gaseous Effluent Management

Argument 4.3-A1-SA2: Gaseous Effluent Management *The Generic SMR-300 will utilise radioactive waste processing systems featuring radioactive decay tanks, HEPA filtration and iodine adsorbers to reduce the activity within gaseous radioactive wastes and the release of radioactivity to the environment.*

The waste hierarchy is deemed to be the fundamental principle for management of waste generated and will be implemented over the SMR-300 lifecycle including design, construction commissioning, operation and decommissioning stages. Operational gaseous wastes that are unavoidably generated will be effectively managed using the generic SMR-300 GRW to minimise the potentially harmful effects on workers, the public and the environment.

The function of the GRW is to collect, process, store and discharge gaseous wastes generated due to plant operations, including Anticipated Operational Occurrences (AOOs). The source of these gaseous wastes is expected to be fuel cladding defects leading to release of radioisotopes into the reactor coolant [129]. The GRW is designed to maintain offsite doses ALARA in accordance with relevant international codes and standards such as ANSI/ANS-55.4 [125] and applicable U.S.NRC regulations.

The gaseous waste is primarily anticipated to arise from the CVC effluent holdup tanks and volume control tanks. In addition, gases from the gaseous sampling system are discharged to the GRW. The GRW utilises the principle of radioactive decay to reduce the activity of the gaseous wastes prior to discharge to the environment. The GRW contains six Gas Decay Tanks (GDTs) located within the RAB which are used to contain the waste until it has sufficiently decayed at which point it is released through a monitored release path to the RAB exhaust vent. By reducing the activity of the gaseous waste through radioactive decay, the GRW ensures that the activity of the waste being discharged to the environment complies with the requirements set out under condition 2.3.2 (a) of the standard RSR permit [38].

The GRW has provision to reuse the gaseous waste contained within the GDTs as cover gas for the effluent holdup tanks and volume control tanks in order to preclude air intrusion. This reuse of gaseous waste minimises the volume of gaseous waste being discharged to the environment thereby reducing the overall activity of gaseous waste released to the environment.

Each of the six GDTs has provision for their contents to be sampled and analysed. In addition, there is redundant oxygen and hydrogen analysers provided to ensure that the oxygen concentration set points are not exceeded. The GRW has provision for flushing and diluting with nitrogen in the event of these set points being exceeded. Through sampling and monitoring of the GDTs themselves as well as monitoring of the discharge path to the atmosphere, the activity of the waste being released will not exceed the allowable limit designated by the RSR permit as gaseous discharge is not permitted if the activity of the gaseous waste is above the discharge limits. In the event of elevated activity levels occurring during discharge, the discharge valve is automatically isolated and requires operator intervention to restart discharge.

The GRW is sized to accommodate the gas generated by both units shutting down and starting up. This assumes that one unit is at 90% core life and the other is at 40%. Two additional GDTs have been added to the system to ensure that there is sufficient capacity for the storage, decay and subsequent release of gaseous radioactive waste such that no gaseous wastes are released without having had their activity reduced ALARA.

The GRW has several reliability features which aid in ensuring that gaseous radioactive wastes are not released to environment prior to their activity being minimised ALARA. The GRW has been designed with dual, redundant compressor systems, the gas analysers are also redundant and the valve on the discharge line fails close upon loss of power or loss of signal to ensure no gaseous radioactive waste is uncontrollably released. The GRW had been designed to maximise fully welded construction and utilise stainless steel to the maximum practicable extent. This aids in reducing the potential for leakage thereby ensuring that the maximum possible volume of gaseous radioactive waste is appropriately decayed within the GDTs before being discharged in a controlled manner through the monitored discharge path.

Following discharge from the GRW, gaseous wastes are discharged from the plant vent stack via the RCV. All active HVAC systems including the Radiologically Controlled Area HVAC System (RCV) and CBV will contain HEPA filters for removal of active particulates. Pre-filters, double banked HEPA filters and redundant fan and filter systems will be identified for areas with high particulate loadings [100]. This is supported by more additional technical detail in the HVAC Design Criteria [144].

HEPA filters are to be placed upstream of iodine adsorbers. Iodine adsorbers (typically impregnated activated carbon) are to be employed where presence of radioiodine is anticipated (for examples as a result on failed fuel, for containment and spent fuel pool serving HVAC systems).

Prefilters are to be employed upstream of HEPA filters where appropriate to reduce particulate loading of the HEPA filters and achieve an acceptable service life which will contribute to waste minimisation. In addition postfilters to be used downstream of adsorbers, if needed to retain carbon fines; and heating elements or cooling coils, or both, if necessary to control humidity before filtration.

6.8.3.1.2.1 Evidence for 4.3-A1-SA2 Gaseous Effluent Management

Evidence associated with the reduction of gaseous radioactive waste activity and releases to the environment are summarised below:

- **Integrated Waste Strategy** [86] – Presents the overall strategy proposed for the management of gaseous radioactive wastes for the generic SMR-300.
- **PER Chapter 5 Monitoring and Sampling** [10] – Further detail surrounding the sampling and monitoring arrangements for gaseous effluents arising including prevention of discharge if levels are above permitted limits.

- **PSR Part B Chapter 13 Radioactive Waste Management** [19] – Provides additional detail surrounding the design and operation of the GRW and its contribution towards reduction of risks ALARP.
- **SDD for GRW** [129] – Provides technical detail on the gaseous radwaste system.
- **SMR-300 Specification – HVAC Design Criteria** [144] – Specifies a set of requirements for generic SMR-300 HVAC systems including (where relevant) HEPA filtration, iodine adsorbers, pre-filters and post-filters.
- **Design Standard for Radiation Protection** [100] – Specifies the requirement for HEPA filtration for HVAC systems with contamination risk and sets design requirements for their implementation.
- **Future Evidence: Gaseous Waste Management BAT Options Appraisal** – Demonstration of environmental optimisation of the storage and abatement options for gaseous radioactive waste. Includes consideration to decay times for gases.
- **GDA Commitment: C_Mec_028** – A high level gap analysis has determined that UK RGP differs from the US approach to designing HVAC SSCs.

6.8.4 Claim 4.4 Impacts of Radioactive Wastes

Claim 4.4: Impacts of Radioactive Wastes *The impacts of radioactive wastes including discharges and disposals from the generic SMR-300 have been minimised. Radiation doses to any individual member of the public and the population as a whole are as low as reasonably achievable. Non-human species are adequately protected against exposures to ionising radiation.*

This forms what the requesting party consider the third main aspect of BAT as introduced in 6.2.2 Scope. After prevention and minimisation of waste comes the minimisation of the impacts of the waste.

The arguments presented in support of this claim are considered to demonstrate compliance with the requirements set out under condition 2.3.2 (c) of the standard RSR environmental permit [38] which states that:

"The operator shall use the best available techniques in respect of the disposal of radioactive waste pursuant to this permit to dispose of radioactive waste at times, in a form, and in a manner so as to minimise the radiological effects on the environment and members of the public" [38].

RPDPs [145] outline the principles for ensuring the public and non-human biota are protected from exposure to ionising radiation:

- ***RPDP1 - optimisation of protection*** - *All exposures to ionising radiation of any member of the public and of the population as a whole shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.*
- ***RPDP2 – dose limits and constraints*** - *Radiation doses to individual people shall be below the relevant dose limits and in general should be below the relevant constraints*

- ***RPDP3 – protection of non-human species*** *- Non-human species should be adequately protected from exposure to ionising radiation.*

In addition the RSMDP7 [33] states *"when making decisions about the management of radioactive substances, the best available techniques should be used to ensure that the resulting environmental risk and impact are minimised".*

This claim also relates to the regulatory GDA guidance for RPs, in which it is stated that the optimisation process for BAT should be used to *"prevent or minimise harm to people and the environment"* [28]. The guidance sets out the requirements on an RP to identify points of discharge, significant radionuclides associated with aqueous and gaseous discharges from the plant, provide an estimate of their monthly discharges taking into account all constituent aspects of normal operations (including unplanned but not unexpected events consistent with the implementation of BAT, otherwise known as Expected Events.

These estimates are compared to operational data from extant comparative plants and used to propose suitable limits taking into account necessary headroom to account for Expected Events and operational fluctuations. Subsequent radiation doses to the public and non-human biota are then determined based on these proposed limits to ensure the impacts are ALARA.

Minimisation of the impacts associated with radioactive wastes also extends to solid and non-aqueous liquid wastes where segregation at source and optimisation of disposal routes ensures that wastes are managed through their lifecycle in a way that minimises impact on the public.

The development of the generic SMR-300 has incorporated the application of BAT so as to prevent and / or minimise the impacts of radioactive wastes. Management arrangements and design aspects considered in the generic SMR-300 to minimise the impacts of radioactive wastes are categorised into four broad arguments:

1. Significant Radionuclides, Discharge estimates and proposal of limits (sub-chapter 6.8.4.1).
2. Radiological Impact Assessment (sub-chapter 6.8.4.2).
3. Appropriate Discharge Points (sub-chapter 6.8.4.3).
4. Optimal Disposal Routes (sub-chapter 6.8.4.4).

Features of the generic SMR-300 particularly important to this claim include:

- Radioactive waste management systems and abatement/treatment techniques.
- Optimised points of discharge to the environment.

6.8.4.1 Argument 4.4-A1: Significant Radionuclides, Discharge Estimates and Proposal of Limits

Argument 4.4-A1: Significant Radionuclides, Discharge estimates and proposal of limits
The Generic SMR-300 has undertaken appropriate calculations to identify significant radionuclides, estimate discharged waste activity and have proposed discharge limits to ensure impacts on people and the environment are minimised.

A key aspect of BAT is to ensure the radiological effects of discharges and disposals on the environment and members of the public are reduced ALARA. As such, it is important to first identify significant radionuclides, estimate anticipated radioactivity from radioactive wastes and propose suitable discharge limits to ensure the effects of ionising radiation are minimised.

Argument 4.4-A1 covers:

- The identification of normal operations source terms associated with operation of the generic SMR-300.
- Estimations of the activity of effluent discharges to the environment of significant radionuclides released to the environment, taking into account effects of radioactive decay, abatement and treatment systems.
- Proposal of reasonable permit limits for effluent discharges to the environment, based on the above estimates, allowing for headroom and potential fluctuations in these discharges.
- Comparisons between estimated discharges and proposed discharge limits for the generic SMR-300 to actual OPEX data from comparable PWRs, and estimated discharges/proposed limits from other GDAs, recognising and adjusting for different power output ratings.
- Allow the RP assess radiological impacts against dose limits set out within the UK legislative and regulatory regime (see Argument 4.4-A2: Radiological Impact Assessment) [38].

This argument is further decomposed in to two sub-arguments as depicted in Figure 17 below.

Further information on the regulatory context can be found in PER Chapter 2 Quantification of Effluent Discharges and Limits [8] and PER Chapter 3 RIA [11].

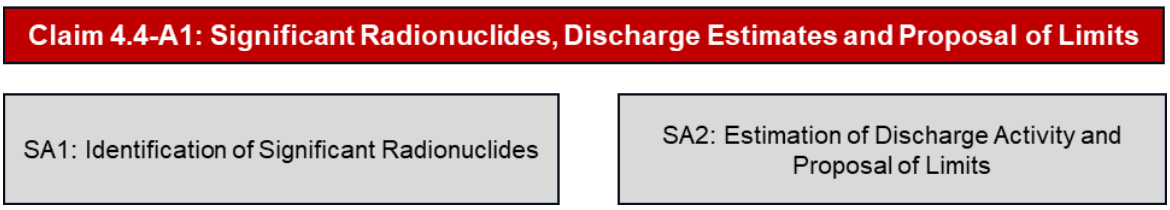

Figure 17: Summary CAE Tree for 4.4-A1 Significant Radionuclides, Discharge Estimates and Proposal of Limits

6.8.4.1.1 Argument 4.4-A1-SA1: Identification of Significant Radionuclides

Argument 4.4-A1-SA1: Identification of Significant Radionuclides *All significant radionuclides relevant to the generic SMR-300 which may impact on people and the environment have been identified.*

The identification of significant radionuclides produced during the reactor lifecycle of the generic SMR-300 is key to defining the release of ionising radiation and subsequent exposure, other radioactive wastes and effluent discharges to people (including workers and the public) and the environment.

According to GDA Guidance for Requesting Parties [28], significant radionuclides are those which:

- Have a radiological impact on people or non-human species.
- Are discharged in high quantities of radioactivity.
- Have long half-lives, may persist or accumulate (or both) in the environment, and may contribute significantly to collective dose.
- Are indicators of facility performance and process control.

The identification of significant radionuclides also facilitates the RP's understanding of resultant impacts from different radionuclides. This allows optimisation of the plant design (in particular of waste abatement and treatment systems) using BAT to reduce exposures to ionising radiation from the disposal and release of radioactive wastes ALARA. These BAT considerations will also cover preferential partitioning of certain radionuclides into the aqueous/gaseous/solid phase in order to minimise resultant dose impacts. Understanding of radionuclides that are key indicators of plant performance can inform operational philosophy to minimise generation of waste, and inform operator actions to ensure BAT is applied.

The principal sources of radionuclide production during normal operation include:

- Direct and prompt activation by radiation from the core.
- Neutron activation in reactor coolant.
- Leakage of fission products from defective fuel.
- Activation of corrosion products in reactor process systems.

The source term of a nuclear reactor refers to the specific magnitude and mix of radionuclides present in the plant within the primary system or associated plant systems during normal operations. The identification of significant radionuclides and discharge source term is reliant on the reactor primary coolant source term (PST). The PST is the specific mix of radionuclides present in the reactor coolant and is dependent on the core source terms (core isotopes & decay heat and fission products), as well as activation and corrosion products. The PST (and the secondary coolant source term) and the methodology for their derivation are detailed in SMR-300 Contained Radiation Sources for Normal Operation [146].

[REDACTED]

Significant radionuclides have been selected as outlined by a series of criterion under EA guidance [147]:

a) *Radionuclides that are significant in terms of radiological impact on people (the dose to the most exposed group at the proposed limit exceeds 1 µSv per year) – determined by the IRAT2 tool* [148] *in PER Chapter 3 Radiological Impact Assessment* [9].
b) *Radionuclides that are significant in terms of radiological impact on non-human species (where the impact on reference organisms from the discharges of all radionuclides at the proposed limits exceeds 40 µGy/hour). – determined by the IRAT2 tool* [148].
c) *Radionuclides that are significant in terms of the quantity of radioactivity discharged (the discharge of a radionuclide exceeds 1 TBq per year) – determined by estimation*

of the discharged source terms in PER Chapter 2 Quantification of Effluent Discharges and Limits [8].

d) *Radionuclides that may contribute significantly to collective dose (where the collective dose truncated at 500 years from the discharges of all radionuclides at the proposed limits exceeds 1 man-sievert per year to any of the UK, European or World populations) - determined using the Consequences of Releases to the Environment Assessment Methodology (PC-CREAM 08) tool* [149] *in PER Chapter 3 Radiological Impact Assessment* [9].

e) *Radionuclides that are constrained under national or international agreements or is of concern internationally – assessed via review of relevant national and international agreements in PER Chapter 2 Quantification of Effluent Discharges and Limits* [8].

f) *Radionuclides that are indicators of plant performance, if not otherwise limited on the above criteria – determined through system analysis in PER Chapter 2 Quantification of Effluent Discharges and Limits* [8].

g) *Radionuclides that for the appropriate generic categories from the RSR Pollution Inventory (e.g. "alpha particulate" and "beta / gamma particulate" for discharges to air) to limit any radionuclides not otherwise covered by the limits set on the above criteria – assessed in PER Chapter 2 Quantification of Effluent Discharges and Limits* [8].

Significant radionuclides identified have been cross-checked against key radionuclides identified in the EU Commission recommendation EU 2004/2/Euratom [150]. The significant radionuclides form the basis of parameters to be monitored for the generic SMR-300 covered in Argument 4.7-A1: Parameters to be Monitored.

6.8.4.1.1.1 Evidence for 4.4-A1-SA1: Identification of Significant Radionuclides

- **SMR-300 Contained Radiation Sources for Normal Operation** [146] – The methodology and estimates for the derivation of the PST and secondary coolant source term are set out in this document with the realistic or Best Estimate PST used for realistic estimations of effluent discharges.
- **PER Chapter 2 QEDL** [8] – Identifies significant radionuclides for the generic SMR-300 based on the criteria c), e), f) and g) set out in EA guidance [147].
- **Estimate of the SMR-300 Gaseous and Liquid Effluent Releases Using the PWR-GALE3.2 Code** [85] – Presents the calculation method and estimation of GBq per year for liquid and gaseous wastes.
- **PER Chapter 3 RIA** [9] – Identifies significant radionuclides relevant to criteria a), b) and d) in EA guidance [147].
- **Future Evidence: Re-evaluation of Significant Radionuclides** – At the site-specific stage of design the significant radionuclides will be reconsidered for proposal of permit limits depending on site-specific parameters, specifically for stack height and if required consideration of a lakeside site.
- **Future Evidence: Cs-134 Individual Limit** – Consideration should be given to proposal of an individual limit at the site-specific stage in the event a lakeside site is selected.

6.8.4.1.2 Argument 4.4-A1-SA2: Estimation of Discharge Activity and Proposal of Limits

Argument 4.4-A1-SA2: Estimation of Discharge Activity and Proposal of Limits

Calculations have been undertaken to estimate the activity of effluent aqueous and gaseous wastes discharged by the generic SMR-300. Suitable limits for their discharge have been proposed taking into account all constituent aspects of normal operations and expected events. Discharge estimates have been compared to similar plants to confirm discharges do not exceed those of comparable PWRs around the world.

The estimation of effluent waste activity produced during the reactor lifecycle of the generic SMR-300 is key to determining the release of ionising radiation and subsequent exposures to people (including workers and the public) and the environment. The estimation of released waste activity is important in the optimisation of the plant to:

- Allow for the optimisation of waste abatement and treatment systems, taking into account radioactive decay and anticipated arisings by using BAT to reduce exposures to ionising radiation from the disposal and release of radioactive wastes to ALARA.
- To benchmark the generic SMR-300 design against similar nuclear power plants, to ensure discharges will not exceed those of comparable PWRs around the world.
- Propose reasonable permit limits for effluent discharges to the environment, based on the above estimates, allowing for headroom and potential fluctuations in these discharges.
- Allow the RP to undertake the radiological impact assessment (see Argument 4.4-A2: Radiological Impact Assessment) to ensure impacts on the public and environment have been minimised and compliance with dose limits set out within the UK legislative and regulatory regime [38] [147].

Prospective effluent discharges have been estimated as per the U.S.NRC Methodology NUREG-0017 using the GALE-PWR 3.2 Code [151] using the PST as input. Decontamination factors associated with abatement/treatment have applied. These estimates were then compared to validation methodologies to confirm credibility of results.

GDA Guidance for Requesting Parties [28] requires that the RP must provide proposed annual site limits (on a rolling 12-month basis) for gaseous discharges and aqueous discharges, and the methodology for deriving these limits must be described. Discharge limits for the generic SMR-300 sufficiently incorporates conservatism into its limits through the use of headroom factors which ensure that discharge limits are sufficient to allow for normal operation discharge fluctuations without breaching said limits. These headroom factors and expected events are then applied to the discharge estimates in order to propose limits for the generic SMR-300.

The limits and method proposed at GDA will likely be refined at the site-specific stage to proposed limits for any future RSR permit application.

6.8.4.1.2.1 Evidence for 4.4-A1-SA2: Estimation of Discharge Activity and Proposal of Limits

- **Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code** [151] – Documents the use of the GALE PWR-3.2 code to implement the methodology detailed in U.S.NRC NUREG-0017 to estimate the gaseous and aqueous effluents released from a single unit SMR-300.

- **PER Chapter 2 QEDL** [8] – Demonstrates that the U.S.NRC NUREG-0017 methodology and GALE PWR-3.2 code represent RGP for the generic SMR-300 consistent with the application of BAT. Describes the methodology for determining appropriate limits for the generic SMR-300 and presents the comparison of generic SMR-300 discharge estimates to existing PWR OPEX.
- **Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Limits** [152] – Describes the primary methodology for the calculation of effluent discharge estimates, and describes the validation methodologies. Validation methodology outputs are compared to the primary methodology results to confirm credibility of the estimates. Identifies expected events associated with generic SMR-300 operations.
- **Holtec SMR-300 GDA Liquid and Gaseous Discharge Report** [153] – Presents generic SMR-300 design input parameters and decontamination factors used to estimate discharges.
- **OPEX Data Selected for PER Chapter 2 Quantification of Effluent Discharge and Limits (QEDLs)** [154] – Document presenting the data selected from a variety of international PWRs for use in the PER Chapter 2 [8]. It also includes a description of the criteria used to select comparable plants, the methods of comparison, and, where possible, provide justification as to why certain plants have been selected for OPEX comparison.
- **Future Evidence: RAB Plant Vent BAT Study** – Present the options assessment of the detailed design to ensure the stack and supporting systems are adequately designed to facilitate discharge monitoring and sampling.
- **Future Evidence: Review the Outputs from GALE** – Provides a means at the site-specific stage to compare and validate methodologies, European and international OPEX to confirm that GALE represents RGP for the generic SMR-300.
- **Future Evidence: Tritium Management Strategy**.
- **Future Evidence: Determination of Cobalt-60 as a Plant Performance Indicator** – Use of a specific individual limit will be reconsidered at the site-specific stage.
- **Future Evidence: Individual Headroom Factor for Iodine-131**.
- **GDA Commitment: C_QEDL_100** – Raised to undertake a detailed assessment of estimated discharge source terms (on an annual and monthly basis) once discharge schedules and process-specific source terms are available, to ensure proposed limits account for the following aspects of normal operation including expected events.
- **GDA Commitment: C_QEDL_101** – Raised to ensure revised methodologies for calculating discharges of Argon-41 and Tritium are developed once the design has matured to a level at which reactor-specific values can be used to remove conservative assumptions.

6.8.4.2 Argument 4.4-A2: Radiological Impact Assessment

Argument 4.4-A2: Radiological Impact Assessment

The Generic SMR-300 has undertaken appropriate dose calculations for exposed members of the public, the environment and non-human species and demonstrates that they are justified in the context of those for comparable nuclear power plants and doses are reduced below limits and constraints.

Based on the discharge estimates and proposed limits defined in PER Chapter 2 Quantification of Effluent Discharges and Limits [8] (See Argument 4.4-A1-SA2: Estimation of Discharge Activity and Proposal of Limits) it has been demonstrated that the doses from effluent discharges to any population and wildlife will be ALARA and in line with EA guidance [155] and constraints and Ionising Radiation Regulations 2017 limits [156]. These assessments will aid in the demonstration that the design of the generic SMR-300 can represent BAT.

The overall approach to assessing the radiological impacts of routine discharges of gaseous and aqueous radioactive effluents from the generic SMR-300 to the environment is based on the staged approach advocated by National Dose Assessment Working Group (NDAWG) in NDAWG Guidance Note 2 [157] and in the EA Principles for the Assessment of Prospective Public Doses [155]. The staged approach comprises three stages of radiological assessments, characterised by increasing level of detail and complexity, see Figure 18 below.

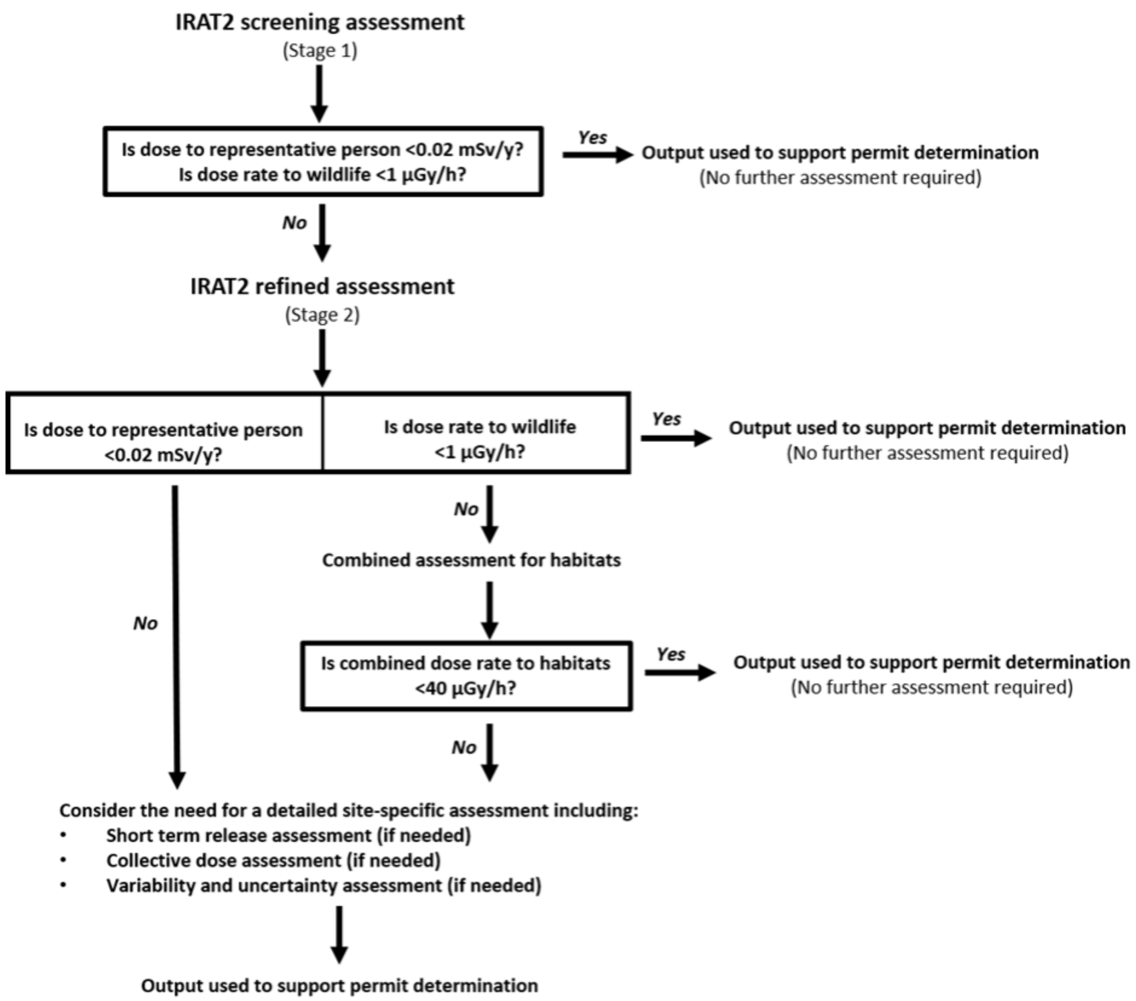

Figure 18: Stages of EA Dose Assessment Process Used When Permitting Discharges of Radioactive Effluents

The EA have produced an initial radiological assessment methodology to support operators and inspectors in assessing radiological impacts from routine radiological discharges. The EA Initial Radiological Assessment Tool 2 (IRAT2) [158]. This methodology addresses stages 1 and 2 of the approach set out in Figure 18 above and will be used for the assessment of the radiological impact of discharges. Within this 2-Step GDA, Stage 1 and 2 assessments have been completed, and methodologies to complete Stage 3 assessments introduced to be undertaken when site-specific parameters are available.

Argument 4.4-A2 is split in to four sub-arguments covering:

- Site characterisation – definition of generic site characteristics to be suitably bounding.
- Calculations to determine human doses from activities related to the generic SMR-300.
- Calculations to determine non-human doses from activities related to the generic SMR-300.

- Calculations to determine exposure to legitimate users of land around the siting of a generic SMR-300 and land uses of the site once the reactor lifecycle has come to an end.

In addition to ensuring exposures to ionising radiation to the public are kept both within statutory dose limits and ALARA, the RIA will also inform BAT optioneering process. Comparison of design options and consideration of approaches to plant operation will consider the potential radiological impact of different radionuclides, as well as preferential partitioning of those radionuclides into different discharge phases to minimise their impacts and ensure BAT is applied.

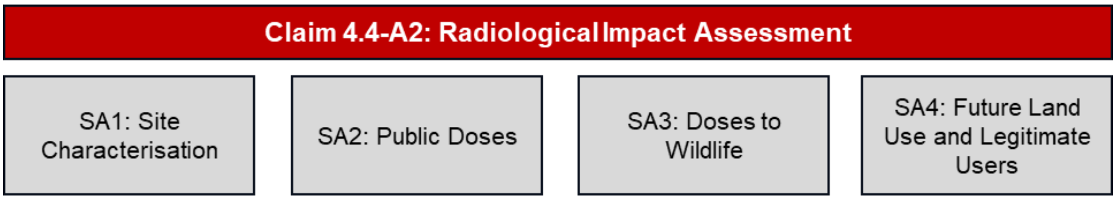

Figure 19: Summary CAE Tree for 4.4-A2 Radiological Impact Assessment

6.8.4.2.1 Argument 4.4-A2-SA1: Site Characterisation

Argument 4.4-A2-SA4: Site Characterisation *The Generic SMR-300 has appropriately defined the generic site characteristics to ensure assessments of impact for future discharges are realistically bounding.*

To meet GDA requirements the RIA must assess the impact from a site that is suitably representative of a potential future SMR-300 nuclear power plant. [REDACTED]. Therefore, a generic site must be defined. This is done through the definition of a Generic Site Envelope (GSE) [159]. The Generic Site Description (GSD), within the GSE Report [159] provides high level, bounding/conservative factors that have been considered to complete this GDA.

The GSE covers three broad areas:

- External Hazards, natural or man-made hazards external to the facility which may affect the operation of the facility;
- Generic Site Information, including features of a site that can be defined on a qualitative basis; and
- the GSD, including the features and characteristics of a site required to enable an assessment of the radiological and conventional impacts of the generic SMR-300 on people and the environment.

The site characteristics defined within the GSE ensure impact assessments of future discharges and their associated dose impacts are realistically bounding.

Full site characterisation, including geology, hydrogeology, meteorology, topography, soil science, marine, riverine or lake parameters, habits and habitats etc. will need to be made at the site-specific stage.

6.8.4.2.1.1 Evidence 4.4-A2-SA1: Site Characterisation

- **Generic Site Envelope Report** [159] – Provides a generic site description and sets out bounding key parameters for the generic site for prospective siting scenarios.
- **Future Evidence: Detailed Site Characterisation** – Including geology, hydrogeology, meteorology, topography, soil science, marine parameters, together with derivation of local data on habits and habitats etc., will be undertaken at the site-specific stage to enable Stage 3 environmental impact assessments to be conducted for each site selected.

6.8.4.2.2 Argument 4.4-A2-SA2: Public Doses

Argument 4.4-A2-SA1: Public Doses The generic SMR-300 has undertaken appropriate dose calculations for members of the public to determine the radiological impact of discharges to the most exposed persons for each of the discharge routes, and to assess the dose to the representative person for the site.

The guidance for RPs [28] requires the RP to provide a radiological impact assessment at the proposed discharge limits in the following areas relevant to doses to humans:

- *annual dose to most exposed members of the public for liquid discharges*
- *annual dose to most exposed members of the public for gaseous discharges (separately identify the dose associated with on-site incineration where applicable)*
- *annual dose to the most exposed members of the public for all discharges from the facility*
- *annual dose from direct radiation to the most exposed members of the public*
- *annual dose to the representative person for the facility*
- *potential short-term doses, including via the food chain, based on the maximum anticipated short-term discharges from the facility in normal operation*
- *a comparison of the calculated doses with the relevant dose constraints*
- *an assessment of whether the build-up of radionuclides in the local environment of the facility, based on the anticipated lifetime discharges, might have the potential to prejudice the activities of other legitimate users or uses of the land or sea*
- *collective dose truncated at 500 years to the UK, European and world populations*

For many of the items identified above the EA recommends use of its IRAT2 tool. The purpose and scope of the initial radiological assessment methodology, IRAT2 Part 1 [158], Part 2 [148] and Summary [160], are to provide a system for undertaking an initial cautious prospective assessment of the dose arising from radioactive waste discharges to the environment, and to identify those discharges for which a more detailed assessment should be undertaken. It should be noted that this methodology is generic for any radiological practice.

The assessment consists of three stages. At the first stage (Stage 1), default values are used in IRAT2. A Stage 2 assessment uses refined data which is more suited to the site in question, with parameters values based on the GSD (See Argument 4.4-A2-SA1: Site Characterisation) again using IRAT2.

IRAT2 provides robust and acceptable screening to identify where further resource should be expended to review radioactive effluent discharge quantities and facility design to ensure impacts on members of the public and non-human species are ALARA. Simple cautious assumptions are made regarding the behaviour of radionuclides in the environment and the habits of persons possibly exposed.

PER Chapter 3 RIA [9], covers in terms of human doses:

- Determines the radiological impact of discharges to the most exposed persons for each of the discharge routes, and then assesses dose to the representative person for the site from all discharges – Stage 1 assessment. Stage 2 assessment completed to the extent possible given current design maturity. Description of methods presented for Stage 3 assessment of dose to the most exposed persons for continuous discharges to be completed at site-specific stage.
- Assesses public doses from all discharged radionuclides to identify significant radionuclides (as per criteria a) and d) in EA guidance [161], see Argument 4.4-A1-SA1: Identification of significant radionuclides) to support derivation of proposed discharge limits.
- Compares results of stage 1 and stage 2 assessments against proposed limits and constraints.
- Presents the method and results of the preliminary assessment of direct radiation dose to members of the public
- Presents methodologies for the assessment of doses to members of the public from short duration elevated discharges; collective doses to populations from the operation of a twin-unit SMR-300 facility, and assessment of impact of the build-up of radioactivity in the environment on future users of the site.
- Includes Sensitivity Analysis of input parameters and how their variation affects the results of the assessments.
- Identifies data needs for site specific assessment.

Worker doses are primarily regulated by the ONR for nuclear facilities, considering the principle of ALARP. These are discussed in PSR Part B Chapter 10 Radiological Protection [18]. However, both public and worker doses will be taken into account in the development and optimisation of the generic SMR-300 as illustrated through the RSR-BAT Guidance [6].

[REDACTED]

6.8.4.2.2.1 Evidence for 4.4-A2-SA2: Public Doses

- **Radiological Impact Assessment Topic Report** [162] – Describes the methods and results of Stage 1 and Stage 2 (where completed) assessments of radiological dose impacts to humans. The document summarises the preliminary assessment of direct radiation dose to members of the public and presents developed methods for Stage 3 assessments to be undertaken at site-specific stage. Conducts sensitivity analysis of input parameters and presents results.
- **PER Chapter 3 RIA** [9] – Summarises the assessments presented in the RIA Topic Report.
- **Dose Management Strategy** [163] – Provides details on the assessment of direct radiation doses to most exposed members of the public and the associated dose limits.

- **Generic Site Envelope Report** [159] – Provides a generic site description and sets out bounding key parameters for the generic site which are input parameters for RIA.
- **Future Evidence: Stage 3 Individual Dose Assessment** – Once detailed site characterisation is completed at the site-specific stage, a Stage 3 individual dose assessment will be carried out using PC-CREAM 08 software to estimate doses from continuous discharges to the representative person for the site, also taking into consideration the impacts of historic and continuing releases from any adjacent nuclear sites.
- **Future Evidence: Stage 3 Collective Dose Assessment** – Once detailed site characterisation is completed at the site-specific stage, a Stage 3 collective dose assessment will be carried out using PC-CREAM 08 software to estimate collective doses from continuous discharges to UK, European and worldwide populations.
- **Future Evidence: Stage 3 Short-term Discharge Impact Assessment** – Transient source terms are determined as per commitment C_QEDL_100 made in PER Chapter 2 QEDL [8], the short-term dose assessment method has been developed, and detailed site characterisation is completed at the site-specific stage, a Stage 3 short-term discharge impact assessment will be carried out to assess doses to members of the public from potential short-term releases.
- **Future Evidence: Sensitivity Analysis** – Once detailed site characterisation is completed at the site-specific stage, sensitivity analysis of parameters for the Stage 3 assessments will be completed to identify which variables have the most significant impact on the results, thereby showing how sensitive the results are to change in input parameters. This will help assess the uncertainty of results and predict potential variations in doses as a result of changes in the environment and local resident habits over the 80-year operational lifetime of the reactor.
- **Future Evidence: Dose Assessment Interpretation** – Presents comparison of continuous and short-term discharge dose assessment results against legal limits, dose constraints and the threshold for optimisation. Identify any areas for optimisation to support the demonstration of BAT.
- **Future Evidence: Benchmarking of Radiological Impacts** – Results of the RIA will be compared to and benchmarked against those of other comparable SMR and PWR designs to support BAT Arguments 4.4-A1 and 4.4-A2.
- **Future Evidence: Optimisation of Radiological Impacts from Discharges** – Radiological impact and dispersion assessments will be carried out at the site-specific stage to optimise the dispersion of discharges, through assessment of stack height with respect to the site (layout, topography, meteorological conditions etc.) and optimisation of aqueous-liquid discharge point.
- **GDA Commitment: C_RIA_100** – Raised to update the generic site description and complete a refined Stage 2 Radiological Impact Assessment once the height and relative position of each stack becomes available to enable more realistic dose estimates.

6.8.4.2.3 Argument 4.4-A2-SA3: Doses to Wildlife

Argument 4.4-A2-SA3: Doses to Wildlife *The Generic SMR-300 has undertaken appropriate dose calculations for non-human species.*

In addition to assessing doses to humans the RP is also required to provide an assessment of dose to non-human species. As for doses to humans the EA recommend use of their IRAT2 tool. In lieu of a defined habitat, IRAT 2 assesses exposures to a set of reference organisms as applicable to terrestrial, freshwater and marine environments [164].

PER Chapter 3 RIA [9], covers in terms of non-human doses:

- Assessment of exposure to wildlife from routine discharges.
- Assessment of doses to wildlife from all discharged radionuclides to identify significant radionuclides ((as per criteria b) in EA guidance [150], see Argument 4.4-A1-SA1: Identification of significant radionuclides) to support derivation of proposed discharge limits.
- Comparison of results against dose constraints.
- Includes sensitivity analysis of parameters and methods for assessments.
- Identifies data needs for site-specific assessment.

The assessments will contribute to ensuring the generic SMR-300 can confirm exposures of wildlife to ionising radiation will not have adverse consequences for ecosystems, designated conservation sites and protected species and are kept both within statutory dose limits and ALARA.

IRAT2 modelling provides a screening dose assessment for a range of terrestrial freshwater and marine wildlife reference organisms. The reference organisms in IRAT2 are taken from the lists of reference organisms in D-ERICA: An integrated approach to the assessment and management of environmental risks from ionising radiation [148] [165].

Dose Per Unit Release (DPUR) values for wildlife presented in IRAT2 for marine and aerial discharges have been generated using Dose Per Unit Concentration (DPUC) data calculated in the ERICA tool [165]. The ERICA tool does not incorporate assessment methods and tools for noble gases; instead, the Ar-Kr-Xe dose calculator for wildlife dose assessment [166], a spreadsheet-based tool was used to derive DPUC factors for noble gas radionuclides used in IRAT2.

In lieu of site-specific data, IRAT 2 has been used to assess exposures to a set of reference organisms as applicable to terrestrial, freshwater and marine environments [148], for the generic SMR-300 located at the generic sites described in the GSD [159].

[REDACTED]

6.8.4.2.3.1 Evidence for 4.4-A2-SA3: Doses to Wildlife

- **Radiological Impact Assessment Topic Report** [162] – Describes the methods and results of Stage 1 and Stage 2 (where completed) assessments of dose rates to wildlife and presents developed methods for Stage 3 assessments to be undertaken at site-specific stage. Conducts sensitivity analysis of input parameters and presents results.

- **PER Chapter 3 RIA** [9] – Summarises the assessments presented in the RIA Topic Report.
- **Future Evidence: Assessment of Impacts on Site Wildlife** – Once detailed site characterisation is completed at the site-specific stage and habitats and critical biota present at the site or in the site vicinity are identified, a detailed assessment of dose rates to wildlife will be conducted using PC-CREAM 08 and / or ERICA (Environmental Risk from Ionising Radiation Contaminants: Assessment and Management).
- **Future Evidence: Optimisation of Radiological Impacts from Discharges** – Radiological impact and dispersion assessments will be carried out at the site-specific stage to optimise the dispersion of discharges. The assessment will take into account stack height with respect to the site (layout, topography, meteorological conditions etc.) and site-specific factors effecting the aqueous-liquid discharge point.

6.8.4.2.4 Argument 4.4-A2-SA4: Future Land Use and Legitimate Users

Argument 4.4-A2-SA4: Future Land Use and Legitimate Users *The Generic SMR-300 has undertaken appropriate impact assessments to ensure future users of the land are not negatively impacted.*

The construction and operation of a nuclear power plant should not lead to the unnecessary or unabated build-up of radionuclides in the environment which have the potential to negatively affect the activities of other legitimate users or uses of the land or sea. It is important that after operations of a nuclear power plant, the land surrounding the plant should be left in a state that allows for future land use rather than being unusable due to previous contamination from radioactivity. Additionally, the land should be clean enough to prevent unacceptable doses to future land users.

The Radiological Impact Assessment Topic Report [162] and PER Chapter 3 [9] presents the calculations that are to be undertaken at the site-specific stage to determine the migration and buildup of radionuclides and doses to the public and the environment covering:

- Development of a methodology that will be utilised in future design stages to support the assessment of the radiological impact on future uses of the land post reactor operations is set out in the Radiological Impact Assessment Topic Report [162].
- The long-term dispersion and accumulation of radionuclides in the environment due to continuous liquid and gaseous radioactive waste discharges from the generic SMR-300 will be modelled using PC-CREAM 08 software which has a proven history of satisfactorily assessing the impacts of discharges of radioactive effluents into the environment at comparable nuclear power plants [149]. The following models in PC_CREAM 08 are to be utilised:
  - Air (PLUME).
  - Soil (GRANIS and FARMLAND).
  - Seawater and seabed sediments (DORIS).
- The RIA as set out in Radiological Impact Assessment Topic Report [162] includes a methodology for the assessment of dose to future users of land from build-up of radionuclides in the environment. This methodology will be utilised in future design

stages to support the assessment of the radiological impact on future uses of the land post reactor operations.

- The doses associated with the potential build-up of radionuclides on land will be assessed using the methodology as described in NRPB-W36 [167] utilising activity concentrations. NRPB-W36 provides a methodology for estimating doses to members of the public from future use of land previously contaminated with radioactivity.
- The Radiological Impact Assessment Topic Report [162] outlines annual effective doses to members of the public calculated considering exposure to contaminated land via eight exposure pathways and through six spatial distributions of possible contamination to determine the bounding future land use scenario.
- The potential future uses of water (including sea use and freshwater use) have been considered and the dose resulting from commercial fishing activities undertaken in the Radiological Impact Assessment Topic Report [162] through the Fishing Family group is the scenario mostly likely to result in the highest occupancy and intake of radionuclides.

The undertaking of the assessment has been captured as future evidence for the site-specific stage once detailed site characterisation is completed to facilitate it.

6.8.4.2.4.1 Evidence for 4.4-A2-SA4: Future Land Use and Legitimate Users

- **Radiological Impact Assessment Topic Report** [162] – Presents developed methods for assessments of the build-up of radionuclides in the local environment from discharges over the reactor lifetime to be undertaken at site-specific stage, to ensure this will not prejudice the activities of future site users.
- **Future Evidence: Impact Assessment of Radionuclide Build-up** – Once detailed site characterisation is completed at the site-specific stage, an impact assessment of radionuclide build-up on future site users will be conducted to ascertain that radionuclide build-up from discharges over the reactor lifetime will not prejudice the activities of future site users. This will include estimation of post-closure radionuclide activity concentrations in the environment, within and adjacent to the site boundary, as a result of build-up from site discharges during operation.

6.8.4.3 Argument 4.4-A3: Appropriate Discharge Points

Argument 4.4-A3: Appropriate Discharge Points *The Generic SMR-300 gaseous and aqueous discharge points and systems are designed to minimise the radiological impacts to people and the environment.*

Discharge points to the environment for radiological aqueous and gaseous wastes for the generic SMR-300 have been identified but not yet defined in detail. Optimised discharge points are a key mechanism by which the generic SMR-300 design will minimise the radiological impacts of discharges from the plant.

Argument 4.4-A3 is decomposed in to two separate sub arguments as depicted in Figure 20 below.

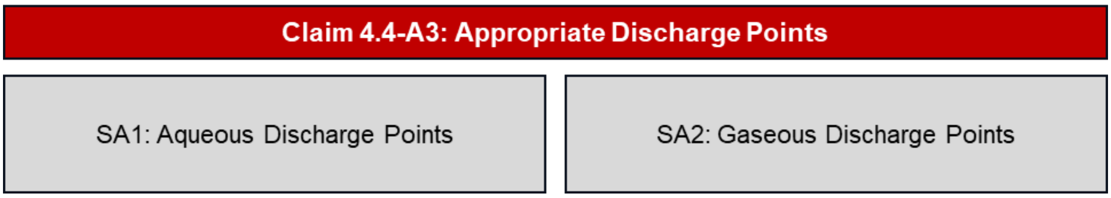

Figure 20: Summary CAE Tree for 4.4-A3 Appropriate Discharge Points

6.8.4.3.1 Argument 4.4-A3-SA1: Aqueous Discharge Points

Argument 4.4-A3-SA1: Aqueous Discharge Points *The Generic SMR-300 aqueous discharge points are designed to minimise impacts of aqueous discharges to the environment.*

Discharge or disposal is the final stage in the waste management lifecycle for waste that cannot be managed any further up the waste hierarchy. Due to their release directly into the environment, discharges are regulated to meet the primary objective of the EA in protecting people and the environment from the harmful effects of ionising radiation [3].

The preferred option of aqueous radioactive wastes, indeed all radioactive wastes, is to “concentrate and contain”, which involves the trapping of radioactivity in a solid concentrated form prior to storage and subsequent disposal. For aqueous wastes this is achieved via filtration and use of ion exchange resins within the CVC and LRW which concentrate activity into solid wastes, however residual activity within aqueous wastes then needs to be discharged into the environment in a way that minimises the impact to public and the environment.

Aqueous radioactive waste is processed and discharged by the LRW, outside of fault and accident conditions. Once determined as suitable for discharge, wastes will be discharged into the environment via the LRW monitoring tanks. For the non-radioactive wastewater system there is monitoring in place (See Argument 4.7-A2-SA1: Aqueous In-process Monitoring and Sampling) to detect ingress of radioactivity into non-active systems and if necessary prevent discharge and redirect wastes to the LRW for treatment.

Following treatment within the LRW, and sampling/analysis to confirm activity is compliant with discharge criteria, the LRW monitoring tanks are discharged via the LRW discharge line to the outfall, where it is mixed with blowdown water from the circulating water system prior to discharge to the environment. Suitable operational controls and valve interlocks will be in place to prevent inadvertent discharge to the environment. Online monitoring is present on the LRW discharge line to detect elevated releases and terminate the discharge on exceedance of a pre-determined setpoint.

Detailed design of the discharge point and outfall is out of scope of this 2-Step GDA given its dependence on site-specific parameters, however future work is planned to demonstrate that the location and design of the outfall will facilitate optimised dispersion of aqueous wastes into the environment and minimise their impacts ALARA.

Discharge systems for conventional aqueous wastes are out of scope of GDA and subject to design development, however suitable monitoring is in place to identify ingress of radioactivity into non-active systems (See Argument 4.7-A2-SA1: Aqueous In-process Monitoring and Sampling) and allow for waste to be redirected to the LRW if needed for treatment. It is planned for discharges to take place at a single outfall which will maximise outfall flow rates to ensure impacts are ALARA.

6.8.4.3.1.1 Evidence for 4.4-A3-SA1 Aqueous Discharge Points

- **SDD for LRW** [128] – Outlines arrangements within the LRW for treatment, sampling and discharge of LRW effluent and it's discharge via the outfall.
- **Future Evidence: Radiological Impact and Aqueous Dispersion Assessments** – Supports the optimisation of discharge dispersion and takes into account the location, structure and dimensions of the outfall.

6.8.4.3.2 Argument 4.4-A3-SA2 Gaseous Discharge Points

Argument 4.4-A3-SA2: Gaseous Discharge Points *The Generic SMR-300 gaseous discharge points are designed to minimise impacts of gaseous discharges to the environment.*

Gaseous radioactive waste discharges will primarily be through the RAB exhaust vent [129]. The preferred option of gaseous radioactive wastes, indeed all radioactive wastes, is to apply the waste hierarchy and the principle of "concentrate and contain", which involves the trapping of radioactivity in a solid concentrated form prior to storage and subsequent disposal, or use of contained decay storage to allow radionuclides to decay prior to discharge.

For gaseous wastes this is achieved via use of decay tanks to allow short-medium half-life radionuclides to decay away prior to discharge. It's also achieved by use of HEPA filtration and iodine adsorbers on active HVAC systems, to capture particulates and radioiodine's within solid waste rather than discharge to atmosphere. This minimises overall impact to the public and the environment.

Residual activity within abated gaseous wastes then needs to be discharged into the environment in a way that minimises it's impact to humans and non-human species. The plant vent(s) are to be designed to discharge at an optimum height to minimise radiological impacts on the public and the environment.

The current design of the generic SMR-300 active-HVAC systems and plant vent stack has not reached a sufficient level of maturity to demonstrate that it is optimised, and it is standard practice to specify the height, dimensions and quantity of the discharge stacks at the site-specific stage, given that site layout and topography are key considerations.

Sizing and design of the stack and number of discharge points will be confirmed at the site-specific stage in line with performance-based criteria. The final design will likely be a compromise of competing criteria that are necessary to balance in order to demonstrate BAT, including height to ensure adequate dispersion, safe and suitable access to platforms and equipment for staff, ensuring adequate space for monitoring and sampling provisions (See Argument 4.7-A3-SA2: Gaseous Effluent Final Discharge Monitoring and Sampling), and ensuring sampling lines are minimised to reduce depositional losses and ensure representative sampling. The plant vent stack will include online radiation monitoring via the RMS system which will allow for automatic isolation of discharges on exceedance of a predetermined activity threshold.

With regards to the RIA (See Argument 4.4-A2: Radiological Impact Assessment) information on stack height, exhaust gas flow velocities, exhaust gas temperature and the height and position of surrounding buildings are required to accurately estimate the effective release height, and therefore impact on the public and environment. Currently conservative bounding assumptions have been made for the purposes of the assessment at GDA Step 2.

6.8.4.3.2.1 Evidence for 4.4-A3-SA2: Gaseous Discharge Points

- **PSR Part B Chapter 5 Reactor Support Facilities** [16] – Provides an overview of HVAC system architecture and gaseous effluent discharge point for the generic SMR-300.
- **PER Chapter 3 RIA** [9] – Sets out design considerations for the plant vent stack relevant to the impact of radioactive discharges on the public and environment, and undertakes sensitivity analysis on how variation in effective stack height affects resultant impacts.
- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of the requirements for design of the plant vent stack to facilitate monitoring and sampling, and current arrangements.
- **Future Evidence: Radiological Impact and Gaseous Dispersion Assessments** – Supports the optimisation of discharge dispersion and takes into account the stack height with respect to the site (layout, topography, meteorological conditions etc.).

6.8.4.4 Argument 4.4-A4: Optimised Disposal Routes

Argument 4.4-A4: Optimised Disposal Routes
The Generic SMR-300 ensures that solid and non-aqueous radioactive wastes have optimised waste disposal routes to minimise the radiological impacts to people and the environment.

An important aspect of the minimisation of impacts is to optimise waste forms and in turn disposal routes . This argument is split into three sub-arguments:

- The characterisation and segregation of waste by considering its physical and chemical form and the types of disposal routes available.
- Ensuring waste management arrangements for the generic SMR-300 are flexible and can account for anticipated future waste arisings.
- The use of established waste routes.

This argument is further decomposed in to three sub-arguments as depicted in Figure 21 below.

Figure 21: Summary CAE Tree for 4.4-A4 Optimised Disposal Routes

6.8.4.4.1 Argument 4.4-A4-SA1: Characterisation and Segregation

Argument 4.4-A4-SA1: Characterisation and Segregation *The Generic SMR-300 radioactive waste management arrangements include appropriate characterisation and segregation to ensure optimised waste forms and disposal routes to minimise impacts on the public and environment.*

The generic SMR-300 has been designed taking into account characterisation needs of each waste type. However, as the design was based on US waste categories it is necessary to demonstrate that the design can meet UK requirements i.e. capable of characterising the waste streams so that they can be segregated into appropriate waste streams aligned with UK waste categories.

Suitable characterisation informs decisions on segregation and enables waste disposal via an optimal waste route that minimises the impacts on the public and the environment and demonstrates BAT. It is recognised that this an area where holistic optioneering can be required as further segregation may result in increased worker dose.

The generic SMR-300 has several systems and strategies align with expectations laid out by SAP RW.4 Characterisation and Segregation [72], and RSMDP 9 Characterisation [33] and were informed by OPEX where available.

6.8.4.4.1.1 Evidence for 4.4-A4-SA1 Characterisation and Segregation

- **PER Chapter 5 Monitoring and Sampling** [10] – Discusses the baseline characterisation approach for each radioactive system and waste type. Shows the capabilities that will be developed to ensure waste is characterised from creation to disposal, allowing the most optimal waste route to be chosen that will have the lowest impact on people and the environment.
- **Integrated Waste Strategy** [86] – Presents the characterisation strategies for waste streams.
- **NWS Expert View Submission** [140] – Presents that wastes will be characterised and segregated in generic SMR-300 to allow optimal waste management.
- **PSR Part B Chapter 13 Radioactive Waste Management** [19] – Introduces the radioactive waste SSCs and the descriptions of their systems, along with how the

designs are aligned with relevant codes and standards expectations. These designs have features for characterisation and segregation capabilities.

- **PSR Part B Chapter 24 Fuel Transport and Storage** [22] – States that NFW components will be characterised and segregated based on their physical characteristics and irradiation history.
- **Future Evidence: Strategy for Waste Characterisation –** Covers the stages from raw waste generation through to disposal should be developed by the waste producer at the site-specific stage. This is highlighted by PER Chapter 5 [10].
- **GDA Commitment: C_RWMA_078** – Confirms that design development on the facilities for ILW storage and LLW handling will be carried out to ensure site specific application is satisfactory supporting BAT for characterisation and segregation of wastes. Design Challenge - ILW and LLW Facilities [139] paper, also states design requirements required for waste processing, from generation to disposal, including the development of the characterisation approach.

6.8.4.4.2 Argument 4.4-A4-SA2: Flexible Waste Management Provisions and Future Arisings

Argument 4.4-A4-SA2: Flexible Waste Management Provisions and Future Arisings
The Generic SMR-300 has considered anticipated arisings and future management in its radioactive waste management arrangements and has included appropriate flexibility in its design aspects and procedures and avoids the non-foreclosure of options.

Part of demonstrating BAT during a GDA is shown by aligning the generic SMR-300 design with the EA's RSMDPs [33]. RSMDP 11 – storage in a passively safe state, requires that disposal options are not unacceptable foreclosed. This is relevant to the generic SMR-300 design because:

- Wastes destined for GDF disposal there is currently no strict WAC, just guidance. This could potentially mean different waste packages and forms could be accepted in the future if guidance is updated or a WAC is created.
- Novel waste containers for the UK could potentially be utilised for interim storage of wastes. In the future these containers could be approved for GDF disposal.

The generic SMR-300 has been designed to provide waste management strategies that meet required safety and environmental objectives but provide flexibility by avoid unnecessary foreclosure of options. Meaning preferred strategies and options for waste management will be selected but it will be specified, where appropriate, how other options could be utilised if they became the BAT option instead at the site-specific stage.

At this stage in the design development there is flexibility in determining waste management and disposal routes. Decisions on BAT waste management and disposal routes will not be made until the site-specific stage. Having this flexibility allows for future BAT/ALARP assessments to be carried out to optimise disposal routes and minimise impact on people and the environment [86]. Generic SMR-300 design provisions and operating techniques supporting this Argument include:

- The LRW has provisions to enable bypassing of relevant ion exchangers and / or filters, if sampling results suggest that they are not required. 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 minimising the generation of solid radioactive waste from the LRW.

- The LRW is designed with flexible connections to use mobile processing units. This provide the option to process any unexpected waste arisings that are incompatible with the permanently installed plant equipment.
- Filtration and ion-exchange are defined as the baseline strategy for the abatement of radioactive liquid wastes generated in the generic SMR-300. However, this does not foreclose other viable options in the basic and detailed design phases of the SMR-300.
- LLW spent resins will be package in a compliant container (e.g. 200 litre drum), and then transferred offsite in bulk in an appropriate transport container (e.g. FHISO or HHISO).

The IWS [86] proposes baseline strategies for waste management but does not foreclose other options. It covers:

- Flexibility in waste processing facilities by being able to utilise permanently installed facilities, mobile facilities or off-site facilities, taking into account the principles of BAT and ALARP.
- Design requirements for appropriate buffer storage to allow flexibility in temporarily accumulating small volumes of LLW, should there be any issues with shipment to an offsite premises for treatment or disposal.
- ILW should be stored in long term safe interim storage, but boundary wastes can be stored on a risk informed basis based of BAT / ALARP optioneering, providing flexibility in routes where possible.
- Opportunities to highlight different ways that flexible waste management options could be used, should there be changes in policy, strategy or available management methods.

6.8.4.4.2.1 Evidence for 4.4-A4-SA2 Flexible Waste Management Provisions and Future Arisings

- **Integrated Waste Strategy** [86] – Presents flexible waste management strategies. As the SMR-300 design maturity increases, this document will be updated.
- **Expert View Submission** [140] – States that there is the option to package some wastes separately and all wastes can be in a non-encapsulated form allowing a non-foreclosure of wase management options, until final disposal.
- **SMR-300 ILW Management Strategy: Options Assessment** [87] – Presents a baseline strategy for managing ILW waste by using a RSC that can be attached to mobile processing systems and provide shielding for flexibility in handling.
- **SMR-300 UK GDA Spent Fuel Management Strategy** [116] – Presents that NFW components will be characterised and segregated based on their physical properties and irradiation history, providing more flexibility in disposal by not mixing components with different activity levels and materials that could impact disposability options. The UMAX system can be used for spent fuel storage and is fully reversable allowing for inspection or repackaging at any stage in the lifecycle. Further, Holtec's dry storage technology avoids the foreclosure of alternative long-term management options e.g. involving off-site consolidated storage, off-site repackaging, or risk-informed

consignment to waste routes, and for spent fuel reprocessing (such strategic opportunities would be subject to policy enablers).

6.8.4.4.3 Argument 4.4-A4-SA3: Use of Established Waste Routes

Argument 4.4-A4-SA3: Use of Established Waste Routes *The Generic SMR-300 has identified waste streams and routes to ensure that all radioactive wastes have an established disposal route and those that do not have an established route.*

Predisposal management of radioactive wastes has been considered and full use of existing waste routes can be utilised [86]. Until a GDF is built, ILW will be stored in a passively safe form as soon as is reasonably practicable for interim storage.

During a 2-Step GDA, the generic SMR-300 has a flexible waste management approach (see Argument 4.4-A4-SA2: Flexible Waste Management Provisions and Future Arisings). However, the RP's baseline waste strategies and engagement with NWS provides confidence that generic SMR-300 waste streams are suitable for established waste routes in line with UK policy. It can be demonstrated that the potential risks and impacts of wastes on people and the environment have been minimised as planned disposal routes represent well researched methods already safely implemented within the UK.

6.8.4.4.3.1 Evidence for 4.4-A4-SA3 Use of Established Waste Routes

- **Integrated Waste Strategy** [86] – Covers the high-level strategy that will be followed for each waste category. It aligns disposal route strategy with expectations taken from RGP and government policy. It highlights assumptions, risks, uncertainties and opportunities made when creating the IWS.
- **NWS Expert View Submission** [140] and **Requesting Party Response to NWS Expert View** [168] – Provides reassurance 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 with which they are already familiar, giving confidence that a disposability case could be made. Evidence provides confidence that at this stage in the design, the generic SMR-300 will not produce any orphan or problematic wastes.
- **PSR Part B Chapter 13 Radioactive Waste Management** [19] – Highlights the radioactive waste management strategy for the wastes coming out the radioactive waste SSCs, stating that the strategy shows confidence there will be no problematic waste arisings. However, the actual disposal routes will be decided by BAT / ALARP optioneering at the site-specific stage.
- **Decommissioning Waste Inventory for the Generic SMR-300 Design** [79] – The qualitative inventory indicates that the generic SMR-300 decommissioning wastes will be similar to other PWRs in the UK and worldwide. This shows that the generic SMR-300 should not produce any problematic or orphan decommissioning wastes but can in fact utilise existing waste routes and management processes.
- **SMR-300 ILW Management Strategy: Options Assessment** [87] – Shows the baseline disposability strategy for ILW. This assessment provides confidence that there are established solutions which can ensure that no orphan wastes are produced.

6.8.5 Claim 4.5 Non-Radioactive Aspects of Radioactive Wastes

Claim 4.5: Non-Radioactive Aspects of Radioactive Wastes *Potentially adverse non-radiological impacts of radioactive wastes are precluded or, where this is not possible minimised.*

The arguments presented in support of this claim are considered to demonstrate compliance with the requirements set out under Condition 2.3.7 of the standard RSR environmental permit [38] which states that:

"Subject to condition 2.3.2, the operator shall carry on the activities in a manner so as to minimise the risk of pollution from any non-radioactive substances in, or any non-radiological properties of, the radioactive waste, except to the extent the risk is addressed in a separate environmental permit".

As well as 1.1.3c

"public and the environment are protected from the non-radiological hazards of disposals of radioactive wastes"

Features of the generic SMR-300 particularly important to this claim include:

- The disposability arrangements of any solid radioactive wastes, including non-radiological hazardous substances arising across the reactor lifecycle.
- The assessment of radioactive waste addressing waste form and any non-radioactive components that could have a bearing on its management and disposability.

Two arguments are presented to substantiate this claim, see Figure 22 below.

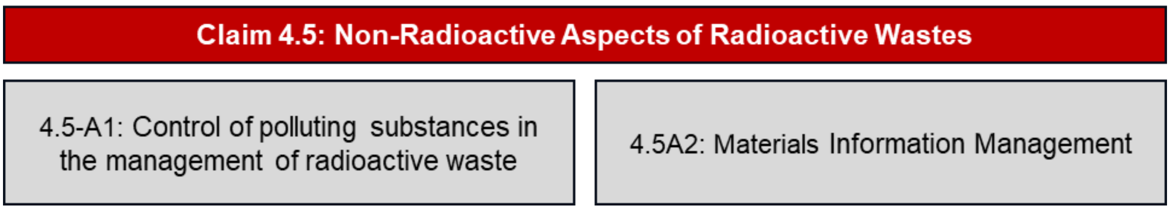

Figure 22: Summary CAE Tree for Claim 4.5: Non-Radioactive Aspects of Radioactive Wastes

6.8.5.1 Argument 4.5-A1: Control of polluting substances in the management of radioactive waste

Argument 4.5-A1: Control of polluting substances in the management of radioactive waste *The Generic SMR-300 ensures that the non-radiological aspects of radioactive wastes are characterised to facilitate appropriate control in radioactive waste management steps to minimise potential environmental impacts of pollution.*

Permit condition 2.3.7 requires that prospective operators of the generic SMR-300 take into account the non-radiological properties of radioactive wastes in their normal operating procedures and radioactive waste management arrangements.

As described in EA permit guidance [38], the consideration of the non-radioactive aspects of radioactive wastes are to ensure that environmental protection is similar to requirements set out in other legislation concerning conventional wastes. Therefore, non-radioactive aspects of radioactive wastes will be considered hand-in-hand with conventional waste management arrangements.

Non-radioactive aspects of radioactive wastes will be managed to minimise their impacts on people and the environment utilising BAT, whether it is governed by legislation and regulation under the RSR or conventional BAT using the BREFs.

6.8.5.1.1 Evidence for 4.5-A1 Control of polluting substances in the management of radioactive waste

- **Integrated Waste Strategy** [86] – To be developed at the site-specific stage to further detail non-radioactive aspects of radioactive wastes.
- **Future Evidence: Site-specific SMR-300 Solid Radioactive Waste Inventory** – The inventory will present the conventional properties of radioactive wastes.

6.8.5.2 Argument 4.5-A2: Materials Information Management

Argument 4.5-A2: Materials Information Management *The Generic SMR-300 ensures that appropriate strategies and procedures are in place to properly record and manage information related to materials procured from the supply chain, including quality assurance and the use of hazardous materials, to minimise the impact of non-radioactive aspects of radioactive wastes.*

The material used within the generic SMR-300 design has a large impact on the generation of waste and subsequent impacts on people and the environment over the reactor lifecycle. As well as having significant roles in minimising activation and corrosion and ensuring suitable structural integrity additionally material selection can reduce the impacts of non-radioactive aspects of radioactive wastes.

Material selection is optimised to demonstrate BAT as the selection of each material is made according to relevant codes and standards which give design and construction companies a universal, up-to-date methodology to follow. This ensures that when a material is selected, there is sufficient evidence in its safety and environmental protection. For further information on material selection as a mechanism to reducing the generation of radioactive wastes, see Argument for 4.1-A1-SA4 Material Selection and Surface Finish.

The procurement process and relevant Quality Assurance will need to take account of the requirements associated with the application and demonstration of BAT. The specification stage is an essential part of the procurement process for materials. During the manufacturing process of components there will be applicable material acceptance criteria, validation inspections and testing. Evidence of these acceptance criteria will be used to verify the materials procured. This information on the materials used for components will be important in characterising the non-radioactive aspects of waste.

During GDA, the project is building the framework to deliver the generic SMR-300 that will lead from generic design to site-specific design and in future a role in the procurement / manufacturing / supply into the UK market [13]. The RP will comply with all relevant environmental and health and safety legislation as proscribed within the UK.

The generic SMR-300 will follow the guidance set out in the ONR Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services [169] document.

6.8.5.2.1 Evidence for 4.5-A2 Materials Information Management

- **The Holtec Nuclear Quality Assurance Manual (QAM)** [170] and **ISO-9001 QAM** [171] – Set out controls to effectively manage procurement.
- **Future Evidence: Plant Chemical Inventory** – Repository of substances information for chemicals used or stored in the NPP.
- **Future Evidence: Materials Management Plan** – Will establish the activities to identify and meet compliance obligation in materials management.
- **Future Evidence: Procurement Specifications** – To support the communication of material requirements (e.g. impurity limits and surface finish) to suppliers for procured components.

6.8.6 Claim 4.6 Conventional and Non-Radioactive Impacts

Claim 4.6: Conventional and Non-Radioactive Impacts *Conventional environmental impacts from the generic SMR-300 are in compliance with all relevant legislation, taking into account BAT reference documents (BREFs) where relevant.*

In addition to the RSR-related requirements, it should be demonstrated that the design of the generic SMR-300 has taken into account and suitably managed sources of conventional (non-radiological) environmental impacts. Further information on the GDA guidelines and regulatory context is provided in PER Chapter 4 Conventional Impact Assessment [4].

Non-RSR BAT was adopted and applied across the European Union (EU) by the European Commission as BAT Conclusions (BATC) under the Industrial Emissions Directive (IED) (Directive 2010/75/EU). Existing BATC continue to have effect in the UK through the EU Withdrawal Act 2018. They are available in BAT reference documents or BREFs [172] [172].

When a prospective operator of an installation applies for a non-RSR related environmental permit (such as for combustion plant, or conventional water discharges) under EPR16, they are required to confirm BAT has been applied to the activities in question, or propose alternative measures. The prospective operator must provide information on how they will:

- Follow the BATC and meet the BAT-associated emissions level (for BAT that are contained in BAT conclusions).
- Follow the BREF note and the technical guidance for activities that don't have BATCs.

Arguments presented in support of this claim are considered to demonstrate compliance with the requirements set out in the EA's GDA Guidance for Requesting Parties [28] which states that in order to undertake a fundamental assessment of conventional environment impacts, there are information requirements in key areas of conventional impact and sustainability. Management arrangements and design aspects considered in the generic SMR-300 to minimise conventional impacts are categorised into five broad arguments:

1. Water use, Abstraction, and Discharges (sub-chapter 6.8.6.1).
2. Air Quality and Combustion Plant (sub-chapter 6.8.6.2).
3. Control of Major Accident Hazards (COMAH) (sub-chapter 6.8.6.3).
4. Ozone-depleting substances (ODS) and Fluorinated Greenhouse Gases (F-Gas) (sub-chapter 6.8.6.4).
5. Sustainability (sub-chapter 6.8.6.5).

Further information on the GDA guidelines and regulatory context for each of these areas is provided in PER Chapter 4 Conventional Impact Assessment [4].

The water use, abstraction and discharges argument is further split in to sub-arguments in order to aid the demonstration and discussions.

It is acknowledged by the RP that BAT as a requirement under RSR and its relevant supporting documents does not apply directly to conventional wastes and non-radioactive impacts (outside those covered under Claim 4.5: Non-radioactive Aspects of Radioactive Waste). Instead, BAT is applied through applicable industrial BREFs. As such claim 4.6 conventional and non-radioactive impacts is presented within this chapter such that the BAT demonstration is complete and does not appear to neglect conventional impacts, but mainly acts as a summary or signpost to PER Chapter 4 Conventional Impact Assessment [4].

It is recognised that at this stage in the design's maturity, the information derived and gathered within the Conventional Impact Assessment topic area forms only the basis of future environmental management work to be conducted through future design development and further assessments at the site-specific stage. Future evidence has been identified for each of the arguments and these will guide work beyond GDA.

Features of the generic SMR-300 particularly important to this claim include:

- Secondary systems including the main steam feedwater system.
- Cooling water systems including the circulating water system, and cooling solution (nominally mechanical draft cooling towers).
- Annular Reservoir.
- Conventional effluent treatment plant
- Combustion plant including auxiliary boiler and standby diesel generators.

- Equipment containing fluorinated gases including HVAC chillers, and fire suppression equipment.

It should be noted that many of the conventional island systems are out of scope of GDA and considering current design maturity, much of the design information provided is provisional and subject to change post-GDA.

Five arguments are presented to substantiate this claim, depicted in Figure 23 below.

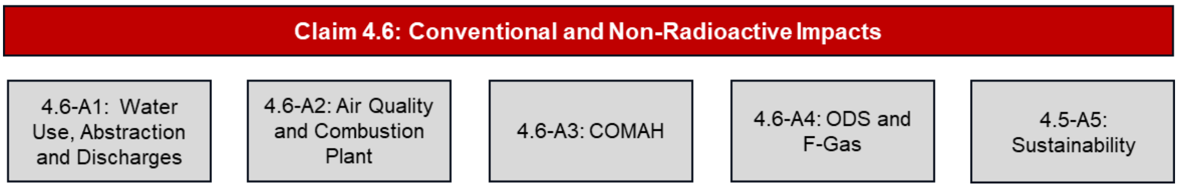

Figure 23: Summary CAE Tree for Claim 4.6: Conventional and Non-Radioactive Impacts

6.8.6.1 Argument 4.6-A1: Water Use, Abstraction and Discharges

Argument 4.6-A1: Water Use, Abstraction and Discharges *The Generic SMR-300 applies good design principles to ensure water use and abstraction has minimal impact where achievable on the site and surrounding area. Discharges to surface water will be minimised wherever practicable, and otherwise adequately treated to meet acceptable limits prior to discharge. Suitable measures will be in place to prevent accidental discharges to groundwater.*

Efficient abstraction, use and discharge of water for the generic SMR-300 covers three key areas:

- Water usage & abstraction – covering overall water usage for the plant, both from potable water sources, and abstracted from local surface water sources.
- Discharges to surface water – discharges of conventional (non-radioactive) effluent following treatment to acceptable limits.
- Discharges to groundwater – description of key measures in place to prevent accidental discharges to groundwater.

Sub-arguments have been developed beneath this argument reflecting this split as depicted in Figure 24 below.

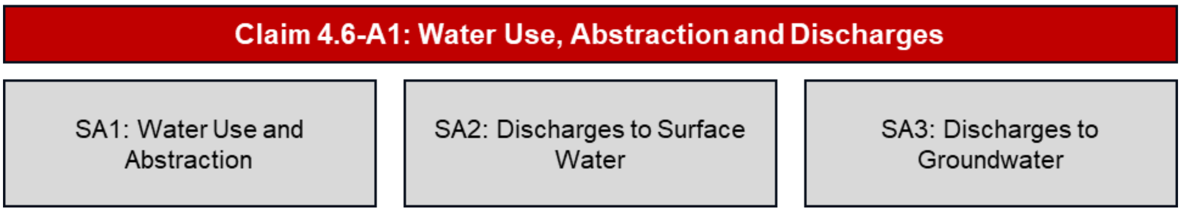

Figure 24: Summary CAE Tree for 4.6-A1 Water Use, Abstraction and Discharges

6.8.6.1.1 Argument 4.6-A1-SA1: Water Use and Abstraction

Argument 4.6-A1-SA1: Water Use and Abstraction *The main uses of water in the generic SMR-300 have been identified, and established where this will require the local potable water supply, or will be abstracted from surface water sources. Total abstracted water usage for the generic SMR-300 has been estimated to establish the need for an abstraction licence (depending on the candidate site).*

The Water Resources Act [173] is the primary legislation providing the framework for managing water usage, abstraction, pollution, and flood defence. With reference to the Water Resources Act, Part II, chapter II, any abstraction of water from a water supply, excluding the open sea, requires a licence where the abstraction is more than 20 cubic meters (20 m^3) over a 24-hour period, which is likely to be the case for the generic SMR-300.

The design and operation of the cooling system is a key consideration for total water usage. Indirect cooling (in this case Mechanical Draft Cooling Towers) have been identified as the primary option for the generic SMR-300 however options have not been foreclosed at this stage.

Due consideration is to be given to the BREF for Industrial Cooling Systems (ICS) [174]. The BREF ICS document is compatible with UK regulatory requirements and recommends techniques that enhance energy efficiency, reduce water consumption, and mitigate negative ecological effects by optimising the cooling process.

As part of any application for an abstraction licence, consideration will be given to appropriate measures for fish protection in order to ensure compliance with the Eels Regulations 2009 [175] and Salmon and Fisheries Act [176]. Any potential engineering measures are dependent on site-specific sensitivities and will therefore be addressed at a later stage of the project.

6.8.6.1.1.1 Evidence for 4.6-A1-SA1: Water Use and Abstraction

- **Holtec SMR-300 Water Use, Abstraction and Discharges report** [177] – Addresses consideration of the design of the generic SMR-300 in relation to water abstraction and usage. A summary of the key conclusions of this report is presented in PER Chapter 4 Conventional Impact Assessment [4].

- **Future Evidence: Cooling Systems Optioneering Report** – An assessment on the potential cooling systems that are viable for use in the design (e.g. air-cooled condensers) as well as thermal efficiency impacts associated with this approach.
- **Future Evidence: Water Balance Report** – Outlines the plant water demand (water balance) for cooling water system operation on the basis of both direct and indirect cooling solutions and other water demands in the design.
- **Future Evidence: Position Paper on SMR-300 Plant Demineralised Water Treatment System Output Quality Considerations and Requirements**.

6.8.6.1.2 Argument 4.6-A1-SA2: Discharges to Surface water

Argument 4.6-A1-SA2: Discharges to Surface Water

Sources of non-radiological aqueous effluent SMR-300 have been identified, and associated water quality requirements specified. Chemicals to be dosed in respective effluent streams and therefore potential contaminants in discharges have been considered to minimise associated environmental impacts. Thermal impacts on discharging bodies have also been considered.

Process effluents associated with the generic SMR-300 have been documented, noting that these are provisional due to the design maturity of the conventional island. The principal sources of process effluent from the generic SMR-300 are:

- Mechanical Draft Cooling Tower systems – including blowdown from cooling towers, Circulatory Water System, (CRS) and Service Water System (SWS).
- Liquid Radwaste (including primary circuit effluents).
- Secondary cooling systems.

Non-process effluents include those which arise from routine operations supporting facilities rather than equipment that's part of the plant itself. Principal sources of non-process effluent streams are:

- Sewage effluent.
- Surface water runoff.
- Laundry wastewater (if applicable).

These systems have set water quality requirements for their effective functioning, and therefore chemicals are added to treat the water prior to its use. Potential contaminants and resultant discharges have been documented.

6.8.6.1.2.1 Evidence for 4.6-A1-SA2: Discharges to Surface water

- **Holtec SMR-300 Water Use, Abstraction and Discharges report** [177] – Takes into consideration the design of the generic SMR-300 in relation to water abstraction and usage.
- **Integrated Waste Strategy** [86] – Update to incorporate detailed information on conventional waste streams.

- **Future Evidence: Emissions Summary Report** – Design information to define the plant emissions and discharges characteristics. Includes expected/modelled emissions to air, water and waste i.e., volumetric flow and all storage and storage approaches of materials on site, as well as details of mitigations employed within the design to ensure impacts have been minimised.
- **Future Evidence: Conventional Effluent Treatment Options Assessment** – Appraisal of viable effluent treatment technologies.

6.8.6.1.3 Argument 4.6-A1-SA3: Discharges to Groundwater

Argument 4.6-A1-SA1: Discharges to Groundwater
There are no planned discharges to groundwater from the generic SMR-300. Below grade areas of the plant are designed to nuclear codes and standards to ensure structural integrity and leak-tightness. Storage of fuels, oils, etc., will utilise best industry practice for leak prevention.

Levels of the plant to be built below grade will be designed to nuclear codes and standards for the prevention of leakages of water or other potential non-radiological pollutants. Nevertheless, the design ensures leakages to groundwater are minimised.

Areas of the facility which could contain sources of non-radioactive pollutants (e.g., diesel fuel storage tank) will be appropriately designed to prevent land and groundwater pollution. Industry practices in using bunding and liners to mitigate consequences of accidental release will be applied in accordance with the Health and Safety Executive Secondary containment Technical Measures Document [178].

It is good practice to include leak detection systems, spill kits and emergency protocols, and ensure good maintenance and repair of any bunding, storage tanks and sumps.

6.8.6.1.3.1 Evidence for 4.6-A1-SA3: Discharges to Groundwater

- **Holtec SMR-300 Water Use, Abstraction and Discharges report** [177] – Addresses considerations of the design of the generic SMR-300 in relation to water abstraction and usage.

6.8.6.2 Argument 4.6-A2: Air Quality and Combustion Plant

Argument 4.6-A2: Air Quality and Combustion Plant
Combustion plant in the Generic SMR-300 will comply with requirements under EPR16, with appropriate permits in place determined by rated thermal inputs, and associated emissions. Combustion plant will need to comply with Emission Limit Values (ELVs) for specified pollutants, primarily sulphur dioxide (SO_2), nitrogen oxides (NO_x) and dust.

Industrial combustion plant, including backup energy generation, and any incineration activities are subject to EPR16 [37] which implements the requirements of IED [179].

Under these regulations, industrial combustion plant is required to have a permit if either of the following conditions apply:

- The site comprises a single combustion source with a rated thermal input of greater than or equal to 50 MWth; or
- The site comprises multiple combustion sources, which have an aggregated thermal input of greater than or equal to 50 MWth and these are operated at the same time by the same operator.

For combustion plant that is less than 50 MW_{th} but greater than 1 MW_{th}, the Medium Combustion Plant Directive (MCPD) [180] would apply and a permit obtained for combustion plant falling within this remit (medium combustion plant).

Though the design of the systems are out of scope of GDA, provisional plans for the generic SMR-300 combustion plant consists of the following:

- Four 2.5 MW_e (~26.16 MW_{th} total) Standby Diesel Generators are used to provide alternating current (AC) power to non-safety systems, such as HVAC and auxiliary systems, in the event of a Loss Of Off-site Power (LOOP) event.
- One 21.7 MW_{th} auxiliary boiler used for start-up and shutdown of the reactor and process systems.

This would result in a total thermal power input of 47.86 MW_{th} putting the generic SMR-300 in the scope of the MCPD; however, given current design maturity, the appropriate permitting regime will need to be confirmed at the site specific stage.

European Commission BREF documents can be consulted, including Monitoring of Emissions to Air and Water from IED Installations [181], and the Large Combustion Plants BREF document [182]. The Large Combustion Plants BREF document specifically addresses combustion plants over 50 MW_{th} input and emphasises the importance of monitoring associated pollutants, but the principles outlined are applicable to smaller combustion plant as well.

6.8.6.2.1 Evidence for 4.6-A2: Air Quality and Combustion Plant

- **Air Quality Report** [183] – Addresses combustion plant design considerations in the generic SMR-300. The key conclusions and summary of this report is presented in PER Chapter 4 Conventional Impact Assessment [4].
- **Future Evidence: Air Quality Assessment** – Conducting a H1 Risk Assessment Tool or other suitable Air Quality Screening Assessment.
- **Future Evidence: UK Emissions Trading Scheme greenhouse gas monitoring methodology & technology comparison**.

6.8.6.3 Argument 4.6-A3: Control of Major Accident Hazards (COMAH)

Argument 4.6-A3: Control of Major Accident Hazards (COMAH) *COMAH status will be confirmed for any UK based SMR-300 including the relevant tier. If COMAH is applicable a major accident prevention policy will be put in place to ensure a high degree of protection of human health and the environment, from major accidents resulting from the misuse or accidental release of dangerous substances.*

Any facility storing priority substances (listed in schedule 1 of the COMAH regulations) on site are subject to COMAH Regulations 2015 [184]. The COMAH regulations define lower and upper tier establishments that relate to the threshold quantity levels of dangerous substances stored. The exact measures to be taken by operators of COMAH facilities depend on the tier, and the type of dangerous substance. Generally, operators of COMAH facilities must undertake all measures necessary to prevent a major accident and identify measures for mitigation in the event of any major accident should it occur.

As part of the COMAH screening assessment a review of early water chemistry design documents and storage tanks was conducted to identify the presence of dangerous chemicals.

Further assessments of the full chemical inventory will be conducted as part of normal design development to eliminate uncertainty. If the generic SMR-300 chemical inventory is determined to qualify as a lower or upper tier COMAH establishment, the required documentation and management protocols will be produced in accordance with COMAH.

6.8.6.3.1 Evidence for 4.6-A3: COMAH

- **COMAH Screening Assessment** [185] – Presents the initial screening assessment for COMAH applicability for the generic SMR-300. A summary of the key conclusions of this assessment is presented in PER Chapter 4 Conventional Impact Assessment [4].
- **Future Evidence: Plant Chemical Inventory** – Repository of substances information for chemicals used or stored in the NPP.
- **Future Evidence: Optioneering on Concentration of Hydrazine Use on Plant** – Presents the justification of the hydrazine option to implement that will contribute to the determination of COMAH tier establishment of the SMR-300 site.

6.8.6.4 Argument 4.6-A4: Ozone Depleting Substances & Fluorinated gases

Argument 4.6-A4: Ozone Depleting Substances (ODS) & Fluorinated Gases (F-gases) *No ODS are planned to be utilised in the generic SMR-300 design. F-gas usage for the generic SMR-300 will take account of substances banned in the UK for new facilities, and global warming potential of substances chosen for use will be minimised wherever practicable.*

No ODS are planned for use in the generic SMR-300 design. As design maturity progresses for conventional island systems this will be confirmed for each relevant system.

The Fluorinated Greenhouse Gases Regulations 2015 [186] regulate the use of F-gases in the UK. These regulations implement the requirements of EU Regulation No. 517/2014 on F-gases. F-gases are expected to be used within the generic SMR-300 as refrigerant for chillers plant within HVAC systems, and as fire suppressant agents in circumstances where water is not appropriate (such as rooms containing electrical switchgear).

The EU regulations on F-gases [186] establishes rules on storage use and disposal of F-gases, limitations of introducing new products using specific F-gases to the market, and limits how F-gases may be used. The UK specific regulations echo these stipulations with references to the EU regulations, giving power to the relevant UK authority (EA or NRW) to prosecute for offences under the regulations.

As the design progresses, F-gases identified for use in the design will be specified and where possible alternative substances with lower global warming potential or minimisation of their usage will be considered, taking into considerations including personnel safety considerations and suitability for use in a nuclear licensed site.

In line with the UK government guidance, use of F-gases and servicing of equipment containing F-gases will require qualified technicians who are authorised to work with F-gases. This is an operational consideration, but management plans and procedures can be set as design develops to ensure environmental protection is embedded in NPP arrangements.

6.8.6.4.1 Evidence for 4.6-A4: ODS & F-gases

- **Fluorinated Gases and Ozone Depleting Substances Technical Note** [187] – Provides an overview of equipment in the generic SMR-300 design which will contain F-gases, consideration of the substances to be used and associated arrangements are considered. A summary of the key conclusions of this technical note is presented in PER Chapter 4 Conventional Impact Assessment [4].
- **Future Evidence: Plant Chemical Inventory** – Repository of substances information for chemicals used or stored in the NPP.
- **Future Evidence: Environmental Risk Assessment** – Will identify and describe the protection measures for systems containing F-gases.

6.8.6.5 Argument 4.6-A5: Sustainability

Argument 4.6-A5: Sustainability *The Generic SMR-300 will apply sustainability principles throughout the design and lifecycle of the plant (construction, commissioning, operations and decommissioning).*

Sustainability is important in the reduction of environmental impacts through efficient resource use, promotion of positive socio-economic impacts and combatting climate change. Therefore, it is important to apply BAT to ensure the generic SMR-300 will be optimised to minimise environmental impacts and complies with all relevant legislative and regulatory requirements. Sustainability covers several areas including:

- Use and minimisation of energy and material resources.
- Wider or future uses of new facilities / equipment / structures.
- Socio-economic impacts including:
    - Sustainable procurement and supply chain opportunities.

  - Noise, landscape and visual Impacts.
  - Transport.
- Recycling of materials.
- Re-use of equipment vs 'one-off' use.
- Land contamination.
- Carbon (emitted and embodied) reduction opportunities.
- Action against climate change.
- Climate change risks and vulnerabilities (to the design from the effects of climate change).

The RP has aligned itself with the definition of 'Sustainable Development' as outlined by the Department of Environment, Food and Rural Affairs (DEFRA) Environmental Principles statement:

"Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves trying to achieve environmental benefit alongside economic growth and social progress and should be considered in a global context" [188].

This definition is aligned with the environment agencies' duty to promote sustainable development while protecting or enhancing the environment. This definition is supported by the statements made by Holtec Britain in their Environmental Policy [41], in which Holtec Britain commit to:

- Support policies that advance the generation and use of low carbon, reliable nuclear power to protect the health, environment and economic well-being of communities.
- Integrate environmental justice considerations and sustainable development principles into our company business practices, including those related to selection of contractors and suppliers.

During Step 2 of GDA, the sustainability expectations outlined in the EA's GDA Guidance to RPs [28] were mapped against the framework of Buildings Research Establishment Environmental Assessment Methodology (BREEAM)® Infrastructure [189], and the United Nations Sustainable Development Goals [190] (SDG). This exercise was recorded and a strategy document developed: the SMR-300 GDA Sustainability Strategy [191].

PSR Part B Chapter 21 External Hazards [218] describes how UK Climate Projections have been used in the derivation of the GSE [176]. Parameters to account for the effects of reasonably foreseeable climate change over the lifetime of the facility include flood risk assessment, cooling loads for projected air temperatures and other potential hazards to the site.

6.8.6.5.1 Evidence for 4.6-A5: Sustainability

- **SMR-300 GDA Sustainability Strategy** [191] – The RP's approach to embedding sustainable development principles into generic SMR-300 design, and the route map for site-specific stage and beyond is presented. The key conclusions and summary of this assessment is presented in PER Chapter 4 Conventional Impact Assessment [4].

- **Holtec Britain Environmental Policy** [41] – Establishes Holtec Britain’s strategic commitments and values towards sustainable development.
- **SMR-300 GDA RSR-BAT Guidance** [6] – Sustainability has been incorporated as criteria in the optioneering process.

6.8.7 Claim 4.7 Monitoring and Sampling

Claim 4.7: Monitoring and Sampling *The Generic SMR-300 includes appropriate monitoring and sampling arrangements for measuring and assessing discharges, disposals and transfers to other premises of radioactive waste to demonstrate compliance with the proposed limits and provide an indication of plant performance.*

Monitoring and sampling is key to supporting the three key aspects of BAT identified by the RP:

1. Prevent the unnecessary creation of radioactive wastes and/or discharges.
2. Minimise the quantity and activity of any radioactive wastes and/or discharges created.
3. Minimise the impacts of radioactive wastes and/or discharges on people and the environment.

There is a very strong interface between the topic of BAT and monitoring and sampling. More details on the arrangements for the generic SMR-300 monitoring and sampling regime can be found in PER Chapter 5 Monitoring and Sampling [10]. It presents technical information as required by the EA's GDA Guidance for Requesting Parties [28]. This sub-chapter presents claims, arguments and evidence in order to demonstrated BAT associated with the topic of Monitoring and Sampling.

The generic developed principles also include a direct link between BAT and monitoring under RSMDP13 [33] *"The best available techniques, consistent with relevant guidance and standards, should be used to monitor and assess radioactive substances, disposals of radioactive wastes and the environment into which they are disposed".*

BAT is applied to monitoring and sampling arrangements and equipment in the generic SMR-300, consistent with relevant guidance and standards [10]. Monitoring and sampling arrangements are in place throughout the plant, covering leak detection, process monitoring of radioactive waste management systems and characterisation of effluents released at discharge points.

The arguments presented in support of this claim demonstrate a suitable level of compliance to RSR permit conditions 3.2.1 to 3.2.6 [38] (listed below) that is appropriate to a 2-Step GDA.

3.2.1 – Requirements to *"take samples and conduct measurements, tests, surveys, analyses and calculations to determine compliance"* with the RSR permit.

3.2.2 – Requirements to *"maintain records of all monitoring"* required.

3.2.3 – *"Monitoring equipment, techniques, personnel and organisations employed for the monitoring of disposals and the environment required by condition 3.2.1 or 3.2.5 shall have either MCERTS certification or MCERTS accreditation (as appropriate), where available, unless otherwise agreed in writing by the Environment Agency".*

3.2.4 – *"Permanent means of access shall be provided to enable sampling and monitoring…"*

3.2.5 – Requirements for other, additional monitoring requirements if defined by the EA.

3.2.6 – *"(a) regular calibration, at an appropriate frequency, of measuring instruments…*

(b) ….such measuring instruments and other systems and equipment are serviceable and correctly used".

Features of the generic SMR-300 particularly important to this claim include:

- Monitoring and sampling capability is provided at discharge points to detect elevated activity that can initiate automatic isolations of systems and discharge lines ensure compliance with proposed discharge limits for significant radionuclides.
- In-process monitoring and sampling of the performance of key systems using or containing radioactive substances that enable operators to undertake recovery actions.

This claim is substantiated by eight arguments as depicted in Figure 25 below. Where appropriate these are further split in to sub-arguments.

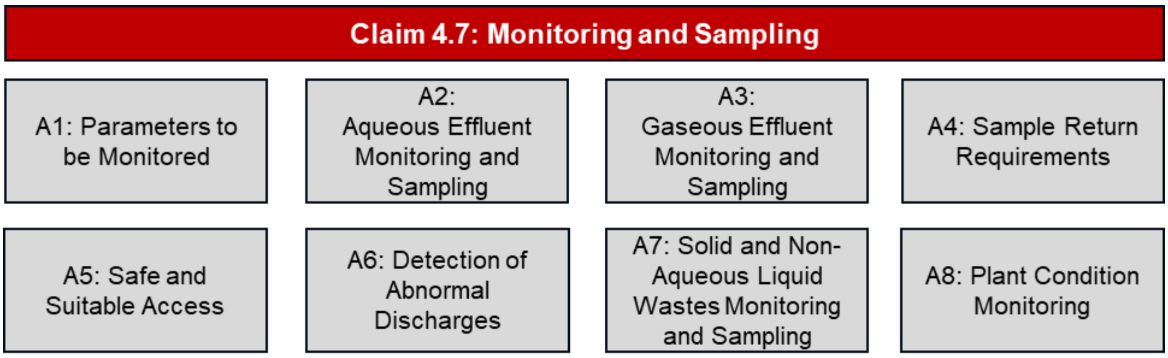

Figure 25: Summary CAE Tree for Claim 4.7: Monitoring and Sampling

6.8.7.1 Argument 4.7-A1: Parameters to be Monitored

Argument 4.7-A1: Parameters to be Monitored

The parameters for monitoring final discharges have been determined based on the radionuclides deemed significant in PER Chapter 2 QEDL and PER Chapter 3 Radiological Impact Assessment. The significant radionuclides were determined using EA guidance and the EU 2004/2/Euratom recommendation

The parameters for monitoring final discharges have been determined based on the radionuclides deemed significant in PER Chapter 2 QEDL [8] and PER Chapter 3 RIA [11]. The significant radionuclides were determined using EA Guidance [161] and the EU 2004/2/Euratom recommendation [150] (Argument 4.4-A1-SA1: Identification of Significant Radionuclides).

Where appropriate radionuclides have been grouped together when proposing limits for ease of analysis. The radionuclides/groupings for which prospective RSR permit limits have been proposed are summarised in Table 7 below, and will form the basis for the generic SMR-300 discharge monitoring requirements.

Table 7: Significant Radionuclides for Gaseous and Aqueous Discharges for the Generic SMR-300

Significant Radionuclides (Gaseous)	Significant Radionuclides (Aqueous)	Other Parameters
Tritium	Tritium	Discharge flow rate
Carbon-14	Carbon-14	
Noble Gases	Caesium-137	
Iodine-131	Other beta/gamma emitting radionuclides	
Other beta-emitting Radionuclides associated with particulate matter		

The significant radionuclides identified for monitoring and reporting at PWRs within the European Commission recommendation 2004/2/Euratom [150] requirements for limits of detection are presented in Table 8 and Table 9 below.

Table 8: Key Radionuclides for Discharge to Atmosphere in 2004/2/Euratom

Significant Radionuclides (Gaseous)	Euratom Limits of Detection (Bq/m^3)
Carbon-14	1E+01
Tritium	1E+03
Cobalt-60	1E-02
Krypton-85	1E-04
Xenon-133	1E+04
Iodine-131	2E-02
Strontium-90	2E-02
Caesium-137	3E-02

Table 9: Key Radionuclides for Aqueous Discharges in 2004/2/Euratom

Significant Radionuclides (Aqueous)	Euratom Limits of Detection (Bq/m^3)
Tritium	1E+05
Cobalt-60	1E+04
Strontium-90	1E+03
Caesium-137	1E+04

The subsequent arguments in Claim 4.7 cover the design provisions that ensure significant radionuclides shown above can be monitored for recording and regulatory reporting purposes in line with the limits of detection set out in the European Commission recommendation.

6.8.7.1.1 Evidence for 4.7-A1: Parameters to be Monitored

- **PER Chapter 2 QEDL** [8] – Determines significant radionuclides for the generic SMR-300 based on EA guidance [161] and the EU 2004/2/Euratom recommendation [150]. Proposes discharge limits for significant radionuclides/groups with which monitoring and sampling arrangements will need to demonstrate compliance.
- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of significant radionuclides to be monitored and the requirements for detection limits.

6.8.7.2 Argument 4.7-A2: Aqueous Effluent Monitoring and Sampling

Argument 4.7-A3: Aqueous Effluent Monitoring and Sampling The Generic SMR-300 includes appropriate monitoring and sampling arrangements for measuring and assessing discharges of aqueous radioactive waste to demonstrate compliance with the proposed limits and provide an indication of plant performance.

The generic SMR-300 has appropriate arrangements in place for monitoring and sampling of aqueous effluents through the management process of the aqueous effluent streams and at the point of discharge. This allows for the quantification of discharges in line with European Commission recommendations (see Argument 4.7-A1: Parameters to be Monitored) and demonstration of compliance with permitted discharge limits. In-process monitoring provides valuable information to the operator to optimise plant operations and minimise generation of radioactive waste.

[REDACTED]

Figure 26: Simplified Diagram of Sampling and Monitoring for Aqueous Radioactive Waste

Figure 26 above illustrates the sampling and monitoring arrangements for radioactive aqueous effluent arising from the generic SMR-300. Effluents from the CVC and residual water from spent resin, radioactive and miscellaneous drains are treated in the LRW to minimise impacts on the environment ALARA.

This argument is decomposed into six sub-arguments in order to aid the discussion, as depicted in Figure 27 below.

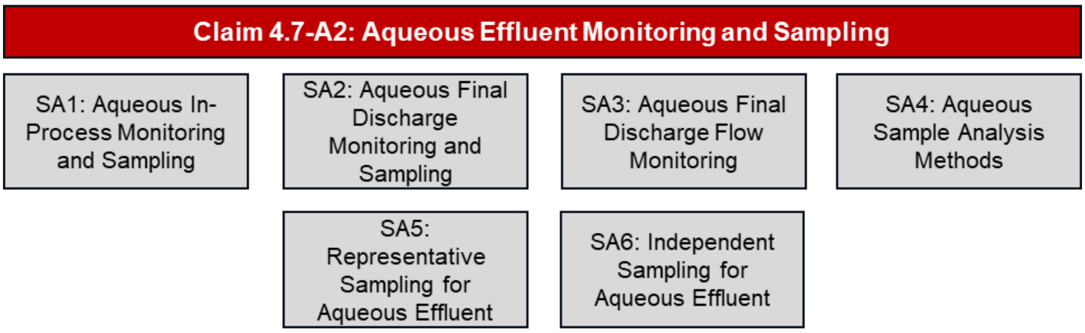

Figure 27: Summary CAE Tree for 4.7-A2 Aqueous Effluent Monitoring and Sampling

6.8.7.2.1 Argument 4.7-A2-SA1: Aqueous In-process Monitoring and Sampling

Argument 4.7-A2-SA1: Aqueous In-process Monitoring and Sampling *The Generic SMR-300 provides appropriate in-process monitoring and sampling of aqueous radioactivity to provide early warning to the operator of elevated activity, understand plant performance and inform operator actions to minimise discharges*

The generic SMR-300 provides in-process sampling and monitoring that facilitates early warning to equipment failures and includes diagnostic capability to identify sources of elevated levels of radioactivity. Aqueous radioactive wastes are to be sampled and monitored as they arise, ideally at the point of generation, throughout the waste management process and at the point of discharge.

The main functions of the in-process sampling and monitoring system for liquid radioactive waste are as follows [128] [192]:

- Radioactive properties are monitored on various systems to detect fuel leaks and egress of radioactive material from the reactor.
- The PSL panel allows for monitoring of radioactivity in the primary circuit and CVC, for understanding generation of radioactivity in the core and to identify issues such as failed fuel or excessive corrosion.
- The CVC VCT is sampled to determine characterisation for effluent recycling or transfer to LRW waste holdup tanks. The CVC effluent storage tanks also feature drains for sampling if required.
- LRW waste holdup tanks and LRW abatement systems such as demineralisers and filters are sampled upstream and downstream, to determine equipment performance.

- LRW monitoring tanks are sampled to ensure compliance with radionuclide levels before release.

For normally accessible locations throughout the plant, PSL local sample connections are provided for manually collecting samples directly from the source. These local sample system connections reduce sample line tubing, provides shielding, maintains radiation exposure to operators ALARA, and reduces volume inputs to LRW [128].

6.8.7.2.1.1 Evidence for 4.7-A2-SA1: Aqueous In-process Monitoring and sampling

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of all in-process monitoring for the generic SMR-300 for each of the purposes outlined above.
- **SDD for Radiation Monitoring System** [120] (RMS) – Specifies the online monitoring within the LRW and secondary side systems to identify elevated releases and automatically isolate systems/provide suitable alarms for operators.
- **SDD for PSL** [192] – Presents the functions and descriptions of PSL monitoring and sampling arrangements.
- **SDD for LRW** [128] – Outlines arrangements within the LRW for in-process sampling and monitoring.
- **PSL P&ID** [193] – Details in-process grab sampling/integrated sampling locations for aqueous effluent, including in the RCS, CVC and LRW.
- **Future Evidence: Confirmation of in-process sampling and monitoring requirements to represent BAT** – Systems with a low design maturity (e.g. RDS) will have applicable equipment confirmed at the site-specific stage.

6.8.7.2.2 Argument 4.7-A2-SA2: Aqueous Final Discharge Monitoring and Sampling

Argument 4.7-A2-SA2: Aqueous Final Discharge Monitoring and Sampling *The Generic SMR-300 will include appropriate arrangements for monitoring and sampling of final discharges of aqueous wastes to facilitate demonstration of compliance with proposed limits*

Effluent is processed and discharged through the LRW in batches. Treated LRW radioactive effluent is sampled in the monitoring tanks by recirculation mixing to enable representative sampling. In line with best practice, appropriate valve interlocks will be installed to prevent inadvertent discharges of tank contents whilst sampling is conducted, and to prevent discharge occurring as the tank is being filled. Analysis of the samples will take place in the on-site laboratory.

Continuous radiation monitoring is provided on the discharge path from the LRW to the outfall. This is situated downstream of LRW monitoring tanks (and LRW treatment) and upstream of the outfall. Detection of high radioactivity in the discharge stream automatically isolates flow, and operator action would be required to re-establish discharge.

6.8.7.2.2.1 Evidence for 4.7-A2-SA2: Aqueous Final Discharge Monitoring and sampling

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of the requirements, current arrangements and operational processes in place for LRW monitoring tank discharges.
- **SDD for RMS** [120] – Specifies the online monitoring for the LRW discharge line, and provisional equipment choice.
- **Design Challenge - Environmental Monitoring and Sampling** [194] – Paper sets out the requirement for the generic SMR-300 design to be developed to meet EA recommendations to ensure sufficient provisions for independent sampling, demonstration of BAT in flow-proportional sampling and to comply with applicable MCERTS requirements.
- **Future Evidence: Assessment of Liquid Effluent Sampling and Monitoring Locations for Representative Sampling** – Will document post-GDA flow modelling and confirming MCERTS requirements for equipment.
- **GDA Commitment: C_Moni_099** – Raised to progress the Design Challenge - Environmental Monitoring and Sampling, through the Design Management [31] process to completion.

6.8.7.2.3 Argument 4.7-A2-SA3: Aqueous Final Discharge Flow Monitoring

Argument 4.7-A2-SA3: Aqueous Final Discharge Flow Monitoring *The Generic SMR-300 will utilise continuous flow monitoring of aqueous effluents using MCERTS equipment calibrated to suitable standards to enable quantification of releases to the environment*

The generic SMR-300 design specifies the use of flowrate monitoring on the liquid discharge line before the liquid effluent stream is mixed with other non-active waste streams at the point of discharge [128]. Flow is continuously monitored on the LRW discharge line as a tank is being discharged.

Sourcing of MCERTS approved equipment is a regulatory requirement and a requirement according to RSR permit conditions [38]. The MCERTS standard requires that liquid flowmeters can be calibrated to suitable standards to enable continuous monitoring of releases to the environment [38].

6.8.7.2.3.1 Evidence for 4.7-A2-SA3: Aqueous Final Discharge Flow Monitoring

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of requirements and best practice to be implemented for aqueous flow monitoring.
- **SDD for LRW** [128] – Sets out the operational process for the discharge of LRW monitoring tanks and the requirements for continuous flow monitoring of discharges.
- **Future Evidence: Specification of MCERTS Flow Monitoring Equipment** – The specification's scope will comprise applicable equipment in the LRW discharge line.

6.8.7.2.4 Argument 4.7-A2-SA4: Aqueous Sample Analysis Methods

Argument 4.7-A2-SA4: Aqueous Sample Analysis Methods

The analytical techniques utilised for the generic SMR-300 for aqueous samples will ensure quantification of activity for all key identified parameters consistent with the detection limits set out in European Commission recommendation EU/2004/Euratom

The liquid sampling arrangements set out in

Argument 4.7-A2-SA1: Aqueous In-process Monitoring and Sampling and Argument 4.7-A2-SA2: Aqueous Final Discharge Monitoring and Sampling result in samples of liquid effluent which can be analysed in the on-site laboratory. Provisional methods identified for analysis of these samples will result in a limit of detection consistent with the requirements of 2004/2/Euratom [150] (see Argument 4.7-A1: Parameters to be Monitored) and are set out in Table 10 below.

Table 10: Analytical Methods for Aqueous Radioactivity

Significant Radionuclides (Gaseous)	Analytical Method
Tritium	Liquid scintillation detection
Carbon-14	
Caesium-137	High Resolution Gamma Spectroscopy (HRGS)

6.8.7.2.4.1 Evidence for 4.7-A2-SA4: Aqueous Sample Analysis Methods

- **PER Chapter 5 Monitoring and Sampling** [10] – Summarises the analytical methods utilised by comparable PWRs to achieve limits of detection in line with 2004/2/Euratom [150].
- **Future Evidence: Selection of Analytical Methods** – Confirmation of techniques for aqueous final discharge sampling that meet EU/2004/Euratom detection limits.
- **Future Evidence: On-site Laboratory Design and Equipment Specification** – Analytical methods will be in accordance with ISO 17025: 2017.

6.8.7.2.5 Argument 4.7-A2-SA5: Representative Sampling for Aqueous Effluent

Argument 4.7-A2-SA5: Representative Sampling for Aqueous Effluent

The design of sampling lines and selection of location, equipment and techniques used for aqueous in-process and final discharge monitoring and sampling shall facilitate the collection of a sample representative of the effluent stream.

Measures are taken to ensure that liquid samples collected from the generic SMR-300 will be representative of the tank or process stream they are collected from. The measures to ensure representativity are dependent on the type of sampling, but will be consistent with the recommendation of ISO 5667:2023.

For PSL process stream samples, sample points for the generic SMR-300 are located in turbulent flow zones to ensure that representative samples are collected. Sample flow rate capabilities are to be selected based on sample point location, line size, and fluid temperature to assure that sample flow is turbulent. A constant flow rate is maintained for continuous samplers to prevent sample line deposits [192]. Samples taken on an intermittent time basis are circulated for a predetermined volume to provide a valid sample at the PSL central panel.

Before PSL samples are drawn, sample lines are purged by opening the appropriate recirculation/purge line isolation valve for sufficient volume to ensure that a representative sample may be obtained from the process line or vessel. When sampling for a mixed phase sample (gas-liquid, liquid-solid), iso-kinetic flow may be required in order to obtain a representative sample. Sample nozzles are provided for iso-kinetic sampling where required [192].

For tank sampling, tank contents circulated for a predetermined volume to provide a valid sample at the central panel or grab sampling point. Sampling is performed following recirculation of tank contents. Sample containers, such as sample pressure vessels, are cleaned and flushed to ensure a representative sample is obtained [192]. For LRW monitoring tanks, recirculation mixing is adopted to enable representative conditions for sampling [128].

6.8.7.2.5.1 Evidence for 4.7-A2-SA5: Representative Sampling for Aqueous Effluent

- **PER Chapter 5 Monitoring and Sampling** [10] – Outlines the measures in place, guidance and best practice to be implemented to ensure representative sampling for aqueous effluents.
- **SDD for PSL** [192] – Outlines how the design of the PSL primary sampling panel, and grab sampling points are designed to ensure a representative sample is collected.
- **PSL P&ID** [193] – Presents locations for PSL monitoring and sampling arrangements, and upstream and downstream flow disturbances.
- **SDD for LRW** [128] – Sets out the process for recirculation of LRW monitoring tank contents, sampling and subsequent discharge on confirmation of acceptable results.
- **Future Evidence: Compliance Matrix for ISO 5667:2023 and IEC 60861:2006 Requirements** – Presents the demonstration that relevant requirements relating to representative sampling for aqueous in-process/discharge sampling have been met.
- **Future Evidence: Assessment of Liquid Effluent Sampling and Monitoring Locations for Representative Sampling** – Documenting post-GDA flow modelling and confirming MCERTS requirements for equipment.

6.8.7.2.6 Argument 4.7-A2-SA6: Independent Sampling for Aqueous Effluent

Argument 4.7-A2-SA6: Independent Sampling for Aqueous Effluent

The Generic SMR-300 will provide for independent sampling facilities for final discharges of aqueous effluents.

The provision of secure and safe independent sampling for final discharges of aqueous effluents is a requirement identified in the EA's Monitoring of radioactive discharges to atmosphere from nuclear facilities [195] guidance. Typically this involves automatic sampling methods on the discharge line such as flow proportional sampling, combined with a radiation monitor and isolatable discharge path.

[REDACTED]

Given the importance of flow proportional sampling as UK best practice, a Design Challenge on Environmental Monitoring and Sampling [194] paper was raised via the RP's Design Management [31] process to ensure this area is addressed in the site-specific design.

6.8.7.2.6.1 Evidence for 4.7-A2-SA6: Independent Sampling for Aqueous Effluent

- **PER Chapter 5 Monitoring and Sampling** [10] – Sets out the approach to independent sampling of aqueous effluent.
- **Design Challenge - Environmental Monitoring and Sampling** [194] – Paper set out the requirement for the generic SMR-300 design to be developed to meet EA recommendations to ensure sufficient provisions for independent sampling, demonstration of BAT in flow-proportional sampling and to comply with applicable MCERTS requirements.
- **GDA Commitment: C_Moni_099** – Raised to progress this Design Challenge through the Design Management [31] process to completion.

6.8.7.3 Argument 4.7-A3: Gaseous Effluent Monitoring and Sampling

Argument 4.7-A3: Gaseous Effluent Monitoring and Sampling *The Generic SMR-300 includes appropriate monitoring and sampling arrangements for measuring and assessing discharges of gaseous radioactive waste to demonstrate compliance with the proposed limits and provide an indication of plant performance.*

The generic SMR-300 has appropriate arrangements in place for monitoring and sampling of gaseous effluents through the management process of the gaseous effluent streams and at the point of discharge. This allows for the quantification of discharges in line with European Commission recommendations (see Argument 4.7-A1: Parameters to be Monitored) and demonstration of compliance with permitted discharge limits. In-process monitoring provides valuable information to the operator to optimise plant operations and minimise generation of radioactive waste.

Figure 28 below illustrates the main gaseous radioactive effluents arising from the generic SMR-300 and their associated sampling and monitoring arrangements. The systems responsible for managing gaseous effluent include the GRW, CBV and RCV (Radiologically Controlled Area HVAC System), which contribute to minimising radiation exposure to members of the public and the environment to ALARA.

[REDACTED]

Figure 28: Overview of Sampling and Monitoring Arrangements for Gaseous Radioactive Effluents

This argument is split in to six sub-arguments as depicted in Figure 29 below.

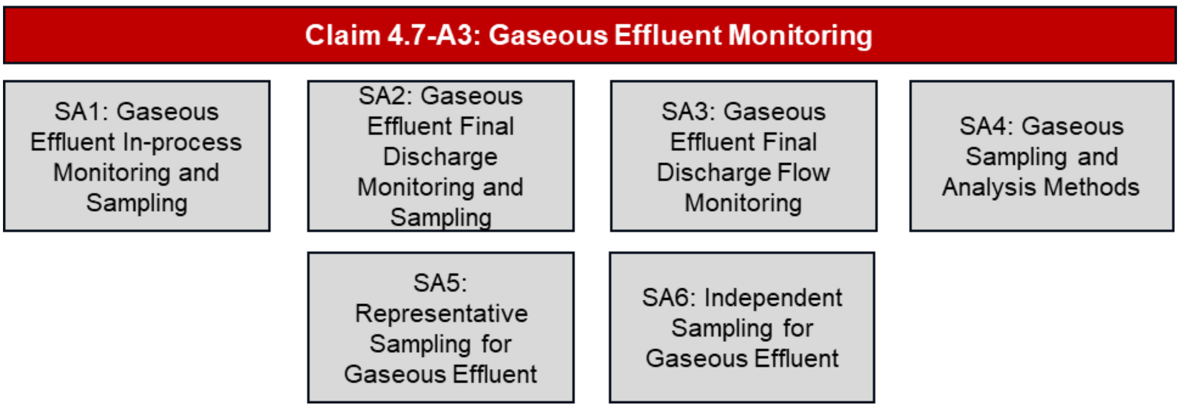

Figure 29: Summary CAE Tree for 4.7-A3 Gaseous Effluent Monitoring

6.8.7.3.1 Argument 4.7-A3-SA1: Gaseous Effluent In-process Monitoring and Sampling

Argument 4.7-A3-SA1: Gaseous Effluent In-Process Monitoring and Sampling *The Generic SMR-300 provides appropriate in-process monitoring and sampling of parameters relevant to waste generation and management, as well as process control so that suitable actions can be taken to optimise processing of radioactive wastes.*

In-process sampling and monitoring provides early warning to the operator of elevated radioactivity in process effluents. It also provides diagnostic capability to identify the source of an increase in radioactivity that has been detected downstream and to understand plant performance.

In-process monitoring and sampling for gaseous effluents is intended for the following purposes:

- **GRW Effluent Monitoring** - Grab sampling can be performed on the decay tanks in the GRW to determine compliance of batches before discharge [129]. The radiation monitoring devices on the discharge line will be designed to continuously monitor radioactivity discharged from the GRW. If out-of-threshold radiation levels are detected, this discharge path will automatically be isolated.
- **HVAC Systems Exhaust Monitoring** - Radiation monitoring is incorporated into the discharge line of active HVAC systems and typically non-active HVAC systems with risk of contamination, in order to provide early indicator to the operator of abnormally elevated activity, and for diagnostic purposes
- **Primary-Secondary Leakage Monitoring** - A Nitrogen-16 monitor is located within the main steam line which in near real-time monitors levels of Nitrogen-16 on the secondary side to detect pinhole leaks between the primary and secondary circuit. Other secondary side/non-active systems include online monitoring to alert the operator to ingress of radioactivity into the system.

6.8.7.3.1.1 Evidence for 4.7-A3-SA1: Gaseous Effluent In-process Monitoring and Sampling

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of all in-process monitoring for the generic SMR-300 for each of the purposes outlined above.
- **SDD for RMS** [120] – Specifies the online monitoring within the GRW, HVAC systems and secondary side systems to identify elevated releases and automatically isolate systems/provide suitable alarms for operators.
- **SDD for PSL** [192] – Sets out in-process grab sampling/integrated sampling locations for gaseous effluent.
- **SDD for GRW** [129] – Outlines arrangements within the GRW for in-process sampling and monitoring, including use of the gas analysers for decay tank sampling.
- **PSL P&ID** [193] – Presents the PSL monitoring and sampling arrangements, including the connection to the VCT.

- **Future Evidence: Confirmation of in-process sampling and monitoring requirements to represent BAT** – Systems with a low design maturity (e.g. RCV) will have applicable equipment confirmed at the site-specific stage.

6.8.7.3.2 Argument 4.7-A3-SA2: Gaseous Effluent Final Discharge Monitoring and Sampling

Argument 4.7-A3-SA2: Gaseous Effluent Final Discharge Monitoring and Sampling *The Generic SMR-300 will utilise continuous flow monitoring of gaseous effluents using MCERTS equipment calibrated to suitable standards to enable quantification of releases to the environment*

The generic SMR-300 design provides sampling and monitoring at the point of discharge to the environment (i.e. the plant vent), to quantify the radionuclides in gaseous discharges to the environment for demonstration of compliance with proposed limits.

An RMS monitor on the plant vent stack detects elevated radioactivity and instigates automatic termination of discharge on exceeding a predetermined setpoint.

The current design of the generic SMR-300 RCV and plant vent stack has not reached a level of maturity for final sampling and monitoring for gaseous discharges to be confirmed, as such a GDA Commitment has been raised to ensure adequate provisions in the design of the RCV and plant vent to enable quantification of discharges of all identified significant radionuclides. Sizing and design of the stack will consider the monitoring and sampling requirements set out in ISO 2889: 2023 [196] including the requirements for sampling points to be located suitable distance upstream and downstream of flow disturbance, to ensure the flow it suitably well-mixed. A commitment has been raised to ensure that suitable final discharge monitoring and sampling is incorporated into the design of the plant vent stack.

6.8.7.3.2.1 Evidence for 4.7-A3-SA2: Gaseous Effluent Final Discharge Monitoring and Sampling

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of the requirements for plant vent stack monitoring and sampling and current arrangements in the design.
- **SDD for RMS** [120] – Specifies the online monitoring for the plant vent stack and provisional equipment choice.
- **Future Evidence: RAB Plant Vent BAT Study** – Options assessment of the detailed design to ensure the stack and supporting systems are adequately designed to facilitate discharge monitoring and sampling.
- **GDA Commitment: C_Moni_119** – Raised to undertake a BAT assessment to confirm that suitable arrangements are in place to quantify gaseous discharges.

6.8.7.3.3 Argument 4.7-A3-SA3: Gaseous Effluent Final Discharge Flow Monitoring

Argument 4.7-A3-SA3: Gaseous Effluent Final Discharge Flow Monitoring

The Generic SMR-300 will utilise continuous flow monitoring of gaseous effluents using MCERTS equipment calibrated to suitable standards to enable quantification of releases to the environment

The generic SMR-300 will have adequate flow monitoring in place to quantify radiological releases. The plant vent stack will have online flow monitoring (with the ability for calibration via manual methods, in line with UK best practice. Continuous flow monitoring is recommended if the flow rate is anticipated to vary by more than 20% per year. Effluent and sample flow rate should be measured within +/- 10%.

Continuous flow monitoring in line with the EA's Monitoring Certification Scheme (MCERTS) will be specified when selecting equipment. Use of MCERTS approved equipment, where available, is required by the EA and is stipulated in RSR permit conditions. There are multiple equipment options available for use in stack flow monitoring. A selected option must facilitate manual calibration of gas flowmeters on the stack, for example, through installation of measurement hatches. This is a requirement of the MCERTS standard for continuous emissions monitoring to the environment.

In addition to the plant vent stack, the GRW design specifies the use of flow monitoring on the GRW to provide discharge flow rate information to enable adequate dispersion of the gas and determination of radioactivity release rates [129].

6.8.7.3.3.1 Evidence for 4.7-A3-SA3: Gaseous Effluent Final Discharge Flow monitoring

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of requirements and best practice to be implemented for gaseous flow monitoring.
- **SDD for GRW** [129] – Specifies the requirements for flow monitoring on the GRW system.
- **Future Evidence: RAB Plant Vent BAT Study** – Options assessment of the detailed design to ensure the stack and supporting systems are adequately designed to facilitate discharge monitoring and sampling and incorporates suitable ports to enable manual flow rate measurements for calibration purposes (as per ISO 10780:1994).
- **Future Evidence: Compliance Matrix for ISO 2889:2023, ISO 10780:1994 and EN 60761-3:2004 Requirements** – Presents the demonstration that relevant requirements have been met.
- **Future Evidence: Specification for MCERTS flow monitoring equipment** – Where available plant flow monitoring equipment for the vent stack will be procured to meet performance criteria listed in EA's Performance Standards and Test Procedures for Automatic Isokinetic Samplers [197] guidance.
- **GDA Commitment: C_Moni_119** – Raised to undertake a BAT assessment to confirm that suitable arrangements are in place to quantify gaseous discharges – this will include specification of an MCERTS continuous flow monitor.

6.8.7.3.4 Argument 4.7-A3-SA4: Gaseous Sampling and Analysis Methods

Argument 4.7-A3-SA4: Gaseous Sampling and Analysis Methods *The gaseous sampling equipment and analytical techniques utilised for the generic SMR-300 will ensure quantification of activity for all key identified parameters consistent with the detection limits set out in EU Commission recommendation EU/2004/Euratom*

In order to obtain measurements for low energy beta emitters tritium and carbon-14, specialised sampling equipment (for example bubblers) is required at the plant vent and in-process monitoring locations. Variants of bubblers can also be used to isolate samples of Carbon-14. These can then undergo analysis at the on-site laboratory.

Similarly, separate or combined particulate/iodine samplers are commonly employed which use filters to capture aerosols, and iodine cartridges with activated carbon to capture iodine samples. Table 11 below presents the analytical methods for the on-site laboratory. OPEX and available analysis techniques has indicated the following methods should be able to achieve detection limits set out in European Commission recommendation EU 2004/2/Euratom [150] (see Argument 4.7-A1: Parameters to be Monitored) for significant radionuclides to be quantified. Full specification of the on-site laboratory will take place at the site-specific stage, in accordance with accreditation standard ISO 17025:2017.

Table 11: Analytical Methods for Gaseous Radioactivity

Significant Radionuclides (Gaseous)	Analytical Method
Tritium	Liquid Scintillation Counting
Carbon-14	
Noble Gases	High Resolution Gamma Spectroscopy (HRGS)

For the RMS, selection of a specific detector type is governed by the required sensitivity, the operating conditions of the process stream and environmental conditions near the point of detection. Three types of detectors can be used in a process radiation monitor: Gas-Filled Detectors, Scintillators, and Solid State Detectors.

6.8.7.3.4.1 Evidence for 4.7-A3-SA4: Gaseous Sampling and Analysis Methods

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of prospective sampling technologies, and associated analytical methods for all significant gaseous radionuclides.
- **SDD for RMS** [120] – Sets out the provisional equipment type for RMS monitors based on sample medium and required sensitivity.
- **Future Evidence: Sampling techniques for the generic SMR-300 will defined in-line with UK best practice and BAT** – Gaseous in-process grab sampling locations will be reviewed to consider that equipment specified will allow measurement of all radionuclides of interest.

- **Future Evidence: Confirmation of Analytical Methods for Gaseous Final Discharge Sampling** – Demonstration that methods meet EU/2004/Euratom detection limits.

6.8.7.3.5 Argument 4.7-A3-SA5: Representative Sampling for Gaseous Effluent

Argument 4.7-A3-SA5: Representative Sampling for Gaseous Effluent *The design of sampling lines and selection of location, equipment and techniques used for gaseous in-process and final discharge monitoring and sampling shall facilitate the collection of a sample representative of the effluent stream.*

The ISO 2889:2023 standard [196] informs the design of sampling systems for airborne contaminants in ducts, stacks and vents to achieve representative sampling conditions. It outlines the following key design requirements are to be considered at detailed design of the generic SMR-300:

- Position sample points at locations where a high degree of mixing is achieved to minimise particulate dropout and increase representativity of samples.
- Sizing of sample lines to enable turbulent flow.
- Where multi-phase flow exists, ensuring iso-kinetic conditions through specification of iso-kinetic nozzles.
- Providing suitable clearance distances between bends and take-off points in ductwork.
- Design of sample points and equipment to enable cleaning and maintenance, and to avoid deposition of samples within sampling lines.
- Performance acceptance testing for sampling equipment to demonstrate representative sampling in operation.
- Fluctuations in process temperature, flow and composition over time and the impact on representative conditions.
- Frequency and timing of sampling.

Demonstration of the design against these criteria will take place at the detailed design stage.

PER Chapter 5 Monitoring and Sampling [10] provides the following information in support of this sub-argument:

- Sampling location requirements to ensure sample points are located where a high degree of mixing will be achieved and methods for determining suitable locations in line with best practice (ISO 10780:1994).
- Summary of how sampling systems are to be designed to ensure isokinetic sampling takes place in order to facilitate a representative sample.
- List of design criteria to minimise depositional losses in gaseous sampling lines for the generic SMR-300, and summarises potential methods for confirming suitability experimentally or with computer modelling.

6.8.7.3.5.1 Evidence for 4.7-A3-SA5: Representative Sampling for Gaseous Effluent

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of requirements and measures for representative sampling.
- **SDD for RMS** [120] – Captures design requirements necessary to ensure gaseous RMS monitor locations and design will facilitate representative sampling.
- **SDD for PSL** [192] – Sets out representativity requirements for PSL sampling points to be achieved during detailed design.
- **Future Evidence: Calculation of Particle Deposition in Transport Lines Between the Extraction Point and Filter** – Determined by experimentally using test aerosol particles by the use of documented computer codes or documented and referenced hand calculations.
- **Future Evidence: Compliance Matrix for ISO 2889:2023, ISO 10780:1994 and BE EN 60761-3:2004 Requirements** – Presents the demonstration that relevant requirements have been met.
- **Future Evidence: RAB Plant Vent BAT Study** – Options assessment of the detailed design to ensure the stack and supporting systems are adequately designed to meet requirements of ISO 2880:2023 on choice of sampling line location to ensure stream is well-mixed and representative.
- **GDA Commitment: C_Moni_119** – Raised to undertake a BAT assessment to confirm that suitable arrangements are in place to quantify gaseous discharges. Will require demonstration against all identified criteria that representative and isokinetic sampling is ensured where relevant.

6.8.7.3.6 Argument 4.7-A3-SA6: Independent Sampling for Gaseous Effluent

Argument 4.7-A3-SA6: Independent Sampling for Gaseous Effluent *The Generic SMR-300 will provide independent sampling facilities for final discharges of gaseous effluents.*

The provision of secure and safe independent sampling facilities for final discharges of gaseous effluents is a UK-specific regulatory requirement [195] and will be incorporated into the design of the generic SMR-300. Typically this is addressed by a redundant (or “backup”) sampling and monitoring train on the plant vent stack with measures in place to enable independent sampling and monitoring (witnessed by the regulator if required). This second set of sampling and monitoring equipment on the plant vent stack also acts as a backup when the primary monitoring and sampling equipment undergo maintenance. Independent sampling and monitoring equipment cabinets are secured using tamper-free seals.

6.8.7.3.6.1 Evidence for 4.7-A3-SA6: Independent Sampling for Gaseous Effluent

- **PER Chapter 5 Monitoring and Sampling** [10] – Sets out the independent sampling arrangements for gaseous effluent.
- **Future Evidence: RAB Plant Vent BAT Study** – Options assessment of the detailed design to ensure the stack and supporting systems are adequately designed to meet

requirements of ISO 2880:2023, to ensure the stream is well-mixed and representative for primary and redundant sampling trains.

- **GDA Commitment: C_Moni_119** – Raised to undertake a BAT assessment will describe the facilities within the generic SMR-300 provided for independent periodic sampling of final discharges of gaseous wastes, once the design of the RCV and plant vent stack have sufficiently matured.

6.8.7.4 Argument 4.7-A4: Sample Return Requirements

Argument 4.7-A4: Sample Return Requirements

Samples will be returned to the duct/pipe at a location downstream of the sampling position, in a manner that minimises the volume of radioactive waste generated in the sampling and monitoring process. Where it may not be possible to return samples downstream, it will be ensured that return of samples do not unduly impact the representativeness of the sampling point.

In line with the EA's Monitoring of radioactive discharges to atmosphere from nuclear facilities [195] guidance, samples should be returned to the duct or stack at a location downstream of the sampling position, in a manner that minimises the volume of radioactive waste generated in the sampling and monitoring process. This is particularly key for gaseous samples where return upstream may impact ability to extract a representative sample at the sampling point.

Where it may not be possible to meet the guidance of samples being returned downstream of the sampling point, the design will ensure the following measures to avoid unduly impacting on the representativeness of the sampling point:

- Samples are returned to a suitably far upstream point; and
- sample volumes are sufficient low in comparison to the total volume of the effluent stream.

For liquid samples, provisions are in place to ensure that samples and purges are returned to their system of origin where practicable, to reduce generation of additional radioactive waste [192]. Most PSL sample lines of primary effluent are re-routed to the VCT in the CVC letdown stream in order to be returned to their point of origin once processed in the PSL [193]. This provides the benefit of recycling effluents where possible and minimising radioactive waste generation. As sampling is not continuous, rerouting samples to the VCT should have no impact on sample representativeness.

6.8.7.4.1 Evidence for 4.7-A4: Sample Return Requirements

- **PER Chapter 5 Monitoring and Sampling** [10] – Sets out sample return requirements for aqueous and gaseous effluents and how these will be ensured at detailed design for the generic SMR-300.
- **SDD for PSL** [192] – Sets out the design features of the PSL that ensure samples are returned to their system or origin avoiding additional waste generation.
- **Future Evidence: Impact assessment of returning samples to their point of origin** – Each sample point will be reviewed considering the principles of BAT at the detailed design stage.

6.8.7.5 Argument 4.7-A5: Safe and Suitable Access

Argument 4.7-A5: Safe and Suitable Access *Discharge and in-process monitoring and sampling equipment shall be located so as to provide easy and safe access, adequate workspace for safe and comfortable operation, testing and maintenance.*

Provisions are made within the design of the generic SMR-300 to permit periodic inspection, maintenance and calibration of sampling and monitoring equipment. Sufficient space will be provided for personnel, inspection equipment, removal space, and temporary storage, handling machinery, and repairs or replacement [192], and suitable environmental conditions.

Areas required for the maintenance of sampling or monitoring equipment will be designed to be accessible and safe for the operator. Maintenance personnel are to have enough space to operate and manoeuvre equipment without injuring themselves or others around them. They will also be protected from heat, dust, radiation, radioactivity or significant temperature fluctuations.

For the PSL [192], samples are transported to the appropriate sample panels or local sample points for collection using stainless-steel tubing. All sample lines are equipped with an isolation valve located immediately downstream of the sample point. Lines that are normally inaccessible within containment are equipped with remote solenoid valve to isolate and route sample fluids.

Before collection, samples are conditioned for area habitability, operator safety and instrument compatibility. To keep radioactive exposure ALARA, a delay coil is provided on the RCS Hot Leg sample lines within the CS boundary to allow for the decay of short-lived radioisotopes. Pressure and temperature-reducing equipment is provided within the primary sample panel to condition samples, as necessary. Local temperature and pressure indicators are provided within the sampling room as well as on the sampling panel lines which enable the operator to determine sample conditions and evaluate equipment performance.

Samples are reduced to pressures compatible with online instrumentation and atmospheric pressure for grab sampling. A sample heat exchanger is provided to reduce fluid temperatures to sufficient levels for handling.

The detailed design of the plant vent stack will include design of platforms and walkways to enable sufficient access for periodic maintenance, inspections and repairs/replacements as required, taking into account the following guidance [198]:

- The sample location must be safely accessible at all times required during the monitoring process.
- Permanent platforms should be used wherever possible platforms which comply with relevant standards, including minimum weight requirements, safety rails etc.
- Measurement ports must be suitably sized to install and remove the equipment used and reach the measurement points and facilitate periodic manual monitoring of key parameters for testing and calibration purposes.

The location of sampling lines will likely be a compromise between competing requirements; the necessity of providing safe and suitable access to the equipment for operators and the recommendation to shorten sampling lines as far as is practicable to minimise depositional losses.

6.8.7.5.1 Evidence for 4.7-A5: Safe and Suitable Access

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of the features of the generic SMR-300 that facilitate safe and suitable access to operators to sampling and monitoring equipment.
- **SDD for PSL** [192] – Outlines the design features or the primary sampling panel and grab sampling spots that ensure that samples can be safely accessed and collected by the operator, with radiation exposure ALARA.
- **Future Evidence: RAB Plant Vent BAT Study** – Options assessment of the detailed design to ensure the stack and supporting systems have been optimised, taking into account human factors for safe access and work environment in operation and during maintenance.

6.8.7.6 Argument 4.7-A6: Detection of Abnormal Discharges

Argument 4.7-A6: Detection of Abnormal Discharges *The Generic SMR-300 will include provisions for detection, warning and identification of abnormal elevated activity and automatic isolation of discharges upon detection of activity above acceptable thresholds.*

Alarms in the generic SMR-300 design are intended to provide early warning of failure and abnormal conditions in the process, instructing further operator actions (e.g. maintenance, inspection or otherwise), as required, to minimise the impact of system failures on discharges. Equipment failures and process alarms shall be acoustically enunciated and visually displayed in the control room. Alarms are to be active for the duration of the deviation conditions.

Alarm systems are associated with online monitors within the RMS system [120]. Where these are in place to detect activity above set thresholds within discharges, or to detect ingress of radioactivity into non-active systems, they alert the main control room of the issue, and if appropriate automatically isolate the discharge line or system in order to prevent further release. This sort of automatic isolation is associated with both the plant vent stack online monitor for gaseous effluents, and the LRW discharge line for aqueous, to ensure prevention of further release.

Airborne RMS monitors which provide operators with information on concentrations of radioactivity at various points in the ventilation system also have associated alarms to alert the main control room and local personnel to elevated activity within certain systems or buildings. This can aid with identifying the source of identified elevated activity within discharges and allow for pro-active operator led actions.

In addition to alarms associated with high activity readings, sampling and monitoring equipment alarms should identify to the operator high and low sample flow rate as this will affect the ability to take a representative sample.

6.8.7.6.1 Evidence for 4.7-A6: Detection of Abnormal Discharges

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides a summary of the RMS system and its' associated measures for prevention of abnormal discharges. It sets out all RMS monitors identified as relevant to application of BAT for aqueous and gaseous discharges, and their associated alarm arrangements.
- **SDD for RMS** [120] – Sets out the detail of the alarm functions associated with RMS monitors and where required, isolation and actuation functions.
- **Future Evidence: Assessment of Alarms providing EPFs** – At the site-specific stage an assessment will be performed to determine that the specified alarms systems for discharge and in-process monitoring are consistent with regulatory guidance, good practice and OPEX.
- **Future Evidence: Compliance Matrix for Alarm Functions Against BS EN 60861:2008 Requirements** – Alarm functionality for online monitoring shall adhere as far as is practicable to BS EN 60861:2008 to facilitate fault identification capability and inform further action by operators to minimise risk of radioactive releases.

6.8.7.7 Argument 4.7-A7: Solid and Non-Aqueous Liquid Wastes Monitoring and Sampling

Argument 4.7-A7: Solid and Non-Aqueous Liquid Wastes Monitoring and Sampling *Suitable monitoring and sampling arrangements are in place for characterisation of solid and non-aqueous liquid wastes at the point of generation, before and during processing, during storage and prior to disposal or transfer off-site.*

The application of BAT is required to minimise the activity and quantity of waste arisings. To contribute to the effective application of the waste hierarchy, and therefore waste management, waste characterisation information is required through sampling and monitoring.

Solid and non-aqueous liquid waste generated by the generic SMR-300 is to be monitored throughout the management process (see Argument 4.2-A3: Radioactive Waste Management Lifecycle) dependent on waste stream:

- **At or close to point of generation** – Radiological properties of the waste are identified to ensure appropriate segregation and treatment. Filter cartridges are analysed before being dewatered and solidified. Samples of ion exchange resins, sludges/oils are sampled as close to the point of generation as is practicable.
- **Before waste processing** – Prior to packaging, waste is characterised in order to ensure it complies with waste stream criteria and will meet relevant waste acceptance criteria for disposal off-site.
- **During storage** – Once waste has been packaged it is stored on-site until transferred off-site for further treatment or disposal. Length of storage period will depend on the its characteristics and category, for example ILW is stored on-site until availability of the GDF. Waste in storage will be monitored to maintain an accurate status of a waste package's radioactive material inventory and integrity.
- **Before off-site transfer** – Once the off-site treatment or disposal facility is available, the waste package will undergo monitoring to confirm adherence to WAC and integrity

of the package. Measurements taken at this stage are incorporated into records submitted to the waste facility receiving the transfer.

At the site-specific stage a strategy for waste characterisation, covering the stages from raw waste generation through to disposal, is to be developed, taking into account the following measures for solid and non-aqueous liquid wastes identified in UK guidance [199]:

- **Radioactivity** – The radioactivity content of the waste should be known with sufficient accuracy and precision to meet key radionuclide limits and WAC. This includes those specified by facilities to which the waste will be directed, in so far as these are known.
- **Dose rate** – Package external dose rates should be known so that compliance with the limits for facilities and equipment in which they will be handled, stored and transported can be demonstrated. Where shielding has been identified as a means of restricting dose, it should be effective under all operating conditions.
- **Surface contamination** – For conditioned wastes, the amount and extent of any non-fixed surface contamination should be known. Suitable and sufficient decontamination provisions should be provided to meet the relevant safety case requirements. Transferable radioactive contamination on the exterior of the waste packages should be maintained within limits established for the storage, transportation, and packaging facilities where these wastes are to be handled.
- **Fissile content** – For wastes containing fissile matter, the nature and quantity of the fissile materials, and any other waste components that may influence the neutron reactivity of the system (e.g. neutron moderating or absorbing material), should be known in sufficient detail to enable assessment of the criticality hazard and to facilitate safe management, safeguards and disposal arrangements.
- **Physical and chemical composition** – The bulk composition and chemical properties of the waste should be understood to the extent that any chemical hazards or challenges posed by the waste can be assessed.

Where comprehensive sampling and characterisation is not practicable, for example due to ALARP and safety considerations, this will be justified and suitable theoretical models/calculations will be used to determine activity.

6.8.7.7.1 Evidence for 4.7-A7: Solid and Non-Aqueous Liquid Wastes Monitoring and Sampling

- **PER Chapter 5 Monitoring and Sampling** [10] – Sets out the approach to characterisation throughout the waste management process and provides an overview of key solid and non-aqueous waste sampling and monitoring parameters for the different types of waste streams.
- **Integrated Waste Strategy** [86] – Presents the baseline management strategies for solid and non-liquid radioactive wastes in the generic SMR-300. Explains how radioactivity and volume of waste streams arising from the SRW will be minimised through characterisation, segregation and further processing.
- **SDD for SRW** [127] – Details the sampling and monitoring arrangements for principal radioactive wet-solid and solid waste streams in the generic SMR-300 managed by the SRW.
- **Design Challenge - ILW and LLW Facilities** [139] – Raised via a design challenge paper to highlight differences between US and UK disposal routes for ILW and LLW.

Radioactive waste management design will be subject to further development at the site-specific stage and as such, options for the design of ILW and LLW management facilities are subject to further assessment. The outcomes of the design challenge will have a direct impact on the solid waste sampling and monitoring design in the generic SMR-300.

- **Future Evidence: Solid Waste Characterisation Strategy** – As the design of the SRW develops, the characterisation strategy for waste generation, treatment, conditioning, storage and disposal will be developed further, and detailed monitoring and sampling arrangements will be specified.

6.8.7.8 Argument 4.7-A8: Plant Condition Monitoring

Argument 4.7-A8: Plant Condition Monitoring *The generic SMR-300 has appropriate arrangements for monitoring and sampling of various key plant parameters that have a direct or indirect impact on the generation/processing of radioactive waste, to provide information to operators to enable them to ensure that BAT continues to be applied.*

In addition to monitoring for radioactivity, various other plant parameters are monitored or sampled in the generic SMR-300 design for the purposes of providing information to the operator and tracking plant performance.

Certain key non-radiological parameters provide information to the operator on the generation of radioactive wastes, and the efficiency/performance of treatment and abatement systems. Tracking these parameters can inform operator decision making, and allow remedial actions to be taken to ensure the application of BAT. These features optimise plant performance, availability and maintenance without directly sampling or monitoring radioactive products.

A comprehensive list of plant condition monitoring for the generic SMR-300 is to be produced at the site-specific stage.

6.8.7.8.1 Evidence for 4.7-A8: Plant Condition Monitoring

- **PER Chapter 5 Monitoring and Sampling** [10] – Provides an overview of plant condition monitoring currently identified within the conceptual generic SMR-300 design relevant to the application of BAT.
- **SDD for PSL** [192] – Sets out the full array or process measurement parameters monitored by the primary sampling panel, or via grab sampling points.
- **SDD for SRW** [127] – Recognises that filter condition is monitored by differential pressure or as otherwise recommended by the selected manufacturer.
- **SDD for LRW** [128] – Recognises process equipment shall have instrument and/or sampling provisions to enable periodic evaluation of the operability and functional performance of active components of the system.
- **SDD for GRW** [129] – States that instrumentation will incorporate the recommendations in American National Standards Institute (ANSI) / American Nuclear Society (ANS) for providing information such as inlet and outlet temperatures of the process gas in heat exchangers, liquid level in the gas condensers, moisture content from gas conditioning

equipment, and adsorber vault temperature, to facilitate equipment performance evaluation and allow corrective measures to be taken when required.

- **PSL Preliminary Chemistry Engineering Justification** [200] – Identifies sampling requirements for chemistry control parameters and evaluates these against the PSL design.
- **SMR-300 Top Level Plant Design Requirements** [47] – Recognises the plant is designed to allow the operator significant time to evaluate the plant condition and decide what, if any, manual action is needed. Also recognises that in line with EPRI URD, the generic SMR-300 will use proven diagnostic monitoring techniques for leak detection, vibration, and other potential problems to minimise failure of critical rotating equipment and high-pressure systems.
- **Future Evidence: Identification of Plant Condition Monitoring Equipment Providing EPFs** – An exhaustive list of plant condition monitoring equipment which serves a role in the demonstration of BAT will be developed during the site-specific stage.

6.9 SUMMARY

This chapter has presented the demonstration of BAT for the design of the generic SMR-300 as far as it currently practicable given current design maturity. Under the high level claims, a comprehensive set of arguments have been presented with suitable underpinning evidence that the design achieves optimisation in minimising the generation, volume / mass and activity of radioactive wastes and reduces their impacts on people and the environment. Suitable future evidence has been outlined for post-GDA and the site specific stage to ensure a comprehensive BAT case is demonstrated as the design matures.

It has been acknowledged that BAT applies across the full lifecycle of a nuclear facility and must be considered in construction, commissioning, operation and decommissioning phases of the SMR-300 design, and this chapter presents a BAT case that will continue to mature and develop as the design of the generic SMR-300 develops. What is BAT for a particular process will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge. BAT is an iterative process, the BAT Case will evolve and require updates at key milestones for development and deployment of the generic SMR-300 in the UK.

The CAE approach for demonstration of BAT for the generic SMR-300 has been outlined consistent with the approach set out in the SMR-300 GDA RSR-BAT Guidance [6].

Two environmental claims are presented which sit in the overarching SSEC CAE:

- Claim 3: Environmental Principles and Requirements – Environmental principles are implemented such that the generic SMR-300 design meets the Environmental Objective.
- Claim 4: Environmental Protection – The generic SMR-300 design is developed so far as is reasonably achievable to provide optimal protection of people and the environment.

The arguments and evidence for these claims are presented in sub-chapter 6.7 and 6.8 respectively. Against each argument evidence is presented with references to supporting documentation where further detail can be found. Where evidence is not yet available GDA Commitments are identified in the chapter and recorded in the GDA Commitments, Assumptions, Requirements Register [90]. No unique BAT GDA Commitments have been defined within this chapter.

Future evidence is proposed throughout the chapter demonstrating the RP's awareness that further work is required and indeed intended in order to fully substantiate claims and arguments. Appendix A presents a route map of claims, arguments and evidence including future evidence.

6.10 REFERENCES

[1] Holtec Britain, "HI-2240333, Holtec SMR GDA PSR Part A Chapter 2 General Design Aspects and Site Characteristics," Revision 1, July 2025.

[2] Nuclear Industry Safety Directors' Forum, "Best Available Technique (BAT) for the Management of the Generation and Disposal of Radioactive Wastes: A Good Practice Guide," Issue 1, December 2010.

[3] Environment Agency, "Guidance: Radioactive Substances Regulation (RSR): Objective and Principles," December 2021. [Online]. Available: https://www.gov.uk/government/publications/radioactive-substances-regulation-rsr-objective-and-principles/radioactive-substances-regulation-rsr-objective-and-principles. [Accessed June 2025].

[4] Holtec Britain, "HI-2240363, Holtec SMR GDA PER Chapter 4 Conventional Impact Assessment," Revision 1, June 2025.

[5] Holtec Britain, "HI-2240359, Holtec SMR GDA Approach and Application to the Demonstration of BAT," Revision 1, May 2025.

[6] Holtec Britain, "HI-2241319, SMR-300 GDA RSR-BAT Guidance," Revision 1, April 2025.

[7] Holtec Britain, "HI-2240360, Holtec SMR GDA PER Chapter 1 Radioactive Waste Management Arrangements," Revision 1, June 2025.

[8] Holtec Britain, "HI-2240361, Holtec SMR GDA PER Chapter 2 Quantification of Effluent Discharges and Limits," Revision 1, July 2025.

[9] Holtec Britain, "HI-2240362, Holtec SMR GDA PER Chapter 3 Radiological Impact Assessment," Revision 1, June 2025.

[10] Holtec Britain, "HI-2240801, Holtec SMR GDA PER Chapter 5 Monitoring and Sampling," Revision 0, June 2025.

[11] Holtec Britain, "HI-2240332, Holtec SMR GDA PSR Part A Chapter 1 Introduction," Revision 1, July 2025.

[12] Holtec Britain, "HI-2240334, Holtec SMR GDA PSR Part A Chapter 3 Claims, Arguments and Evidence," Revision 1, July 2025.

[13] Holtec Britain, "HI-2240335, Holtec SMR GDA PSR Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance," Revision 1, July 2025.

[14] Holtec Britain, “HI-2240336, Holtec SMR GDA PSR Part A Chapter 5 Summary of ALARP and SSEC,” Revision 1, July 2025.

[15] Holtec Britain, “HI-2240776, Holtec SMR GDA PSR Part B Chapter 2 Reactor Fuel and Core,” Revision 1, June 2025.

[16] Holtec Britain, “HI-2240777, Holtec SMR GDA PSR Part B Chapter 5 Reactor Supporting Facilities,” Revision 1, June 2025.

[17] Holtec Britain, “HI-2240340, Holtec SMR GDA PSR Part B Chapter 9 Conduct of Operations,” Revision 1, June 2025.

[18] Holtec Britain, “HI-2240341, Holtec SMR GDA PSR Part B Chapter 10 Radiological Protection,” Revision 1, June 2025.

[19] Holtec Britain, Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management, HI-2240344,, Revision 1, 2025.

[20] Holtec Britain, “HI-2240356, Holtec SMR GDA PSR Part B Chapter 19 Mechanical Engineering,” Revision 1, June 2025.

[21] Holtec Britain, “HI-2240352, Holtec SMR GDA PSR Part B Chapter 23 Reactor Chemistry,” Revision 1, June 2025.

[22] Holtec Britain, “HI-2240353, Holtec SMR GDA PSR Part B Chapter 24 Fuel Transport and Storage,” Revision 1, June 2025.

[23] Holtec Britain, “HI-2240354, Holtec SMR GDA PSR Part B Chapter 25 Construction and Commissioning Approach,” Revision 1, June 2025.

[24] Holtec Britain, “HI-2240355, Holtec SMR GDA PSR Part B Chapter 26 Decommissioning Approach,” Revision 1, June 2025.

[25] Holtec International, “HI-2240077, SMR-300 Plant Overview,” Revision 1, April 2025.

[26] Holtec International, “HI-2250494, A Comparative Assessment of Light Water Small Modular Reactor Technologies. Revision 1,” April 2025.

[27] Holtec Britain, “HI-2241147, SMR-300 GDA Design Stability Toolkit,” Revision 0, November 2024.

[28] Environment Agency, Office for Nuclear Regulation & Natural Resources Wales, “New Nuclear Power Plants: Generic Design Assessment Guidance for Requesting Parties,” October 2023. [Online]. Available: https://www.gov.uk/government/publications/new-nuclear-power-plants-generic-design-assessment-guidance-for-requesting-

parties/new-nuclear-power-plants-generic-design-assessment-guidance-for-requesting-parties. [Accessed June 2025].

[29] Holtec Britain, "Holtec SMR-300 GDA - Non-Fuel Waste Packaging BAT Workshop Output Report (worked example)," Revision 0, March 2025.

[30] Holtec Britain, "HI-2241563, Holtec SMR-300 GDA BAT Statement - Li Enrichment," Revision 0, December 2024.

[31] Holtec Britain, "HPP-3295-0017, Design Management," Revision 1, December 2024.

[32] Environment Agency, "Guidance: RSR Generic Developed Principles: Regulatory Assessment," May 2024. [Online]. Available: https://www.gov.uk/government/publications/radioactive-substances-regulation-rsr-objective-and-principles/radioactive-substances-regulation-rsr-objective-and-principles#:~:text=Principle%204%3A%20protecting%20wildlife,-Radioactive%20substances%20activitie. [Accessed June 2025].

[33] Environment Agency, "Guidance: Radioactive substances management: generic developed principles," May 2024. [Online]. Available: https://www.gov.uk/government/publications/rsr-generic-developed-principles-regulatory-assessment/radioactive-substances-management-generic-developed-principles. [Accessed June 2025].

[34] Environment Agency, "Guidance: Engineering: Generic Developed Principles," May 2024. [Online]. Available: https://www.gov.uk/government/publications/rsr-generic-developed-principles-regulatory-assessment/engineering-generic-developed-principles. [Accessed June 2025].

[35] Environment Agency, "Guidance: Contaminated Land and Groundwater: Generic Developed Principles," May 2024. [Online]. Available: https://www.gov.uk/government/publications/rsr-generic-developed-principles-regulatory-assessment/contaminated-land-and-groundwater-generic-developed-principles. [Accessed June 2025].

[36] Environment Agency, "Guidance: RSR guidance for nuclear sites undergoing decommissioning," February 2024. [Online]. Available: https://www.gov.uk/government/publications/the-decommissioning-of-nuclear-facilities/rsr-guidance-for-nuclear-sites-undergoing-decommissioning. [Accessed June 2025].

[37] United Kingdom Government, "The Environmental Permitting (England and Wales) Regulations 2016," 2016.

[38] Environment Agency, "Guidance: RSR Permits for Nuclear Licensed Sites: How to Comply," February 2020. [Online]. Available:

https://www.gov.uk/government/publications/rsr-permits-for-nuclear-licensed-sites-how-to-comply/rsr-permits-for-nuclear-licensed-sites-how-to-comply. [Accessed June 2025].

[39] Holtec Britain, “HI-2241304, SMR-300 UK GDA ALARP Guidance Document,” Revision 0, November 2024.

[40] Holtec Britain, “Non-Fuel Waste Packaging BAT Assessment: Workshop Briefing Pack,” Revision 0, January 2025.

[41] Holtec Britain, “CD-48, Environmental Policy,” Revision 1, November 2024.

[42] Holtec Britain, “HI-2240342, Holtec SMR GDA PSR Part B Chapter 11 Environmental Protection,” Revision 1, June 2025.

[43] Holtec Britain, “HI-2240344, Holtec SMR GDA PSR Part B Chapter 13 Radioactive Waste Management,” Revision 1, June 2025.

[44] Holtec Britain, “HI-2250394, Holtec SMR-300 GDA Environmental Protection Functions Report,” Revision 1, July 2025.

[45] United States Department of Energy, “Office for Nuclear Energy, Benefits of Small Modular Reactors (SMR),” September 2024.

[46] Holtec Britain, “HI-2240357, Holtec SMR GDA PSR Part B Chapter 20 Civil Engineering,” Revision 1, June 2025.

[47] Holtec International, “HI-2240251, SMR-300 Top Level Plant Design Requirements,” Revision 2, April 2025.

[48] Holtec Britain, “Holtec SMR-300 Technical Report Containment Structure System Based View, HI-2250348,” 2025.

[49] U.S. Nuclear Regulatory Commission, “Westinghouse Technology Systems Manual,” July 2020. [Online]. Available: https://www.nrc.gov/docs/ML2116/ML21166A218.pdf. [Accessed June 2025].

[50] AREVA & EDF, “PCSR - Sub-chapter 20.2 - Decommissioning - Implementation for the EPR,” June 2012.

[51] AREVA & EDF, “UKEPR-002-041, PCSR - Sub-chapter 4.1 Summary description,” Issue 04, July 2012.

[52] Holtec International, “HI-2240146, System Design Description for the PAssivre Core Cooling System, Revision 0,” August 2024.

[53] Holtec International, “DWG-15209, General Arrangements of Containment Structure Internals for SMR-300, Revision 02,” December 2024.

[54] Holtec Britain, “HI-2250348, Containment Structure System Based View,” Revision 0,” May 2025. .

[55] Holtec Britain, “HI-2241588, Holtec SMR-300 GDA Passive Systems Report,” Revision 0,” April 2025. .

[56] Holtec Britain, “HI-2240648, GDA Design Reference Point,” Revision 2, May 2025.

[57] Holtec Britain, “HI-2241455, Holtec SMR-300 Through-Life Safety, Security and Environmental Case (SSEC) Strategy,” Revision 0, December 2024.

[58] Holtec Britain, “HI-2241229, Design Reference and GDA Scope Change Proposal No 1,” Revision 0, October 2024.

[59] Holtec Britain, “HI-2241408, Mechanical Codes and Standards Report,” Revision 0, December 2024.

[60] Holtec Britain, “HI-2241293, Codes and Standards Applicability Report for Civil Engineering,” Revision 0, November 2024.

[61] Holtec Britain, “HI-2241059, UK Gap Analysis of SMR-300 Design Philosophy Against Chemistry Codes and Standards,” Revision 0, August 2024.

[62] Holtec Britain, “HI-2241204 UK-US Radiological Protection Regulatory Framework Comparison,” Revision 0, September 2024.

[63] Holtec Britain, “HI-2250562, SMR-300 SSG-52 Compliance Report,” Revision 0, May 2025.

[64] International Atomic Energy Agency, “SSG-52, Design of the Reactor Core for Nuclear Power Plants,” 2019.

[65] Holtec Britain, “HI-2240127, UK/US Regulatory Framework Principles Report,” Revision 1, January 2005.

[66] Holtec Britain, “HI-2240126, Codes and Standards Report,” Revision 0, February 2024.

[67] International Atomic Energy Agency, “No. NP-T-2.10, Safety of Nuclear Power Plants: Commissioning,” 2016.

[68] Nuclear Energy Agency, “Electric Power Research Institute: Utility Requirement Document,” February 2015.

[69] Holtec Britain, "HI-2241359, Environmental Protection Functions and Measures Identification Methodology," Revision 0, October 2024.

[70] Holtec Britain, "HI-2250519, Holtec SMR-300 GDA Pilot Identification of Environmental Protection Measures Study Report," Revision 0, July 2025.

[71] Office for Nuclear Regulation, "Licence Condition Handbook," February 2017.

[72] Office for Nuclear Regulation, "Safety Assessment Principles For Nuclear Facilities," Revision 1, January 2020.

[73] Office for Nuclear Regulation, "NS-TAST-GD-026, Decommissioning," Issue 6, January 2024.

[74] Office for Nuclear Regulation, "ONR-GDA-GD-007, New Nuclear Power Plants: Generic Design Assessment Technical Guidance," Revision 0, May 2019.

[75] Environment Agency, "Guidance: Decommissioning of nuclear sites and release from regulation," July 2018. [Online]. Available: https://www.gov.uk/government/publications/decommissioning-of-nuclear-sites-and-release-from-regulation/decommissioning-of-nuclear-sites-and-release-from-regulation. [Accessed June 2025].

[76] United Kingdom Government, "The Energy Act, Funded Decommissioning Programme Guidance for New Nuclear Power Stations," December 2008.

[77] Holtec Britain, "HI-2241256, UK SMR-300 GDA Decommissioning Strategy Assessment," Revision 0, November 2024.

[78] Holtec International, "HPP-160-3020, SMR-160 Design Standard for Decommissioning," Revision 0, December 2018.

[79] Holtec Britain, "HI-2241428, Decommissioning Waste Inventory for the Generic SMR-300 Design," Revision 0, December 2024.

[80] Environment Agency, Scottish Environment Protection Agency and Natural Resources Wales, "Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation," july 2018.

[81] Scottish Environment Protection Agency, "Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation," Version 1, July 2018.

[82] Environment Agency, "On-site disposal of solid radioactive waste on nuclear licensed sites Joint Regulators' Statement of Common Understanding," Version 2, February 2021.

[83] United Kingdom Government, "The Nuclear Installations Act," 1965.

[84] Holtec Britain, "HI-2241449, Calculation of SMR-300 Solid Radiological Waste (SRW) Inventories," Revision 0, January 2025.

[85] Holtec Britain, "Estimate of the SMR-300 Gaseous and Liquid Effluent releases using the PWR-GALE3.2 Code," 2025.

[86] Holtec Britain, "HI-2241151, Integrated Waste Strategy," Revision 0, January 2025.

[87] Holtec Britain, "HI-2241183, SMR-300 ILW Management Strategy: Options Assessment," Revision 0, 2024.

[88] Holtec Britain, "HI-2241494, Holtec SMR-300 GDA Non-Fuel Waste Packaging BAT Assessment Workshop Output Report (worked example)," Revision 0, March 2025.

[89] Holtec Britain, "HI-2250414, Holtec SMR-300 GDA BAT Statement - Prospective Design Change CES & CS," Revision 1, July 2025.

[90] Holtec Britain, "HI-2251168, UK GDA - Commitments, Assumptions and Requirements Register," Revision 0, July 2025.

[91] Holtec Britain, "HPP-3295-0013, Holtec SMR-300 Generic Design Assessment Capturing and Managing Commitments, Assumptions and Requirements, HPP-3295-0013," Revision 1, January 2025.

[92] U.S. Nuclear Regulatory Commission, "NUREG-0800, Standard Review Plan, 4.2 Fuel System Design Rev 3," 2007.

[93] Holtec International, "HI-2240459, Primary Water Chemistry Strategic Plan," Revision 0, 2024.

[94] Framatome, "HI-2250601, Applicability of Framatome Fuel Methods for Holtec Fuel, ANP-4139NP," Revision 0, April 2025.

[95] Holtec Britain, "HI-2220602, SMR-160 Fuel Assembly Material Corrosion Evaluation," Revision 0, 2022.

[96] Holtec Britain, "HI-2241458, Holtec SMR-300 GDA Nuclear Design Basis," Revision 1, 2025.

[97] Holtec Britain, "HI-2241327, Holtec SMR-300 GDA Fuel Design Criteria and Limits," Revision 1, May 2025.

[98] Holtec Britain, "HI-2240861, Overview of Holtec SMR-300 Fuel Design and Core Components," Revision 1, May 2025.

[99] Holtec Britain, "HI-2241288, Holtec SMR-300 GDA Thermal and Mechanical Design Basis," Revision 1, May 2025.

[100] Holtec International, "HPP-8002-0026, Design Standard for Radiation Protection," Revision 0, March 2025.

[101] Holtec International, "HI-2156788, Design Specification for the SMR-300 Steam Generator," Revision 2, 2024.

[102] Holtec International, "HI-2240207, Spent Fuel Pool Cooling System Requirements, Open Items, and Interface Requirements Notebook," Revision 0, 2024.

[103] Holtec International, "HI-2241505, Equipment and Piping Layout Guidelines for Ensuring Radiation Exposures ALARA," Revision 1, March 2025.

[104] Holtec Britain, "HI-2250036, Shielding Basis of Design," Revision 0, March 2025.

[105] Holtec Britain, "HI-2241512, Dose Management Strategy," Revision, June 2025.

[106] Holtec Britain, "HI-2240459, SMR-300 Primary Water Chemistry Strategic Plan," Revision 0, 2024.

[107] Holtec International, "HI-2240166, System Design Description for the Chemical and Volume Control System," Revision 0, June 2024.

[108] Holtec International, "HI-2240167, System Design Description for Spent Fuel Pool Cooling System," Revision 0, April 2024.

[109] Holtec International, "HI-2240165, System Design Description for the Reactor Coolant System," Revision 0, April 2025.

[110] Holtec International, "HI-2240471, Position Paper on SMR-300 Plant Demineralized Water Treatment System Output Quality Considerations and Requirements," Revision 0, April 2024.

[111] Holtec International, "HI-2240462, SMR-300 Nuclear Island Minimalization Strategy of Activity Generation and Accumulation," Revision 0, December 2024.

[112] Holtec International, "HI-2241579, Evaluation of SMR-300 Calculated Source Terms Against Publicly Available Information," Revision 0, 2024.

[113] Holtec International, "HI-2188434, SMR-160 Fuel Handling and Storage," Revision 1, March 2020.

[114] Holtec Britain, "HI-2250267, Holtec SMR-300 GDA NWS Expert View on Disposability Output Letter," Revision 0, April 2025.

[115] Holtec International, "HI-2115090, Final Safety Analysis Report for the HI-STORM Underground Maximum Capacity (UMAX) System," Revision 8, October 2024.

[116] Holtec Britain, "HI-2241163, SMR-300 UK GDA Spent Fuel Management Strategy," Revision 0, November 2024.

[117] Holtec International, "HI-2210376, Spent Fuel Pool Cooling System Regulatory Compliance Report," Revision 0, December 2022.

[118] International Atomic Energy Agency, "No. NP-T-3.13, Stress Corrosion Cracking in Light Water Reactors: Good Practices and Lessons Learned," 2011.

[119] Holtec International, "HI-2240583, System Design Description for Containment Ventilation System," Revision 0, November 2024.

[120] Holtec International, "HI-2240619, System Design Description for Radiation Monitoring System," Revision 0, March 2025.

[121] Holtec Britain, "HI-2250348, Containment Structure System Based View," Revision 0, May 2025.

[122] American Nuclear Society, ANSI/ANS-55.6-1993 (R2007) Liquid Radioactive Waste Processing System for Light Water Reactor Plants.

[123] EPRI, "Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13," 2014.

[124] US Nuclear Regulatory Commission, Regulatory Guide 4.21 - MINIMIZATION OF CONTAMINATION AND RADIOACTIVE WASTE GENERATION: LIFE-CYCLE PLANNING, Revision 0, 2008.

[125] American Nuclear Society, "ANSI/ANS-55.4-1993 (R2007), American National Standard for Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants".

[126] American Nuclear Society, "ANSI/ANS-55.1 Solid Radioactive Waste Processing for Light-Water-Cooled Reactor Plants," American National Standards Institute, 2021.

[127] Holtec International, "HI-2240582, System Design Description for Solid Radwaste System," Revision 0, August 2024.

[128] Holtec International, "HI-2240497, System Design Description for Liquid Radwaste System," Revision 0, August 2024.

[129] Holtec International, "HI-2240581, System Design Description for Gaseous Radwaste System," Revision 0, January 2025.

[130] Holtec International, "HI-2240159, Design Specification for the Containment Structure," Revision 1, 2024.

[131] U.S. Code of Federal Regulations, "10 CFR 50, App. A General Design Criteria for Nuclear Power Plants".

[132] Holtec International, "HI-2240235, SMR-300 Acceptance Criteria for Deterministic Safety Analysis," Revision 2, August 2024.

[133] Holtec Britain, "HI-2241518, UK GDA [DC08] Design Challenge - Reduction in GDA Scope for the HI-STORM UMAX System," Dec 2024.

[134] Holtec International, "HI-2188323, Design Specification for Reactor Auxiliary Building," Revision 1, August 2019.

[135] Nuclear Decommissioning Authority, "The NDA Value Framework," Version 2, August 2021.

[136] Holtec International, "HI-2240598, SMR-300 Secondary Water Chemistry Strategic Plan," Revision 0, October 2024.

[137] Holtec International, "HI-2240599, SMR-300 Closed Cooling Water Chemistry Strategic Plan," Revision 0, November 2024.

[138] Holtec Britain, "HI-2240016, SMR-300 Source Terms," Revision 0, October 2024.

[139] Holtec Britain, "HI-2241553, Holtec SMR-300 GDA Design Challenge – ILW and LLW Facilities," Revision 0, January 2025.

[140] Holtec Britain, "HI-2240759, NWS Expert View Submission," Revision 1, 2024.

[141] Nuclear Decommissioning Authority, "Nuclear Industry Aqueous Waste Management Good Practice Guidance," Issue 1, December 2020.

[142] Holtec International, DWG-15545-01, LRW-LIQUID RADWASTE SYSTEM PIPING & INSTRUMENTATION DIAGRAM, Revision 0, June 2024.

[143] American Nuclear Society, ANSI/ANS-40.37-2009 (R2016) Mobile Low-Level Radioactive Waste Processing Systems.

[144] Holtec International, "PS-8002-0034, SMR-300 Specification – HVAC Design Criteria," January 2025.

[145] Environment Agency, "Radiological Protection of People and the Environment: Generic Developed Principles," 2021.

[146] Holtec International, "HI-2240242, SMR-300 Contained Radiation Sources for Normal Operation," Revision 0, December 2024.

[147] Environment Agency, "Criteria for Setting Limits on the Discharge of Radioactive Waste from Nuclear Sites," Revision 1, 2012.

[148] Environment Agency, "Initial Radiological Assessment Tool 2: Part 2 Methods and Input Data - Chief Scientist Group Report," November 2022.

[149] J. S. J. Smith, The Methodology for Assessing the Radiological Consequences of Routine Discharges to the Environment used in PC CREAM 08, HPA-RPD-058, 2009.

[150] European Union, "2004/2/Euratom," 06 01 2004. [Online]. Available: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:002:0036:0046:EN:PDF.

[151] Holtec Britain, "HI-2241452, Estimate of the SMR-300 Gaseous and Liquid Effluent Releases using the GALE-PWR 3.2 Code," Revision 0, April 2025.

[152] Holtec Britain, "HI-2241435, Methodology for Calculating Liquid and Gaseous Discharges to Determine Monthly and Annual Levels," Revision 0, 2025.

[153] Holtec Britain, "HI-2241562, Holtec SMR-300 GDA Liquid and Gaseous Discharge Report," Revision 0, February 2025.

[154] Holtec Britain, "HI-2241271, OPEX data selected for PER Chapter 2 Quantification of Effluent Discharges and Limits," Revision 0, October 2024.

[155] Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency, Health Protection Agency, Food Standards Agency, "Principles for the Assessment of Prospective Public Doses arising from Authorised Discharges of Radioactive Waste to the Environment," 2012.

[156] United Kingdom Government, “The Ionising Radiations Regulations 2017 SI 2017/1075,” 2018.

[157] National Dose Assessment Working Group, “Guidance on Initial/Simple Assessment Tools (NDAWG Guidance Note 2),” 2008.

[158] Environment Agency, “Initial Radiological Assessment Tool 2: Part 1 User Guide,” 2022.

[159] Holtec Britain, “HI-2240069, Generic Site Envelope Report for SMR-300 UK GDA,” Revision 2, January 2025.

[160] Environment Agency, “Initial Radiological Assessment Tool 2: Summary,” 2022. [Online]. Available: https://www.gov.uk/government/publications/initial-radiological-assessment-methodology/initial-radiological-assessment-tool-2-summary.

[161] Environment Agency, Developing guidance for setting limits on radioactive discharges to the environment from nuclear licensed sites, 2005.

[162] Holtec Britain, “HI-2250373, Radiological Impact Assessment Topic Report,” Revision 0, May 2025.

[163] Holtec Britain, “HI-2241512, Dose Management Strategy,” Revision 0, June 2025.

[164] EURATOM FP6, “Environmental Risk from Ionising Contaminants: Assessment and Management (ERICA),” [Online]. Available: https://erica-tool.com/.

[165] European Commission, “D-ERICA: An Integrated Approach to the Assessment and Management of Environmental Risks from Ionising Radiation. Description of Purpose, Methodology and Application,” February 2007.

[166] J. V. I. e. a. Batlle, “A Methodology for Ar-41, Kr-85, 88 and Xe131m, 133 Wildlife Dose Assessment,” *Journal of Environmental Radioactivity,* pp. 152-161, April 2015.

[167] W. &. M. S. Oatway, Methodology for Estimating the Doses to Members of the Public from the Future Use of Land Previously Contaminated with Radioactivity, NRPB-W36, 2003.

[168] Holtec Britain, “HI-2240760, Holtec SMR-300 GDA Requesting Party Response to NWS Expert View on Disposability,” Revision 0, March 2025.

[169] Office for Nuclear Regulation, “ONR Guide NS-TAST-GD-077, Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services”.

[170] Holtec International, "CD-03, Nuclear Quality Assurance Manual," Revision 15, August 2022.

[171] Holtec International, "CD-06, ISO QA Manual," Revision 2, May 2024.

[172] Department of Environment, Food & Rural Affairs, "Policy Paper - Establishing the Best Available Techniques for the UK (UK BAT)," 2022.

[173] United Kingdom Government, "The Water Resources Act 1991 (as amended)," 1991.

[174] European Commission, "Industrial Cooling Systems BREF document," 2001.

[175] UK Statutory Instruments, "Eels (England and Wales) Regulations 2009," 2009.

[176] UK Public General Acts, "Salmon and Freshwater Fisheries Act 1975," 1975.

[177] Holtec Britain, "HI-2240918, Holtec SMR-300 Water Use, Abstraction and Discharges Report," Revision 0, January 2025.

[178] Health and Safety Executive, "Secondary containment," [Online]. Available: https://www.hse.gov.uk/comah/sragtech/techmeascontain.htm. [Accessed June 2025].

[179] EU, "Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (recast) (Text with EEA relevance)," 2010.

[180] EU, "Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants," 2015.

[181] European Commission, "Monitoring of Emissions to Air and Water from IED Installations BREF Document," 2017.

[182] European Commission, "Best Available Techniques (BAT) Reference Document for Large Combustion Plants," 2017.

[183] Holtec Britain, HI-2240920, Holtec SMR-300 GDA Air Quality Report, Revision 0, January 2025.

[184] UK Statutory Instruments, "The Control of Major Accident Hazards Regulations 2015," 2015.

[185] Holtec Britain, "HI-2240917, Holtec SMR-300 GDA Control of Major Accident Hazards (COMAH) Screening Assessment," Revision 0, December 2024.

[186] UK Statutory Instruments, "The Fluorinated Greenhouse Gases Regulations 2015," 2015.

[187] Holtec Britain, "HI-2240919, Fluorinated Gases and Ozone Depleting Substances Technical Note," Revision 0, November 2024.

[188] Environment Agency, "Environmental Principles Policy Statement," 2023.

[189] BRE Global, BREEAM Infrastructure Projects UK & Ireland - Technical Manual Version 6, 2022.

[190] United Nations, "The 17 Goals," 2024. [Online]. Available: https://sdgs.un.org/goals.

[191] Holtec Britain, "HI-2250028, SMR-300 GDA Sustainability Strategy," Revision 0, February 2025.

[192] Holtec International, "HI-2240168, System Design Description for Primary Sampling System," Revision 0, April 2024.

[193] Holtec International, "DWG-15217, Primary Sampling System Piping & Instrumentation Diagram," Revision 1, March 2025.

[194] Holtec Britain, "HI-2250824, UK GDA [DC32] Design Challenge - Environmental Monitoring and Sampling," Revision 0, 2025.

[195] Environment Agency, "LIT 14887, Monitoring of radioactive discharges to atmosphere from nuclear facilities," June 2024.

[196] International Standards Organisation, ISO 2889:2023 Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities, Edition 4, 2023.

[197] Environment Agency, "Performance Standards and Test Procedures for Automatic Isokinetic Samplers," September 2016.

[198] Environment Agency, "Monitoring stack emissions: measurement locations," 2022.

[199] Office for Nuclear Regulation, Environment Agency, Natural Resources Wales, Scottish Environmental Protection Agency, "The management of higher activity radioactive waste on nuclear licensed sites," July 2021. [Online]. Available: https://www.onr.org.uk/media/by2nkmad/waste-management-joint-guidance.pdf.

[200] Holtec Britain, "HI-2241595-R0.0, PSL - Preliminary Chemistry Engineering Justification," Revision 0, February 2025.

6.11 LIST OF APPENDICES

Appendix A PER Chapter 6 CAE Route Map

Table 12: PER Chapter 6 CAE Route Map

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